Appendix A

The Proposed Tellus Sandy Ridge Facility - Public Environmental Review (2016)

(This is the original PER document referred to the EPA under s.38 of the EP Act)

A-1 Environmental Scoping Document and Compliance Checklist

A-2 Environmental Risk Assessment

A-3 Flora and Vegetation Surveys

A-4 Geological Evolution Report

A-5 Soils and Materials Characterisation

A-6 Baseline Radiation and Metals Report

A-7 Landform Evolution Modelling

A-8 Terrestrial Fauna Surveys

A-9 Checklists for Biodiversity

A-10 Hydrology Assessment

A-11 Hydrogeology Assessment

A-12 Infiltration and Seepage Modelling

A-13 Heritage Survey

A-14 Radiation Assessments

A-15 Outline Safety Case

A-16 Outline Operating Strategy

A-17 Environmental Management Policy

A-18 Waste Facility Decommissioning and Closure Plan

A-19 Mine Closure Plan

A-20 Drinking Water Quality Management Plan

A-21 International Peer Review of Engineering Design of Waste Cell

A-22 Emergency Response Flow Chart

A-23 Engineering Designs of Waste Cells

A-24 Waste Acceptance Criteria and Supporting Documents

Environmental Scoping Document

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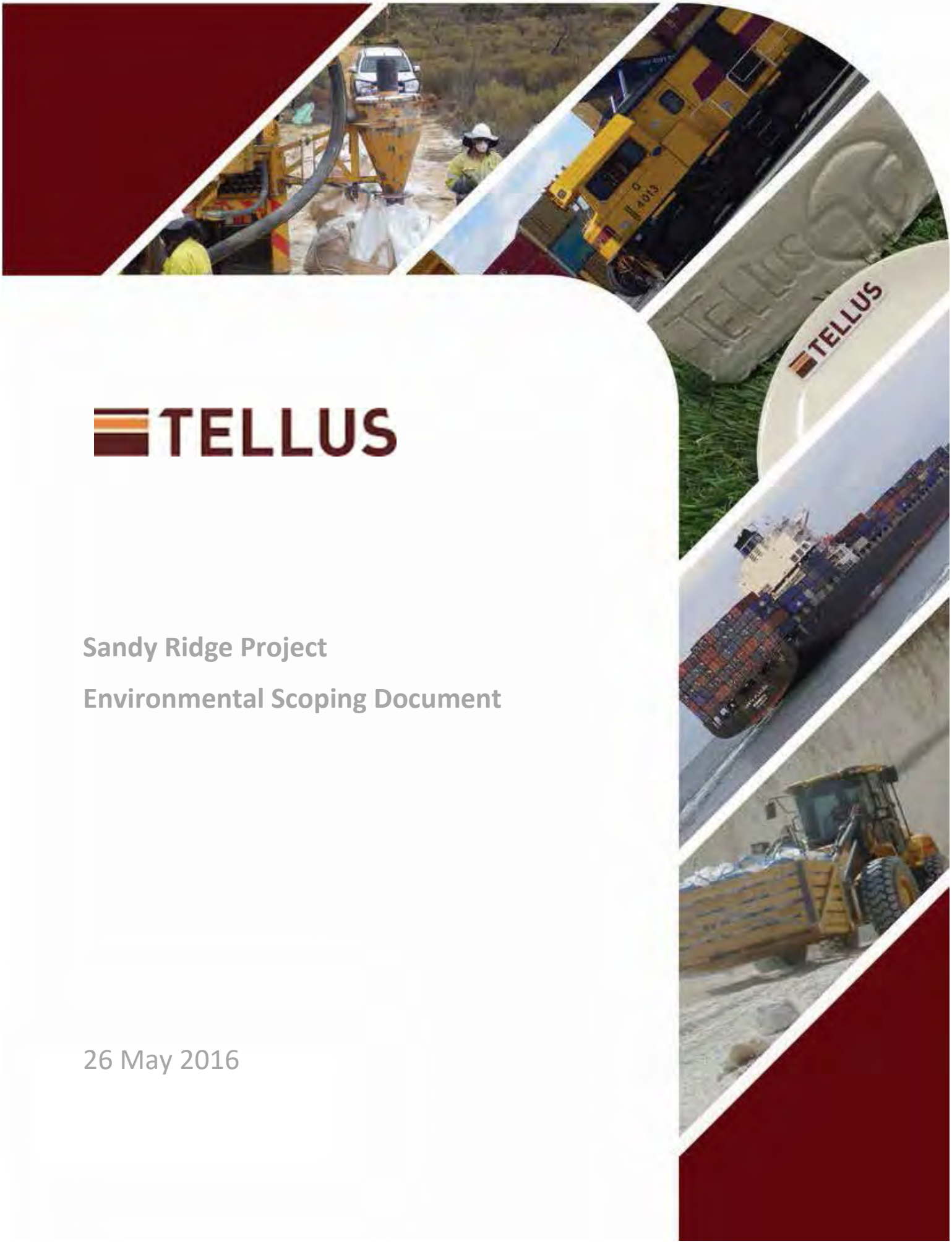

TELLUS

Sandy Ridge Project

Environmental Scoping Document

26 May 2016

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ENVIRONMENTAL SCOPING DOCUMENT

PROPOSAL NAME:	**SANDY RIDGE PROJECT**
ASSESSMENT NUMBER:	**2057**
LOCATION:	**APPROXIMATELY 75 KILOMETRES NORTH–EAST OF KOOLYANOBBING**
LOCAL GOVERNMENT AREA:	**SHIRE OF COOLGARDIE**
PROPONENT:	**TELLUS HOLDINGS LTD**
PUBLIC REVIEW PERIOD:	**10 WEEKS**
EPBC REFERENCE NO.:	**2015/7478**

1 INTRODUCTION

The proposal is being assessed by the Environmental Protection Authority (EPA) under Part IV of the *Environmental Protection Act 1986* (EP Act) at the level of Public Environmental Review (PER). This Environmental Scoping Document (ESD) sets out the requirements for the environmental review of the proposal. The purpose of an ESD is to:

- Provide proposal-specific guidelines to direct the proponent on the preliminary key environmental factors or issues that are to be addressed during the environmental review and preparation of the environmental review report.
- Identify the required work that needs to be carried out.
- Outline the timing of the environmental review.

The proponent must conduct the environmental review in accordance with this ESD and then report to the EPA in an environmental review report (PER document). As well as the proposal-specific requirements for the environmental review identified in this ESD, the PER document must also address the generic information requirements listed in section 10.2.4 of the EPA's *Environmental Impact Assessment (Part IV Divisions 1 and 2) Administrative Procedures 2012* (Administrative Procedures). When the EPA is satisfied that the PER document adequately addresses both of these requirements, the proponent will be required to release the document for a public review period of 10 weeks.

This ESD has been prepared by Aurora Environmental for Tellus Holdings Ltd (the proponent) in consultation with the EPA, decision-making authorities and interested agencies consistent with EPA *Environmental Assessment Guideline (EAG) 10 — Scoping a proposal*. This ESD is subject to a public review period of two weeks. The ESD will be available on the EPA website (www.epa.wa.gov.au) upon endorsement and must be appended to the PER document.

1.1 Assessment under bilateral agreement

The proposal has been referred and determined to be a controlled action under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) and is being assessed under the Bilateral Agreement between the Commonwealth of Australia and the State of Western Australia made under Section 45 of that Act. The relevant matters of national environmental significance (MNES) for this proposal are:

- The environment because the proposal is a nuclear action (s21 and 22A).

This ESD is inclusive of work required to be carried out and reported on in the PER document in relation to MNES. The PER will include a section identifying MNES and discussing how those matters have been addressed within the PER, including identifying any offsets that would be appropriate.

Schedule 4 of the *Environmental Protection and Biodiversity Conservation Regulations 2000* lists the matters to be addressed in a draft PER under the EPBC Act. The following requirements will be addressed in the PER:

General information

- The title of the action;
- The full name and postal address of the designated proponent;

- How the action relates to any other actions (of which the proponent should reasonably be aware) that have been, or are being, taken or that have been approved in the region affected by the action;
- The current status of the action; and
- The consequences of not proceeding with the action.

Environmental record of person proposing to take the action

- Details of any proceedings under a Commonwealth, State or Territory law for the protection of the environment or the conservation and sustainable use of natural resources against:
  - the person proposing to take the action; and
  - for an action for which a person has applied for a permit, the person making the application.

Information Sources

- For information given in a draft PER, the draft must state:
  - the source of the information;
  - how recent the information is;
  - how reliability of the information was tested and
  - what uncertainties (if any) are in the information.

2 THE PROPOSAL

2.1 Introduction

The subject of the ESD is the proponent's proposal to develop the Sandy Ridge Project (the Proposal) (Figure 1). The Proposal is to develop a kaolin open cut mine and use the mine voids for the secure storage and isolation of hazardous, intractable and low level radioactive waste using best practice storage and isolation safety case.

The Proposal is located approximately 75 kilometres (km) north-east of Koolyanobbing, Western Australia (Figure 1). Access is via a 100 km road to the Intractable Waste Disposal Facility (IWDF) Mount Walton East (Crown Reserve No. 44102) that extends northward from the Boorabbin Siding on Great Eastern Highway; a 4.5 km westwards section along an existing road; and a 5.3 km northwards section of new site access road into the development envelope (Figures 2 and 3).

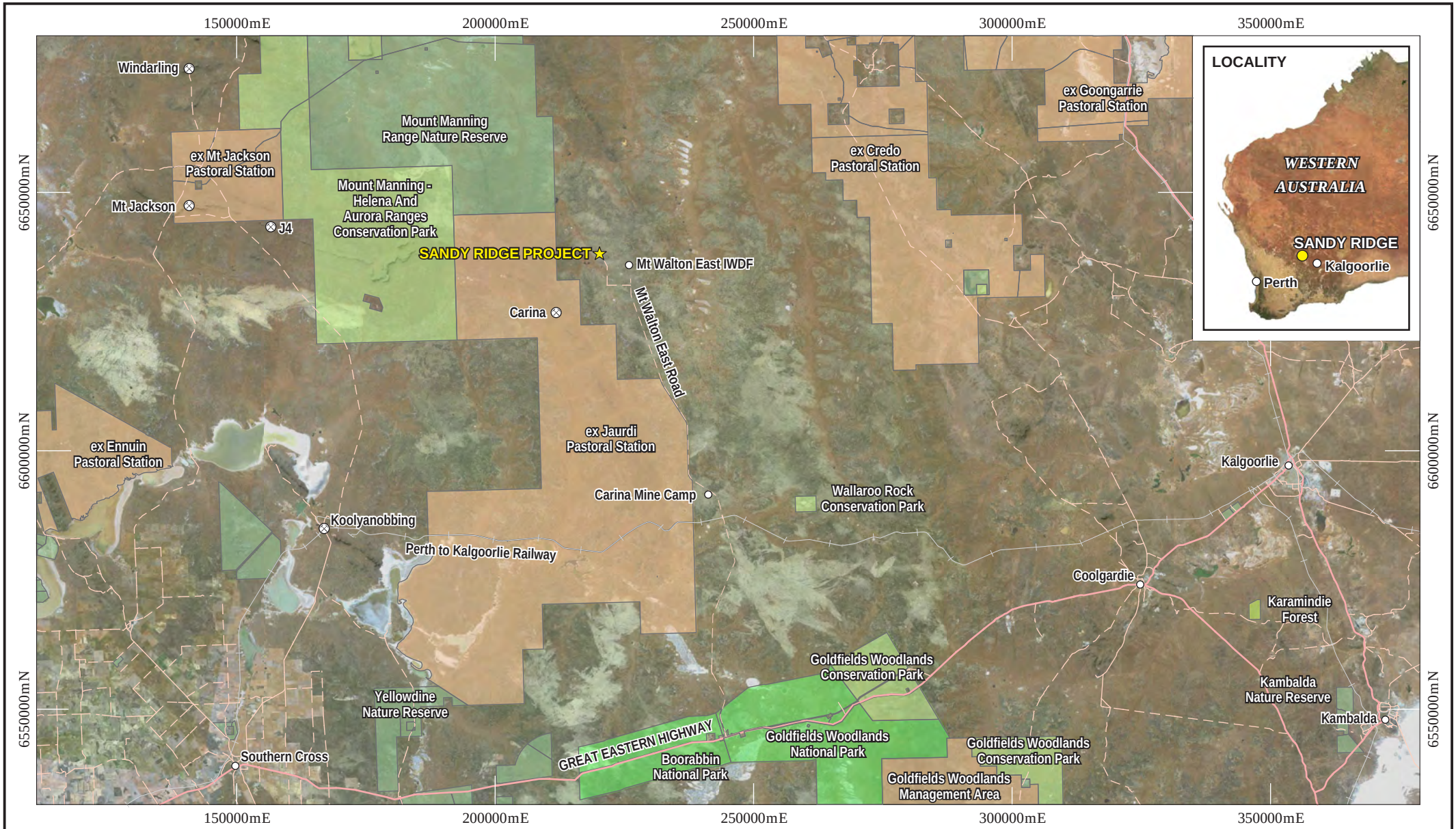
There are no sensitive receptors within 5 km of the location of the Proposal. The nearest operation is the Class V IWDF Mount Walton East located approximately 6 km to the east, which operates on a campaign basis and does not have permanent residents. The nearest mining camp is the Carina Iron Ore Mine Accommodation Camp located approximately 52 km to the south east of Sandy Ridge

The location of the Sandy Ridge Project has been specifically chosen to meet the requirements of International and National codes relating to the siting of a near surface geological repository. These site characteristics include:

- **Geologically stable** — the development envelope sits within the Archean Yilgarn Block and is geologically typical of areas overlying deeply weathered granite domes. It has very low seismicity (no earthquakes have been recorded at Sandy Ridge) and no volcanic or tectonic activity.
- **Natural geological barrier** — the clay bed is laterally extensive (80 km long and 40 km wide), has been stable for approximately 20 million years and is up to 36 m thick. This is capped by erosion resistant silcrete and laterite layers typically 4 to 6 metres thick in total.
- **Semi-arid desert Mediterranean climate** — averages just over 250 mm of rainfall per annum and evaporation is greater than 2,000 mm per annum. This means very little rainfall occurs across the site and generally water will evaporate before it infiltrates.
- **No surface water receptors** - there are no channels or creeks in the development envelope.
- **Very little (if any) surface water runoff** – Due to the low rainfall, high evaporation, permeable upper soil profile and gently sloping topography, significant rainfall events infiltrate quickly. There is a low likelihood of surface flows in the local catchments and any flows are short-lived and local in nature.
- **Lack of commercial mineral deposits** – there is no evidence to suggest that there is potential for economic mineral or hydrocarbon deposits beneath the kaolin deposit.
- **Topography** – the development envelope is flat to gently undulating and suitable for the construction of infrastructure and heavy vehicle movement.
- **Absence of Population** – located in an area with no population, the nearest population centre is a non-permanent camp approximately 52 km away.

- **Agricultural land use** – there is no potential for medium to high value agriculture.
- **Environmental values** – the environmental values of the development envelope are currently unknown and will be determined through investigation.
- **Heritage –**no special cultural or historical significance has been identified through a completed heritage study (undertaken in 2015) and consultation with stakeholders familiar with the area.
- **No flooding** – the development envelope is not subject to flooding, nor is it predicted to be in the future. The site is at very low risk of encountering cyclones.
- **Very low rates of erosion** – the development envelope is not subject to the erosive forces of high winds or rain due to the climate, soil types and topography and has been stable for thousands of years.

It can be concluded on the basis of the characteristics described above, that there is little credible risk to human health or the environment from suitably conditioned and packaged hazardous or intractable wastes that might be stored and isolated in appropriately designed disposal cell at Sandy Ridge.



Legend:
- Iron Ore Mine
- Rail
- Major Road
- Minor Road

DPaW Managed Lands:
- Conservation Park
- Former Leasehold
- National Park
- Nature Reserve
- State Forest

Client: TELLUS

0 20km
Scale 1:1,000,000
MGA94 (Zone 51)
CAD Ref: g2294_ESD_001.dgn
Date: Dec 2015 | Rev: B | A4

Aurora environmental
Author: C. Dorrington | AE Ref: THO2014-003
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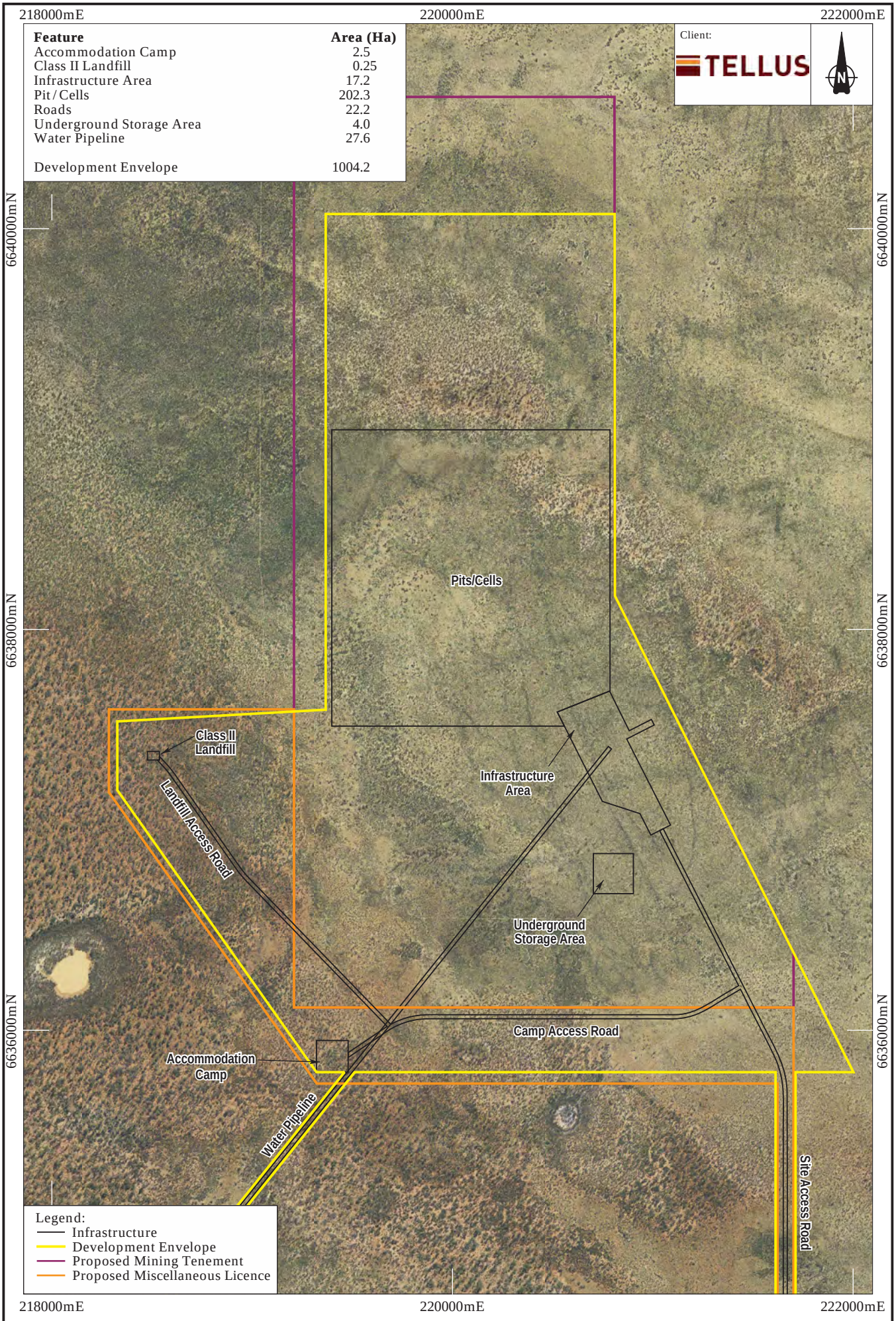
Sandy Ridge Project

Regional Location

Environmental Scoping Document

Figure: **1**



Feature	Area (Ha)
Accommodation Camp	2.5
Class II Landfill	0.25
Infrastructure Area	17.2
Pit / Cells	202.3
Roads	22.2
Underground Storage Area	4.0
Water Pipeline	27.6
Development Envelope	1004.2

0 400m

Scale 1:25,000
MGA94 (Zone 51)

CAD Ref: g2294_ESD_F004.dgn

Date: October 2015 | Rev: B | A4

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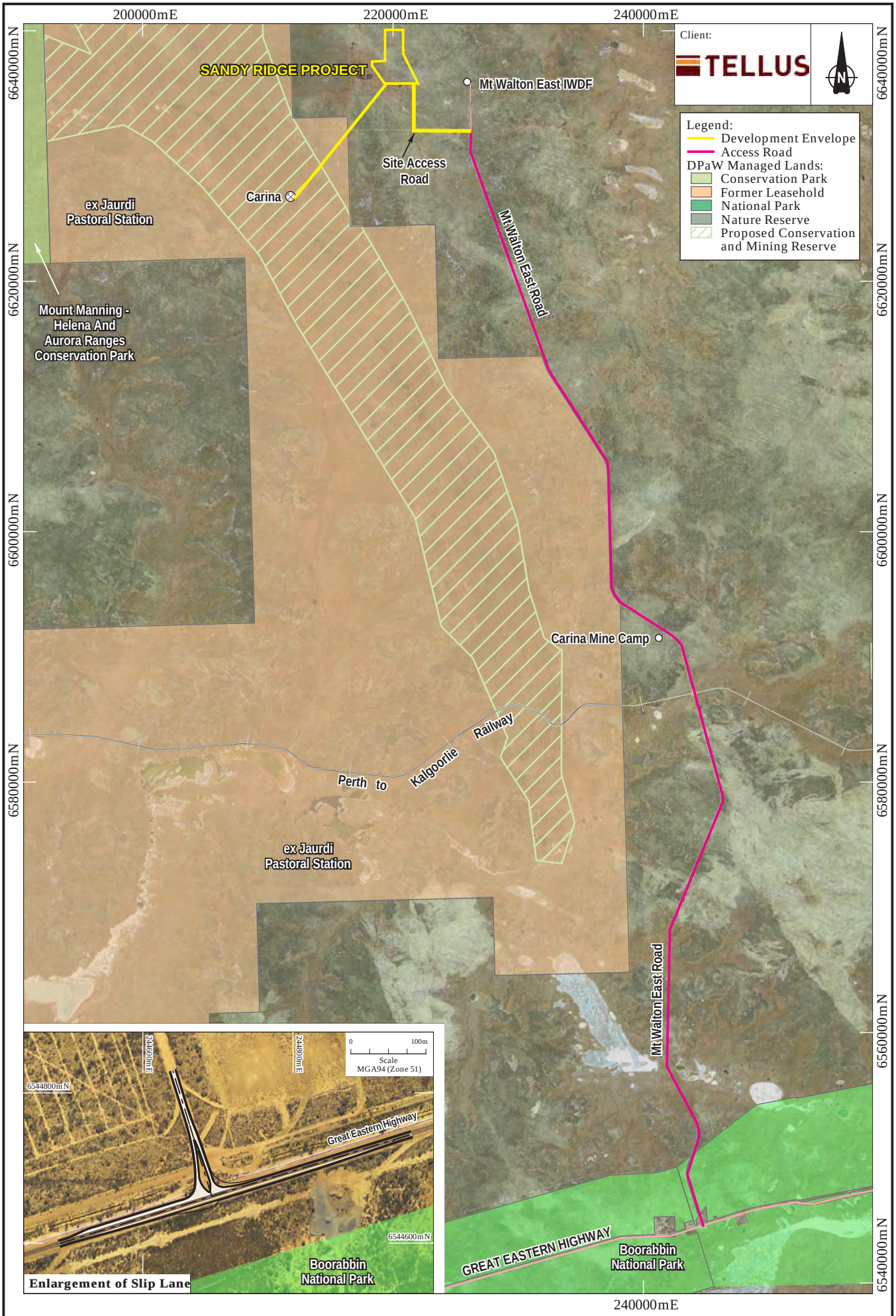
Sandy Ridge Project

Development Envelope

Environmental Scoping Document

Figure: **2**



0 5km

Scale 1:400,000
MGA94 (Zone 51)

CAD Ref: g2294_ESD_005.dgn

Date: December 2015 | Rev: B | A4

Aurora environmental

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Sandy Ridge Project

Access to Sandy Ridge

Environmental Scoping Document

Figure:

3

2.2 Elements of the Proposal

The proposal would produce up to 290,000 tonnes per annum (tpa) of kaolin through the development and operation of open cut mine pits. The ore would be processed via an onsite processing plant and the kaolin products transferred from Sandy Ridge to the domestic market or to Fremantle Port for export overseas. All overburden would be returned to the pits, and topsoil returned and the surface revegetated.

The waste aspect of the proposal involves disposing of up to 100,000 tpa of intractable, hazardous and low level radioactive wastes in the mine voids (herein referred to as 'cells') over a 25 year period (i.e. 2,500,000 tonnes in total). Wastes would be accepted from across Australia with indicative transport routes into Western Australia shown on Figure 4. Waste acceptance criteria will be presented in the PER.

Transport of waste is not part of the proposal as it will be addressed under the appropriate legislation, guidelines and codes such as; *Radiation Safety (Transport of Radioactive Substances) Regulations 2002* (Western Australia), *Environmental Protection (Controlled Waste) Regulations 2004*, Transport of Dangerous Goods by Road or Rail (Commonwealth of Australia, 2014), *National Environment Protection (Movement of Controlled Waste between States and Territories) Measure 1998* and the Code for Safe Transport of Radioactive Material (ARPANSA, 2014).

Cells would be filled in layers with multiple sections in each layer. Each layer would be divided into sections containing wastes of similar characteristics. Each section will be backfilled, compacted and all air pockets/voids excluded. Each layer will be compacted, until approximately 7m below the ground surface, where a thick capping layer of low permeability clay will be installed to prevent water ingress into the cell. Following this more backfilling and a clay domed cap would be situated on the top of the cell, to shed any landing rainfall. During the waste disposal process a roof canopy is positioned over the cell to exclude rainfall prior to the thick capping layer being installed.

Likely chemical wastes to be disposed of in the cells include; arsenic or arsenic containing compounds, cyanide inorganic compounds, chromium (VI) compounds, lead or lead compounds, spent pot liners, soils contaminated with heavy metals, asbestos and pesticides, hydrocarbon wastes and phosphates from the agricultural industry. Likely radioactive wastes to be disposed of in the cells within specific shafts include those that can meet the <3,700 Becquerel per gram and < 30 years half–life criteria. These radioactive wastes are generally generated by; medical research and industry, operation of research facilities (e.g. laboratory coats, overshoes, gloves), Naturally Occurring Radioactive Materials (NORMs) occurring on pipework and scale from industry, oil spills containing NORMs and orphan sources (i.e. gauges and instrumentation). Wastes which will not be disposed of into cells include; infectious materials, nuclear material, uncertified waste, putrescible waste and gases. The Proposal does not include the acceptance of nuclear waste as defined by Part 3 of the *Nuclear Waste Storage and Transportation (Prohibition) Act 1999* (WA). This will be further clarified in the PER.

Infrastructure required to support the mining and waste disposal operation include; access roads, mine infrastructure (process plant, offices, warehouses, hardstands, weighbridges, explosives magazine etc.), water pipeline, Class II landfill (for putrescible waste generated at the site), accommodation camp, ore and overburden stockpiles, mobile plant, water tanks, power generators and sewerage treatment systems.

0 100km

Scale 1:10,000,000
MGA94 (Zone 52)

CAD Ref: g2294_ESD_006.dgn

Date: October 2015 | Rev: A | A4

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Sandy Ridge Project

Indicative Transport Routes

Environmental Scoping Document

Figure: 4

Table 2–1 outlines the key physical and operational elements of the proposal.

Table 2–1: Key proposal characteristics

SUMMARY OF THE PROPOSAL		
Proposal title	Sandy Ridge Project	
Proponent name	Tellus Holdings Ltd	
Short description	The Proposal is to develop a kaolin open cut mine and use the voids resulting from mining for the secure storage and isolation of hazardous, intractable waste and low level radioactive waste using best practice storage and isolation safety case. The Proposal is located approximately 75 km north-east of Koolyanobbing, Western Australia (Figure 1).	
PHYSICAL ELEMENTS		
Element	**Location**	**Proposed Extent Authorised**
Pits/Cells	Figure 2	Clearing no more than 202.3 hectares (ha) within 1004.2 ha development envelope
Mine Infrastructure	Figure 2	Clearing no more than 17.2 ha within 1004.2 ha development envelope
Accommodation Camp	Figure 2	Clearing no more than 2.5 ha within 1004.2 ha development envelope
Class II Landfill	Figure 2	Clearing no more than 0.25 ha within 1004.2 ha development envelope
Underground storage area	Figure 2	Clearing no more than 4 ha within 1004.2 ha development envelope
Access Roads	Figure 3	Clearing no more than 22.2 ha within 1004.2 ha development envelope.
Water pipeline	Figure 2 and 3	Clearing no more than 27.6 ha within 1004.2 ha development envelope
Total disturbed area		Clearing no more than 276.05 ha within 1004.2 ha development envelope
OPERATIONAL ELEMENTS		
Element	**Location**	**Proposed Extent Authorised**
Ore Processing	Kaolin Plant, Figure 2, coordinates: 220800mE, 6637520mN	Processing of no more than 290,000 tpa
Class IV and Class V waste disposal	Pits/Cells, Figure 2 coordinates: 219920mE, 6638195mN	Disposal of no more than 100,000 tpa. Average amount per annum 66,000 t. Maximum amount disposed 2,500,000 t over a 25 year period.
Class II Landfill for waste generated on the site.	Class II Landfill, Figure 2 coordinates: 218507mE, 6637370mN	Disposal of no more than 500 tpa

SUMMARY OF THE PROPOSAL		
Water Use	Water Tanks, Figure 2 coordinates: 220770mE, 6637430mN	0.18 GL/year sourced from water tanks onsite that are supplied via a water pipeline from the Mineral Resources Carina Iron Ore Mine.

2.3 Potential Impacts of the Proposal

The aspects of the Proposal which pose potential significant risks to the environment include the handling and storage of hazardous, intractable and radioactive waste. The construction and operation of the mine and waste facility have the potential to impact; flora and vegetation, land and soils, terrestrial fauna, inland waters environmental quality and human health. Tellus plan to manage each aspect of the project to ensure any potential impacts to these key environmental factors are as low as reasonably practicable.

2.4 Operation and Closure

The project lifecycle includes mining and disposal of wastes until approximately year 25, monitoring and rehabilitation of waste cells until year 45, and following this an institutional control period (ICP) will apply. The ICP will ensure the wastes stored in the geological repository are undisturbed for a period of time until they no longer pose a risk to human activities conducted on the surface of the waste cells. The ICP is yet to be agreed with the Radiological Council of Western Australia.

Tellus will provide ample financial provisioning to the State to cover any environmental monitoring required during the ICP. It is envisaged that funding will be deposited into an Escrowed Fund established by Tellus through an impost built into waste charges. The level of funding will be determined based on the estimated cost of monitoring during the ICP with an allowance based on an independent risk assessment for rehabilitation works during the ICP.

3 PRELIMINARY KEY ENVIRONMENTAL FACTORS AND SCOPE OF WORK

The key proposal characteristics in Table 2–1 have informed the identification of the preliminary key environmental factors for the proposal, in accordance with *EAG 8 Environmental principles, factors and objectives*. The preliminary key environmental factors for this proposal and the EPA's objective for each of those factors are identified in Table 3–1.

To provide context to the preliminary key environmental factors, Table 3-1 also identifies the aspects of the proposal that cause the factors to be key factors, and the potential impacts and risks likely to be relevant to the assessment. All of this in turn has informed the work required to be conducted in the environmental review.

Finally Table 3–1 identifies the policy documents that establish how the EPA expects the environmental factors to be addressed in the environmental review and the PER document that follows. In addition to these policy documents, the following EPA policies apply to the proposal and environmental impact assessment process:

- EAG 1 *Defining the key characteristics of a proposal* (EPA, 2012)
- EAG 8 *Environmental principles, factors and objectives* (EPA, 2015)
- EAG 9 *Application of a significance framework in the environmental impact assessment process* (EPA, 2013)
- EAG 17 *Preparation of Management Plans under Part IV of the Environmental Protection Act 1986* (EPA, 2015).

The EPA expects that the proponent will consider all relevant contemporary policy documents, including revisions or updates of the policy documents listed and any new, relevant policy that is published during the development of the PER.

Impacts associated with proposals are to be considered at a local and regional scale, including evaluation of cumulative impacts, and provide details of proposed management/mitigation measures. This includes whether environmental offsets are required by application of the mitigation hierarchy, consistent with the Government of Western Australia (2014) WA Environmental Offsets Guidelines.

The PER document will explicitly demonstrate and document, how the relevant considerations of the principles of the *Environmental Protection Act 1986*, Section 4A, and the policies and guidelines listed in Table 3–1 are considered in the PER.

Table 3–1: Preliminary key environmental factors and required work

FLORA AND VEGETATION	
EPA objective	To maintain representation, diversity, viability and ecological function at the species, population and community level.
Relevant aspects	• Handling and storage of hazardous and intractable waste. • Creation of development elements including mine pits. • Fire protection measures. • Blasting generating dust. • Use of saline water for dust suppression. • Introduction of weeds. • Failure of waste cell containment and generation of leachate. • Construction and operation of a water pipeline from Carina pit to the infrastructure area.
Potential impacts and risks	• Direct clearing of native vegetation. • Gamma radiation exposure to flora and vegetation. • Radon emanating from waste cells. • Altered fire regime, and lack of flowering. • Changed hydrology (quality and quantity of surface water) and effects on downstream vegetation. • Dust deposition on vegetation and subsequent smothering inducing death. • Uptake of saline water from dust suppression. • Introduction and spread of weeds that compete with native vegetation. • Transpiration of leachate from waste cell and the subsequent death of vegetation. • Potential for fire and loss of vegetation. • The construction and operation of the water pipeline could directly (e.g. clearing) and indirectly (e.g. leak of saline water) impact native flora and vegetation.
Required work	1. Undertake flora and vegetation surveys in accordance with the requirements of EPA Guidance Statement No. 51 in areas that are likely to be directly or indirectly impacted as a result of the proposal. This should include a description of the surveys undertaken, the baseline data collected, and the environmental values identified. 2. Describe the existing flora and vegetation within the development envelope including its relevance within a wider regional context. The development envelope includes: pit/cells area, mine infrastructure area, underground storage area, accommodation camp, Class II landfill, water pipeline corridor and access roads. 3. Assess the direct and indirect impacts associated with the proposal on the flora and vegetation within the development envelope. A quantitative analysis of the likely extent of these impacts on vegetation units and conservation significant flora species (as defined in Guidance Statement 51, page 29). Analysis of impacts on vegetation to include: • The area (in ha) of each vegetation unit to be impacted (directly and indirectly) in a 'worst case' scenario.

	• The total area (in ha) of each vegetation unit within the development envelope. • A summary of the known regional distribution of vegetation units. • Identification of vegetation units which may be a component of Threatened or Priority Ecological Communities. • Identification of any significant species and if present, an analysis of impacts on conservation significant species to include: - The number of plants, and number of populations of plants, to be impacted (directly and indirectly) in a 'worst case' scenario. - The total number of plants and populations within the local area/study area. - A summary of the known populations of the species including distribution, number of populations and the number of plants or an estimate of the number of plants. 4. Address the potential for environmental impacts on Department of Parks and Wildlife managed lands and values including; Former Jaurdi Pastoral Lease, Mount Manning Range Nature Reserve and Mount Manning — Helena–Aurora Ranges Conservation Park. 5. Provide figure(s) showing the extent of clearing or predicted extent of loss of vegetation and conservation significant flora species from both direct and indirect impacts (including, but not limited to, changed hydrology and dust). 6. Assess potential radiation impacts on flora and vegetation using the Environmental Risk from Ionising Contaminants: Assessment and Management (ERICA) tool. Australian specific data should be used where available. 7. Provide a discussion of the proposed management, monitoring and mitigation methods to be implemented demonstrating that the design of the proposal has addressed the mitigation hierarchy in relation to impacts (direct and indirect) on flora and vegetation and consideration of alternatives. 8. Outline the outcomes/objectives, management, monitoring, trigger and contingency actions, to ensure impacts (direct and indirect) are not greater than predicted. 9. Complete EPA's checklist for documents submitted for Environmental Impact Assessment (EIA) on terrestrial biodiversity. 10. To the extent that significant residual impacts cannot be avoided, reduced, mitigated, or subsequently restored – identify appropriate offsets. 11. Provide a statement of how the proponent considers the EPA's objective for this factor has been addressed.
Relevant policies	The following relevant policies and any future revisions apply: *Relevant EPA policies and guidelines* • Checklist for documents submitted for EIA on marine and terrestrial biodiversity. • Position Statement 2: Environmental Protection of Native Vegetation in Western Australia, Perth, Western Australia (EPA, 2000). • Position Statement 3: Terrestrial Biological Surveys as an Element of Biodiversity Protection, Perth, Western Australia (EPA, 2002). • Guidance Statement No. 51: Terrestrial Flora and Vegetation Surveys for Environmental Impact Assessment in Western Australia June 2004, Perth, Western Australia (EPA, 2005). • Environmental Offsets Policy, Perth, Western Australia (Government of Western Australia, 2011). • Environmental Offsets Guidelines, Perth, Western Australia (Government of Western

	Australia, 2014). • Technical Guide – Flora and Vegetation Surveys for Environmental Impact Assessment (EPA and Department of Parks and Wildlife, 2015). *Relevant Commonwealth policies and guidelines* • *Environment Protection and Biodiversity Conservation Act 1999* Environmental Offsets Policy (DSEWPAC, 2012). • Outcomes–based Conditions Policy *Environment Protection and Biodiversity Conservation Act 1999* — Draft (Commonwealth of Australia, 2015).
Relevant technical guidelines	The following relevant technical guidelines and any future revisions apply: • A review of existing Australian radionuclide activity concentration data in non-human biota inhabiting uranium mining environments. Technical Report 167 (Australian Radiation Protection and Nuclear Safety Agency (ARPANSA), 2014).
TERRESTRIAL ENVIRONMENTAL QUALITY	
EPA objective	To maintain the quality of land and soils so that the environment values, both ecological and social, are protected.
Relevant aspects	• Handling and storage of hazardous and intractable waste. • Creation of mine pits. • Rehabilitation.
Potential impacts and risks	• Sterilisation of minerals beneath the cells. • Degradation of stockpiled soils over time. • Gamma radiation exposure on surrounding soils. • Radon emanating from waste cells. • Soil contamination from leaks/spills. • Subsidence and instability of waste cell allowing infiltration of water and generation of leachate. • Change in landform to surrounding landscape.
Required work	12. Conduct a baseline soils assessment of the development envelope which includes recommendations for soil handling to minimised degradation of stockpiled soils. 13. Conduct long term (10,000 years) Landform Evolution Modelling of behaviour and performance of landforms and associated containment systems, including waste cell capping systems, modelled under a range of climatic events. 14. Assess potential impacts on the surrounding environment if leachate was generated from the waste cells. 15. Assess potential radiation impacts on surrounding soils/land using the Environmental Risk from Ionising Contaminants: Assessment and Management (ERICA) tool. Australian specific data should be used where available. 16. Provide details of the engineering design of waste cells to minimise risk of environmental exposure to as low as reasonably achievable. The design of waste cells would ensure long term encapsulation of wastes that reduces any risks to the environment and environmental values to an acceptable level. 17. Provide a graphical conceptual representation of the final landform within the pit/cells

	area once all cells have been filled and capped. 18. Provide evidence of the stability of the site from a geotechnical and geochemical perspective. Include a subsidence monitoring program upon closure of a cell. 19. Show how the proposal will meet the requirements of the National Waste Policy, and State Waste Strategy, including but not limited to: • The need for a large class V facility in Western Australia; • The benefit and risks of the facility receiving waste from all of Australia; • How the facility would not result in an increased production of hazardous waste; • The volumes and types of waste it will receive and if other treatment options are available for these wastes; • The potential for recycling of wastes at the facility; and • Reducing the viability of the site for future disposal of Class V wastes through the disposal of Class IV waste. 20. Describe the proposed management, monitoring and mitigation methods to be implemented demonstrating that the design of the proposal has addressed the mitigation hierarchy in relation to impacts (direct and indirect) on soils/land. 21. Provide a Mine Closure Plan. Rehabilitation and closure management and mitigation measures should be described in a Mine Closure Plan. A final mine closure plan should be provided as an appendix to the PER and prepared in accordance with the Guidelines for Preparing Mine Closure Plans jointly prepared by the DMP and the EPA. 22. Provide a Waste Facility Decommissioning and Closure Management Plan as an appendix to the PER to describe the closure of the waste cells. 23. Provide a Radioactive Waste Management Plan as an appendix to the PER to describe the high-level management to be implemented to mitigate the risks associated with radioactive waste. 24. Outline the outcomes/objectives, trigger and contingency actions to ensure impacts (direct and indirect) are not greater than predicted. 25. Provide a statement of how the proponent considers the EPA's objective for this factor has been addressed.
Relevant policy	The following relevant policies and any future revisions apply: *Relevant EPA policies and guidelines* • Guidance for the Assessment of Environmental Factors. Rehabilitation of Terrestrial Ecosystems. No. 6 (EPA, 2006). • Environmental Protection Bulletin No. 19 EPA involvement in mine closure (EPA, 2015). • Guidelines for Preparing Mine Closure Plans, Perth, Western Australia (EPA & DMP, 2015). *Relevant Commonwealth policies and guidelines* • National Waste Policy: Less Waste, More Resources (Department of the Environment, Water, Heritage and the Arts, 2009). • Outcomes–based Conditions Policy Environment Protection and Biodiversity Conservation Act 1999 — Draft (Commonwealth of Australia, 2015).
Relevant technical guidelines	The following relevant technical guidelines and any future revisions apply: • Leading practice sustainable development program for the mining industry (DRET, 2008).

TERRESTRIAL FAUNA	
EPA objective	To maintain representation, diversity, viability and ecological function at the species, population and assemblage level.
Relevant aspects	• Handling and storage of hazardous and intractable waste. • Creation of development elements including mine pits. • Fire protection measures. • Generation of noise from blasting. • Presence of infrastructure (e.g. water pond, landfill, mine voids). • Failure of waste cell containment and generation of leachate.
Potential impacts and risks	• Direct clearing of habitat resulting in the loss or fragmentation of fauna habitat. • Gamma radiation exposure to fauna. • Radon emanating from waste cells. • Temporary or permanent hearing loss to fauna in the vicinity of blasting. • Displacement of fauna, increased predation and competition for resources. • Increase in feral fauna and pests attracted to the water and food resources at the site. • Injury or death from fauna ingress into pit/cell. • Injury or death of fauna from collision (i.e. vehicle strike) with waste carrier, vehicles and equipment. • Generation of void space and subsequent collapse/instability of the waste cell, leading to exposure of fauna on the waste cell surface. Exposure may range from injury to death. • Potential for fire and loss of fauna/fauna habitat.
Required work	26. Conduct a Level 1 Fauna Survey in accordance with the requirements of Guidance Statement 56 to provide a comprehensive listing of fauna known or likely to occur in the habitat present, and identification of conservation significant fauna species likely to occur in the development envelope. 27. A Level 2 Fauna Survey will be conducted in accordance with Guidance Statement 56 (EPA, 2004) if the Level 1 Survey indicates that a survey at this level is justified. 28. Conduct a Targeted Malleefowl Survey. 29. Describe the terrestrial fauna within the development envelope including its relevance within a wider regional context. 30. Provide a description of all direct and indirect impacts including fire. 31. Assess potential radiation impacts on terrestrial fauna using the Environmental Risk from Ionising Contaminants: Assessment and Management (ERICA) tool. Australian specific data should be used where available. 32. Discussion of the proposed management, monitoring and mitigation methods to be implemented demonstrating that the design of the proposal has minimised impacts on terrestrial fauna and habitat. 33. Outline the outcomes/objectives, trigger and contingency actions to ensure impacts (direct and indirect) are not greater than predicted. 34. Complete EPA's checklist for documents submitted for Environmental Impact Assessment (EIA) on terrestrial biodiversity.

	35. To the extent that significant residual impacts cannot be avoided, reduced, mitigated, or subsequently restored – identify appropriate offsets. 36. Provide a statement of how the proponent considers the EPA's objective for this factor has been addressed.
Relevant policy	The following relevant policies and any future revisions apply: *Relevant EPA policies and guidelines* • Checklist for documents submitted for EIA on marine and terrestrial biodiversity. • EPA Position Statement No. 3 Terrestrial Biological Surveys as an Element of Biodiversity Protection (EPA, 2002). • Guidance Statement No. 56 Terrestrial Fauna Surveys for Environmental Impact Assessment in Western Australia June 2004 (EPA, 2004). • Guidance Statement No. 20 Sampling of Short Range Endemic Invertebrate Fauna for Environmental Impact Assessment (EPA, 2009). • Technical Guide – Terrestrial Vertebrate Fauna Surveys for Environmental Impact Assessment. Technical report of the Environmental Protection Authority and the Department of Environment and Conservation (Hyder et al., 2010). • Environmental Offsets Policy, Perth, Western Australia (Government of Western Australia, 2011). • Environmental Offsets Guidelines, Perth, Western Australia (Government of Western Australia, 2014). *Relevant Commonwealth policies and guidelines* • *Environment Protection and Biodiversity Conservation Act 1999* Environmental Offsets Policy (DSEWPAC, 2012). • Outcomes–based Conditions Policy Environment Protection and Biodiversity Conservation Act 1999 — Draft (Commonwealth of Australia, 2015). • Guide for Radiation Protection of the Environment. RPS G–1 (ARPANSA, 2015). • National Recovery Plan for Malleefowl *Leipoa ocellata* (Benshemesh, 2007). • Survey Guidelines for Australia's Threatened Birds. EPBC Act survey guidelines 6.2 (Department of the Environment, Water, Heritage and the Arts, 2010). • Outcomes–based Conditions Policy Environment Protection and Biodiversity Conservation Act 1999 — Draft (Commonwealth of Australia, 2015).

INLAND WATERS ENVIRONMENTAL QUALITY	
EPA objective	To maintain the quality of groundwater and surface water, sediment and biota so that the environmental values, both ecological and social, are protected.
Relevant aspects	Handling and storage of hazardous and intractable waste.
Potential impacts and risks	• Leak/spill from waste package may contaminate surface water runoff and groundwater. • Generation of leachate from waste package may contaminate surface water runoff and groundwater.
Required work	37. Conduct a hydrogeological assessment to determine the presence of an aquifer. 38. Conduct a hydrology assessment to assess impacts to surface water runoff and surface water bodies. 39. Conduct modelling to assess the potential for a leachate plume to develop. 40. Conduct long term (10,000 years) Landform Evolution Modelling of behaviour and performance of landforms and associated containment systems, including waste cell capping systems, modelled under a range of climatic events. 41. Describe the existing hydrogeological and hydrological setting of the development envelope. 42. Describe how waste will be contained within the cells. 43. Describe the impacts from this proposal on the associated inland water quality including direct and indirect impacts. 44. Assess the impacts to water quality from sourcing water from the Carina Iron Ore Mine over 25 years. 45. Provide a graphical conceptual representation of the final landform within the pit/cells area once all cells have been filled and capped. 46. Provide a Mine Closure Plan. Rehabilitation and closure management and mitigation measures should be described in a Mine Closure Plan. A final mine closure plan should be provided as an appendix to the PER and prepared in accordance with the Guidelines for Preparing Mine Closure Plans jointly prepared by the DMP and the EPA. 47. Provide a Waste Facility Decommissioning and Closure Management Plan as an appendix to the PER to describe the closure of the waste cells. 48. Provide a Radioactive Waste Management Plan as an appendix to the PER to describe the high-level management to be implemented to mitigate the risks associated with radioactive waste. 49. Outline the outcomes/objectives, management, monitoring, trigger and contingency actions to ensure impacts (direct and indirect) are not greater than predicted. 50. Provide a statement of how the proponent considers the EPA's objective for this factor has been addressed.
Relevant policy	The following relevant policies and any future revisions apply: *Relevant EPA policies and guidelines* • Guidance for the Assessment of Environmental Factors. Rehabilitation of Terrestrial Ecosystems. No. 6 (EPA, 2006). • Guidelines for Preparing Mine Closure Plans, Perth, Western Australia (EPA & DMP, 2015)

	• Environmental Protection Bulletin No. 19 EPA involvement in mine closure (EPA, 2015). *Relevant Commonwealth policies and guidelines* • Outcomes–based Conditions Policy *Environment Protection and Biodiversity Conservation Act 1999* — Draft (Commonwealth of Australia, 2015).
Relevant technical guidelines	The following relevant technical guidelines and any future revisions apply: • Leading practice sustainable development program for the mining industry (DRET, 2008). • Water Quality Protection Notes, Perth, Western Australia (DoW, various published dates). • Operational Policy No.5.12 – Hydrogeological reporting associated with a groundwater well licence, Perth, Western Australia (DoW, 2009).
HUMAN HEALTH	
EPA objective	To ensure that human health is not adversely affected.
Relevant aspects	• Handling and storage of hazardous and intractable waste. • Failure of waste cell containment structures.
Potential impacts and risks	• Leak/spill during; unpacking of waste, temporary storage, handling or placement in cell. • Radiation exposure (internal exposure pathways and external exposure pathways) to workers during unpacking of waste, temporary storage, handling or placement in cell. • Radon emanating from waste cells. • Generation of void space and subsequent collapse/instability of the waste cell, leading to exposure of humans on the waste cell surface. Exposure may range from injury to death. • Dust emission from kaolin mining and subsequently the handling and processing of materials on site. • Potential for fire and loss of life.
Required work	51. Define and model the radiation exposure pathways (internal exposure pathways and external exposure pathways); provide exposure estimates of the workforce and any other identified critical groups, during operation and post closure. 52. Conduct long term (10,000 years) Landform Evolution Modelling of behaviour and performance of landforms and associated containment systems, including waste cell capping systems, modelled under a range of climatic events. 53. Conduct a desktop assessment of the radionuclides and metals likely to be present in the geology of the development envelope, based on an interpretation of the site geology, exploration drilling data previously collected, and publically available geophysical mapping. The assessment should explain if naturally occurring radionuclides and metals are likely to be of environmental significance or detrimental to human health during the development of the project and throughout operations. 54. Conduct an assessment of potential impacts to human health. 55. Conduct an assessment of risks to human health from bush tucker consumption in the region from radiological sources and other contaminants. This should be based upon local diet, determined through consultation with the local community. 56. Discuss the proposed management (including fire management measures), monitoring and mitigation methods to be implemented demonstrating that the design of the proposal has addressed the mitigation hierarchy in relation to impacts on human health. 57. Outline the outcomes/objectives, management, monitoring, trigger and contingency

	actions to ensure impacts (direct and indirect) are not greater than predicted. 58. Provide information on how the proposal will be compliant with the *Food Act 2008* and Australian Drinking Water Quality Guidelines and prepare a Drinking Water Quality monitoring and compliance plan. 59. Provide information on management of asbestiform materials should they be found during construction of the proposal, or if they are received at the site. 60. Provide details of the engineering design of waste cells to minimise risk of human exposure to as low as reasonably achievable. The design of waste cells would ensure long term encapsulation of wastes that reduces any risks to human health, the environment and environmental values to an acceptable level. 61. Provide details of the engineering design of waste cells to show best practice design for containment of wastes. This will draw on international best practice and expertise in encapsulating similar wastes around the world. 62. Undertake an independent peer review of the engineering design of waste cells to confirm best practice design has been met. 63. Provide a graphical conceptual representation of the final landform within the pit/cells area once all cells have been filled and capped. 64. Provide a Mine Closure Plan. Rehabilitation and closure management and mitigation measures should be described in a Mine Closure Plan. A final mine closure plan should be provided as an appendix to the PER and prepared in accordance with the Guidelines for Preparing Mine Closure Plans jointly prepared by the DMP and the EPA. 65. Provide a Waste Facility Decommissioning and Closure Management Plan as an appendix to the PER to describe the closure of the waste cells. 66. Provide a Radioactive Waste Management Plan as an appendix to the PER to describe the high-level management to be implemented to mitigate the risks associated with radioactive waste. This will include details of how radioactive waste is handled, stored, monitored in accordance with relevant legislation and policies. 67. Prepare and provide an Operating Strategy for the proposal. The Operating Strategy will be prepared to an appropriate level and include a high level description of components and where necessary detail elements such as waste acceptance criteria to facilitate environmental assessment. The Operating Strategy will provide details of how waste is handled, stored, monitored accordance with *Environmental Protection (Controlled waste) Regulations 2004*. 68. Provide information on wastewater management on site. 69. Provide an Emergency Response and Management Plan as an Appendix to the PER to describe the management actions to be implemented to respond to an emergency. 70. Provide a statement of how the proponent considers the EPA's objective for this factor has been addressed.
Relevant policy	The following relevant policies and any future revisions apply: *Relevant EPA policies and guidelines* • Guidance Statement No. 55: Guidance for the assessment of environmental factors – Implementing best practice in proposals submitted to the environmental impact assessment process, Perth, Western Australia (EPA, 2003). • Guidance Statement No. 3 Separation Distances between Industrial and Sensitive Land Uses (EPA, 2005). • Guidance for the Assessment of Environmental Factors. Rehabilitation of Terrestrial

	Ecosystems. No. 6 (EPA, 2006). • Consideration of environmental impacts from noise (EAG13) (EPA, 2014). • Guidelines for Preparing Mine Closure Plans, Perth, Western Australia (EPA & DMP, 2015). • Environmental Protection Bulletin No. 19 EPA involvement in mine closure (EPA, 2015). *Relevant Commonwealth policies and guidelines* • Outcomes–based Conditions Policy *Environment Protection and Biodiversity Conservation Act 1999* — Draft (Commonwealth of Australia, 2015). • National Environment Protection (Movement of Controlled Waste between States and Territories) Measure 1998 (as amended) (NEPC, 1998).
Relevant technical guidelines	The following relevant technical guidelines and any future revisions apply: National • Code of Practice for the near-surface disposal of radioactive waste in Australia (NHMRC, 1992). • Classification and Disposal of Radioactive Waste in Australia – Consideration of Criteria for Near Surface Burial in an Arid Area. Technical Report Series No. 152 (ARPANSA, 2010). • Leading practice sustainable development program for the mining industry (DRET, 2008). • Australian Drinking Water Guidelines (NHMRC, as amended 2015). State • Landfill Waste Classification and Waste Definitions (DEC, 1996 as amended 2009). • Assessment and Management of Contaminated Sites (DER, 2014). • Managing naturally occurring radioactive material (NORM) in mining and mineral processing – Guidelines: - NORM–4.1 Controlling dust strategies - NORM–5 Dose assessment. (DMP, 2010). • Guidelines for the Assessment, Remediation and Management of Asbestos–Contaminated Sites in Western Australia (Department of Health, 2009). • Guidance Note on Public Health Risk Management of Asbestiform Materials Associated with Mining (Department of Health, 2013).
HERITAGE	
EPA objective	To ensure that historical and cultural associations, and natural heritage, are not adversely affected.
Relevant aspects	Clearing of vegetation of cultural significance. Excavating land of cultural significance. Storage of waste underground.
Potential impacts and risks	Disturbance to aboriginal heritage sites and / or cultural associations within the development envelope.
Required work	71. Identify sites of cultural significance. 72. Assess potential impacts on any heritage sites and / or cultural associations in accordance with EPA (2004) *Assessment of Aboriginal Heritage guidelines*.

	73. If heritage sites and/or cultural associations are identified, and are likely to be impacted, propose management measures to avoid or minimise impacts. If this is not possible propose restoration measures or offset any impacts. 74. Provide a statement of how the proponent considers the EPA's objective for this factor has been addressed.
Relevant policy	The following relevant policies and any future revisions apply: *Relevant EPA policies and guidelines* • Guidance Statement No. 41 Assessment of Aboriginal Heritage (EPA, 2004). *Relevant Commonwealth policies and guidelines* • Outcomes–based Conditions Policy *Environment Protection and Biodiversity Conservation Act 1999* — Draft (Commonwealth of Australia, 2015).
Relevant technical guidelines	The following relevant technical guidelines and any future revisions apply: • Aboriginal Heritage – Due Diligence Guidelines. Version 3.0. (DAA & DPC, 2013).
OFFSETS (INTEGRATING FACTOR)	
EPA objective	To counterbalance any significant residual environmental impacts or uncertainty through the application of offsets.
Relevant aspects	Residual environmental impacts or uncertainty resulting from implementation of proposal and subsequent application of mitigation hierarchy to reduce impacts and/or uncertainty.
Potential impacts and risks	• Waste will be buried underground in perpetuity. • Disturbance to native vegetation (direct and indirectly). • Impacts to significant species or communities. • Loss or alteration of terrestrial fauna habitat. • Changes in fauna movement as a result of changes in habitat connectivity. • Alterations to hydrological processes, quality and quantity associated with surface and/or groundwater that may sustain conservation significant terrestrial fauna.
Required work	75. All residual (following management) risks and impacts from the proposal to be considered in terms of their significance, and whether the proposal will result in significant residual impacts that require offsetting in accordance with the Western Australian Government's offset policy and guidelines. 76. Provide a statement of how the proponent considers the EPA's objective for this factor has been addressed.
Relevant policy	The following relevant policies and any future revisions apply: *Relevant EPA policies and guidelines* • Environmental Offsets Policy, Perth, Western Australia (Government of Western Australia, 2011) • Environmental Offsets Guidelines, Perth, Western Australia (Government of Western Australia, 2014). • Environmental Protection Bulletin No. 1 – Environmental offsets (EPA, 2014).

	Relevant Commonwealth policies and guidelines • *Environment Protection and Biodiversity Conservation Act 1999* Environmental Offsets Policy (DSEWPAC, 2012). • Outcomes–based Conditions Policy *Environment Protection and Biodiversity Conservation Act 1999* — Draft (Commonwealth of Australia, 2015).
REHABILITATION AND DECOMMISSIONING (INTEGRATING FACTOR)	
EPA objective	To ensure that premises are decommissioned and rehabilitated in an ecologically sustainable manner.
Relevant aspects	• Rehabilitation of the site. • Decommissioning of the site. • Revegetation of clay caps. • Long-term management of the site.
Potential impacts and risks	• Waste cell subsides allowing infiltration of water and generation of leachate. • Topsoil is degraded and unable to support a functioning ecosystem. • Erosion/ gullies/ deep rooted vegetation create cracks in the clay capping which allows water to infiltrate and generate leachate from the stored waste. • Vegetation does not grow and is unable to support a functioning ecosystem. • Fauna does not return to the vegetation and therefore a functioning ecosystem is not achieved. • Long term impacts to Human Health, Terrestrial Environmental Quality and Inland Waters Environmental Quality.
Required work	77. Conduct long term (10,000 years) Landform Evolution Modelling of behaviour and performance of landforms and associated containment systems, including waste cell capping systems, modelled under a range of climatic events. 78. Provide a graphical conceptual representation of the final landform within the pit/cells area once all cells have been filled and capped. 79. Provide a Mine Closure Plan. Rehabilitation and closure management and mitigation measures should be described in a Mine Closure Plan. A final mine closure plan should be provided as an appendix to the PER and prepared in accordance with the Guidelines for Preparing Mine Closure Plans jointly prepared by the DMP and the EPA. 80. Provide a Waste Facility Decommissioning and Closure Management Plan as an appendix to the PER to describe the closure of the waste cells. 81. Provide a Radioactive Waste Management Plan as an appendix to the PER to describe the high-level management to be implemented to mitigate the risks associated with radioactive waste. 82. Provide a statement of how the proponent considers the EPA's objective for this factor has been addressed.
Relevant policy	The following relevant policies and any future revisions apply: *Relevant EPA policies and guidelines* • Guidance for the Assessment of Environmental Factors. Rehabilitation of Terrestrial Ecosystems. No. 6 (EPA, 2006)

	• Guidelines for Preparing Mine Closure Plans (EPA & DMP, 2015). • Environmental Protection Bulletin No. 19 EPA involvement in mine closure (EPA, 2015). *Relevant Commonwealth policies and guidelines* • Outcomes–based Conditions Policy *Environment Protection and Biodiversity Conservation Act 1999* — Draft (Commonwealth of Australia, 2015).
Relevant technical guidelines	The following relevant technical guidelines and any future revisions apply: • Leading practice sustainable development program for the mining industry (DRET, 2008).

4 STAKEHOLDER CONSULTATION

The EPA expects that the proponent will consult with stakeholders who are interested in, or affected by, the Proposal. This includes decision-making authorities (DMAs), other relevant State government departments and local government authorities, environmental non-government organisations and the local community.

The proponent must document the stakeholder consultation undertaken and the outcomes, including any adjustments to the proposal and any future plans for consultation. This is to be addressed in a specific section of the PER document and, in addition, key outcomes of consultation are to be reported against the preliminary key environmental factors as relevant.

It is expected that as a part of the consultation with DMA's there will be discussion around each agency's specific regulatory approvals, and a demonstration that other factors can be managed by another regulatory body.

The first phase of stakeholder consultation for the Proposal has been completed which included providing information to key government stakeholders including the following:

- Government Departments; Mines and Petroleum, Finance, Lands, Environment Regulation, State Development, Aboriginal Affairs, Fire and Emergency Services, and Health (Radiation Health Branch).
- Principal Policy Advisors to the; Minister for Finance and Mines and Petroleum, Minister for Environment and Heritage.
- Chairman of the EPA and Office of the EPA personnel.
- Commonwealth Department of the Environment.
- Australian Radiation Protection and Nuclear Safety Agency (ARPANSA).
- Regional politicians (of all political parties).
- Local governments; Coolgardie, Southern Cross and Kalgoorlie-Boulder.
- The local communities of Coolgardie and Kalgoorlie (February 2016).
- Local aboriginal families, Goldfields Land and Sea Council and local politicians.

A specific focus meeting regarding the ESD was held on 14 October 2015 and attended by the; Department of Lands, Department of Environment Regulation, Department of Mines and Petroleum and the Commonwealth Department of the Environment. Several other departments were invited to this meeting but were unable to attend; Radiation Health Branch of the Department of Health, Department of Parks and Wildlife, Department of Water and Department of Aboriginal Affairs. Tellus will continue consulting all key decision making authorities and interested parties throughout the preparation of the PER and post submission of the PER. Information will be provided via the Tellus website (http://www.tellusholdings.com/) and regular news updates will be emailed to interested people.

5 OTHER FACTORS OR MATTERS

During assessment of proposals, other factors or matters will be identified as relevant to the proposal, but not of significance to warrant further assessment by the EPA, or impacts can be regulated by other statutory processes to meet the EPA's objectives.

These factors do not require further work as part of the environmental review, or detailed discussion and evaluation in the PER document, although they must be included in the PER document in a summarised, tabular format noting that the PER document will be subject to public review.

In some circumstances other factors, while not being considered as preliminary key environmental factors, may require greater emphasis in the PER document. This may be due to high public interest or at the request of another stakeholder, so that the potential impacts and management measures associated with the other factor are sufficiently articulated for the public review. For this assessment, the other factor of Amenity, in relation to noise, dust and visual, needs to be concisely described and discussed in the PER document.

Impacts to visual amenity of people utilising the existing and proposed reserve system (including the Mount Manning Range Nature Reserve, Mount Manning — Helena–Aurora Ranges Conservation Park and the Former Jaurdi Pastoral Lease) will be assessed in terms of:

- Impacts to nature based tourism, that is travel routes and the use of public viewpoints in the existing and proposed reserve system; and
- Impacts to scientific study in the existing and proposed reserve system.

Furthermore following consultation with Department of Health and Department of Lands on health and land matters, Tellus will make the following commitment in the PER:

Prior to ground disturbance Tellus will conduct detailed baseline soil sampling in accordance with Department of Health and Department of Lands requirements.

Matters in relation to the water source and viability of this source for the project life will be described in the PER specifically addressing:

- the site water demand, and agreements in place to secure the water source over the project life.
- assess the viability of using the Carina Iron Ore Mine as a water source for 25 years.

It is also important that the proponent be aware that other factors or matters may be identified during the course of the environmental review that were not apparent at the time that this ESD was prepared. If this situation arises, the proponent must consult with the EPA to determine whether these factors and/or matters are to be addressed in the PER document, and if so, to what extent.

6 AGREED ASSESSMENT TIMELINE

Table 6–1 sets out the timeline for the assessment of the proposal agreed between the EPA and the proponent. Proponents are expected to meet the agreed timeline, and in doing so, provide adequate, quality information to inform the assessment.

Table 6–1: Assessment timeline

Key Stages of Assessment	Agreed Completion Date
EPA approval of ESD	May meeting
Proponent submits first adequate draft PER document	6 June 2016
Office of the Environmental Protection Authority (OEPA) provides comment on first adequate draft PER document	20 July 2016
Proponent submits adequate revised draft PER document	18 August 2016
EPA authorises release of PER document for public review	1 September 2016
Public review of PER document	2 September 2016 – 11 November 2016
EPA provides Summary of Submissions	1 December 2016
Proponent provides Response to Submissions	29 December 2016
OEPA reviews the Response to Submissions	13 February 2017
OEPA assesses proposal for consideration by EPA	3 April 2017
Preparation and finalisation of EPA assessment report (including two weeks consultation on draft conditions with proponent and key Government agencies)	19 May 2017

If any stage in the agreed timeline is not met or inadequate information is submitted by the proponent, the timing for the completion of subsequent stages of the process will be revised. Equally, where the EPA is unable to meet an agreed completion date in the timeline, the proponent will be advised and the timeline revised.

The proponent should refer to EPA's EAG 6 — Timelines for environmental assessment of proposals for information regarding the responsibilities of proponents and the EPA for achieving timely and effective assessment of proposals.

7 DECISION–MAKING AUTHORITIES

At this stage the authorities listed in Table 7–1 have been identified as DMAs for the proposal. Additional DMAs may be identified during the course of the assessment.

Table 7–1: Decision-making authorities

Authority	Legislation
Minister for Environment	*Environmental Protection Act 1986* *Wildlife Conservation Act 1950*
Minister for Water	*Rights in Water and Irrigation Act 1914*
Minister for Mines and Petroleum	*Mining Act 1978*
Minister for Health	*Radiation Safety Act 1975*
Minister for Lands	*Land Administration Act 1997*
Commonwealth Minister for Environment	*Environment Protection and Biodiversity Conservation Act 1999*
Department of Environment Regulation	*Part V of the Environmental Protection Act 1986* *Environmental Protection (Controlled Waste) Regulations 2004* *Environmental Protection Regulations 1987*
Department of Mines and Petroleum	*Mining Act 1978* *Dangerous Goods and Safety Act 2004* *Dangerous Goods Safety (Storage and handling of non-explosives) Regulation 2007* *Mines Safety and Inspection Act 1994* *Mines Safety and Inspection Regulations 1995*
Radiological Council of Western Australia	*Radiation Safety Act 1975* *Radiation Safety (Transport of Radioactive Substances) Regulations 2002*
Minister for Aboriginal Affairs	*Aboriginal Heritage Act 1972*
Shire of Coolgardie	*Planning Development Act 2005*

8 PARALLEL PROCESSING

The EP Act constrains DMAs from making any decision that could have the effect of causing or allowing the proposal to be implemented. However, the proponent is encouraged to pursue other approvals in parallel with the EPA's assessment noting that the constraint only relates to making an approval decision.

9 PER DOCUMENT

When the EPA is satisfied with the standard of the PER document (refer to section 4.4 of EAG 6) it will provide written authorisation for the release of the document for public review. The proponent must not release the PER document for public review until this authorisation is provided.

The proponent is responsible for advertising the release and availability of the PER document in accordance with instructions that will be issued to the proponent by the EPA. The EPA must be consulted on the timing and details for advertising.

REGULATORY COMPLIANCE CHECKLIST

Environmental Scoping Document Checklist

ESD category	Work required for the PER	PER reference
Flora and vegetation	• Undertake flora and vegetation surveys in accordance with the requirements of EPA Guidance Statement No. 51 in areas that are likely to be directly or indirectly impacted as a result of the proposal. This should include a description of the surveys undertaken, the baseline data collected, and the environmental values identified.	• Section 9.1.
	• Describe the existing flora and vegetation within the development envelope including its relevance within a wider regional context. The development envelope includes: pit/cells area, mine infrastructure area, accommodation camp, Class II landfill, water pipeline corridor and access roads.	• Section 9.1.
	• Assess the direct and indirect impacts associated with the proposal on the flora and vegetation within the development envelope. A quantitative analysis of the likely extent of these impacts on vegetation units and conservation significant flora species (as defined in Guidance Statement 51, page 29).	• Section 10.2.33.
	• Analysis of impacts on vegetation to include:	• Section 10.2.33. • Table 10-2.
	- The area (in ha) of each vegetation unit to be impacted (directly and indirectly) in a 'worst case' scenario.	• Table 9-1.
	- The total area (in ha) of each vegetation unit within the development envelope.	• Section 9.1.2.
	- A summary of the known regional distribution of vegetation units.	• Section 9.1.2.
	- Identification of vegetation units which may be a component of Threatened or Priority Ecological Communities.	• Section 10.2.3.
	- Identification of any significant species and if present, an analysis of impacts on conservation significant species to include:	• Section 10.2.3.

ESD category	Work required for the PER	PER reference
	- The number of plants, and number of populations of plants, to be impacted (directly and indirectly) in a 'worst case' scenario. - The total number of plants and populations within the local area/study area. • A summary of the known populations of the species including distribution, number of populations and the number of plants or an estimate of the number of plants. • Address the potential for environmental impacts on Department of Parks and Wildlife managed lands and values including; Former Jaurdi Pastoral Lease, Mount Manning Range Nature Reserve and Mount Manning — Helena–Aurora Ranges Conservation Park. • Provide figure(s) showing the extent of clearing or predicted extent of loss of vegetation and conservation significant flora species from both direct and indirect impacts (including, but not limited to, changed hydrology and dust). • Assess potential radiation impacts on flora and vegetation using the Environmental Risk from Ionising Contaminants: Assessment and Management (ERICA) tool. Australian specific data should be used where available. • Provide a discussion of the proposed management, monitoring and mitigation methods to be implemented demonstrating that the design of the proposal has addressed the mitigation hierarchy in relation to impacts (direct and indirect) on flora and vegetation and consideration of alternatives. • Outline the outcomes/objectives, management, monitoring, trigger and contingency actions, to ensure impacts (direct and indirect) are not greater than predicted. • Complete EPA's checklist for documents submitted for Environmental Impact Assessment (EIA) on terrestrial biodiversity. • To the extent that significant residual impacts cannot be avoided, reduced, mitigated, or subsequently restored – identify appropriate offsets. • Provide a statement of how the proponent considers the EPA's objective for this factor has been addressed.	• Section 10.2.3. • Section 9.1. • Section10.2.3 and Table 10-4. • Figure 9-1; Figure 9-2a and Figure 9-2b. • Section 10.2.3. • Section 10.2.4. • Section 10.2.4 and 10.2.5. • Appendix A.6. • Section 10.8. • Section 10.2.5.

ESD category	Work required for the PER	PER reference
Terrestrial environmental quality	• Conduct a baseline soils assessment of the development envelope which includes recommendations for soil handling to minimised degradation of stockpiled soils.	• Section 9.2.15; Figure 9-9 and Section 10.3.5.
	• Conduct long term (10,000 years) Landform Evolution Modelling of behaviour and performance of landforms and associated containment systems, including waste cell capping systems, modelled under a range of climatic events.	• Appendix A.7, Section 10.9.3; Figure 10-8 and Figure 10-9.
	• Assess potential impacts on the surrounding environment if leachate was generated from the waste cells.	• Section 10.3.3.
	• Assess potential radiation impacts on surrounding soils/land using the Environmental Risk from Ionising Contaminants: Assessment and Management (ERICA) tool. Australian specific data should be used where available.	• Section 10.3.3.
	• Provide details of the engineering design of waste cells to minimise risk of environmental exposure to as low as reasonably achievable. The design of waste cells would ensure long term encapsulation of wastes that reduces any risks to the environment and environmental values to an acceptable level.	• Section 5.10.2; Section 5.12; Table 5-7; Appendix A.24.
	• Provide a graphical conceptual representation of the final landform within the pit/cells area once all cells have been filled and capped.	• Figure 10-8 and 10-9 and Appendix A.19.
	• Provide evidence of the stability of the site from a geotechnical and geochemical perspective. Include a subsidence monitoring program upon closure of a cell.	• Section 2.3, Appendix A.4 and A.19.
	• Show how the proposal would meet the requirements of the National Waste Policy, and State Waste Strategy, including but not limited to: - The need for a large class V Facility in Western Australia; - The benefit and risks of the Facility receiving waste from all of Australia; - How the Facility would not result in an increased production of hazardous waste; - The volumes and types of waste it would receive and if other treatment options are available for these wastes; - The potential for recycling of wastes at the facility; and	• Section 2.4, Chapter 4 and Chapter 5.

ESD category	Work required for the PER	PER reference
	- Reducing the viability of the site for future disposal of Class V wastes through the disposal of Class IV waste. • Describe the proposed management, monitoring and mitigation methods to be implemented demonstrating that the design of the proposal has addressed the mitigation hierarchy in relation to impacts (direct and indirect) on soils/land. • Provide a Mine Closure Plan. Rehabilitation and closure management and mitigation measures should be described in a Mine Closure Plan. A final mine closure plan should be provided as an appendix to the PER and prepared in accordance with the Guidelines for Preparing Mine Closure Plans jointly prepared by the DMP and the EPA. • Provide a Waste Facility Decommissioning and Closure Management Plan as an appendix to the PER to describe the closure of the waste cells. • Provide a Radioactive Waste Management Plan as an appendix to the PER to describe the high-level management to be implemented to mitigate the risks associated with radioactive waste. • Outline the outcomes/objectives, trigger and contingency actions to ensure impacts (direct and indirect) are not greater than predicted. • Provide a statement of how the proponent considers the EPA's objective for this factor has been addressed.	• Section 5.5.4 and Section 10.3.4. • Appendix A.19. • Appendix A.18. • Appendix A.14.A.17 • Section 10.4.5. • Section 10.4.5.
Terrestrial Fauna	• Conduct a Level 1 Fauna Survey in accordance with the requirements of Guidance Statement 56 to provide a comprehensive listing of fauna known or likely to occur in the habitat present, and identification of conservation significant fauna species likely to occur in the development envelope. • A Level 2 Fauna Survey would be conducted in accordance with Guidance Statement 56 (EPA, 2004) if the Level 1 Survey indicates that a survey at this level is justified. • Conduct a Targeted Malleefowl Survey. • Describe the terrestrial fauna within the development envelope including its relevance within a wider regional context. • Provide a description of all direct and indirect impacts including fire.	• Section 9.3.1 and 10.4.2 and Appendix A.8. • Section 9.3.1 and 10.4.2 and Appendix A.8. • Section 9.3.3 and Appendix A.8. • Section 9.3.1 and Appendix A.8. • Section 10.4.3. • Section 10.4.3 and Appendix A.14.

ESD category	Work required for the PER	PER reference
	• Assess potential radiation impacts on terrestrial fauna using the Environmental Risk from Ionising Contaminants: Assessment and Management (ERICA) tool. Australian specific data should be used where available. • Discussion of the proposed management, monitoring and mitigation methods to be implemented demonstrating that the design of the proposal has minimised impacts on terrestrial fauna and habitat. • Outline the outcomes/objectives, trigger and contingency actions to ensure impacts (direct and indirect) are not greater than predicted. • Complete EPA's checklist for documents submitted for Environmental Impact Assessment (EIA) on terrestrial biodiversity. • To the extent that significant residual impacts cannot be avoided, reduced, mitigated, or subsequently restored – identify appropriate offsets. • Provide a statement of how the proponent considers the EPA's objective for this factor has been addressed.	• Section 10.4.4. • Section 10.4.5. • Appendix A.9. • Section 10.8. • Section 10.4.5.
Inland Waters Environmental Quality	• Conduct a hydrogeological assessment to determine the presence of an aquifer. • Conduct a hydrology assessment to assess impacts to surface water runoff and surface water bodies. • Conduct modelling to assess the potential for a leachate plume to develop. • Conduct long term (10,000 years) Landform Evolution Modelling of behaviour and performance of landforms and associated containment systems, including waste cell capping systems, modelled under a range of climatic events. • Describe the existing hydrogeological and hydrological setting of the development envelope. • Describe how waste would be contained within the cells. • Describe the impacts from this proposal on the associated inland water quality including direct and indirect impacts.	• Section 9.4. • Section 9.4. • Appendix A.11 and Section 10.3.3. • Appendix A.7 and Section 10.3.3. • Section 9.4 and Figure 5-15 to 5- 17. • Section 5.5.4 and Appendix A.23. • Section 10.5.3. • Section 5.9.2 and Section 10.5.3. • Figures 10-8 and 10-9.

ESD category	Work required for the PER	PER reference
	• Assess the impacts to water quality from sourcing water from the Carina Iron Ore Mine over 25 years. • Provide a graphical conceptual representation of the final landform within the pit/cells area once all cells have been filled and capped. • Provide a Mine Closure Plan. Rehabilitation and closure management and mitigation measures should be described in a Mine Closure Plan. A final mine closure plan should be provided as an appendix to the PER and prepared in accordance with the Guidelines for Preparing Mine Closure Plans jointly prepared by the DMP and the EPA. • Provide a Waste Facility Decommissioning and Closure Management Plan as an appendix to the PER to describe the closure of the waste cells. • Provide a Radioactive Waste Management Plan as an appendix to the PER to describe the high-level management to be implemented to mitigate the risks associated with radioactive waste. • Outline the outcomes/objectives, management, monitoring, trigger and contingency actions to ensure impacts (direct and indirect) are not greater than predicted. • Provide a statement of how the proponent considers the EPA's objective for this factor has been addressed.	• Appendix A.19. • Appendix A.18. • Appendix A.14. • Section 10.5.3 and 10.5.4. • Section 10.5.4.
Human Health	• Define and model the radiation exposure pathways (internal exposure pathways and external exposure pathways); provide exposure estimates of the workforce and any other identified critical groups, during operation and post closure. • Conduct long term (10,000 years) Landform Evolution Modelling of behaviour and performance of landforms and associated containment systems, including waste cell capping systems, modelled under a range of climatic events. • Conduct a desktop assessment of the radionuclides and metals likely to be present in the geology of the development envelope, based on an interpretation of the site geology, exploration drilling data previously collected, and publicly available geophysical mapping. The assessment should explain if naturally occurring radionuclides and metals are likely to be of environmental significance or detrimental to human health during the development of the Proposal9 and throughout operations.	• Appendix A.14. • Appendix A.7 and Section 10.9.3. • Appendix A.6.

ESD category	Work required for the PER	PER reference
	• Conduct an assessment of potential impacts to human health.	• Section 10.6.3.
	• Conduct an assessment of risks to human health from bush tucker consumption in the region from radiological sources and other contaminants. This should be based upon local diet, determined through consultation with the local community.	• Section 10.6.3.
	• Discuss the proposed management (including fire management measures), monitoring and mitigation methods to be implemented demonstrating that the design of the proposal has addressed the mitigation hierarchy in relation to impacts on human health.	• Section 10.6.4.
	• Outline the outcomes/objectives, management, monitoring, trigger and contingency actions to ensure impacts (direct and indirect) are not greater than predicted.	• Section 10.6.4.
	• Provide information on how the proposal would be compliant with the *Food Act 2008* and Australian Drinking Water Quality Guidelines and prepare a Drinking Water Quality monitoring and compliance plan.	• Section 10.6.4 and Appendix A.20.
	• Provide information on management of asbestiform materials should they be found during construction of the proposal, or if they are received at the site.	• Section 10.6.4.
	• Provide details of the engineering design of waste cells to minimise risk of human exposure to as low as reasonably achievable. The design of waste cells would ensure long term encapsulation of wastes that reduces any risks to human health, the environment and environmental values to an acceptable level.	• Sections 5.5 and Appendix A.16.
	• Provide details of the engineering design of waste cells to show best practice design for containment of wastes. This would draw on international best practice and expertise in encapsulating similar wastes around the world.	• Section 5.5.
	• Undertake an independent peer review of the engineering design of waste cells to confirm best practice design has been met.	• Appendix A.21.
	• Provide a graphical conceptual representation of the final landform within the pit/cells area once all cells have been filled and capped.	• Figures 10-8 and 10-9 and Appendix A.7
	• Provide a Mine Closure Plan. Rehabilitation and closure management and mitigation measures should be described in a Mine Closure Plan. A final mine closure plan should	• Appendix A.19.

ESD category	Work required for the PER	PER reference
	be provided as an appendix to the PER and prepared in accordance with the Guidelines for Preparing Mine Closure Plans jointly prepared by the DMP and the EPA. • Provide a Waste Facility Decommissioning and Closure Management Plan as an appendix to the PER to describe the closure of the waste cells. • Provide a Radioactive Waste Management Plan as an appendix to the PER to describe the high-level management to be implemented to mitigate the risks associated with radioactive waste. This would include details of how radioactive waste is handled, stored, monitored in accordance with relevant legislation and policies. • Prepare and provide an Operating Strategy for the proposal. The Operating Strategy would be prepared to an appropriate level and include a high level description of components and where necessary detail elements such as waste acceptance criteria to facilitate environmental assessment. The Operating Strategy would provide details of how waste is handled, stored, monitored accordance with *Environmental Protection (Controlled waste) Regulations 2004*. • Provide information on wastewater management on site. • Provide an Emergency Response and Management Plan as an Appendix to the PER to describe the management actions to be implemented to respond to an emergency. • Provide a statement of how the proponent considers the EPA's objective for this factor has been addressed.	• Appendix A.18. • Appendix A.14. • Appendix A.16 and Appendix A.3. • Section 10.6.4. • Appendix A.22. • Section10.6.4 and 10.6.5.
Heritage	• Identify sites of cultural significance. • Assess potential impacts on any heritage sites and / or cultural associations in accordance with EPA (2004) *Assessment of Aboriginal Heritage guidelines*. • If heritage sites and/or cultural associations are identified, and are likely to be impacted, propose management measures to avoid or minimise impacts. If this is not possible, propose restoration measures or offset any impacts. • Provide a statement of how the proponent considers the EPA's objective for this factor has been addressed.	• Section 9.5. • Section10.7.3. • Section 10.7.4. • Section 10.7.5.

ESD category	Work required for the PER	PER reference
Offsets (Integrating Factor)	• All residual (following management) risks and impacts from the proposal to be considered in terms of their significance, and whether the proposal would result in significant residual impacts that require offsetting in accordance with the Western Australian Government's offset policy and guidelines. • Provide a statement of how the proponent considers the EPA's objective for this factor has been addressed.	• Section 10.8.2. • Section 10.8.3.
Rehabilitation and Decommissioning (Integrating Factor)	• Conduct long term (10,000 years) Landform Evolution Modelling of behaviour and performance of landforms and associated containment systems, including waste cell capping systems, modelled under a range of climatic events. • Provide a graphical conceptual representation of the final landform within the pit/cells area once all cells have been filled and capped. • Provide a Mine Closure Plan. Rehabilitation and closure management and mitigation measures should be described in a Mine Closure Plan. A final mine closure plan should be provided as an appendix to the PER and prepared in accordance with the Guidelines for Preparing Mine Closure Plans jointly prepared by the DMP and the EPA. • Provide a Waste Facility Decommissioning and Closure Management Plan as an appendix to the PER to describe the closure of the waste cells. • Provide a Radioactive Waste Management Plan as an appendix to the PER to describe the high-level management to be implemented to mitigate the risks associated with radioactive waste. • Provide a statement of how the proponent considers the EPA's objective for this factor has been addressed.	• Appendix A.7. • Appendix A.7 and Figures 10-8 and 10-9. • Appendix A.19. • Appendix A.18. • Appendix A.14. • Section 10.9.5.

Schedule 4 of the Environment Protection and Biodiversity Conservation Regulations 2000 (Cwlth) Checklist

Regulation	Description	PER reference
1 General information	1.01 The background of the action including: (a) the title of the action;	Section 1.1 and Table 1-2.
	(b) the full name and postal address of the designated proponent;	Section 1.4.
	(c) a clear outline of the objective of the action;	Section 1.6.1.
	(d) the location of the action;	Section 1.3.
	(e) the background to the development of the action;	Section 2.4.1 and Section 2.4.2.
	(f) how the action relates to any other actions (of which the proponent should reasonably be aware) that have been, or are being, taken or that have been approved in the region affected by the action.	Section 10.2.3.
	(g) the current status of the action.	Public Review of the PER.
	(h) the consequences of not proceeding with the action.	Section 2.2.
2 Description	2.01 A description of the action, including: (a) all the components of the action;	Chapter 5.
	(b) the precise location of any works to be undertaken, structures to be built or elements of the action that may have relevant impacts;	Chapter 5.
2 Description	(c) how the works are to be undertaken and design parameters for those aspects of the structures or elements of the action that may have relevant impacts	Section 5.5.
	(d) relevant impacts of the action	Chapter 10.
	(e) proposed safeguards and mitigation measures to deal with relevant impacts of the action;	Chapter 10 and Chapter 12.
	(f) any other requirements for approval or conditions that apply, or that the proponent reasonably believes are likely to apply, to the proposed action;	Chapter 4.
	(g) to the extent reasonably practicable, any feasible alternatives to the action, including: (i) if relevant, the alternative of taking no action. (ii) a comparative description of the impacts of each alternative on the matters protected by the controlling provisions for the action. (iii) sufficient detail to make clear why any alternative is preferred to another.	Chapter 2.
	(h) any consultation about the action, including: (i) any consultation that has already taken place. (ii) proposed consultation about relevant impacts of the action.	Chapter 6.

	(iii) if there has been consultation about the proposed action—any documented response to, or result of, the consultation.	
	(i) identification of affected parties, including a statement mentioning any communities that may be affected and describing their views.	Chapter 6.
3 Relevant impacts	3.01 Information given under paragraph 2.01(d) must include: (a) a description of the relevant impacts of the action. (b) a detailed assessment of the nature and extent of the likely short term and long term relevant impacts. (c) a statement whether any relevant impacts are likely to be unknown, unpredictable or irreversible. (d) analysis of the significance of the relevant impacts. (e) any technical data and other information used or needed to make a detailed assessment of the relevant impacts.	Chapter 10.
4 Proposed safeguards and mitigation measures	4.01 Information given under paragraph 2.01(e) must include: (a) a description, and an assessment of the expected or predicted effectiveness of, the mitigation measures.	Chapter 10.
	(b) any statutory or policy basis for the mitigation measures;	Chapter 4.
	(c) the cost of the mitigation measures;	Costs for mitigation would be developed during detailed design.
	(d) an outline of an environmental management plan that sets out the framework for continuing management, mitigation and monitoring programs for the relevant impacts of the action, including any provisions for independent environmental auditing.	Chapter 11. Appendix A.18. Appendix A.19.
	(e) the name of the agency responsible for endorsing or approving each mitigation measure or monitoring program.	Overall management plans are endorsed by the WA OEAP, DMP and DER.
	(f) a consolidated list of mitigation measures proposed to be undertaken to prevent, minimise or compensate for the relevant impacts of the action, including mitigation measures proposed to be taken by State governments, local governments or the proponent.	Table 12-1.
5 Other approvals and conditions	5.01 Information given under paragraph 2.01(f) must include: (a) details of any local or State government planning scheme, or plan or policy under any local or State government planning system that deals with the proposed action, including: (i) what environmental assessment of the proposed action has been, or is being, carried out under the scheme, plan or policy.	Section 4.6.1 and 4.7.

	(ii) how the scheme provides for the prevention, minimisation and management of any relevant impacts.	
	(b) a description of any approval that has been obtained from a State, Territory or Commonwealth agency or authority (other than an approval under the EPBC Act), including any conditions that apply to the action.	Section 4.4.
	(c) a statement identifying any additional approval that is required.	Section 4.4.
	(d) a description of the monitoring, enforcement and review procedures that apply, or are proposed to apply, to the action.	Table 12-1.
6 Environmental record of person proposing to take the action	6.01 Details of any proceedings under a Commonwealth, State or Territory law for the protection of the environment or the conservation and sustainable use of natural resources against: (a) the person proposing to take the action; and (b) for an action for which a person has applied for a permit, the person making the application.	Section 1.5.
	6.02 If the person proposing to take the action is a corporation, details of the corporation's environmental policy and planning framework.	Section 1.5 and Chapter 11.
7 Information sources	7.01 For information given in a draft public environment report or environmental impact statement, the draft must state: (a) the source of the information. (b) how recent the information is. (c) how the reliability of the information was tested. (d) what uncertainties (if any) are in the information.	Chapter 15.

Environmental Risk Assessment

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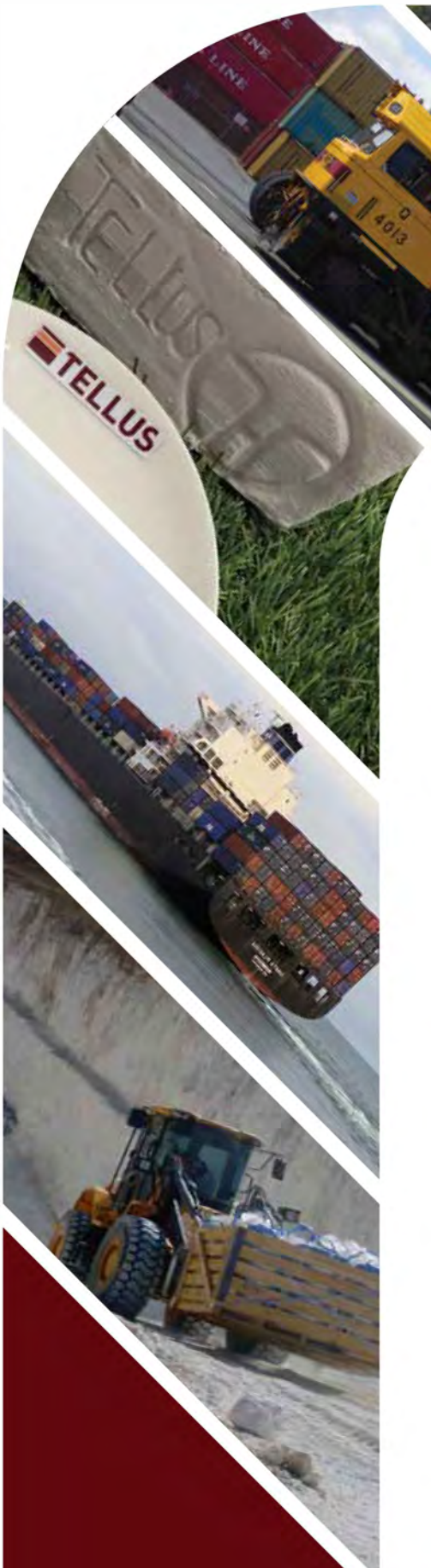

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Sandy Ridge Facility
Environmental Risk Assessment

June 2016

SANDY RIDGE FACILITY ENVIRONMENTAL RISK ASSESSMENT

Draft Report | June 2016

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DISTRIBUTION

Report File Name	Report Status	Author	Date	Distribution
Environmental Risk Assessment –V0.1	V0.1 (Draft)	Aurora Environmental	15 February 2016	Tellus Holdings Ltd
Environmental Risk Assessment –V0.2	V0.2 (Draft)	Aurora Environmental	12 April 2016	Tellus Holdings Ltd
Environmental Risk Assessment	vA	Tellus Holdings Ltd	7 June 2016	OEPA

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ABBREVIATIONS

ADT	Articulated dump truck
Bq/g	Bequerels per gram
DotE	Department of the Environment (Cwlth)
DG	Dangerous goods
DPAW	Department of Parks and Wildlife (WA)
EMS	Environmental Management System
EP Act	*Environmental Protection Act 1986* (WA)
EPBC Act	*Environment Protection and Biodiversity Conservation Act 1999* (Cwlth)
JSA	Job safety analysis
mm	millimetre
PEC	Priority Ecological Community
PER	Public Environmental Review
PPE	personal protective equipment
QA	quality assurance
QC	quality control
TEC	Threatened Ecological Community

1 INTRODUCTION

Tellus Holdings Limited (Tellus) proposes to construct and operate the Sandy Ridge Project. The details of the Sandy Ridge Project are provided in the *Sandy Ridge Project Public Environmental Review* (PER) (Tellus, 2016).

The environmental risks associated with the operational aspects of the project have been assessed by the project team at a workshop. The outcomes of the workshop are documented in this report.

Risks associated with closure were addressed at a separate workshop. The outcomes of that workshop are presented in the Mine Closure Plan and Waste Facility Decommissioning and Closure Plan. These plans are appended to the PER.

2 METHODOLOGY

Tellus adopted the international (*ISO 31000:2009*) and national (*AS/NZS ISO 31000:2009*) (SAI Global, 2009) standard processes for managing environment–related risks. An environmental risk assessment has been undertaken for all operational aspects of the project, in accordance with the procedures outlined in *AS/NZS ISO 31000:2009 Risk Management–Principles and Guidelines* and the handbook *HB 203:2012 Managing Environment–Related Risk* (SAI Global, 2012), using Tellus' Risk Assessment Matrix (AppendixA.1). The risk assessment process is illustrated in Figure 2–1.

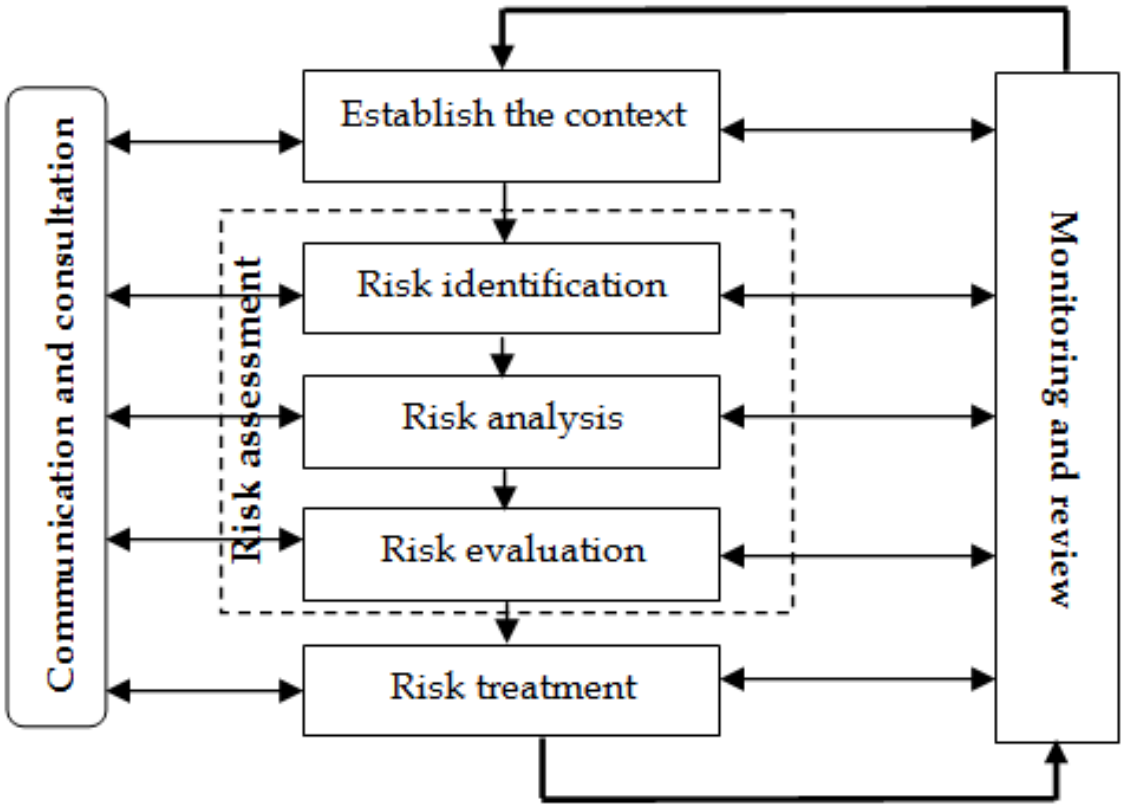

Figure 2–1 Risk assessment process as outlined in HB 203:2012

Each step of the process is described below.

3 ESTABLISH THE CONTEXT

As the project is proposed to be located within Western Australia, the definition of 'environment' for the purpose of the environmental risk assessment was the definition provided under the Western Australian *Environmental Protection Act 1986* (EP Act):

***environment**, subject to subsection (2), means living things, their physical, biological and social surroundings, and interactions between all of these (*Part 1, section 3, subsection 1).

For the purposes of the definition of environment in subsection (1), the social surroundings of man are his aesthetic, cultural, economic and social surroundings to the extent that those surroundings directly affect or are affected by his physical or biological surroundings (Part 1, section 3, subsection 2).

The project is also being assessed by the Commonwealth Department of the Environment (DotE) under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act). Section 528 of the EPBC Act defines environment to include:

(a) ecosystems and their constituent parts, including people and communities; and

(b) natural and physical resources; and

(c) the qualities and characteristics of locations, places and areas; and

(d) Heritage values of places; and

(e) the social, economic and cultural aspects of a thing mentioned in paragraph (a), (b), or (c).

The EPBC Act's definition for environment was also considered in establishing the context of the risk assessment.

The glossary of other terminology used during the environmental risk assessment was as per *HB 203:2012 Managing Environment–Related Risk* as listed below:

Consequence	includes cascade effects and impacts to the organization's business and activities arising from environmental-related issues (e.g. regulatory fines, clean-up costs, and damaged reputation as well as enhanced reputation, continued licence to operate, and regulatory approvals).
Environmental Aspect	element of an organization's activities, products or services that can interact with the environment.
Environmental impact	any change to the environment, whether adverse or beneficial, wholly or partially resulting from an organization's activities, products or services.
Hazard	source of potential harm.

Likelihood	chance of something happening, whether defined, measured or determined objectively or subjectively, qualitatively or quantitatively, and described using general terms or mathematically.
Risk	the effect of uncertainty on objectives.
Risk Source	a tangible or intangible element that alone or in combination has the intrinsic potential to give rise to risk.

4 RISK ASSESSMENT

4.1 Risk identification

The sources of risks, environmental aspects and potential environmental impacts, as defined by *HB 203:2012* were identified in a workshop attended by the Tellus Project Leader, Tellus Environment and Approvals Manager, Tellus Engineer, and Aurora Environmental representatives. The identified environmental aspects were categorised into 'planned' that is those aspects which Tellus know will occur during the project, and those that are 'unplanned' and may credibly occur during the project, but which Tellus has no control over the frequency of occurrence. The identified potential environmental impact is based on the 'worst–case' credible impact.

4.2 Risk analysis

Qualitative risk analysis was used to evaluate the significance of the likelihood of the consequence (Table 4–1). Analysis of the inherent risk was undertaken assuming no management/mitigation controls were in place. The group then discussed appropriate management and mitigation measures that would be implemented to reduce the likelihood or consequence, and then analysed the final residual risk.

Table 4–1 Environmental risk register

Risk Number	Environmental Aspect	Sources of Risk (Hazard)	Potential Environmental Impact (Worst case)	Pre–management risk	Management and Mitigation Measures	Post–management Risk		Residual risk
						Likelihood	Consequence	
1	**Transport of hazardous/intractable waste.**	Chemical spill (40 t) from the shipping container. Chemical spill onto roads.	Death and/or acute or chronic illness in humans and biota exposed to the spill.	Extreme	Waste packaged in bulka bags/drums. Bulka bags/drums transported inside shipping container. Shipping container securely fastened to truck. Dangerous goods (DG) rated trucks (e.g. better brakes, rollover systems) are used only. Trucks travel on sealed roads or controlled site access roads. Transport contractor on Tellus Register of Approved Transporters. Audits of transport contractor's procedural controls. For high risk loads (e.g. arsenic trioxide) individual risk assessment and transport management plan. Emergency Response and Management Plan.	Rare	Catastrophic	High
2	**Explosions.**	Fuel storage facility, storage and use of gas. Diesel fuel tank and piping reticulation. Explosives magazine.	Degradation of air quality (localised). Death/injury of humans and biota within the vicinity of the blast zone or in the path of the fire. Creates bushfire.	Extreme	Fuel storage facilities and systems designed to meet relevant Code. Inspection to ensure compliance including maintenance. Firebreaks. Firefighting equipment. Operational procedures. Hot work permits. Restricted access to the explosives store (i.e. must hold shot firer licence).	Rare	Major	High
3	**Transport of hazardous/intractable waste.**	Truck crash.	Death and injury to humans.	High	Trucks travel on sealed main roads only. Transport contractor on Tellus Register of Approved Transporters. Well maintained trucks. Approved, experienced and licensed drivers. Audits of transport contractor's procedural controls. Emergency Response and Management Plan. Police, emergency services.	Rare	Catastrophic	High
4	**Transport of hazardous/intractable waste.**	Chemical spill (e.g. flyash/ SPL) on the road, into surrounding environment (e.g. river).	Death and/or injury to fauna and flora.	High	Waste packaged as appropriate to level of hazard. Bulka bags/drums transported inside shipping container. Shipping container securely fastened to truck. DG rated trucks (e.g. better brakes, rollover systems) are used only. Trucks travel on sealed roads or	Possible	Moderate	High

Risk Number	Environmental Aspect	Sources of Risk (Hazard)	Potential Environmental Impact (Worst case)	Pre–management risk	Management and Mitigation Measures	Post–management Risk		Residual risk
						Likelihood	Consequence	
					controlled site access roads. Transport contractor on Tellus Register of Approved Transporters. Audits of transport contractor's procedural controls. For high risk loads (e.g. arsenic trioxide) individual risk assessment and transport management plan. Emergency Response and Management Plan.			
5	**Transport of hazardous/intractable waste.**	Collision with native fauna.	Road kill of Threatened/Priority fauna.	High	Trucks travel on sealed main roads only. Transport contractor on Tellus Register of Approved Transporters. Well maintained trucks. Approved, experienced and licensed drivers. Audits of transport contractor's procedural controls. Report to DPAW and DotE. Where feasible control speed and use headlights.	Possible	Moderate	High
6	**Creation of mine pits.**	Clearing native vegetation.	Loss of native vegetation.	High	Avoid Priority species. Engineering design to minimise amount of vegetation to be cleared. Supervision of clearing. Operational Procedure. Regular toolbox meeting. Training of Operators.	Almost Certain	Insignificant	High
7	**Creation of firebreak.**	Clearing native vegetation.	Opportunity for weeds to establish.	High	Weed monitoring and removal.	Almost Certain	Insignificant	High
8	**Transport of radioactive waste.**	Radioactive waste spill (200L drum).	Humans within the vicinity of the spill will receive a one off higher dose of radiation above background levels.	High	Small quantities received on average annually. Drums transported inside shipping container. Shipping container securely fastened to truck. Priority given to transporting on heavy haulage routes. For all radioactive waste an individual risk assessment is completed. Disposal permit issued by government. Transport contractor on Tellus Register of Approved Transporters. Audits of transport contractor's procedural controls. Emergency Response and Management Plan. Inform Radiation Health Branch WA.	Unlikely	Moderate	Moderate
9	**Presence of infrastructure (e.g. turkeys nest, landfill, mine voids).**	Attraction of birds, mammals, vermin and feral animals to water source. Fauna falling into pit/cell.	Injury or death of Threatened/Priority fauna.	High	Fencing of contaminated water pond. Fencing around landfill. Covering of landfill once the trench is	Unlikely	Moderate	Moderate

Risk Number	Environmental Aspect	Sources of Risk (Hazard)	Potential Environmental Impact (Worst case)	Pre–management risk	Management and Mitigation Measures	Post–management Risk		Residual risk
						Likelihood	Consequence	
		Presence of vermin carrying disease at landfill, being eaten by predators.			full. Weekly litter inspection and clean-up. Weekly toolbox meeting. Training of operators. Operational bunding around cell. Ramps into and out of cell. Daily inspection of water ponds for trapped/injured fauna. Daily inspections of access roads for roadkill.			
10	**Naturally occurring events.**	Bushfire.	Injury of workers and site visitors. Toxic smoke plume. Contaminated fire water. Soil contamination.	High	Emergency Response and Management Plan. Low fuel load in woodlands. Firebreaks. Firefighting facilities onsite. Minimal flammable waste, facilities and goods onsite.	Rare	Moderate	Moderate
11	**Introduction of weeds.**	Incoming waste carriers. Incoming supply vehicles and 4wds. Incoming site visitors, staff vehicles. Bird poo.	Establishment of weeds on the site and competition for resources (e.g. water) with native vegetation.	High	Weed monitoring procedures. Inspections of light vehicles and brush downs. Mining plant wash down before its used onsite. Weed removal where necessary.	Likely	Insignificant	Moderate
12	**Accidental fire within infrastructure.**	Flammable goods packed into shipping container. Vehicle fire in cell. Fire in buildings.	Release of toxic gas, adverse health impacts to workers/public/fauna.	High	Equipment maintenance. Fire detection/ suppression systems. Design codes for waste storage. Operational procedures. Regular toolbox meetings. Training of operators. Chemical wastes stored in shipping containers. Use of diesel engines instead of petrol in storage areas. Multiple waste storages areas in container hardstand.	Rare	Moderate	Moderate
13	**Handling of hazardous/intractable waste.**	Chemical spill during offloading of waste from ADT into cell. Chemical spill during manoeuvring of waste package into place in the cell.	Death of worker in the cell.	Extreme	PPE. Training of operators. Regular toolbox meetings. Operating procedures. Restricted access to the cell. Recirculating air throughout cabs. JSAs specific to waste being handled. Equipment maintained. Secondary egress from cell. Everyone in the cell immediately evacuates.	Unlikely	Minor	Low
14	**Creation of cell and waste disposal progressing.**	Surface water runoff into cell.	Generation of leachate and degradation of groundwater.	Extreme	Roof canopy over open cell. Operational bunding around cell, drains into V drain and sump. Levees to divert surface water flow. Backfill around waste packages with high matric suction potential.	Rare	Insignificant	Low

Risk Number	Environmental Aspect	Sources of Risk (Hazard)	Potential Environmental Impact (Worst case)	Pre–management risk	Management and Mitigation Measures	Post–management Risk		Residual risk
						Likelihood	Consequence	
					Primary containment in place in each waste package (e.g. liner in bulka bag).			
15	**Handling of hazardous/intractable waste.**	Chemical spill during unloading/reloading of waste from/into shipping container in Waste Inspection Shed. Chemical spill during sampling and testing of waste package in laboratory.	Death and/or acute or chronic illness in humans exposed to the spill.	High	Operating procedures. Training of operators. Regular toolbox meetings. PPE. Regular equipment maintenance. Visual assessment. Safety shower. Spill kits. First aiders/first aid kit. Evacuation procedure.	Rare	Minor	Low
16	**Handling of hazardous/intractable waste.**	Vehicle collision with ADT. Loss of containment from shipping container subsequent spill of solids.	Localised soil contamination. Damage to vegetation. Toxic dust dispersal affecting vegetation/fauna off the development envelope.	High	Operating procedures. Training of operators. Regular toolbox meetings. Onsite traffic management. Speed limits. Two-way communications. Regular equipment maintenance. Visual assessment. Spill kit.	Rare	Minor	Low
17	**Handling of radioactive waste.**	NORMs spill during unloading/reloading of waste from/into shipping container in Waste Inspection Shed.	Humans within the vicinity of the spill will receive a one off higher dose of radiation above background levels.	High	Operating procedures. Training of operators. Regular toolbox meetings. PPE. Regular equipment maintenance. Visual assessment. Safety shower. Spill kits. First aiders/first aid kit. Dose meters on workers. Radiation measurements.	Rare	Minor	Low
18	**Handling of radioactive waste.**	Gamma exposure during offloading of waste from ADT into shaft.	Humans within the vicinity of the shaft above with higher dose of radiation above background levels or chemical exposure.	High	Operating procedures. Training of operators. Regular toolbox meetings. Engineering design. Dose meters. Radiation measurements. Exclusion zones.	Rare	Insignificant	Low
19	**Wash down of shipping containers.**	Contaminated wash water washes off the wash down pad. Dust on hardstand from, residual of wash down. Containment overflows during extreme rainfall event. Liner faulty/fails.	Soil contamination.	High	Operating procedures. QA/QC testing on liner. Engineering design (500mm freeboard, ponds sufficient capacity). Shallow monitoring bores. Contain the overflow through secondary sump. Clean-up/disposal of contaminated soil.	Unlikely	Minor	Low

Risk Number	Environmental Aspect	Sources of Risk (Hazard)	Potential Environmental Impact (Worst case)	Pre–management risk	Management and Mitigation Measures	Post–management Risk		Residual risk
						Likelihood	Consequence	
20	**Creation of mine pits.**	Blasting. Physical removal of topsoil, subsoil and kaolin.	Dust emissions affecting workers. Dust emissions settling on plant leaves, affecting photosynthesis and potentially killing plants. Noise emissions affecting workers. Noise emissions temporarily or permanently damaging the hearing of fauna in the vicinity of the blast.	High	Operating procedures. Blasting conducted once per year, duration of a few seconds. PPE for workers.	Unlikely	Insignificant	Low
21	**Construction and operation of water pipeline.**	Leak/spill of saline water.	Death of vegetation through osmosis of saline water.	High	Design controls to monitor flow through pipeline, any loss will immediately trigger an alarm in the process control unit. Close isolation valves. Cease pumping water. Inspect water pipeline and repair damaged section.	Unlikely	Minor	Low
22	**Use of saline water for dust suppression**	Watering of native vegetation along roadsides.	Uptake of saline/brackish water and death of vegetation.	High	Use a dribble bar on the back of the water cart instead of a spray bar. Equipment maintenance. Operational procedures.	Unlikely	Minor	Low
23	**Fencing of the waste cells.**	Exclusion of fauna from potential habitat.	Forced translocation of fauna into other habitat and increased predation in new habitat. Potential for injury/death of Threatened/Priority fauna.	High	Fences to be removed following revegetation of cells.	Rare	Insignificant	Low
24	**Waste Laboratory.**	Minor spill of sample during testing of waste.	Radiation exposure of workers. Injury (e.g. chemical burn) to workers.	High	Building enclosed and contains fume hoods. PPE. Operational procedures for waste testing. Training of operators. Regular toolbox meetings.	Unlikely	Minor	Low
25	**Water retention ponds.**	Leak/crack in pond liners.	Release of contaminated water to underlying and surrounding soils and potentially damage vegetation associated with those soils.	High	Shallow monitoring bores. Low hydraulic conductivity means water will not move far from the spill site. Contain and clean-up the spill. Operational procedure for management of contaminated soils.	Unlikely	Insignificant	Low
26	**Naturally occurring events.**	Earthquakes (size 3)	Slight subsidence of cell, consolidates backfill and potential creates a void.	High	Post event inspection and records kept. Repair cap if needed. Subsidence monitoring.	Possible	Insignificant	Low
27	**Naturally occurring events.**	Cyclones/flood	Increased rainfall at the site, overflow of contaminated water ponds which may impact surrounding soils, cause widespread flooding of contaminated surface water and injure/kill biota. Cell fills with water and leachate generated and then overflows to surrounding environment.	High	Small quantities of water. 24 hour duration. Pumping out of ponds prior to cyclone. Roof canopy over open cell. Operational bunds around cells. Waste still in shipping containers. Waste disposal halted if cyclone expected.	Unlikely	Insignificant	Low

Risk Number	Environmental Aspect	Sources of Risk (Hazard)	Potential Environmental Impact (Worst case)	Pre–management risk	Management and Mitigation Measures	Post–management Risk		Residual risk
						Likelihood	Consequence	
28	**Aboriginal heritage.**	Destruction of aboriginal heritage site and/or cultural association. E.g. clearing native vegetation of significance, excavating land of significance, and storing waste on significant land.	Degradation of heritage value of the local area.	High	Aboriginal heritage pre-construction survey. Operational procedure for encountering aboriginal cultural material. Contact WA Police if skeletal material is uncovered.	Rare	Minor	Low
29	**Malleefowl mound.**	Construction of pipeline. Construction of road and plant.	Removal or damage to an active nesting mound.	High	Malleefowl survey pre-construction to identify new active mounds. Re-design pipeline route to avoid mound. Report disturbance to an active mound to DPAW and DotE.	Rare	Insignificant	Low
30	**Landform.**	Change in landform by placing domed caps up to 5m higher than the landscape.	Ponding around the toe of the landform. Erosion.	Moderate	Engineering design. Engineering design as constructed plans demonstrated cell backfilling/capping competently constructed. Long term erosion modelling. Revegetation present.	Unlikely	Insignificant	Low
31	**Transport of chemical and radioactive waste.**	Leak of liquid material (e.g. NORM and/or hydrocarbons) from shipping container.	Humans within the vicinity of the leaked material may receive a one off higher dose of radiation above background levels or chemical exposure.	Low	Waste packaged as appropriate to level of hazard. Trucks travel on sealed roads or controlled site access roads. Transport contractor on Tellus Register of Approved Transporters. DG rated trucks (e.g. carry clean-up equipment and drivers are trained to manage a leak). Audits of transport contractor's procedural controls. Truck parked up. Source of the leak is investigated and contained. Clean-up undertaken. Emergency Response and Management Plan.	Rare	Insignificant	Low
32	**Subsurface waste disposal**	Permanent isolation of waste over geological time.	Gamma radiation exposure at the surface on surrounding humans, soils, flora and vegetation and fauna.	Low	Safety Case and Safety Assessment. Baseline radiation survey. Engineering design - depth of burial in shaft and materials used in construction. Institutional control period.	Rare	Insignificant	Low
33	**Creation of mine pits**	Alteration to surface water runoff.	Changes hydrology (quality and quantity) and effects on downstream vegetation.	Low	High infiltration rate (500mm/day). High evaporation rate (2400mm/year). Vegetation likely to be dependent only on landing rainfall, not runoff. Vegetation adapted to low rainfall (<250mm/year).	Rare	Insignificant	Low
34	**Kaolin Process Plant**	Operation of the plant. Incorrect disposal of wastes (e.g. waste oil, oily rags)	Dust emissions affecting workers. Dust emissions settling on plant leaves, affecting photosynthesis and potentially killing	Low	Wet process. Building enclosed and contains dust extraction system (e.g. baghouse).	Rare	Insignificant	Low

Risk Number	Environmental Aspect	Sources of Risk (Hazard)	Potential Environmental Impact (Worst case)	Pre–management risk	Management and Mitigation Measures	Post–management Risk		Residual risk
						Likelihood	Consequence	
			plants. Noise emissions affecting workers. Noise emissions temporarily or permanently damaging the hearing of fauna in the vicinity. Hydrocarbon contamination of soils.		PPE. Noise levels monitored to comply with OHS Regulations. Operational procedures. Training of operators. Regular toolbox meetings. Oily waste disposed offsite.			
35	**Water abstraction from Carina pit**	Create a cone of depression within the Carina pit.	Change to groundwater aquifer (quality and quantity) at Carina pit	Low	Measurements of quality and drawdown of the water within the pit. Monitor abstraction volumes. Groundwater modelling to confirm cone of depression.	Unlikely	Insignificant	Low
36	**Failure of waste cell containment, cell instability/collapse during operations.**	Placement of liquid/gas waste packages into the cell. Over time voids are created in the cell. Generation of leachate as water infiltrates the cell. Failure of cell wall and/or cap. Faulty design. Faulty construction - waste package placement/backfill. Differential settlement. Earthquake. Intentional disturbance to the cell to retrieve radioactive material.	Degradation of groundwater quality.	Low	Seepage rate low. High evaporation rate. High evapotranspiration rates. High energy hydrological environment. Large unsaturated zone and storage capacity beneath each cell. Backfill material is unsaturated and can store water. No aquifer within weathered granite. No groundwater dependent vegetation, Threatened species or TECs/PECs. Engineering design/site selection based on international best practice for near surface geological repositories. Operational procedures for appropriate wastes and waste acceptance criteria. Training of operators. Subsidence monitoring of cap. Groundwater monitoring.	Rare	Insignificant	Low
37	**Waste package comprising a sealed source arrives with an activity concentration >3,700 Bq/g arrives at the site.**	The waste package exceeds the waste acceptance criteria and will not be <370 Bq/g at the end of the institutional control period (300 years).	Potential exposure of workers during handling of the waste package.	Low	Disposal permit issued. Proforma issued. Inspection and measurement of all sealed sources on arrival at site. Dose meters attached to workers.	Rare	Minor	Low
38	**Waste package comprising a sealed source arrives with a half-life greater than 30 years and is placed in the cell.**	The waste package exceeds the waste acceptance criteria and will not be <370 Bq/g at the end of the institutional control period (300 years).	Acute or chronic radiation exposure possible to the public utilising the land in 300 years' time.	Low	Disposal permit issued. Proforma issued. Inspection and measurement of all sealed sources on arrival at site. Depth of burial. Operational procedures.	Rare	Insignificant	Low
39	**Erection of buildings**	Kaolin processing plant will be the tallest building. Tourists will not be allowed to enter the mine site.	Change to visual amenity of people conducting nature based tourism activities in Mount Manning Range Nature Reserve, Mount Manning - Helena - Aurora Ranges Conservation Park.	Low	Normal travel routes on existing roads will not be affected by Tellus operations. 10 km distance from nearest existing reserve (Mount Manning Range) and unlikely the kaolin processing plant	Rare	Insignificant	Low

Risk Number	Environmental Aspect	Sources of Risk (Hazard)	Potential Environmental Impact (Worst case)	Pre–management risk	Management and Mitigation Measures	Post–management Risk		Residual risk
						Likelihood	Consequence	
			Interference with scientific studies in existing and proposed reserve system.		will be visible from this distance. There is not expected to be an encounter with scientists within ex-Jaurdi Pastoral Lease, given operations will be outside of the Lease area.			
40	**Surface water**	Leak or spill from a waste package.	Degradation of water quality.	Low	Minimal volumes of surface water that will be present at the time of a spill/leak (i.e. surface water flows only in extreme rainfall events). Various barriers around, and integrity of, the waste package itself. Factors that affect leachability of solid waste. Unloading of waste packages within enclosed warehouses with bunded concrete floors. Distance to nearest receptor (48 km away).	Rare	Insignificant	Low

4.3 Risk evaluation

The outcome of the risk assessment included the identification of 40 credible risks, of these 28 are planned (i.e. elements of Tellus activities that will interact with the environment) and 12 are unplanned (unexpected interactions with the environment). With the implementation of management and mitigation measures, the division of the residual risks for the project were:

- 7 – High residual risks.
- 5 – Moderate residual risks.
- 28 – Low residual risks.

The residual risks were evaluated using the Tellus risk criteria (Table 4–2).

Table 4–2 Risk criteria

	Extreme	**Unacceptable** further management review required to reduce risk.
	High	**Tolerable** if management determine and accepts risk has been reduced to as low as reasonably practicable.
	Moderate	**Acceptable** with management review for continuous improvement.
	Low	**Acceptable** no further management required.

As stated in *HB 203:2012 Managing Environment–Related Risk:*

'Tolerable' refers to the willingness to live with a risk to secure benefits, on the understanding that it is being properly controlled. 'Tolerability' does not mean 'acceptability'. Tolerating a risk does not mean that it is regarded as negligible, or something that can be ignored, but rather as something that should be kept under review such that if and when feasible and appropriate it can be reduced still further.

'Acceptable' relates to risks that do not need further treatment at this stage. The expression acceptable level of risk refers to the level at which it is decided that further action is not worthwhile, e.g. additional effort will not result in significant reductions in risk levels.

5 RISK TREATMENT

The purpose of risk treatment is to achieve objectives by managing uncertainty as effectively as possible. As no 'Extreme' risks have been identified, and the residual risk levels for all hazards have been evaluated as **Tolerable** or **Acceptable** it is considered no further treatment of risks is required at this stage.

In future environmental risk assessments, if the risk profile is elevated to 'Extreme' risk treatment will be undertaken by Tellus.

6 MONITORING AND REVIEW

Monitoring and review of the environmental risks associated with the project will be conducted using the following methods:

1. Monitor the environment itself – monitoring requirements specified in the PER and the Environmental Management System (EMS) will be undertaken. The outcomes of the monitoring, and any new risks identified will be outlined in future risk assessments.
2. Monitor and respond to losses and incidents – incidents which occur during the construction and operations phase, that potentially lead to environmental harm, will be documented and reviewed.
3. Monitor the implementation of the Emergency Response and Management Plan and where possible continuously improve the procedures outlined in the plan.
4. Use internal and external audits in accordance with EMS requirements.

7 REFERENCES

SAI Global, 2009, *AS/NZS ISO 31000:2009 Risk Management–Principles and Guidelines,* available at: http://infostore.saiglobal.com/store/details.aspx?ProductID=1378670

SAI Global, 2012, *HB 203:2012 Managing Environment–Related Risk,* available at: http://infostore.saiglobal.com/store/details.aspx?ProductID=1516912

APPENDIX

A.1 Risk matrix

Consequence descriptors

Consequences	Insignificant	Minor	Moderate	Major	Catastrophic
Safety and Health	Near miss / hazard.	First aid treatment required.	Medical treatment required, no lost time.	Lost time injury(s) (LTIs).	Potential fatality / multiple LTIs.
Regulatory	No breach of works approval/licence/approval condition	Breach of one works approval/licence/approval condition.	Injunction under the EPBC Act. Infringement notice issued under the EP Act. Breach of several licence conditions/ministerial statement conditions/proponent commitment.	Directed environmental audits under the EPBC Act. Environmental Field Notice, Caution Notice, Management Letter or Non Compliance Notice issued under the EP Act.	Civil and criminal penalties under the EPBC Act and EP Act. Suspension or revocation of works approval/licence.
Pollution	No noise emitted from operation. Minor spill cleaned up in hours to days. No residual contamination following clean-up, no effect on watercourses, water bodies or aquifers.	Low level of noise emitted but not received at noise sensitive premise. Contamination of a watercourse, water body and/or aquifer, cleaned up in days to months.	Moderate level of noise emitted but expected to be below Noise Regulation limits at noise sensitive premises. Massive contamination of a watercourse, water body or aquifer, with clean-up over months to years.	High level of noise emitted and expected to be above the Noise Regulation limits at noise sensitive premises. Massive irreverable contamination of a watercourse, water body or aquifer.	Noise emitted causes temporary or permanent hearing loss. Toxic release off site with massive detrimental effect. Massive pollution with significant remedial work required. Global media interest.
Flora / Fauna	Damage to flora. Death or Injury of individual fauna.	Damage to priority flora. Death or injury of individual priority fauna. Destruction of fauna habitat.	Damage to Threatened/declared rare flora. Destruction of priority flora species. Death of priority fauna species. Death or injury of individual Threatened or Migratory fauna. Damage of critical fauna habitat.	Damage to critically endangered flora. Destruction of Threatened/declared rare flora species. Destruction of critical fauna habitat. Death or injury of individual critically endangered fauna.	Extinction of fauna species. Extinction of flora species. Destruction of critical habitat.

Consequences	Insignificant	Minor	Moderate	Major	Catastrophic
Socio / Political	Localised temporary impact	Localised, short term impact, closure of access roads, temporary loss of amenity.	Localised, long term impact but manageable. Evacuation of site and closure of neighbouring operations.	Localised, long term impact with unmanageable outcomes. Evacuation of site, and people within 200 km of the site, closure of major highway.	Long term regional or national impact, permanent isolation from the site and region.
Heritage	Damage or disturbance occurring near to (but not at) an Aboriginal Site. Access to an Aboriginal Site lost for up to two weeks.	Unauthorised access to or interference with an Aboriginal Site (e.g. movement of an artefact) without causing damage. Access to an Aboriginal Site lost for up to one month.	Minor damage to an Aboriginal Site or to an artefact at an Aboriginal Site. Access to Aboriginal Site lost for up to three months.	Major damage to an Aboriginal Site or to an artefact at an Aboriginal Site. Access to Aboriginal Site lost for up to six months.	Destruction of an Aboriginal Site or an artefact at an Aboriginal Site. Permanent loss of access to an Aboriginal Site.
Financial / Legal	<$50,000	$50,000 - 250,000	$250,000 - 400,000	$400,000 - 10M	>$10m

Likelihood descriptors

Rare	Unlikely	Possible	Likely	Almost Certain
5%	20%	50%	80%	95%
Highly unlikely to occur on this project	Given current practices and procedures, this incident is unlikely to occur on this project	Incident has occurred on a similar project	Incident is likely to occur on this project	Incident is very likely to occur on this project, possibly several times

Risk matrix				Consequence				
				Insignificant	Minor	Moderate	Major	Catastrophic
				1	2	3	4	5
Likelihood	A	Almost Certain	95%					
	B	Likely	80%					
	C	Possible	50%					
	D	Unlikely	20%					
	E	Rare	5%					

Risk criteria

	Extreme	**Unacceptable** further management review required to reduce risk.
	High	**Tolerable** if management determine and accepts risk has been reduced to as low as reasonably practicable.
	Moderate	**Acceptable** with management review for continuous improvement.
	Low	**Acceptable** no further management required.

Flora & Vegetation Surveys

TELLUS

SANDY RIDGE PROJECT,
EXPLORATION TENEMENT E16/440

LEVEL 1 FLORA AND VEGETATION SURVEY

Prepared for:	Tellus Holdings P/L
Report Date:	7 November 2016
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pgv ENVIRONMENTAL

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Table 2: Likelihood of identified significant flora species occurring on the site

Table 3: Vegetation condition rating scale

Plates

Plate 1: *Triodia* Open Grassland

Plate 2: *Acacia /Allocasuarina* Open Heath with Scattered *Eucalyptus* sp.

Plate 3: Open Woodland

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Figure 1: Site Boundary and Layout

Appendices

Appendix 1: DPaW Flora Database Searches

Appendix 2: NatureMap Report

Appendix 3: Protected Matters Search Tool Report

Appendix 4: DPaW TEC and PEC Database Search

Appendix 5: Soil Mapping

Appendix 6: Conservation Codes

1 INTRODUCTION

1.1 Background

Tellus Holdings Ltd is proposing to develop a kaolin mine with complimentary storage and waste disposal business on Exploration Tenement E16/440, (the site). The site is located in the Shire of Coolgardie and is approximately 140km north-west of Kalgoorlie and 75km north-east of Koolyanobbing. The site boundary is shown in Figure 1.

The site is zoned Rural/Mining in the Shire of Coolgardie Town Planning Scheme No. 4 (District Scheme) Consolidated Scheme (TPS4) (WAPC, 2003).

1.2 Proposed Mining Operation

The potential development envelope for the proposed mining operation is 875ha (Figure 1). Within the development envelope there is a maximum of approximately 52ha that is proposed to be cleared for the Mine Pit (37.2ha), Mine Infrastructure (11.8ha), Accommodation Camp (2.5ha) and Class II Waste Disposal Facility (0.258ha) (Figure 1).

The end use for the pit, once mining has ceased will be to accommodate a waste storage facility.

1.3 Scope of Works

The report is required to accompany environmental impact assessment documentation and referral documentation for submission to the Environmental Protection Authority (EPA) and Department of the Environment (DoE).

The Level 1 Flora and Vegetation Survey was undertaken in accordance with the Environmental Protection Authority (EPA) Guidance Statement 51: *Terrestrial Flora and Vegetation Surveys for Environmental Impact Assessment in Western Australia* (EPA, 2004) and included the following:

- Desktop search and review of the Department of Parks and Wildlife's (DPaW) Declared Rare and Priority Flora database and Threatened Ecological Communities database;
- A search of DPaW's NatureMap database for Threatened and Priority Species;
- A search of the Department of Environment's *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) Protected Matters Search Tool to identify any species protected under the EPBC Act;
- Examination of recent aerial photography and contour maps to provisionally identify vegetation types and condition;
- Desktop searches to determine land use, topography, geology and soils and hydrology. These desktop searches will be undertaken using Department of Water (DoW), DPaW and Department of Agriculture and Food Western Australia (DAFWA) databases and online resources;
- Review of other flora and vegetation survey reports in the vicinity of the site.

2 METHODOLOGY

Desktop studies were undertaken to identify potential threatened species and communities that may occur on the site. The searches were for an area with a 20km radius from the approximate centre of the proposed development area. The databases used were:

- DPaW Flora databases (Appendix 1):
  - Threatened Flora Database (DEFL) (Appendix 1);
  - WA Herbarium database (WAHerb); and
  - Declared Rare and Priority Flora Species List (TFPL).
- DPaW Naturemap Database (Appendix 2);
- *Environment Protection Biodiversity Conservation Act 1999* (EPBC Act) Protected Matters Search Tool (Appendix 3); and
- DPaW's Threatened (TEC) and Priority Ecological Communities (PEC) database (Appendix 4).

The preferred habitat of each species and community identified on the database searches was examined to determine the likelihood of that species being located on the site and therefore impacted by the proposal.

The vegetation was also examined using photographs as supplied by the proponent and aerial photography (Nearmap, Landgate Map Viewer and Google Earth). The appearance of the vegetation was correlated with the known locations of where the photographs were taken.

3 RESULTS

3.1 Past and Existing Land Use

The site is vegetated with some basic camp infrastructure installed. No other development has been undertaken on the site.

3.2 Topography

The site is undulating between approximately 460m Australian Height Datum (AHD) to 480mAHD. . The site generally slopes up to the north-east.

3.3 Geology and Soils

The site is located on the Yilgarn Craton and based on granitoid rock. The soil system on the site is the Norseman Zone (266) on which the soils are described as calcareous loamy earths, yellow sandy and loamy earths, red loamy earths, red deep sands and salt lake soils (DAFWA, 2015).

The soils on the site are predominately a deep yellow sand over clay as mapped by Landloch (2015). There is an area in the western part of the site being described as red sandy duplex soils (Appendix 5).

3.4 Hydrology

3.4.1 Surface Water

The area lies just to the south of one of the driest regions in Western Australia. The site is in the Raeside-Ponton Catchment Basin in the Salt Lake Sub-catchment (Landgate, 2015). Surface water drains to lower lying areas. There is one lake on the western boundary of the tenement but outside of the proposed development envelope. There are no wetlands or surface expressions of groundwater on the site.

3.4.2 Groundwater

The site is situated in an area that does not have a regional water table as any rain falling in the region is either evaporated, evapo-transpirated or runs off at the surface through minor ephemeral drainage and watercourses. The lack of groundwater is also due to the thickness and permeability of the geologic profile, which includes 2m to 5m of impermeable silcrete and up to 40m of low permeability clay. Monitoring wells in the area have been tested for more than 20 years and have always been dry (Aurora, 2015).

3.5 Bioregional Data

The site is located in the Coolgardie Interim Biogeographic Regionalisation for Australia (IBRA) Bioregion which covers the interzone between mulga and spinifex country, and eucalypt environments (DoE, 2015) over an area of 129,117km^2.

Within the Coolgardie Bioregion, the site is located in the Southern Cross IBRA sub-region that is 60,108 km^2 in size (DoE, 2015). The Southern Cross Sub-Region comprises the western section of the Yilgarn Craton and is comprised of gently undulating uplands dissected by broad valleys with bands of

low greenstone hills (Cowan *et al.* 2001). The granite strata of the Yilgarn Craton are interrupted by parallel intrusions of Archaean Greenstone. Diverse Eucalyptus woodlands (*Eucalyptus salmonophloia, Eucalyptus salubris, Eucalyptus transcontinentalis* and *Eucalyptus longicornis*) are common in the region. Granite basement outcrops occur at mid-levels in the landscape and support swards of *Borya constricta*, with stands of *Acacia acuminata* and *Eucalyptus loxophleba*. Upper levels in the landscape are the eroded remnants of a lateritic duricrust yielding yellow sandplains, gravelly sandplains and laterite breakaways. Mallees (*Eucalyptus leptopoda*, *Eucalyptus platycorys* and *Eucalyptus scyphocalyx*) and scrub-heaths (*Allocasuarina corniculata*, *Callitris preissii*, *Melaleuca uncinata* and *Acacia beauverdiana*) occur on these uplands (Cowan *et al*. 2001).

3.6 Flora Database Searches

There are 50 species that are listed as Endangered, Threatened or Priority that have been located within a 20km radius of the site. The results from the database searches are shown in Table 1.

Table 1: Conservation significant flora known to occur near the site

Species	Common Name	Conservation Status WA	Status Under EPBC Act 1999
Myriophyllum lapidicola	Chiddarcooping Myriophyllum	Threatened	Endangered
Ricinocarpos brevis		Threatened	Endangered
Tetratheca paynterae	Paynter's Tetratheca	Threatened	Endangered
Cryptandra polyclada subsp. *aequabilis*		Priority 1	
Cyathostemon sp. Mt Dimer (C. McChesney TRL 4/72) PN		Priority 1	
Dampiera sp. Jaurdi (D. Angus DA 268) PN		Priority 1	
Lepidosperma sp. Parker Range (N. Gibson & M. Lyons 2094)		Priority 1	
Leucopogon sp. Yellowdine (M. Hislop & F. Hort MH 3194)		Priority 1	
Phebalium appressum		Priority 1	
Tecticornia flabelliformis		Priority 1	
Xanthoparmelia fumigata		Priority 1	
Baeckea sp. Jaurdi Station (L.W. Sage & F. Hort 2229)		Priority 2	
Daviesia sarissa subsp. *redacta*		Priority 2	
Elachanthus pusillus		Priority 2	
Goodenia jaurdiensis		Priority 2	
Hakea rigida		Priority 2	
Hemigenia tenelliflora		Priority 2	
Lissanthe scabra		Priority 2	
Malleostemon sp. Adelong (G.J. Keighery 11825)		Priority 2	
Acacia cylindrica		Priority 3	
Acacia desertorum var. *nudipes*		Priority 3	
Austrostipa blackii	Crested Spear-grass	Priority 3	
Banksia lullfitzii		Priority 3	
Bossiaea celata		Priority 3	

Species	Common Name	Conservation Status WA	Status Under EPBC Act 1999
Calytrix creswellii		Priority 3	
Cyathostemon verrucosus		Priority 3	
Eucalyptus exigua		Priority 3	
Eutaxia actinophylla		Priority 3	
Gastrolobium semiteres		Priority 3	
Gnephosis intonsa	Shaggy Gnephosis	Priority 3	
Gnephosis sp. Norseman (K.R. Newbey 8096)		Priority 3	
Gompholobium cinereum		Priority 3	
Grevillea georgeana		Priority 3	
Hibbertia lepidocalyx subsp. *tuberculata*		Priority 3	
Homalocalyx grandiflorus		Priority 3	
Labichea eremaea		Priority 3	
Lepidium genistoides		Priority 3	
Melichrus sp. Bungalbin Hill (F.H. & M.P. Mollemans 3069)		Priority 3	
Mirbelia ferricola		Priority 3	
Stenanthemum newbeyi		Priority 3	
Stylidium choreanthum	Dancing Triggerplant	Priority 3	
Verticordia mitodes		Priority 3	
Verticordia stenopetala		Priority 3	
Banksia arborea	Yilgarn Dryandra	Priority 4	
Eremophila caerulea subsp. *merrallii*		Priority 4	
Eucalyptus formanii		Priority 4	
Grevillea erectiloba		Priority 4	
Haegiela tatei		Priority 4	
Lepidosperma lyonsii		Priority 4	
Sowerbaea multicaulis	Many Stemmed Lily	Priority 4	

Definitions of the Conservation Codes are in Appendix 6.

Table 2 examines the preferred habitat of each species and the likelihood of the species listed in Table 1 to occur on the site given the characteristics of soil type and landform.

Table 2: Likelihood of identified significant flora species occurring on the site

Scientific Name	Preferred Habitat*	Likelihood of Presence on Site
Myriophyllum lapidicola	Ephemeral pools 20 to 50 cm deep on granite outcrops +	Unlikely
Ricinocarpos brevis	Shallow sandy soils on rocky banded ironstone outcrops ®	Unlikely
Tetratheca paynterae	Rock crevices, in shallow pockets of soil of rich red loam	Unlikely
Cryptandra polyclada subsp. *aequabilis*	Sand	Possible

Scientific Name	Preferred Habitat*	Likelihood of Presence on Site
Cyathostemon sp. Mt Dimer (C. McChesney TRL 4/72) PN	Yellow sand	Possible
Dampiera sp. Jaurdi (D. Angus DA 268) PN	Associated species: *Allocasuarina corniculata, Gyrostemon racemiger, Acacia sibina, Eucalyptus leptopoda subsp. subluta, Calytrix creswellii* ~ Interpreted habitat: Yellow sand, gravel, sandplains	Possible
Lepidosperma sp. Parker Range (N. Gibson & M. Lyons 2094)	Recorded on ridge/slope. Well-drained. Dry brown clay loam over granite. 10-30% of loose rock on soil surface #	Unlikely
Leucopogon sp. Yellowdine (M. Hislop & F. Hort MH 3194)	Recorded on Flat. Moist yellow sand. Burnt >5 years ^	Unlikely
Phebalium appressum	Yellow sandplain	Possible
Tecticornia flabelliformis	Clay. Saline flats.	Highly Unlikely
Xanthoparmelia fumigata	Recorded on ridge with bare to littered, stoney crusted brown clayey sand <	Unlikely
Baeckea sp. Jaurdi Station (L.W. Sage & F. Hort 2229)	Light brown-yellow sand. Sandplains	Possible
Daviesia sarissa subsp. *redacta*	Yellow sand. Plains	Possible
Elachanthus pusillus	Open depression in plain system. Sandy clay loam &	Unlikely
Goodenia jaurdiensis	Red clayey loam with laterite or banded ironstone gravel or quartz pebbles. Low-lying plains and lower slopes	Unlikely
Hakea rigida	Sandy soils, yellow sand	Possible
Hemigenia tenelliflora	Sandplain @	Possible
Lissanthe scabra	Dry, white to orange-brown clay, sandy gravel loams, granite. Breakaways, uplands	Unlikely
Malleostemon sp. Adelong (G.J. Keighery 11825)	Red sand, mid-slope, interdunal$^{\beta}$	Unlikely
Acacia cylindrica	Yellow/brown sand, gravelly soils. Undulating plains, flats	Possible
Acacia desertorum var. *nudipes*	Yellow sand, lateritic gravel. Sandplains, flats.	Possible
Austrostipa blackii	Recorded on a gentle upper North slope. Brown loam over red loam with granite fragments at 5 cm %	Unlikely
Banksia lullfitzii	Yellow sand. Sandplains.	Possible
Bossiaea celata	Deep sand. Open mallee	Possible
Calytrix creswellii	Yellow sand, sometimes with lateritic gravel. Sandplains	Possible
Cyathostemon verrucosus	Flat yellow sandy clay plain >	Unlikely
Eucalyptus exigua	Sandy loam, white sand. Sandplains	Possible
Eutaxia actinophylla	Red-brown clay loam, red clay loam over granite, gravel. Small depressions	Unlikely

Scientific Name	Preferred Habitat*	Likelihood of Presence on Site
Gastrolobium semiteres	Deep yellow sand, yellow to brown sandy clay, gravel, granite. Broad sand dunes, around rocks, undulating plains	Possible
Gnephosis intonsa	Red/brown clay, stony saline loam	Unlikely
Gnephosis sp. Norseman (K.R. Newbey 8096)	Sub-saline loam. Moderately exposed flat	Unlikely
Gompholobium cinereum	Yellow sand, clayey sand, brown loam, sandy gravel, laterite. Well-drained open sites, slopes, plains, roadsides	Possible
Grevillea georgeana	Stony loam/clay. Ironstone hilltops and slopes.	Highly Unlikely
Hibbertia lepidocalyx subsp. *tuberculata*	Yellow-orange loam, ironstone gravel	Possible
Homalocalyx grandiflorus	Yellow sand. Sandplains.	Possible
Labichea eremaea	Red sand.	Unlikely
Lepidium genistoides	Sandy loam	Possible
Melichrus sp. Bungalbin Hill (F.H. & M.P. Mollemans 3069)	Yellow sandplain [=]	Possible
Mirbelia ferricola	Recorded on skeletal red loam soils on massive banded iron formation [“]	Unlikely
Stenanthemum newbeyi	Clayey sand, clay or loam over laterite or ironstone. Hillslopes	Unlikely
Stylidium choreanthum	White/yellow or red sand. Plains	Possible
Verticordia mitodes	Yellow sand. Undulating plains	Possible
Verticordia stenopetala	Yellow sand, sometimes with gravel. Undulating plains.	Possible
Banksia arborea	Stony loam. Ironstone hills.	Unlikely
Eremophila caerulea subsp. *merrallii*	Sand, clay or loam. Undulating plains.	Possible
Eucalyptus formanii	Red sand. Ironstone slopes	Unlikely
Grevillea erectiloba	Gravelly loam. Lateritic ridges	Unlikely
Haegiela tatei	Clay, sandy loam, gypsum. Saline habitats.	Unlikely
Lepidosperma lyonsii	Orange skeletal sandy loam with banded ironstone gravel and rock, well-drained shallow stony loamy with quartz. Gentle hill slopes, upper slopes of large hill.	Unlikely
Sowerbaea multicaulis	Yellow-brown sand.	Possible

* Sourced from Florabase (DPaW, 2015) unless otherwise annotated as per the list below.

® DoE SPRAT Database (DoE, 2015)
+ Patten and Brown (2004)
~ Western Australian Herbarium (2015a)
# Western Australian Herbarium (2015b)
^ Western Australian Herbarium (2015c)
< Western Australian Herbarium (2015d)
@ Western Australian Herbarium (2015e)
= Western Australian Herbarium (2015f)
β Western Australian Herbarium (2015g)
& State Herbarium of South Australia (2015a)
% State Herbarium of South Australia (2015b)
> Australian National Herbarium (2015)
“ National Herbarium of New South Wales (2015)

Of the 50 species identified in the database searches 25 are considered to be possibly present on the site. There are four species ranked as Priority 1, four as Priority 2, fifteen as Priority 3 and two as Priority 4 in the list of species that potentially could occur on the site.

A total of 23 species identified in the database searches are considered to be 'Unlikely' to be present on the site as they are usually located on Banded Ironstone Formations. All three species listed as Threatened under the *Wildlife Conservation Act 1950* (WC Act) and Endangered under the EPBC Act are considered 'Unlikely' to be present on the site. There are two species considered Highly Unlikely to occur on the site

3.7 Vegetation Types

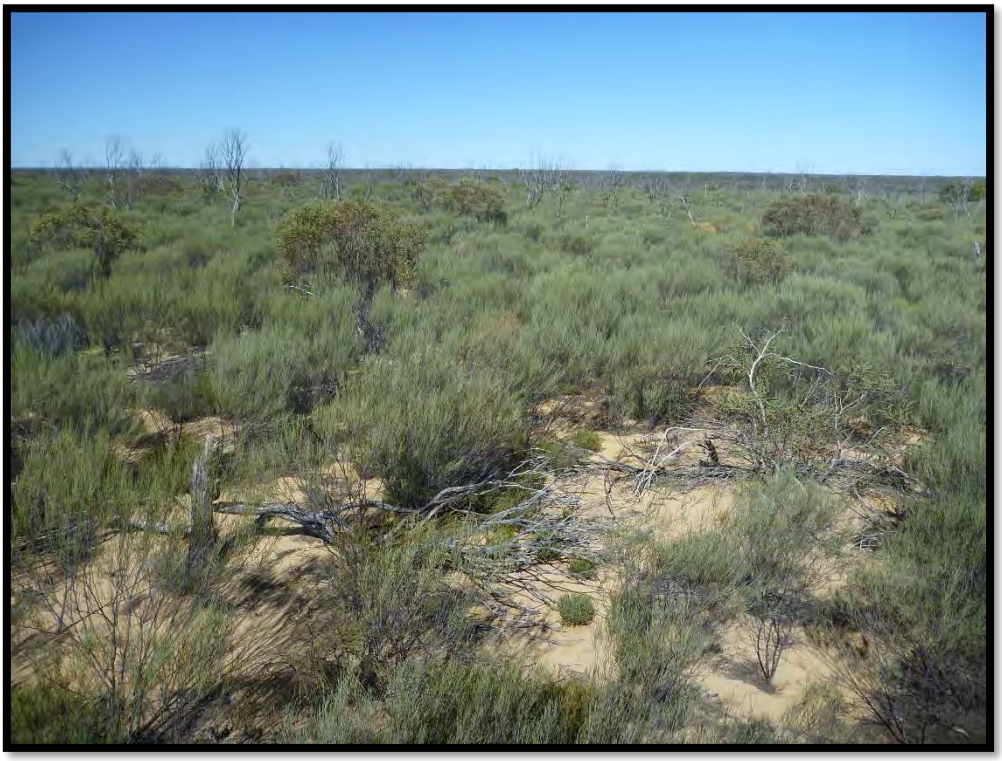
Vegetation as shown in on-site photography and using aerial photographs has been described as three broad vegetation types.

The sandy ridge areas that are in the proposed mine area are dominated by *Triodia* sp. (Spinifex) (Plate 1) and is described as *Triodia* Open Grassland.

Plate 1: *Triodia* Open Grassland

There are large areas on the site that are dominated by *Acacia* and *Allocasuarina* species with scattered Mallee *Eucalyptus* common (Plate 2).

Plate 2: *Acacia /Allocasuarina* Open Heath with Scattered *Eucalyptus* sp.



On the western side of the site there is an area that is most likely to be dominated by Eucalypts. The understorey is likely to consist of *Melaleuca uncinata* and *Allocasuarina* sp. Plate 3 shows the woodland.

Plate 3: Open Woodland

3.8 TEC/PEC Database Searches

A search of DPaW's Threatened (TEC) and Priority Ecological Communities (PEC) database was conducted for the site (02-0415EC) (Appendix 4). Three Priority 1 ecological communities were found to potentially occur within the vicinity of the site as described below:

- Finnerty Range/Mt Dimer/Yendilberin Hills vegetation complexes (banded ironstone formation);
- Hunt Range vegetation complexes (banded ironstone formation); and
- Lake Giles vegetation complexes (banded ironstone formation).

None of these ecological communities are likely to occur on the site. These communities are all associated with a Banded Iron Formation which does not occur on the proposed mining site. The interpreted vegetation types are not representative of these PECs.

3.9 Vegetation Condition

The site has very few disturbance factors. The Mount Walton East Intractable Waste Disposal Facility (IWDP) which is located approximately 7km to the east contains very similar vegetation types to the study area. No weeds were recorded on the IWDF site during a flora survey in 2014 (PGV, 2015). Therefore if the condition of the vegetation were to be assessed according to the system devised by Keighery and described in Bush Forever (Government of Western Australia, 2000) (Table 3) the vegetation would most likely be in Pristine condition over most of the site.

Table 3: Vegetation Condition Rating Scale

Condition	Description
Pristine	Pristine or nearly so, no obvious signs of disturbance.
Excellent	Vegetation structure intact, disturbance affecting individual species and weeds are non-aggressive species.
Very Good	Vegetation structure altered, obvious signs of disturbance. For example, disturbance to vegetation structure caused by repeated fires, the presence of some more aggressive weeds, dieback, logging and grazing.
Good	Vegetation structure significantly altered by very obvious signs of multiple disturbance. Retains basic vegetation structure or ability to regenerate it. For example, disturbance to vegetation structure caused by very frequent fires, the presence of some very aggressive weeds at high density, partial clearing, dieback and grazing.
Degraded	Basic vegetation structure severely impacted by disturbance. Scope for regeneration but not to a state approaching good condition without intensive management. For example, disturbance to vegetation structure caused by very frequent fires, the presence of very aggressive weeds, partial clearing, dieback and grazing.
Completely Degraded	The structure of the vegetation is no longer intact and the area is completely or almost completely without native species. These are often described as 'parkland cleared' with the flora comprising weed or crop species with isolated native trees or shrubs.

Source: Government of Western Australia, 2000.

3.10 Conservation Significance of Flora and Vegetation

Flora

A total of 25 Priority species were determined from the desktop database search as possibly occurring on the site due to the sandy soil types in which they occur. None of these species are listed as Threatened under the State *Wildlife Conservation Act, 1950* (WC Act) or the Commonwealth *Environment Protection and Biodiversity Conservation Act, 1999* (EPBC Act).

Vegetation

The vegetation on the site belongs to the Southern Cross sub-region that is 60,108 km^2in size (DoE, 2015) and at this stage is largely undisturbed. Therefore the vegetation is not bio-regionally significant.

The vegetation is also highly unlikely to be representative of any Threatened Ecological Community listed under the WC Act or the EPBC Act or any Priority Ecological Community.

Linkages

The area surrounding the site is vegetated and the proposed mining and waste storage operations will result in a small area of localised clearing which will not impact on the linkage of the surrounding vegetation.

4 SUMMARY AND CONCLUSIONS

This Level 1 Flora and Vegetation Survey concludes the flora and vegetation on the proposed development envelope of the Sandy Ridge Kaolin Mine Project has the following characteristics:

- The vegetation is highly unlikely to have been disturbed in the past.
- The site is located within the Coolgardie IBRA Bioregion, in the Southern Cross sub-region;
- A total of 50 species were identified on the database searches that are known to occur within a 20km radius of the site. Of these 25 species were considered to potentially occur on the site given the soil and landform characteristics;
- None of the species identified as possibly present on the site identified are listed as Threatened under the State *Wildlife Conservation Act, 1950* (WC Act) or the Commonwealth *Environment Protection and Biodiversity Conservation Act, 1999* (EPBC Act);
- Based on inference from site photographs, soil type and aerial photography three broad vegetation types occur on the site:
  - *Triodia* Open Grassland;
  - *Acacia / Allocasuarina* Open Heath with Scattered *Eucalyptus* sp; and
  - *Eucalyptus* Low Woodland over *Melaleuca uncinata / Allocasuarina* sp Open Shrubland
- Three PECs were identified in the database searches but are highly unlikely to be present on the site as they are associated with the Banded Ironstone Formation. No TECs were identified as occurring in the region as likely to occur on the site.
- Based on studies undertaken at Mount Walton East Intractable Waste Disposal Facility and photographs of the site most of the vegetation is expected to be in Pristine Condition due to the lack of disturbance.
- The clearing of the vegetation for the proposed mine and infrastructure will not impact on any regional ecological linkage.
- A targeted survey for the priority species possibly present in the development envelope should be undertaken prior to the commencement of development to determine the presence and abundance of any conservation significant species.

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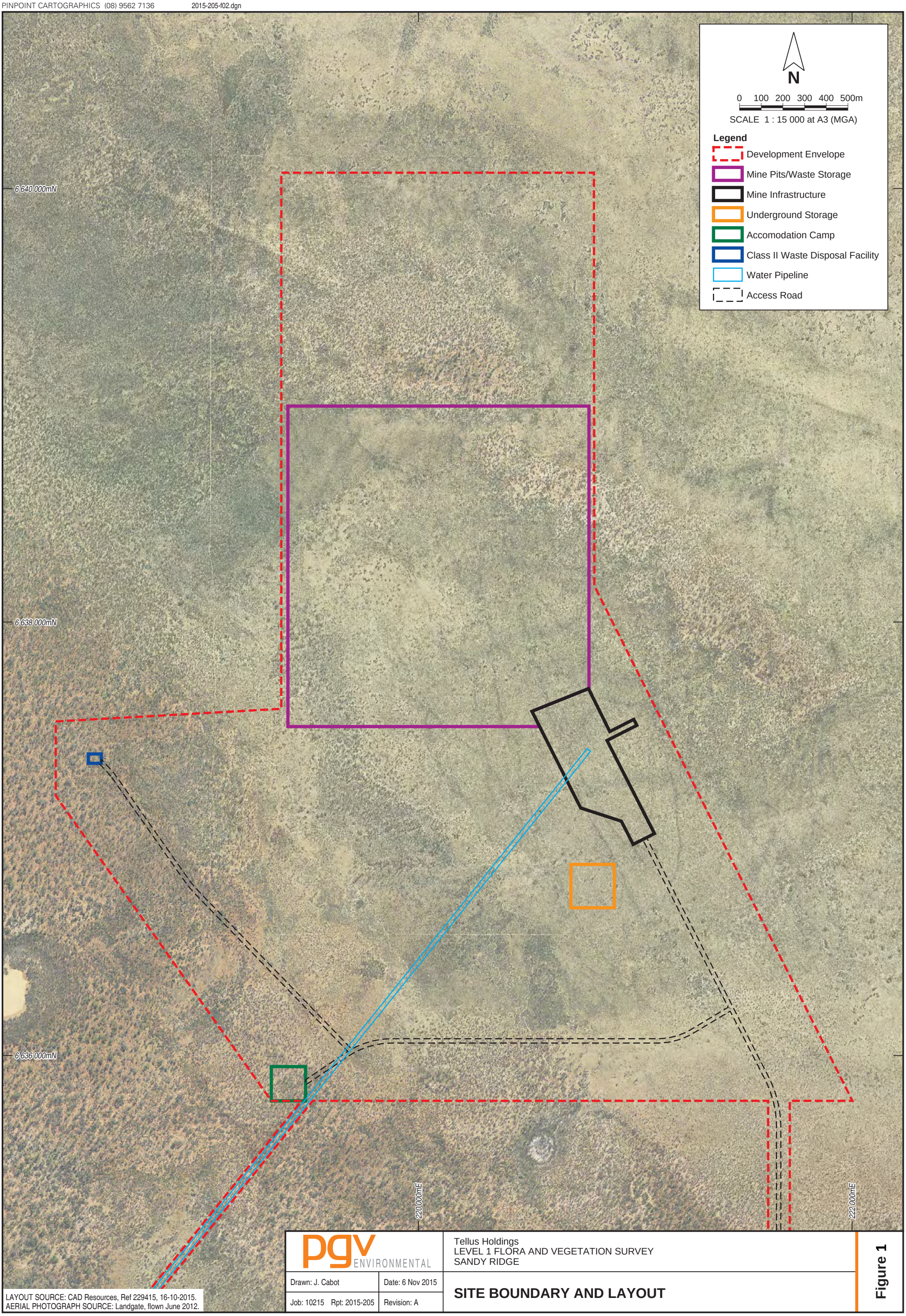
FIGURES



LAYOUT SOURCE: CAD Resources, Ref 229415, 16-10-2015.
AERIAL PHOTOGRAPH SOURCE: Landgate, flown June 2012.

pgv ENVIRONMENTAL

Tellus Holdings
LEVEL 1 FLORA AND VEGETATION SURVEY
SANDY RIDGE

Drawn: J. Cabot	Date: 6 Nov 2015
Job: 10215 Rpt: 2015-205	Revision: A

SITE BOUNDARY AND LAYOUT

Figure 1

APPENDIX 1

DPaW Flora Database Searches

FID_	Sheet	NameID	Taxon	Cons_Code	Plant_Des	Site_Descr	Vegetation	Frequency	Notes	Locality
	8284873	16621	Phebalium appressum	1	Shrub, 40 cm tall. Mostly with flower buds, some plants with few white flowers.	Flat. Dry yellow sand. Fire ca 5 years ago.	Open Eucalyptus rigidula mallee over Acacia nigripilosa subsp. nigripilosa, Acacia inaequiloba and mixed shrubs over Triodia.	5 plants seen locally.		Adjacent to the Mount Dimer - Mount Walton Waste Facility track ca 18 km ESE of Mount Dimer
	5642701	5448	Calytrix creswellii	3	Low shrub 20-60 cm.	Yellow-brown sand. Slope.	Allocasuarina/Acacia resinomarginea shrubland-Eucalyptus woodland. Associated species: Acacia resinomarginea, Allocasuarina acutivalvis, A. corniculata, Eucalyptus loxophleba, Euc. transcontinentalis.			Mount Walton Intractable Waste Disposal compound, 100 km NE Koolyanobbing,
	1153536	2009	Grevillea georgeana	3		Banded ironstone.				Mount Dimer, Jaurdi Station
	1362704	2009	Grevillea georgeana	3	Shrub to 2 m high.	On Banded Ironstone.	With Acacia quadrimarginea.			Jaurdi Station, Mount Walton
	6296467	2009	Grevillea georgeana	3	Perennial shrub ca 1.5 m high. Red flowers.	Hill. Crest and slopes of rocky ridge. Skeletal red soil. Banded chert and laterite. Banded ironstone.	Low Woodland B. Acacia/Grevillea thicket with scattered trees and shrubs over shrubs and herbs.	frequent.		Site J1-7. Banded ironstone hill, ca 1 km E on Mount Dimer mine access road from the Jaurdi - Mount Manning track, Jaurdi Station
	7683170	2009	Grevillea georgeana	3		Rocky outcrop. Silica rich. Dry, light brown loam over sheet boulder.	Open Tall Shrubland over moderate Baeckea elderiana dominated low shrubland over rocky outcrops and stony soils. Acacia acuminata, Allocasuarina acutivalvis subsp. acutivalvis, Melaleuca hamata, Baeckea elderiana, Acacia acuminata, Leucopogon breviflorus			Mt Finnerty Project Area, 70 km N of Southern Cross
	8088683	2009	Grevillea georgeana	3	180 cm high.	Flat. Red-brown clay. Low disturbance. Fire > 10 years prior to collection.	Malleostemon roseus, Grevillea zygoloba, Leucopogon breviflorus, Phebalium canaliculatum, Prostanthera grylloana.			Bungalbin - Kooyanobbing
	8589801	2009	Grevillea georgeana	3	Shrub.	Low slope. Ironstone gravel on red sand.	Acacia burkittii, Prostanthera grylloeana, Grevillea obliquistigma, Santalum spicatum, Prostanthera campbellii, Eremophila granitica.			S of Mount Manning, 105 km NE of Southern Cross
	8600694	2009	Grevillea georgeana	3	Perennial shrub to 80 cm high.	Mid slope in mining lease site. Red clay.	Mixed shrubs with low emergent eucalypts. Associated species: Eucalyptus clelandii, Scaevola spinescens, Allocasuarina campestris, Eremophila oppositifolia subsp. angustifolia, Olearia muelleri, Melaleuca leiocarpa.		Reproductive stage: fruit.	Bungalbin, c. 105 km NE of Southern Cross
	8629625	2009	Grevillea georgeana	3	Shrub 2-3 m. Flowering.	Banded Iron formation over BIF.	Eremophila, Banksia arborea.			59 km N-E of Taipan Hill

FID_	Sheet	NameID	Taxon	Cons_Code	Plant_Des	Site_Descr	Vegetation	Frequency	Notes	Locality
	8284946	3666	Labichea eremaea	3	Shrub, 80 cm tall. Yellow flowers.	Undulating sandplain. Dry yellow sand.	Open mallee of Eucalyptus rigidula over Acacia shrubs over Triodia.	1 plant seen.		Adjacent to the Mount Dimer - Mount Walton Waste Facility track ca 21 km ESE of Mount Dimer
	8285055	41785	Melichrus sp. Bungalbin Hill (F.H. & M.P. Mollemans 3069)	3	Small shrub, 30 cm tall. Red/pink flowers.	Flat. Dry yellow orange sand. Fire: ca 5 years ago.	Open shrubland of Acacia resinimarginea with Acacia sibina.	ca 70 plants locally in 50 x 50 m.		Ca 14.5 km S-E of Mount Dimer. Ca 12.7 km N of Mount Walton. Just S of E-W track that runs from old Mount Dimer mine site to the Mount Walton track
	1102257	41785	Melichrus sp. Bungalbin Hill (F.H. & M.P. Mollemans 3069)	3						16 km NE of Yendilberin Hills (NE of Southern Cross)
	1102265	41785	Melichrus sp. Bungalbin Hill (F.H. & M.P. Mollemans 3069)	3						16 km NE of Yendilberin Hills (NE of Southern Cross).
	5645166	6121	Verticordia stenopetala	3	Low shrub.	Yellow sand-gravel over laterite. Slope.	Sparse Eucalyptus transcontinentalis over moderately dense Acacia signata. Associated species: Acacia resinomarginea, Phebalium canaliculatum, Grevillea paradoxa, Astroloma microphyllum, Thryptomene urceolaris.			Mount Walton Retractable Waste Storage Facility, 100 km NE Koolyanobbing,
	6163092	32685	Banksia arborea	4	Tree. Ca 3 m high. Yellow flowers. Fruiting.	Hill. Crest and slopes of rocky ridge. Skeletal red soil. Banded chert and laterite. Banded ironstone.	Low Woodland B. Acacia/Grevillea thicket with scattered trees and shrubs over shrubs and herbs.	locally abundant.		Site J1-7. Banded ironstone hill, ca 1 km E on Mount Dimer mine access road from the Jaurdi - Mount Manning track, Jaurdi Station
	1804243	32685	Banksia arborea	4	Tree, to 3 m, flowers yellow.	Ironstone ridges.		common.		Mount Dimer, S end Hunt Ranges
	6163106	32685	Banksia arborea	4	Tree. Ca 3.5 m high. Yellow flowers. Fruiting.	Hill. Crest and slopes of rocky ridge. Skeletal red soil. Banded chert and laterite. Banded ironstone.	Low Woodland B. Acacia/Grevillea thicket with scattered trees and shrubs over shrubs and herbs.	locally abundant.		Site J1-7. Banded ironstone hill, ca 1 km E on Mount Dimer mine access road from the Jaurdi - Mount Manning track, Jaurdi Station
	8629528	32685	Banksia arborea	4	Tree. Flowering, fruiting, covered in black scale (common at this locality).	Banded Iron formation over BIF.	Grevillea georgeana, Eremophila.			59 km N-E of Taipan Hill

FID_	PopId	Nameid	Taxon	ConsStatus	WARank	PopNumber	SubPopCode	PopStatus	Location	District	Vesting	Purpose 1	Purpose 2	CountDate	Method	MatureCoun	LiveTotal	inFlower
	96399	32685	Banksia arborea	4		9			UCL, Lot 131. Ex Jaurdi Station. Exploration Lease E77/1418. Site J1-7, Banded Ironstone hill ca. 1km E on Mt Dimer mine access Rd from the Jaurdi-Mt Manning Track. [Ca. 5.6km S of Mt Dimer].	KALGOORLIE	NON	UCL	EPL	5/10/1999 0:00		0	0	N
	96359	32685	Banksia arborea	4		14			UCL, Lot 131, Exploration Lease. Ex Jaurdi Station. Mount Dimer, S end of Hunt Range.	KALGOORLIE	NON	UCL	EXL	13/05/1978 0:00		0	0	N
	87651	5448	Calytrix creswellii	3		8			Intractable Waste Storage Site (CR42001), Lot 73. Mt Walton Intractable Waste Disposal compound, 100km NE of Koolyanobbing. [Ca. 49km E of Bungalbin Hill].	KALGOORLIE	RDL	OTH		20/11/1996 0:00		0	0	N
	87640	5448	Calytrix creswellii	3		10			UCL. Ca. 14km SE of Mt Walton Waste Facility. Ca. 18km ENE of Mt Walton, ca. 80km NE of Koolyanobbing.	KALGOORLIE	NON	UCL		23/09/2010 0:00	ACT_IND	348	348	N
	87642	5448	Calytrix creswellii	3		12			UCL. Ca. 11.5km S of Mt Walton Waste Disposal Facility, east of Yendilberin Hills. Ca. 11.5km ENE of Mt Walton. Near north-south track that runs south from the Mt Walton Waste Disposal (not the main access track).	KALGOORLIE	NON	UCL		22/09/2010 0:00	ESTMT	60	60	N
	87643	5448	Calytrix creswellii	3		13			UCL. Ca. 13.5km S of Mt Walton Waste Disposal Facility, east of Yendilberin Hills. Ca. 10.5km ENE of Mt Walton. Near north-south track that runs south from the Mt Walton Waste Disposal (not the main access track).	KALGOORLIE	NON	UCL		22/09/2010 0:00	ESTMT	21	21	N
	85544	2009	Grevillea georgeana	3		17			UCL, Lot 131. Ex-Jaurdi Station. Exploration Lease E77/1418. 5km SW of Mt Dimer. [Just E of Taipan Mine].	KALGOORLIE	NON	UCL	EPL	4/10/1991 0:00	ESTMT	70	70	Y
	85545	2009	Grevillea georgeana	3		18			UCL, Lot 131. Ex-Jaurdi Station. Exploration Lease E77/1418. On Hill NMF 398 in Yendilberin Hills. Site J1-7, banded ironstone hill, ca. 1km E on Mt Dimer Mine Access Rd from the Jaurdi-Mt Manning track.	KALGOORLIE	NON	UCL	EPL	5/10/1999 0:00		0	0	Y
	85546	2009	Grevillea georgeana	3		19			UCL, Lot 131. Ex-jaurdi Station. Exploration Lease E77/1418. Ca. 105km NE of Southern Cross. [Ca. 2.7km S of Mt Dimer]. [Ca. 26.8km E of Bungalbin Hill].	KALGOORLIE	NON	UCL	EPL	22/08/2007 0:00		0	0	N
	85548	2009	Grevillea georgeana	3		20			UCL, Lot 131. Ex-jaurdi Station. Exploration Lease E77/1418. Mount Dimer.	KALGOORLIE	NON	UCL	EPL	7/11/1989 0:00		0	0	N
	85549	2009	Grevillea georgeana	3		21			UCL, Lot 131. Ex-jaurdi Station. Mining Lease M77/1244. Carina Prospect, Yendilberin Hills. [Ca. 14.5km SE of Mt Dimer].	KALGOORLIE	NON	UCL	EPL	30/03/2009 0:00		0	0	Y
	85555	2009	Grevillea georgeana	3		27			UCL, Lot 131, Ex-Jaurdi Station. Exploration Lease E77/1115. Chameleon Prospect, 105km NE of Southern Cross. [Yendilberin Hills]. [Ca. 1.2km N of Mt Walton].	KALGOORLIE	NON	UCL	EXL	29/05/2008 0:00		5	5	N
	85556	2009	Grevillea georgeana	3		28			UCL, Lot 131, Ex-Jaurdi Station. Mt Finnerty Project Area, [105km NE of Southern Cross]. [Ca. 2.3km SE of Mt Walton].	KALGOORLIE	NON	UCL		25/09/2004 0:00		0	0	N
	88113	5811	Homalocalyx grandiflorus	3		12			UCL. Ca. 14km SE of Mt Walton Waste Facility. Ca. 18km ENE of Mt Walton. Ca. 80km NE of Koolyanobbing.	KALGOORLIE	NON	UCL		23/09/2010 0:00	ACT_IND	2	2	N

FID_	PopId	Nameid	Taxon	ConsStatus	WARank	PopNumber	SubPopCode	PopStatus	Location	District	Vesting	Purpose 1	Purpose 2	CountDate	Method	MatureCoun	LiveTotal	inFlower
	88115	5811	Homalocalyx grandiflorus	3		14			UCL. Ca. 13km S of Mt Walton Waste Disposal facility, E of Yendilberin Hills. Ca. 11km ENE of Mt Walton. Near N-S track that runs south of the Mt Walton Waste Disposal facility (not the main access track).	KALGOORLIE	NON	UCL		22/09/2010 0:00	ESTMT	10	10	N
	88116	5811	Homalocalyx grandiflorus	3		15			UCL. Ca. 13.5km S of Mt Walton Waste Disposal facility, E of Yendilberin Hills. Ca. 10.5km ENE of Mt Walton. Near N-S track that runs south of the Mt Walton Waste Disposal facility (not the main access track).	KALGOORLIE	NON	UCL		22/09/2010 0:00	ACT_IND	38	38	N
	86566	3666	Labichea eremaea	3		9			UCL. Ca. 21km ESE of Mt Dimer. Ca. 15km NNE of Mt Walton. Ca. 5km SW of Mt Walton Waste Facility. Near east-west track that runs from Mt Dimer minesite to the Mt Walton track.	KALGOORLIE	NON	UCL		22/09/2010 0:00	ACT_IND	1	1	Y
	96768	36059	Leucopogon sp. Yellowdine (M. Hislop & F. Hort MH 3194)	1		3			UCL. Ca. 13km S of Mt Walton Waste Disposal faciility. E of Yendilberin Hills. Ca. 11km ENE of Mt Walton. Near the N-S track that runs south from the Mt Walton Waste Disposal facility (not the main access track).	KALGOORLIE	NON	UCL		22/09/2010 0:00	ESTMT	30	30	N
	94445	41785	Melichrus sp. Bungalbin Hill (F.H. & M.P. Mollemans 3069) PN	3		19			UCL. Ca. 15.5km SSE of Mt Walton Waste Facility. Ca. 18km ENE of Mt Walton. Ca. 80km NE of Koolyanobbing.	KALGOORLIE	NON	UCL		23/09/2010 0:00	ACT_IND	5	5	N
	94447	41785	Melichrus sp. Bungalbin Hill (F.H. & M.P. Mollemans 3069) PN	3		20			UCL. Ca. 14km SE of Mt Walton Waste Facility. Ca. 18km ENE of Mt Walton. Ca. 80km NE of Koolyanobbing.	KALGOORLIE	NON	UCL		23/09/2010 0:00		2	2	N
	94448	41785	Melichrus sp. Bungalbin Hill (F.H. & M.P. Mollemans 3069) PN	3		21			UCL. Ca. 16km SE of Mt Dimer. Ca. 12.5km NNE of Mt Walton. Near east-west track that runs from Mt Dimer minesite to the Mt Walton track.	KALGOORLIE	NON	UCL		22/09/2010 0:00	ESTMT	600	600	Y
	94449	41785	Melichrus sp. Bungalbin Hill (F.H. & M.P. Mollemans 3069) PN	3		22			UCL. Ca. 14.5km SE of Mt Dimer. Ca. 12.7km N of Mt Walton. Just south of east-west track that runs from Mt Dimer minesite to the Mt Walton track.	KALGOORLIE	NON	UCL		22/09/2010 0:00	ESTMT	70	70	Y
	93376	16621	Phebalium appressum	1		3			UCL. Ca. 18km ESE of Mt Dimer. Ca. 12.5km NNE of Mt Walton. Near E-W track that runs from Mt Dimer minesite to the Mt Walton track [Mt Walton Rd].	KALGOORLIE	NON	UCL		22/09/2010 0:00	ACT_IND	5	5	Y
	88246	6121	Verticordia stenopetala	3		3			UCL, Mount Walton intractable waste storage facility (R 42001), [S of southern boundary of reserve], 100km NE of Koolyanobbing. Shire of Coolgardie.	KALGOORLIE	NON	UCL		8/11/1996 0:00		0	0	N

Taxon	Status	Rank	IUCNCriteria	EPBC	DPaWRegion	DPaWDistrict	Distribution	FloweringPeriod	RecoveryPlan
Acacia cylindrica	3				GOLD,WHTB	KALGOORLIE,CENTRAL WHEATBELT	Southern Cross, Mt Correll, Kulja, Hunt Range, Kalannie, Chiddarcooping N.R., Mollerin N.R., Mt Manning Range, Ennuin Stn.		
Acacia desertorum var. nudipes	3				GOLD,WHTB	KALGOORLIE,CENTRAL WHEATBELT	Ghooli, Southern Cross, Yellowdine, Mt Dimer		
Austrostipa blackii	3				GOLD,MWST,WHTB	KALGOORLIE,GERALDTON,GREAT SOUTHERN,CENTRAL WHEATBELT	Merredin, Dalwallinu, Jaurdi, Widgiemooltha, eastern States, Tutanning Nature Reserve, Beverley, Blue Hills Range, Yandanoo Hills,Mt Manning Range, Barcooting Hill		
Baeckea sp. Jaurdi Station (L.W. Sage & F. Hort 2229)	2				GOLD	KALGOORLIE	Jaurdi Station	Oct	
Banksia arborea	4				GOLD	KALGOORLIE	Koolyanobbing, Die Hardy Range, Jaurdi Stn., Mt Elvire Stn., Diemals Stn., Helena and Aurora Range, Hunt Range, Bungalbin Hill, Mt Jackson, Manning Range	Mar-May, Sept-Oct	
Banksia lullfitzii	3				GOLD,SCST,WHTB	ESPERANCE,KALGOORLIE,GREAT SOUTHERN,CENTRAL WHEATBELT	Southern Cross, Frank Hann N.P., Coolgardie, Mt Manning Range, Ravensthorpe	Mar-May	
Bossiaea celata	3				GOLD	KALGOORLIE	Duri, Boorabbin	Sep,Oct	
Calytrix creswellii	3				GOLD	KALGOORLIE	Helena & Aurora Range,Credo Stn., Mt Manning Range, Wallaroo Rock	Nov-Dec	
Cryptandra polyclada subsp. aequabilis	1				GOLD	KALGOORLIE	Boorabbin	Oct	
Cyathostemon sp. Mt Dimer (C. McChesney TRL 4/72) PN	1				GOLD	KALGOORLIE	Mt Dimer		
Cyathostemon verrucosus	3				GOLD	KALGOORLIE	Bungalbin Hill, Helena & Aurora Ranges, Queen Victoria Rocks, Kalgoorlie, Boorabbin	Sep-Dec,Mar	
Dampiera sp. Jaurdi (D. Angus DA 268) PN	1				GOLD	KALGOORLIE	Jaurdi	Sep	
Daviesia sarissa subsp. redacta	2				GOLD	KALGOORLIE	Boorabbin	Sep	
Elachanthus pusillus	2				GOLD,SCST	ESPERANCE,KALGOORLIE	Orchid Rock, Cocklebiddy, Kalgoorlie, Jaurdi Stn	Oct	
Eremophila caerulea subsp. merrallii	4				GOLD,WHTB	KALGOORLIE,CENTRAL WHEATBELT	Bruce Rock, Jilbadji, Hunt Range, Burra Rock	Aug-Jan	
Eucalyptus exigua	3				GOLD,SCST,WHTB	ESPERANCE,KALGOORLIE,GREAT SOUTHERN,CENTRAL WHEATBELT	Lake Cronin, Hyden, Mt Day, Middle Ironcap, Lake Varley, Narembeen, Benari,Moorine Rock, Yellowdine, Jaurdi Stn., Mt Holland	-	
Eucalyptus formanii	4				GOLD	KALGOORLIE	Mt Jackson, Pigeon Rock, Diemals, Die Hardy Rg, Mt Dimer	Dec-Apr	
Eutaxia actinophylla	3				GOLD,SCST,WHTB	ESPERANCE,KALGOORLIE,CENTRAL WHEATBELT	Norseman, Salmon Gums, Mt Newmont, Bruce Rock, Wallaroo Rock, Mt Willgonarinya	Sep-Dec	
Gastrolobium semiteres	3				GOLD,SCST,WHTB	ESPERANCE,KALGOORLIE,CENTRAL WHEATBELT	Boorabbin Rock, Southern Cross, Koorarawalyee, Disapponitment Rock	Aug-Oct	
Gnephosis intonsa	3				GOLD,SCST,WHTB	ALBANY,ESPERANCE,KALGOORLIE,CENTRAL WHEATBELT	Gibraltar, Boorabbin, Dundas, Ravenshtorpe, North Ironcap, Ora Banda, Lake Cowan, Parker Range	Sep	
Gnephosis sp. Norseman (K.R. Newbey 8096)	3				GOLD,SCST	ESPERANCE,KALGOORLIE	Jaurdi Stn, Norseman	Sep,Oct	
Gompholobium cinereum	3				GOLD,MWST,WHTB	KALGOORLIE,GERALDTON,CENTRAL WHEATBELT	Wongan Hills, Mullewa, Wilroy, Mt Burges, Merredin, Koolyanobbing, Boorabbin, Maya	Sep-Oct	
Goodenia jaurdiensis	2				GOLD	KALGOORLIE	Jaurdi, Helena-Aurora Range	Sep-Oct	
Grevillea erectiloba	4				GOLD	KALGOORLIE	Bungalbin Hill, Mt Jackson, Mt Dimer	Sep	
Grevillea georgeana	3				GOLD	KALGOORLIE	Die Hardy Range, Mt Manning, Mt Correll, Helena and Aurora Range, Bungalbin Hill	Jul	
Haegiela tatei	4				GOLD,MWST,SCST,WHTB	ESPERANCE,KALGOORLIE,GERALDTON,GREAT SOUTHERN	Grass Patch, Lake Lockhart, Lake King, Badja Station, Peak Charles N.P., Lake Grace, Lake Magenta N.R., Lake Lockhart, Lake Cronin, Jaurdi Stn.	-	
Hakea rigida	2				GOLD,WHTB	KALGOORLIE,CENTRAL WHEATBELT	Campion, Bullfinch, Wallaroo Rock, Mt Burges	Sep	
Hemigenia tenelliflora	2				GOLD	KALGOORLIE	Jaurdi	Oct	
Hibbertia lepidocalyx subsp. tuberculata	3				GOLD	KALGOORLIE	Hunt Range, Helena and Aurora Range, Koolyanobbing Range	Jul	
Homalocalyx grandiflorus	3				GOLD	KALGOORLIE	Bungalbin, Comet Vale, Goongarrie Stn., Mt Manning N.R.	Dec	
Lepidium genistoides	3				GOLD,WHTB	KALGOORLIE,CENTRAL WHEATBELT	Walyahmoning Rock, Boorabbin, (Cowcowing), Marvel Loch, (Mukinbudin), Koorda, Ennuin Stn, Merredin	Oct-Dec	
Lepidosperma lyonsii	4				GOLD,WHTB	KALGOORLIE,CENTRAL WHEATBELT	Jaurdi, Karonie, Charles Gardner N.R., Totadgin Conservation Park		
Lissanthe scabra	2				GOLD,WHTB	KALGOORLIE,CENTRAL WHEATBELT	Jaurdi Stn, Marvel Loch, Southern Cross, Frog Rock Nature Reserve	Aug,Sep	
Malleostemon sp. Adelong (G.J. Keighery 11825)	2				GOLD	KALGOORLIE	Adelong Stn, Mt Manning, Johnston Range	Oct	
Mirbelia ferricola	3				GOLD,MWST,SCST	ESPERANCE,KALGOORLIE,GERALDTON	Helena and Aurora Range, Jaurdi Stn, Coorara Soak, Mt Manning N.R, Bremer Range, Koolanooka Hills, Perenjori Hills, Diemals Stn.,	Sep	
Sowerbaea multicaulis	4				GOLD,WHTB	KALGOORLIE,CENTRAL WHEATBELT	Bullfinch, Karroun Hill, Lake Deborah (Bremer Range - Lake Hope, Lake Cronin)	Nov	
Stenanthemum newbeyi	3				GOLD,WHTB	KALGOORLIE,CENTRAL WHEATBELT	Bungalbin Hill, Koolyanobbing, Die Hardy Range, Ennuin Stn, Mt Manning,Helena and Aurora Range, Mt Jackson	Au-Sep,De-Ja	
Stylidium choreanthum	3				GOLD,WHTB	KALGOORLIE,CENTRAL WHEATBELT	Helena & Aurora Range, Ghooli, Southern Cross, Kambalda, Koolyanobbing, Jaurdi Station, Ennuin Stn	Sep-Oct	
Tecticornia flabelliformis	1				GOLD,WHTB	KALGOORLIE,CENTRAL WHEATBELT	Lake Yindarlgooda, Lake Deborah, Widgiemooltha, Eastern States		
Verticordia mitodes	3				GOLD,WHTB	KALGOORLIE,CENTRAL WHEATBELT	Chiddarcooping, Moorine Rock to Mt Holland, Boorabbin NR, bungalbin Hill, Marvel Loch, Bootraan, Koorarawalyee, Wogarl	Dec	
Verticordia stenopetala	3				GOLD,WHTB	KALGOORLIE,CENTRAL WHEATBELT	Mt Holland, Moorine Rock, Queen Victoria Rock, Marvel Loch, Carrabin, Mt Walton, Holleton	Oct	
Xanthoparmelia fumigata	1				GOLD	KALGOORLIE	Boorabbin, South Australia		

APPENDIX 2

NatureMap Report

NatureMap
Mapping Western Australia's biodiversity

NatureMap Species Report

Created By Jackalyn Hams on 28/04/2015

Current Names Only	Yes
Core Datasets Only	Yes
Method	'By Circle'
Centre	120°05' 20" E,30°22' 19" S
Buffer	20km
Group By	Conservation Status

Conservation Status	Species	Records
Non-conservation taxon	208	479
Priority 1	3	4
Priority 2	1	3
Priority 3	6	35
Priority 4	2	8
Rare or likely to become extinct	1	1
TOTAL	**221**	**530**

	Name ID	Species Name	Naturalised	Conservation Code	[1]Endemic To Query Area
Rare or likely to become extinct					
1.	24557	*Leipoa ocellata (Malleefowl)*		T	
Priority 1					
2.	30438	*Lepidosperma sp. Parker Range (N. Gibson & M. Lyons 2094)*		P1	
3.	36059	*Leucopogon sp. Yellowdine (M. Hislop & F. Hort MH 3194)*		P1	
4.	16621	*Phebalium appressum*		P1	
Priority 2					
5.	20860	*Goodenia jaurdiensis*		P2	
Priority 3					
6.	5448	*Calytrix creswellii*		P3	
7.	2009	*Grevillea georgeana*		P3	
8.	5811	*Homalocalyx grandiflorus*		P3	
9.	3666	*Labichea eremaea*		P3	
10.	41785	*Melichrus sp. Bungalbin Hill (F.H. & M.P. Mollemans 3069)*		P3	
11.	6121	*Verticordia stenopetala*		P3	
Priority 4					
12.	32685	*Banksia arborea (Yilgarn Dryandra)*		P4	
13.	31763	*Lepidosperma lyonsii*		P4	
Non-conservation taxon					
14.	3200	*Acacia acuminata (Jam, Mangard)*			
15.	3324	*Acacia erinacea*			
16.	3366	*Acacia hemiteles*			
17.	3393	*Acacia jennerae*			
18.	3545	*Acacia sibina*			
19.	23525	*Acacia steedmanii subsp. steedmanii*			
20.	3577	*Acacia tetragonophylla (Kurara, Wakalpuka)*			
21.	24559	*Acanthagenys rufogularis (Spiny-cheeked Honeyeater)*			
22.	24265	*Acanthiza uropygialis (Chestnut-rumped Thornbill)*			
23.	1720	*Allocasuarina acutivalvis*			
24.	13904	*Allocasuarina acutivalvis subsp. acutivalvis*			
25.	13906	*Allocasuarina eriochlamys subsp. eriochlamys*			
26.	6565	*Alyxia buxifolia (Dysentery Bush)*			
27.	12025	*Amphipogon caricinus var. caricinus*			
28.	2369	*Amyema benthamii*			
29.		*Aname tepperi*			
30.	24561	*Anthochaera carunculata (Red Wattlebird)*			
31.	24285	*Aquila audax (Wedge-tailed Eagle)*			
32.	207	*Aristida contorta (Bunched Kerosene Grass)*			
33.	210	*Aristida holathera*			
34.	24353	*Artamus cyanopterus (Dusky Woodswallow)*			

	Name ID	Species Name	Naturalised	Conservation Code	[1]Endemic To Query Area
35.	2451	*Atriplex bunburyana (Silver Saltbush)*			
36.	2452	*Atriplex cinerea (Grey Saltbush)*			
37.	2469	*Atriplex nummularia (Old Man Saltbush)*			
38.	11516	*Atriplex nummularia subsp. spathulata (Old Man Saltbush)*			
39.	2481	*Atriplex vesicaria (Bladder Saltbush)*			
40.	17237	*Austrostipa elegantissima*			
41.	17247	*Austrostipa platychaeta*			
42.	17252	*Austrostipa scabra subsp. scabra*			
43.	5344	*Baeckea elderiana*			
44.	5375	*Balaustion pulcherrimum (Native Pomegranate)*			
45.	11201	*Boronia ternata var. ternata*			
46.	3722	*Bossiaea walkeri*			
47.	4999	*Brachychiton gregorii (Desert Kurrajong, Ngalta)*			
48.	7413	*Brunonia australis (Native Cornflower)*			
49.	2848	*Calandrinia corrigioloides (Strap Purslane)*			
50.	7903	*Calotis hispidula (Bindy Eye)*			
51.	7916	*Centaurea melitensis (Maltese Cockspur)*	Y		
52.		*Cethegus fugax*			
53.	31	*Cheilanthes austrotenuifolia*			
54.	3168	*Cheiranthera filifolia*			
55.	25675	*Colluricincla harmonica (Grey Shrike-thrush)*			
56.	25568	*Coracina novaehollandiae (Black-faced Cuckoo-shrike)*			
57.	24420	*Cracticus nigrogularis (Pied Butcherbird)*			
58.	25595	*Cracticus tibicen (Australian Magpie)*			
59.	25596	*Cracticus torquatus (Grey Butcherbird)*			
60.	3137	*Crassula colorata (Dense Stonecrop)*			
61.	7951	*Cratystylis subspinescens (Australian Sage, Spiny Grey Bush)*			
62.	24873	*Ctenophorus fordi (Mallee Sand Dragon)*			
63.	13158	*Dampiera tenuicaulis var. curvula*			
64.	25673	*Daphoenositta chrysoptera (Varied Sittella)*			
65.	41025	*Dasymalla terminalis (Native Foxglove)*			
66.	6218	*Daucus glochidiatus (Australian Carrot)*			
67.	3836	*Daviesia purpurascens (Purple-leaved Daviesia)*			
68.	1259	*Dianella revoluta (Blueberry Lily)*			
69.	24929	*Diplodactylus granariensis subsp. granariensis*			
70.	4769	*Dodonaea lobulata (Bead Hopbush)*			
71.	4770	*Dodonaea microzyga*			
72.	24470	*Dromaius novaehollandiae (Emu)*			
73.	3106	*Drosera macrantha (Bridal Rainbow)*			
74.	399	*Eragrostis xerophila (Knotty-butt Neverfail)*			
75.	7180	*Eremophila alternifolia (Poverty Bush)*			
76.	13807	*Eremophila caperata*			
77.	7189	*Eremophila clarkei (Turpentine Bush)*			
78.	14895	*Eremophila decipiens subsp. decipiens*			
79.	7211	*Eremophila georgei*			
80.	7219	*Eremophila granitica (Thin-leaved Poverty Bush)*			
81.	15112	*Eremophila interstans subsp. interstans*			
82.	7226	*Eremophila ionantha (Violet-flowered Eremophila)*			
83.	16363	*Eremophila maculata subsp. brevifolia (Native Fuchsia)*			
84.	15003	*Eremophila oldfieldii subsp. angustifolia*			
85.	7247	*Eremophila oppositifolia (Weeooka)*			
86.	18570	*Eremophila oppositifolia subsp. angustifolia*			
87.	7267	*Eremophila scoparia (Broom Bush ()*			
88.	4333	*Erodium cicutarium (Common Storksbill)*	Y		
89.	4335	*Erodium cygnorum (Blue Heronsbill)*			
90.	14377	*Erymophyllum ramosum subsp. ramosum*			
91.	5592	*Eucalyptus clelandii (Cleland's Blackbutt)*			
92.	5641	*Eucalyptus ewartiana (Ewart's Mallee)*			
93.	12886	*Eucalyptus flavida (Yellow-flowered Mallee)*			
94.	5665	*Eucalyptus griffithsii (Griffith's Grey Gum)*			
95.	5673	*Eucalyptus horistes*			
96.	13037	*Eucalyptus loxophleba subsp. lissophloia*			
97.	20091	*Eucalyptus oleosa subsp. oleosa*			
98.	12380	*Eucalyptus ravida (Silver-topped Gimlet)*			
99.	5766	*Eucalyptus salmonophloia (Salmon Gum, Wurak)*			
100.	5767	*Eucalyptus salubris (Gimlet)*			
101.	5793	*Eucalyptus transcontinentalis (Redwood, Pungul)*			
102.	34775	*Eucalyptus vittata*			
103.	5802	*Eucalyptus yilgarnensis (Yorrell)*			
104.	10977	*Exocarpos aphyllus (Leafless Ballart)*			

	Name ID	Species Name	Naturalised	Conservation Code	[1]Endemic To Query Area
105.	5204	*Frankenia interioris*			
106.	24735	*Glossopsitta porphyrocephala (Purple-crowned Lorikeet)*			
107.	7495	*Goodenia berardiana*			
108.	7527	*Goodenia mimuloides*			
109.	7531	*Goodenia occidentalis*			
110.	1949	*Grevillea acuaria*			
111.	13453	*Grevillea didymobotrya subsp. didymobotrya*			
112.	19314	*Grevillea hookeriana subsp. apiciloba*			
113.	8834	*Grevillea incrassata*			
114.	2051	*Grevillea obliquistigma*			
115.	15981	*Grevillea obliquistigma subsp. obliquistigma*			
116.	2057	*Grevillea paradoxa (Bottlebrush Grevillea)*			
117.	2104	*Grevillea teretifolia (Round Leaf Grevillea)*			
118.	15982	*Grevillea zygoloba*			
119.	2182	*Hakea minyma*			
120.	6174	*Haloragis gossei*			
121.	6180	*Haloragis trigonocarpa*			
122.	5122	*Hibbertia eatoniae*			
123.	5124	*Hibbertia exasperata*			
124.	5165	*Hibbertia rostellata*			
125.		*Hogna pexa*			
126.	12742	*Hyalosperma demissum*			
127.	5220	*Hybanthus epacroides (Spiny Hybanthus)*			
128.	19892	*Keraudrenia velutina subsp. velutina*			
129.	13284	*Lawrencella rosea*			
130.	13260	*Leucochrysum fitzgibbonii*			
131.	16049	*Leucopogon sp. Clyde Hill (M.A. Burgman 1207)*			
132.	25659	*Lichenostomus leucotis (White-eared Honeyeater)*			
133.	25661	*Lichmera indistincta (Brown Honeyeater)*			
134.	2396	*Lysiana casuarinae*			
135.	2544	*Maireana georgei (Satiny Bluebush)*			
136.	2567	*Maireana tomentosa (Felty Bluebush)*			
137.	2568	*Maireana trichoptera (Downy Bluebush)*			
138.	5866	*Malleostemon tuberculatus*			
139.	41544	*Malva weinmanniana*			
140.	24583	*Manorina flavigula (Yellow-throated Miner)*			
141.	5929	*Melaleuca leiocarpa*			
142.	9183	*Melaleuca nematophylla (Wiry Honey-myrtle)*			
143.	25693	*Microeca fascinans (Jacky Winter)*			
144.	8106	*Millotia tenuifolia (Soft Millotia)*			
145.	490	*Monachather paradoxus*			
146.	24970	*Nephrurus stellatus*			
147.	6976	*Nicotiana occidentalis (Native Tobacco)*			
148.	25748	*Ninox novaeseelandiae (Boobook Owl)*			
149.	8140	*Olearia muelleri (Goldfields Daisy)*			
150.	8145	*Olearia pimeleoides (Pimelea Daisybush, Burrobunga)*			
151.	8151	*Olearia stuartii*			
152.	24618	*Oreoica gutturalis (Crested Bellbird)*			
153.	24619	*Pachycephala inornata (Gilbert's Whistler)*			
154.	25680	*Pachycephala rufiventris (Rufous Whistler)*			
155.	25682	*Pardalotus striatus (Striated Pardalote)*			
156.	40424	*Pentameris airoides subsp. airoides*	Y		
157.	24409	*Phaps chalcoptera (Common Bronzewing)*			
158.	18537	*Philotheca brucei subsp. brucei*			
159.	18519	*Philotheca coccinea*			
160.	18506	*Philotheca tomentella*			
161.	11910	*Pimelea suaveolens subsp. flava*			
162.	34760	*Plantago cunninghamii*			
163.	7299	*Plantago debilis*			
164.	7300	*Plantago drummondii (Sago Weed)*			
165.	8173	*Podolepis capillaris (Wiry Podolepis)*			
166.	8177	*Podolepis lessonii*			
167.	25722	*Polytelis anthopeplus (Regent Parrot)*			
168.	24683	*Pomatostomus superciliosus (White-browed Babbler)*			
169.	4691	*Poranthera microphylla (Small Poranthera)*			
170.	6912	*Prostanthera campbellii*			
171.	6916	*Prostanthera grylloana*			
172.	6917	*Prostanthera incurvata*			
173.	12702	*Prostanthera sericea*			
174.	13255	*Pterochaeta paniculata*			

	Name ID	Species Name	Naturalised	Conservation Code	[1]Endemic To Query Area
175.	2707	*Ptilotus carlsonii*			
176.	2727	*Ptilotus gaudichaudii*			
177.	2732	*Ptilotus holosericeus*			
178.	2746	*Ptilotus nobilis (Tall Mulla Mulla)*			
179.	41001	*Ptilotus nobilis subsp. nobilis (Yellow Tails)*			
180.	2747	*Ptilotus obovatus (Cotton Bush)*			
181.	42344	*Purnella albifrons (White-fronted Honeyeater)*			
182.	2581	*Rhagodia drummondii*			
183.	25614	*Rhipidura leucophrys (Willie Wagtail)*			
184.	13301	*Rhodanthe floribunda*			
185.	13294	*Rhodanthe laevis*			
186.	13253	*Rhodanthe rubella*			
187.	13254	*Rhodanthe stricta*			
188.	6599	*Rhyncharrhena linearis (Bush Bean, Wintjulanypa)*			
189.	6018	*Rinzia carnosa*			
190.	40425	*Rytidosperma caespitosum*			
191.	2356	*Santalum acuminatum (Quandong, Warnga)*			
192.	2359	*Santalum spicatum (Sandalwood, Wilarak)*			
193.	7644	*Scaevola spinescens (Currant Bush, Maroon)*			
194.	8200	*Schoenia cassiniana (Schoenia)*			
195.	1002	*Schoenus nanus (Tiny Bog Rush)*			
196.	2609	*Sclerolaena diacantha (Grey Copperburr)*			
197.	2615	*Sclerolaena fusiformis*			
198.	17645	*Senna artemisioides*			
199.	12276	*Senna artemisioides subsp. filifolia*			
200.	19712	*Sida sp. dark green fruits (S. van Leeuwen 2260)*			
201.	30948	*Smicrornis brevirostris (Weebill)*			
202.	8231	*Sonchus oleraceus (Common Sowthistle)*	Y		
203.	44484	*Spartothamnella canescens*			
204.	16200	*Stenanthemum stipulosum*			
205.	3076	*Stenopetalum filifolium*			
206.	25597	*Strepera versicolor (Grey Currawong)*			
207.	8238	*Streptoglossa liatroides*			
208.	4258	*Templetonia sulcata (Centipede Bush)*			
209.	1701	*Thelymitra antennifera (Vanilla Orchid)*			
210.	1338	*Thysanotus manglesianus (Fringed Lily)*			
211.	6279	*Trachymene ornata (Spongefruit)*			
212.	7658	*Velleia discophora (Cabbage Poison)*			
213.	7664	*Velleia rosea (Pink Velleia)*			
214.	8265	*Vittadinia eremaea*			
215.	8275	*Waitzia acuminata (Orange Immortelle)*			
216.	13331	*Waitzia acuminata var. acuminata*			
217.	4385	*Zygophyllum apiculatum (Gallweed)*			
218.	4389	*Zygophyllum eremaeum*			
219.	4391	*Zygophyllum glaucum (Pale Twinleaf)*			
220.	4392	*Zygophyllum iodocarpum*			
221.	4394	*Zygophyllum ovatum (Dwarf Twinleaf)*			

Conservation Codes
T - Rare or likely to become extinct
X - Presumed extinct
IA - Protected under international agreement
S - Other specially protected fauna
1 - Priority 1
2 - Priority 2
3 - Priority 3
4 - Priority 4
5 - Priority 5

[1] For NatureMap's purposes, species flagged as endemic are those whose records are wholely contained within the search area. Note that only those records complying with the search criterion are included in the calculation. For example, if you limit records to those from a specific datasource, only records from that datasource are used to determine if a species is restricted to the query area.

APPENDIX 3

Protected Matters Search Tool Report

Australian Government

Department of the Environment

EPBC Act Protected Matters Report

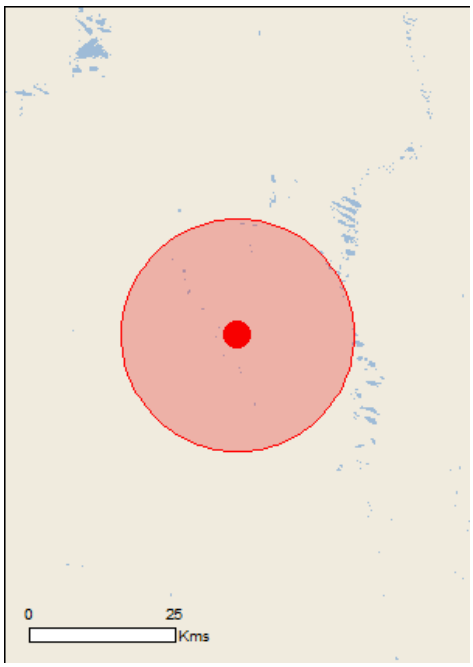
This report provides general guidance on matters of national environmental significance and other matters protected by the EPBC Act in the area you have selected.

Information on the coverage of this report and qualifications on data supporting this report are contained in the caveat at the end of the report.

Information is available about Environment Assessments and the EPBC Act including significance guidelines, forms and application process details.

Report created: 28/04/15 15:35:51

- Summary
- Details
  - Matters of NES
  - Other Matters Protected by the EPBC Act
  - Extra Information
- Caveat
- Acknowledgements



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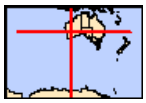
Coordinates
Buffer: 20.0Km



Summary

Matters of National Environmental Significance

This part of the report summarises the matters of national environmental significance that may occur in, or may relate to, the area you nominated. Further information is available in the detail part of the report, which can be accessed by scrolling or following the links below. If you are proposing to undertake an activity that may have a significant impact on one or more matters of national environmental significance then you should consider the Administrative Guidelines on Significance.

World Heritage Properties:	None
National Heritage Places:	None
Wetlands of International Importance:	None
Great Barrier Reef Marine Park:	None
Commonwealth Marine Area:	None
Listed Threatened Ecological Communities:	None
Listed Threatened Species:	5
Listed Migratory Species:	4

Other Matters Protected by the EPBC Act

This part of the report summarises other matters protected under the Act that may relate to the area you nominated. Approval may be required for a proposed activity that significantly affects the environment on Commonwealth land, when the action is outside the Commonwealth land, or the environment anywhere when the action is taken on Commonwealth land. Approval may also be required for the Commonwealth or Commonwealth agencies proposing to take an action that is likely to have a significant impact on the environment anywhere.

The EPBC Act protects the environment on Commonwealth land, the environment from the actions taken on Commonwealth land, and the environment from actions taken by Commonwealth agencies. As heritage values of a place are part of the 'environment', these aspects of the EPBC Act protect the Commonwealth Heritage values of a Commonwealth Heritage place. Information on the new heritage laws can be found at http://www.environment.gov.au/heritage/index.html

A permit may be required for activities in or on a Commonwealth area that may affect a member of a listed threatened species or ecological community, a member of a listed migratory species, whales and other cetaceans, or a member of a listed marine species.

Commonwealth Land:	None
Commonwealth Heritage Places:	None
Listed Marine Species:	5
Whales and Other Cetaceans:	None
Critical Habitats:	None
Commonwealth Reserves Terrestrial:	None
Commonwealth Reserves Marine:	None

Extra Information

This part of the report provides information that may also be relevant to the area you have nominated.

State and Territory Reserves:	1
Regional Forest Agreements:	None
Invasive Species:	10
Nationally Important Wetlands:	None
Key Ecological Features (Marine)	None

Details

Matters of National Environmental Significance

Listed Threatened Species		[Resource Information]
Name	Status	Type of Presence
Birds		
Leipoa ocellata Malleefowl [934]	Vulnerable	Species or species habitat likely to occur within area
Mammals		
Dasyurus geoffroii Chuditch, Western Quoll [330]	Vulnerable	Species or species habitat may occur within area
Plants		
Myriophyllum lapidicola Chiddarcooping myriophyllum [55940]	Endangered	Species or species habitat known to occur within area
Ricinocarpos brevis [82879]	Endangered	Species or species habitat likely to occur within area
Tetratheca paynterae Paynter's Tetratheca [66451]	Endangered	Species or species habitat may occur within area

Listed Migratory Species		[Resource Information]
* Species is listed under a different scientific name on the EPBC Act - Threatened Species list.		
Name	Threatened	Type of Presence
Migratory Marine Birds		
Apus pacificus Fork-tailed Swift [678]		Species or species habitat likely to occur within area
Migratory Terrestrial Species		
Merops ornatus Rainbow Bee-eater [670]		Species or species habitat may occur within area
Migratory Wetlands Species		
Ardea alba Great Egret, White Egret [59541]		Species or species habitat likely to occur within area
Ardea ibis Cattle Egret [59542]		Species or species habitat may occur within area

Other Matters Protected by the EPBC Act

Listed Marine Species [Resource Information]

* Species is listed under a different scientific name on the EPBC Act - Threatened Species list.

Name	Threatened	Type of Presence
Birds		
Apus pacificus Fork-tailed Swift [678]		Species or species habitat likely to occur within area
Ardea alba Great Egret, White Egret [59541]		Species or species habitat likely to occur within area
Ardea ibis Cattle Egret [59542]		Species or species habitat may occur within area
Merops ornatus Rainbow Bee-eater [670]		Species or species habitat may occur within area
Thinornis rubricollis Hooded Plover [59510]		Species or species habitat may occur within area

Extra Information

State and Territory Reserves [Resource Information]

Name	State
Mount Manning Range	WA

Invasive Species [Resource Information]

Weeds reported here are the 20 species of national significance (WoNS), along with other introduced plants that are considered by the States and Territories to pose a particularly significant threat to biodiversity. The following feral animals are reported: Goat, Red Fox, Cat, Rabbit, Pig, Water Buffalo and Cane Toad. Maps from Landscape Health Project, National Land and Water Resouces Audit, 2001.

Name	Status	Type of Presence
Birds		
Columba livia Rock Pigeon, Rock Dove, Domestic Pigeon [803]		Species or species habitat likely to occur within area
Streptopelia senegalensis Laughing Turtle-dove, Laughing Dove [781]		Species or species habitat likely to occur within area
Mammals		
Capra hircus Goat [2]		Species or species habitat likely to occur within area
Equus asinus Donkey, Ass [4]		Species or species habitat likely to occur

Name	Status	Type of Presence
		within area
Equus caballus Horse [5]		Species or species habitat likely to occur within area
Felis catus Cat, House Cat, Domestic Cat [19]		Species or species habitat likely to occur within area
Mus musculus House Mouse [120]		Species or species habitat likely to occur within area
Oryctolagus cuniculus Rabbit, European Rabbit [128]		Species or species habitat likely to occur within area
Vulpes vulpes Red Fox, Fox [18]		Species or species habitat likely to occur within area
Plants		
Carrichtera annua Ward's Weed [9511]		Species or species habitat likely to occur within area

Caveat

The information presented in this report has been provided by a range of data sources as acknowledged at the end of the report.

This report is designed to assist in identifying the locations of places which may be relevant in determining obligations under the Environment Protection and Biodiversity Conservation Act 1999. It holds mapped locations of World and National Heritage properties, Wetlands of International and National Importance, Commonwealth and State/Territory reserves, listed threatened, migratory and marine species and listed threatened ecological communities. Mapping of Commonwealth land is not complete at this stage. Maps have been collated from a range of sources at various resolutions.

Not all species listed under the EPBC Act have been mapped (see below) and therefore a report is a general guide only. Where available data supports mapping, the type of presence that can be determined from the data is indicated in general terms. People using this information in making a referral may need to consider the qualifications below and may need to seek and consider other information sources.

For threatened ecological communities where the distribution is well known, maps are derived from recovery plans, State vegetation maps, remote sensing imagery and other sources. Where threatened ecological community distributions are less well known, existing vegetation maps and point location data are used to produce indicative distribution maps.

For species where the distributions are well known, maps are digitised from sources such as recovery plans and detailed habitat studies. Where appropriate, core breeding, foraging and roosting areas are indicated under 'type of presence'. For species whose distributions are less well known, point locations are collated from government wildlife authorities, museums, and non-government organisations; bioclimatic distribution models are generated and these validated by experts. In some cases, the distribution maps are based solely on expert knowledge.

Only selected species covered by the following provisions of the EPBC Act have been mapped:

- migratory and
- marine

The following species and ecological communities have not been mapped and do not appear in reports produced from this database:

- threatened species listed as extinct or considered as vagrants
- some species and ecological communities that have only recently been listed
- some terrestrial species that overfly the Commonwealth marine area
- migratory species that are very widespread, vagrant, or only occur in small numbers

The following groups have been mapped, but may not cover the complete distribution of the species:

- non-threatened seabirds which have only been mapped for recorded breeding sites
- seals which have only been mapped for breeding sites near the Australian continent

Such breeding sites may be important for the protection of the Commonwealth Marine environment.

Coordinates

-30.34459 120.08838

Acknowledgements

This database has been compiled from a range of data sources. The department acknowledges the following custodians who have contributed valuable data and advice:

-Department of Environment, Climate Change and Water, New South Wales
-Department of Sustainability and Environment, Victoria
-Department of Primary Industries, Parks, Water and Environment, Tasmania
-Department of Environment and Natural Resources, South Australia
-Parks and Wildlife Service NT, NT Dept of Natural Resources, Environment and the Arts
-Environmental and Resource Management, Queensland
-Department of Environment and Conservation, Western Australia
-Department of the Environment, Climate Change, Energy and Water
-Birds Australia
-Australian Bird and Bat Banding Scheme
-Australian National Wildlife Collection
-Natural history museums of Australia
-Museum Victoria
-Australian Museum
-SA Museum
-Queensland Museum
-Online Zoological Collections of Australian Museums
-Queensland Herbarium
-National Herbarium of NSW
-Royal Botanic Gardens and National Herbarium of Victoria
-Tasmanian Herbarium
-State Herbarium of South Australia
-Northern Territory Herbarium
-Western Australian Herbarium
-Australian National Herbarium, Atherton and Canberra
-University of New England
-Ocean Biogeographic Information System
-Australian Government, Department of Defence
-State Forests of NSW
-Geoscience Australia
-CSIRO
-Other groups and individuals

The Department is extremely grateful to the many organisations and individuals who provided expert advice and information on numerous draft distributions.

Please feel free to provide feedback via the Contact Us page.

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APPENDIX 4

DPaW TEC and PEC Database Search

OBJECTID	OCC_UNIQUE	COM_ID	COM_NAME	CT_DESC	S_ID_COUNT	FIRST_S_ID	LAST_S_ID	BUFFER	OCC_CONFID	BDY_ID	Shape_Leng	Shape_Area
2479	5238	Finnerty Range/Mt Dimer/Yendilberin Hills BIF	Finnerty Range/Mt Dimer/Yendilberin Hills vegetation complexes (banded ironstone formation)	Priority 1	1	Yendiberin1		500	No	2935	0.14591331988	0.00110327027
2480	5239	Finnerty Range/Mt Dimer/Yendilberin Hills BIF	Finnerty Range/Mt Dimer/Yendilberin Hills vegetation complexes (banded ironstone formation)	Priority 1	1	Yendiberin2		500	No	2936	0.16651421023	0.00146249346
2481	5240	Finnerty Range/Mt Dimer/Yendilberin Hills BIF	Finnerty Range/Mt Dimer/Yendilberin Hills vegetation complexes (banded ironstone formation)	Priority 1	1	Yendiberin3		500	No	2937	0.05886183862	0.00023600915
2482	5241	Finnerty Range/Mt Dimer/Yendilberin Hills BIF	Finnerty Range/Mt Dimer/Yendilberin Hills vegetation complexes (banded ironstone formation)	Priority 1	1	MtDimer1		500	No	2938	0.16921418512	0.00125621746
2483	5242	Finnerty Range/Mt Dimer/Yendilberin Hills BIF	Finnerty Range/Mt Dimer/Yendilberin Hills vegetation complexes (banded ironstone formation)	Priority 1	1	MtDimer2		500	No	2939	0.07977504842	0.00037015595
2484	5243	Finnerty Range/Mt Dimer/Yendilberin Hills BIF	Finnerty Range/Mt Dimer/Yendilberin Hills vegetation complexes (banded ironstone formation)	Priority 1	1	MtDimer3		500	No	2940	0.07956326810	0.00039137607
2485	5245	Finnerty Range/Mt Dimer/Yendilberin Hills BIF	Finnerty Range/Mt Dimer/Yendilberin Hills vegetation complexes (banded ironstone formation)	Priority 1	1	MtDimer5		500	No	2942	0.10611341008	0.00054104484
14421	5244	Finnerty Range/Mt Dimer/Yendilberin Hills BIF	Finnerty Range/Mt Dimer/Yendilberin Hills vegetation complexes (banded ironstone formation)	Priority 1	1	MtDimer4		500	No	2941	0.18543806994	0.00155993717
14441	2582	Hunt Range BIF	Hunt Range vegetation complexes (banded ironstone formation)	Priority 1	1	Mount Dimer		500	No	1275	0.50314667890	0.00581675185
14477	2618	Lake Giles (northern Yerilgee Hills) BIF	Lake Giles vegetation complexes (banded ironstone formation)	Priority 1	1	Lake Giles		500	No	1193	1.79401781058	0.04145420920

APPENDIX 5

Soil Mapping

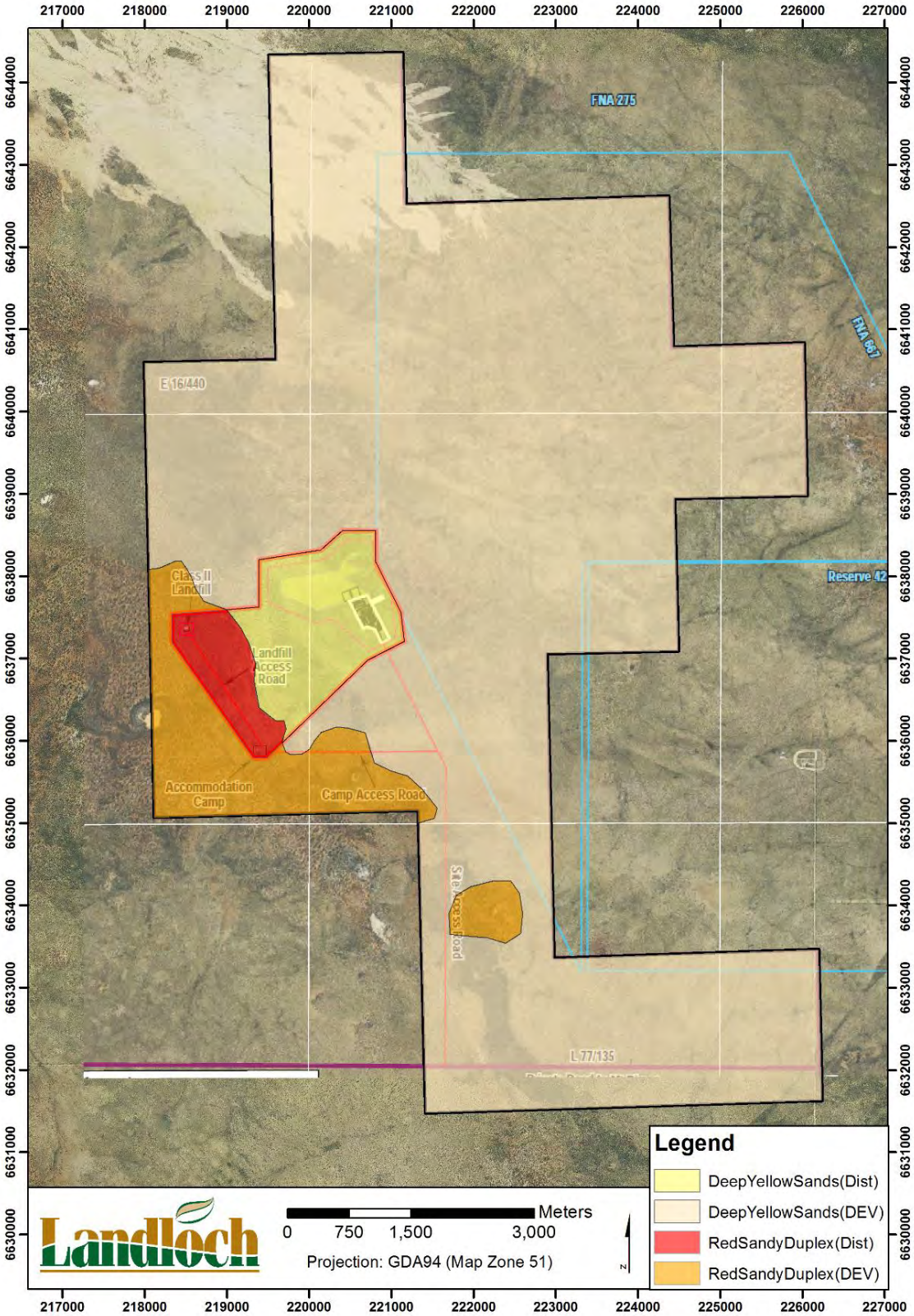

Figure 6: Map of the soil types found at the Sandy Ridge Mine Site. Note that soils in the development area (DEV) are inferred and have a lower confidence level than the soils mapped in the disturbance area (Dist).

APPENDIX 6

Conservation Codes

Conservation Codes for Western Australian Flora and Fauna

T Threatened species

Listed as Specially Protected under the Wildlife Conservation Act 1950, published under Schedule 1 of the Wildlife Conservation (Specially Protected Fauna) Notice for Threatened Fauna and Wildlife Conservation (Rare Flora) Notice for Threatened Flora (which may also be referred to as Declared Rare Flora).

- Fauna that is rare or likely to become extinct are declared to be fauna that is in need of special protection
- Flora that are extant and considered likely to become extinct, or rare and therefore in need of special protection, are declared to be rare flora

Species* which have been adequately searched for and are deemed to be, in the wild, either rare, at risk of extinction, or otherwise in need of special protection, and have been gazetted as such. The assessment of the conservation status of these species is based on their national extent.

X Presumed extinct species

Listed as Specially Protected under the Wildlife Conservation Act 1950, published under Schedule 2 of the Wildlife Conservation (Specially Protected Fauna) Notice for Presumed Extinct Fauna and Wildlife Conservation (Rare Flora) Notice for Presumed Extinct Flora (which may also be referred to as Declared Rare Flora).

Species which have been adequately searched for and there is no reasonable doubt that the last individual has died, and have been gazetted as such.

IA Migratory birds protected under an international agreement

Listed as Specially Protected under the Wildlife Conservation Act 1950, listed under Schedule 3 of the Wildlife Conservation (Specially Protected Fauna) Notice.

Birds that are subject to an agreement between the government of Australia and the governments of Japan (JAMBA), China (CAMBA) and The Republic of Korea (ROKAMBA), relating to the protection of migratory birds.

S Other specially protected fauna

Listed as Specially Protected under the Wildlife Conservation Act 1950. Fauna declared to be in need of special protection, otherwise than for the reasons mentioned for Schedules 1, 2 or 3, are published under Schedule 4 of the Wildlife Conservation (Specially Protected Fauna) Notice.

Threatened Fauna and Flora are ranked according to their level of threat using IUCN Red List categories and criteria. For example: Carnaby's Cockatoo (*Calyptorynchus latirostris*) is listed as 'Specially Protected' under the Wildlife Conservation Act 1950, published under Schedule 1, and referred to as a 'Threatened' species with a ranking of 'Endangered'.

CR Critically Endangered - considered to be facing an extremely high risk of extinction in the wild.

EN Endangered - considered to be facing a very high risk of extinction in the wild.

VU Vulnerable - considered to be facing a high risk of extinction in the wild.

A list of the current rankings can be downloaded from the Parks and Wildlife Threatened Species and Communities webpage at http://dpaw.wa.gov.au/plants-and-animals/threatened-species-and-communities/

P Priority species

Species that maybe threatened or near threatened but are data deficient, have not yet been adequately surveyed to be listed under the Schedules of the Wildlife Conservation (Specially Protected Fauna) Notice or the Wildlife Conservation (Rare Flora) Notice, are added to the Priority Fauna or Priority Flora Lists under Priorities 1, 2 or 3. These three categories are ranked in order of priority for survey and evaluation of conservation status so that consideration can be given to their declaration as threatened flora or fauna. Species that are adequately known, are rare but not threatened, or meet criteria for near threatened, or that have been recently removed from the threatened list for other than taxonomic reasons, are placed in Priority 4. These species require regular monitoring. Conservation dependent species that are subject to a specific conservation program are placed in Priority 5.

Assessment of Priority codes is based on the Western Australian distribution of the species, unless the distribution in WA is part of a contiguous population extending into adjacent States, as defined by the known spread of locations.

1: Priority One: Poorly-known species

Species that are known from one or a few locations (generally five or less) which are potentially at risk. All occurrences are either: very small; or on lands not managed for conservation, e.g. agricultural or pastoral lands, urban areas, road and rail reserves, gravel reserves and active mineral leases; or otherwise under threat of habitat destruction or degradation. Species may be included if they are comparatively well known from one or more locations but do not meet adequacy of survey requirements and appear to be under immediate threat from known threatening processes. Such species are in urgent need of further survey.

2: Priority Two: Poorly-known species

Species that are known from one or a few locations (generally five or less), some of which are on lands managed primarily for nature conservation, e.g. national parks, conservation parks, nature reserves and other lands with secure tenure being managed for conservation.

Species may be included if they are comparatively well known from one or more locations but do not meet adequacy of survey requirements and appear to be under threat from known threatening processes. Such species are in urgent need of further survey.

3: Priority Three: Poorly-known species

Species that are known from several locations, and the species does not appear to be under imminent threat, or from few but widespread locations with either large population size or significant remaining areas of apparently suitable habitat, much of it not under imminent threat. Species may be included if they are comparatively well known from several locations but do not meet adequacy of survey requirements and known threatening processes exist that could affect them. Such species are in need of further survey.

4: Priority Four: Rare, Near Threatened and other species in need of monitoring

(a) Rare. Species that are considered to have been adequately surveyed, or for which sufficient knowledge is available, and that are considered not currently threatened or in need of special protection, but could be if present circumstances change. These species are usually represented on conservation lands.
(b) Near Threatened. Species that are considered to have been adequately surveyed and that do not qualify for Conservation Dependent, but that are close to qualifying for Vulnerable.
(c) Species that have been removed from the list of threatened species during the past five years for reasons other than taxonomy.

5: Priority Five: Conservation Dependent species

Species that are not threatened but are subject to a specific conservation program, the cessation of which would result in the species becoming threatened within five years.

*Species includes all taxa (plural of taxon - a classificatory group of any taxonomic rank, e.g. a family, genus, species or any infraspecific category i.e. subspecies, variety or forma).

Commonwealth of Australia Conservation Codes

The Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* has the following nine conservation codes for Flora and Fauna.

Extinct
Taxa not definitely located in the wild during the past 50 years

Extinct in the Wild
Taxa known to survive only in captivity

Critically Endangered
Taxa facing an extremely high risk of extinction in the wild in the immediate future

Endangered
Taxa facing a very high risk of extinction in the wild in the near future

Vulnerable

Taxa facing a high risk of extinction in the wild in the medium-term

Near Threatened

Taxa that risk becoming Vulnerable in the wild

Conservation Dependent

Taxa whose survival depends upon ongoing conservation measures. Without these measures, a conservation dependent taxon would be classified as Vulnerable or more severely threatened.

Data Deficient (Insufficiently Known)

Taxa suspected of being Rare, Vulnerable or Endangered, but whose true status cannot be determined without more information.

Least Concern

Taxa that are not considered Threatened

SANDY RIDGE PROJECT,
EXPLORATION TENEMENT E16/440

FLORA AND VEGETATION SURVEY

Prepared for:	Tellus Holdings P/L
Report Date:	2 November 2016
Version:	5
Report No.	2015-224

pgv ENVIRONMENTAL

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1 INTRODUCTION

1.1 Purpose

Tellus Holdings Ltd is proposing to develop a kaolin mine with complimentary storage and waste disposal business on Exploration Tenement E16/440 (the site). The site is located in the Shire of Coolgardie and is approximately 140km north-west of Kalgoorlie and 75km north-east of Koolyanobbing. The site boundary is shown in Figure 1.

The site is zoned Rural/Mining in the Shire of Coolgardie Town Planning Scheme No. 4 (District Scheme) Consolidated Scheme (TPS4) (WAPC, 2003).

The potential development envelope for the proposed mining operation is 921.6ha (Figure 1). The site currently is undeveloped and consists of native vegetation. The mining operation is proposed to consist of the following elements:

- Mine Pit and disposal cells (202.3ha)
- Mine Infrastructure area (17.2ha)
- Accommodation Camp (2.5ha)
- Class II Waste Disposal Facility (0.25ha)
- Water Pipeline from the Carina Minesite (11km)
- Site access road (3.75km)
- Internal roads (approx. 5km)
- Potential widening of the Mt Dimer Road (4.5km)

PGV Environmental was commissioned by Tellus Holdings Ltd to undertake a Level 2 Flora and Vegetation Survey of the parts of the site that will or may require clearing of native vegetation.

1.2 Scope of Works

The Level 2 Flora and Vegetation Survey was undertaken in accordance with Guidance Statement 51: *Terrestrial Flora and Vegetation Surveys for Environmental Impact Assessment in Western Australia* (EPA, 2004) and included the following:

- Desktop search and review of Department of Parks and Wildlife's (DPaW's) Declared Rare and Priority Flora database and Threatened Ecological Communities database;
- Examination of recent aerial photography and contour maps to provisionally identify vegetation types and condition;
- Field survey in spring using quadrats to record native and introduced species as well as a site walkover of any areas of native vegetation;
- Recording of any significant plant species using a hand-held GPS;
- Description and mapping of vegetation types and vegetation condition; and
- Compilation of a flora list.

2 EXISTING ENVIRONMENT

2.1 Land Use

The site is vegetated with some basic camp infrastructure installed. No other development has been undertaken on the site.

2.2 Topography

The site is undulating between approximately 460m Australian Height Datum (AHD) to 480m AHD (DAFWA, 2015). The site generally slopes up to the north-east.

2.3 Geology and Soils

The site is located on the Yilgarn Craton and based on granitoid rock. The soil system on the site is the Norseman Zone (266) on which the soils are described as calcareous loamy earths, yellow sandy and loamy earths, red loamy earths, red deep sands and salt lake soils (DAFWA, 2015).

The soils on the site are predominately a deep yellow sand over clay as mapped by Landloch (2015). There is an area in the western part of the site being described as red sandy duplex soils.

2.4 Hydrology

2.4.1 Surface Water

The area lies just to the south of one of the driest regions in Western Australia. The site is in the Raeside-Ponton Catchment Basin in the Salt Lake Sub-catchment (Landgate, 2015). Surface water drains to lower lying areas. There is one lake on the western boundary of the tenement but outside of the proposed development envelope. There are no wetlands or surface expressions of groundwater on the site.

2.4.2 Groundwater

The site is situated in an area that does not have a regional water table as any rain falling in the region is either evaporated, evapo-transpired or runs off at the surface through minor ephemeral drainage and watercourses. The lack of groundwater is also due to the thickness and permeability of the geologic profile, which includes 2m to 5m of impermeable silcrete and up to 40m of low permeability clay. Monitoring wells in the area have been tested for more than 20 years and have always been dry (Aurora Environmental, 2015).

3 FLORA AND VEGETATION

3.1 Methodology

A flora and vegetation survey of the site was conducted by Dr Paul van der Moezel and assistant over 3 days from 30 September 2015 to 2 October 2015. The survey included sampling from 25 non-permanent 20m x 20m quadrats as well as several traverses through the area on proposed road and pipeline alignments.

The survey focussed on the parts of the site that are likely to have some degree of vegetation disturbance including the following:

- Mine Pit and disposal cells (202.3ha)
- Mine Infrastructure area (17.2ha)
- Accommodation Camp (2.5ha)
- Class II Waste Disposal Facility (0.25ha)
- Water Pipeline from the Carina Minesite (11km)
- Site access road (3.75km)
- Internal roads (approx. 5km)
- Potential widening of the Mt Dimer Road (4.5km)

The total area of potential disturbance is around 276ha of the 949ha development envelope as well as 3.7km of a new access road and 11km water pipeline route.

Site coverage was moderate due to the large size of the site, remoteness and paucity of tracks.

Access to the mine pit and disposal cells area, mine infrastructure and underground storage areas was relatively easy on the network of tracks cleared to access drilling locations. The tracks were all open and readily trafficable at the time of the survey. Access to the Class II Waste Disposal Facility and Accommodation Camp areas was on foot using GPS navigation. Most of the proposed access roads and all of the water pipeline route were walked the entire length.

The vegetation of the areas not surveyed was inferred by cross-referencing the on-ground results with the patterns observed on aerial photography. The impact of old fire scars on the aerial photography made interpretation difficult.

3.2 Desktop Searches

A search of the Department of Parks and Wildlife's (DPaW's) Threatened Flora Database, WA Herbarium database and Declared Rare and Priority Flora Species List (Parks and Wildlife, 2015) (Appendix 1), the Naturemap database (Appendix 1) and the Protected Matters Search Tool (Appendix 1) identified 50 Endangered, Threatened or Priority plant species that have been recorded within 20km of the site (Table 1).

Table 1: List of Flora Species Identified from Database Searches within 20km of the Site

Species	Common Name	Conservation Status WA	Status Under EPBC Act 1999
Myriophyllum lapidicola	Chiddarcooping Myriophyllum	Threatened	Endangered
Ricinocarpos brevis		Threatened	Endangered
Tetratheca paynterae	Paynter's Tetratheca	Threatened	Endangered
Cryptandra polyclada subsp. *aequabilis*		Priority 1	
Cyathostemon sp. Mt Dimer (C. McChesney TRL 4/72) PN		Priority 1	
Dampiera sp. Jaurdi (D. Angus DA 268) PN		Priority 1	
Lepidosperma sp. Parker Range (N. Gibson & M. Lyons 2094)		Priority 1	
Leucopogon sp. Yellowdine (M. Hislop & F. Hort MH 3194)		Priority 1	
Phebalium appressum		Priority 1	
Tecticornia flabelliformis		Priority 1	
Xanthoparmelia fumigata		Priority 1	
Baeckea sp. Jaurdi Station (L.W. Sage & F. Hort 2229)		Priority 2	
Daviesia sarissa subsp. *redacta*		Priority 2	
Elachanthus pusillus		Priority 2	
Goodenia jaurdiensis		Priority 2	
Hakea rigida		Priority 2	
Hemigenia tenelliflora		Priority 2	
Lissanthe scabra		Priority 2	
Malleostemon sp. Adelong (G.J. Keighery 11825)		Priority 2	
Acacia cylindrica		Priority 3	
Acacia desertorum var. *nudipes*		Priority 3	
Austrostipa blackii	Crested Spear-grass	Priority 3	
Banksia lullfitzii		Priority 3	
Bossiaea celata		Priority 3	
Calytrix creswellii		Priority 3	
Cyathostemon verrucosus		Priority 3	
Eucalyptus exigua		Priority 3	
Eutaxia actinophylla		Priority 3	
Gastrolobium semiteres		Priority 3	
Gnephosis intonsa	Shaggy Gnephosis	Priority 3	
Gnephosis sp. Norseman (K.R. Newbey 8096)		Priority 3	
Gompholobium cinereum		Priority 3	
Grevillea georgeana		Priority 3	
Hibbertia lepidocalyx subsp. *tuberculata*		Priority 3	
Homalocalyx grandiflorus		Priority 3	
Labichea eremaea		Priority 3	
Lepidium genistoides		Priority 3	
Lepidosperma lyonsii		Priority 3	
Melichrus sp. Bungalbin Hill (F.H. & M.P. Mollemans 3069)		Priority 3	
Mirbelia ferricola		Priority 3	
Stenanthemum newbeyi		Priority 3	

Species	Common Name	Conservation Status WA	Status Under EPBC Act 1999
Stylidium choreanthum	Dancing Triggerplant	Priority 3	
Verticordia mitodes		Priority 3	
Verticordia stenopetala		Priority 3	
Banksia arborea	Yilgarn Dryandra	Priority 4	
Eremophila caerulea subsp. *merrallii*		Priority 4	
Eucalyptus formanii		Priority 4	
Grevillea erectiloba		Priority 4	
Haegiela tatei		Priority 4	
Sowerbaea multicaulis	Many Stemmed Lily	Priority 4	

Table 2 examines the preferred habitat of each species and the likelihood of the species listed in Table 1 to occur on the site given the characteristics of soil type and landform.

Table 2: Likelihood of Identified Significant Flora Species occurring on the Site

Scientific Name	Preferred Habitat*	Likelihood of Presence on Site
Myriophyllum lapidicola	Ephemeral pools 20 to 50 cm deep on granite outcrops +	Unlikely
Ricinocarpos brevis	Shallow sandy soils on rocky banded ironstone outcrops ®	Unlikely
Tetratheca paynterae	Rock crevices, in shallow pockets of soil of rich red loam	Unlikely
Cryptandra polyclada subsp. *aequabilis*	Sand	Possible
Cyathostemon sp. Mt Dimer (C. McChesney TRL 4/72) PN	Yellow sand	Possible
Dampiera sp. Jaurdi (D. Angus DA 268) PN	Associated species: *Allocasuarina corniculata, Gyrostemon racemiger, Acacia sibina, Eucalyptus leptopoda subsp. subluta, Calytrix creswellii* ~ Interpreted habitat: Yellow sand, gravel, sandplains	Possible
Lepidosperma sp. Parker Range (N. Gibson & M. Lyons 2094)	Recorded on ridge/slope. Well-drained. Dry brown clay loam over granite. 10-30% of loose rock on soil surface #	Unlikely
Leucopogon sp. Yellowdine (M. Hislop & F. Hort MH 3194)	Recorded on Flat. Moist yellow sand. Burnt >5 years ^	Unlikely
Phebalium appressum	Yellow sandplain	Possible
Tecticornia flabelliformis	Clay. Saline flats.	Highly Unlikely
Xanthoparmelia fumigata	Recorded on ridge with bare to littered, stoney crusted brown clayey sand <	Unlikely
Baeckea sp. Jaurdi Station (L.W. Sage & F. Hort 2229)	Light brown-yellow sand. Sandplains	Possible
Daviesia sarissa subsp. *redacta*	Yellow sand. Plains	Possible
Elachanthus pusillus	Open depression in plain system. Sandy clay loam &	Unlikely
Goodenia jaurdiensis	Red clayey loam with laterite or banded ironstone gravel or quartz pebbles. Low-lying plains and lower slopes	Possible on pipeline route

Scientific Name	Preferred Habitat*	Likelihood of Presence on Site
Hakea rigida	Sandy soils, yellow sand	Possible
Hemigenia tenelliflora	Sandplain @	Possible
Lissanthe scabra	Dry, white to orange-brown clay, sandy gravel loams, granite. Breakaways, uplands	Unlikely
Malleostemon sp. Adelong (G.J. Keighery 11825)	Red sand, mid-slope, interdunal β	Unlikely
Acacia cylindrica	Yellow/brown sand, gravelly soils. Undulating plains, flats	Possible
Acacia desertorum var. *nudipes*	Yellow sand, lateritic gravel. Sandplains, flats.	Possible
Austrostipa blackii	Recorded on a gentle upper North slope. Brown loam over red loam with granite fragments at 5 cm %	Unlikely
Banksia lullfitzii	Yellow sand. Sandplains.	Possible
Bossiaea celata	Deep sand. Open mallee	Possible
Calytrix creswellii	Yellow sand, sometimes with lateritic gravel. Sandplains	Possible
Cyathostemon verrucosus	Flat yellow sandy clay plain >	Unlikely
Eucalyptus exigua	Sandy loam, white sand. Sandplains	Possible
Eutaxia actinophylla	Red-brown clay loam, red clay loam over granite, gravel. Small depressions	Unlikely
Gastrolobium semiteres	Deep yellow sand, yellow to brown sandy clay, gravel, granite. Broad sand dunes, around rocks, undulating plains	Possible
Gnephosis intonsa	Red/brown clay, stony saline loam	Unlikely
Gnephosis sp. Norseman (K.R. Newbey 8096)	Sub-saline loam. Moderately exposed flat	Unlikely
Gompholobium cinereum	Yellow sand, clayey sand, brown loam, sandy gravel, laterite. Well-drained open sites, slopes, plains, roadsides	Possible
Grevillea georgeana	Stony loam/clay. Ironstone hilltops and slopes.	Possible on pipeline route
Hibbertia lepidocalyx subsp. *tuberculata*	Yellow-orange loam, ironstone gravel	Possible
Homalocalyx grandiflorus	Yellow sand. Sandplains.	Possible
Labichea eremaea	Red sand.	Unlikely
Lepidium genistoides	Sandy loam	Possible
Melichrus sp. Bungalbin Hill (F.H. & M.P. Mollemans 3069)	Yellow sandplain =	Possible
Mirbelia ferricola	Recorded on skeletal red loam soils on massive banded iron formation "	Possible on pipeline route
Stenanthemum newbeyi	Clayey sand, clay or loam over laterite or ironstone. Hillslopes	Possible on pipeline route
Stylidium choreanthum	White/yellow or red sand. Plains	Possible
Verticordia mitodes	Yellow sand. Undulating plains	Possible
Verticordia stenopetala	Yellow sand, sometimes with gravel. Undulating plains.	Possible
Banksia arborea	Stony loam. Ironstone hills.	Possible on pipeline route

Scientific Name	Preferred Habitat*	Likelihood of Presence on Site
Eremophila caerulea subsp. *merrallii*	Sand, clay or loam. Undulating plains.	Possible
Eucalyptus formanii	Red sand. Ironstone slopes	Possible on pipeline route
Grevillea erectiloba	Gravelly loam. Lateritic ridges	Unlikely
Haegiela tatei	Clay, sandy loam, gypsum. Saline habitats.	Unlikely
Lepidosperma lyonsii	Orange skeletal sandy loam with banded ironstone gravel and rock, well-drained shallow stony loamy with quartz. Gentle hill slopes, upper slopes of large hill.	Possible on pipeline route
Sowerbaea multicaulis	Yellow-brown sand.	Possible

* Sourced from Florabase (DPaW, 2015) unless otherwise annotated as per the list below.

® DoE SPRAT Database (DoE, 2015)
+ Patten and Brown (2004)
~ Western Australian Herbarium (2015a)
# Western Australian Herbarium (2015b)
^ Western Australian Herbarium (2015c)
< Western Australian Herbarium (2015d)
@ Western Australian Herbarium (2015e)
= Western Australian Herbarium (2015f)
β Western Australian Herbarium (2015g)
& State Herbarium of South Australia (2015a)
% State Herbarium of South Australia (2015b)
> Australian National Herbarium (2015)
“ National Herbarium of New South Wales (2015)

Of the 50 species identified in the database searches 25 are considered to be possibly present on the tenement site and a further 7 could occur on the pipeline route where soil mapping indicates the presence of some ironstone soils. There are four species ranked as Priority 1, five as Priority 2, eighteen as Priority 3 and five as Priority 4 in the list of species that potentially could occur on the site and pipeline route.

All three species listed as Threatened under the *Wildlife Conservation Act 1950* (WC Act) and Endangered under the EPBC Act are considered ‘Unlikely’ to be present on the site.

A search of DPaW’s Threatened (TEC) and Priority Ecological Communities (PEC) database was conducted for the site (02-0415EC) (Appendix 1). Three Priority 1 ecological communities were found to potentially occur within the vicinity of the site as described below:

- Finnerty Range/Mt Dimer/Yendilberin Hills vegetation complexes (banded ironstone formation);
- Hunt Range vegetation complexes (banded ironstone formation); and
- Lake Giles vegetation complexes (banded ironstone formation).

None of these ecological communities are likely to occur on the site. These communities are all associated with a Banded Iron Formation which does not occur on the proposed mining site or pipeline route. The interpreted vegetation types are not representative of these PECs.

3.3 Survey Conditions

The conditions that the survey was undertaken in are presented in Table 3 in order to assess the adequacy of the survey. In summary, there were some constraints to the survey due to the remoteness and large size of the site. Most of the vegetation was recovering from a fire that appears

to have occurred less than 5 years ago. These constraints were considered unlikely to have a significant impact on the results.

Table 3: Statement of Botanical Survey Conditions

ISSUE	CONSTRAINTS (YES/NO); SIGNIFICANT, MODERATE OR NEGLIGIBLE	COMMENT
Competency/experience of the consultant conducting the survey	No constraints	Dr Paul van der Moezel has botanical survey experience in the Goldfields region including a recent 2014 survey of the adjoining IWDF site.
Proportion of the flora identified	No constraints	The timing of the survey in early October should have identified most of the native species on the parts of the site surveyed. The uniformity of the vegetation on the lease site means it is unlikely that many more species would have been recorded outside surveyed areas of the lease.
Sources of information (historic/recent or new data)	No constraints	Florabase and other flora and vegetation surveys nearby on similar landforms
Proportion of the task achieved and further work that may need to be undertaken	No constraints	Follow-up surveys required for any clearing outside of surveyed areas.
Timing/weather/season/cycle	No constraints	Early October survey ideal for identifying maximising flowering of most species, including ephemerals.
Intensity of survey (e.g. In retrospect was the intensity adequate)	No constraints	Relevant areas to be cleared surveyed adequately.
Completeness (e.g. was relevant area fully surveyed)	No constraints	
Resources (e.g. degree of expertise available for plant identification)	No constraints	Experienced botanist undertook plant identifications on site and at Perth Reference Herbarium.
Remoteness and/or access problems	No constraints	Remote site, access to most areas through a network of easily driven tracks. Walking other areas easy through open woodland understorey and open heath and shrublands.
Availability of contextual (e.g. bioregional) information for the study area.	No constraints	A Biodiversity Audit of WA (DPaW)

Fungi and nonvascular flora (e.g. algae, mosses and liverworts) were not specifically surveyed for during the survey.

3.4 Results

3.4.1 Flora

A total of 97 species from 27 Families and 50 Genera were recorded in the flora survey (Appendix 2). The most common Families were the Myrtaceae (21 species), Fabaceae (13 species), Proteaceae (8 species) and Asteraceae (8 species). The Genera with the most species were *Acacia* (11), *Eucalyptus*

(8), *Grevillea* (7) and *Melaleuca* (5). These same four Genera were the top genera recorded in the flora survey of the nearby Carina Iron Ore Project: Mt Walton Siding Vegetation (Recon Environmental, 2010).

No introduced species were recorded on the site.

No Threatened (Declared Rare) species listed under the *Wildlife Conservation Act 1950* or *Environment Protection and Biodiversity Act 1999* were recorded on the site.

One Priority 3 species, *Calytrix creswellii*, was recorded at one location in *Acacia resinimarginea* Open Heath on loamy sand in the middle of the Mine Pits/Cells area (Figure 2). Numerous plants were recorded in the quadrat and nearby.

Plate 1 Calytrix creswellii (P3). Source: FloraBase.

Calytrix creswellii is currently known to occur within the Coolgardie and Murchison bioregions of the Eremaean province (Florabase). It has previously been recorded on nearby sites including the IWDF site (Ecologia, 1997), the Mt Walton access road (Mattiske Consulting, 2012) and the Carina Iron Ore Project site (Recon Environmental, 2010). The Mattiske Consulting survey recorded many separate populations of the species with population sizes greater than 50 common. *Calytrix creswellii* is a small shrub 0.25-1m high with white flowers from September to December (Florabase).

One Priority 4 species, *Lepidosperma lyonsii*, was recorded on the proposed pipeline route between the Mt Dimer Road and the tenement (Figure 2). Several plants were recorded in *Eucalyptus pileata/Acacia resinimarginea* Shrub Mallee/Open Heath vegetation. *Lepidosperma lyonsii* is a sedge species up to 50cm high and is known to occur in several locations in the Coolgardie Botanical District and has previously been recorded on the Carina Iron Ore Project Site (Recon Environmental, 2010) and the Mt Walton access road (Mattiske Consulting, 2012).

Five populations of the undescribed sedge species, *Lepidosperma* sp., were recorded in *Acacia resinimarginea* dominated vegetation on the site (Figure 2). The species is likely to be more widespread on the site than the populations recorded. The species was not able to be identified to specific level but was not considered to be any of the three Priority species previously recorded in the

vicinity of the site (Table 1). In their survey of the yellow sandplain vegetation on the Mt Walton Road to the south of the site Mattiske Consulting Pty Ltd (2012) recorded 13 species of *Lepidosperma* which were not able to be identified to species level mostly due to the species being undescribed. The taxonomy of *Lepidosperma* is being reviewed by the Western Australian Herbarium staff (R. Barrett) and until those results are published the *Lepidosperma* recorded on the site should be treated as potentially having some conservation value.

3.4.2 Vegetation

Regional Vegetation

The site is located in the Coolgardie 2 COO2 – Southern Cross Biogeographic subregion (DPaW, 2002). The sub-region contains banded-ironstone hill flora, sandplain Acacias and Myrtaceae and Goldfields woodlands.

Most of the vegetation in the tenement area belongs to Beard vegetation association 437 'Shrublands; mixed acacia thicket on sandplain' with the southwestern area belonging to association 141 'Medium woodland; York gum, salmon gum and gimlet' (Figure 4). The vegetation in the pipeline and access road areas is also mostly association 437 with some 141. The southwestern end of the pipeline contains Beard association 538 'Eucalyptus open woodland/Triodia open hummock grassland' and a small area of 435 'Acacia sparse shrubland/Cryptandra mixed sparse heath'.

Vegetation Types

A range of different vegetation types were described and mapped on the site (Figure 2 and 3). Many of the vegetation types intergrade and could be considered variations of the main types. The impact of a fire around 5 years ago has affected the structure of large parts of the dominant *Acacia resinimarginea* Open Heath. *Callitris preissii* shrubs which were clearly evident as a dead shrub up to 2-3m high were killed by the fire and the regenerating seedlings are growing very slowly at less than 0.3m tall.

Vegetation descriptions are provided below. Quadrat data for each vegetation type are provided in Appendix 3.

Ar *Acacia resinimarginea* Open Heath

This is one of the most dominant vegetation types in the tenement site. *Acacia resinimarginea* is consistently 1-1.2m high and 40-50% cover. Other common species include *Phebalium filifolium, Phebalium canaliculatum, Homalocalyx thryptomenoides, Melaleuca uncinata* and *Callitris preissii* although the *Callitris* plants are small seedlings 0.2-0.3m high regenerating after a fire. Spinifex (*Triodia scariosa*) is also common in part but at low density. The soils are light yellow to orange-brown loamy sands. Quadrats SR 3, 6, 8, 9 and 10A are representative of this vegetation type.

CpAr *Callitris preissii/Acacia resinimarginea* Tall Shrubland

This vegetation type is essentially a variety of the Ar vegetation type that escaped the fire of several years ago. As a result the *Callitris preissii* trees are up to 3-4m high and the *Acacia resinimarginea* and *Melaleuca uncinata* can be up to 2-2.5m high. *Homalocalyx thryptomenoides* is a common small

shrub. The soils are light yellow-brown loamy sands. Quadrats SR 12 and 14 are representative of this vegetation type.

ArAa *Acacia resinimarginea/Allocasuarina acutivalvis* Open Heath

A small pocket of this vegetation type was recorded at the northern end of the mine pit/cell area. It is very similar in structure and composition to the Ar vegetation type but contains *Allocasuarina acutivalvis* which is virtually absent from the Ar vegetation. The presence of ironstone pebbles at the surface of the loamy sand may be a reason for the *Allocasuarina* in this area. Quadrat SR 1 is representative of this vegetation type.

ArMu *Acacia resinimarginea/Melaleuca uncinata* Open Low Heath

This vegetation type occurs on the water pipeline route just north of the Mt Dimer Road. *Acacia resinimarginea* and *Melaleuca uncinata* co-dominate at around 1m and 20-25% each. The vegetation is slightly more species rich than the Ar vegetation and sub-units on the tenement site. The soils area light orange-brown loamy sand with ironstone pebbles at the surface. Quadrat SR 18 is representative of this vegetation type.

Lr *Leptospermum roei* Open Heath

Several stands of *Leptospermum roei* occur up to 1.8m high and 50% cover with little to no *Acacia resinimarginea* present. The composition of the smaller shrubs is, however, similar to the Ar vegetation type with *Homalocalyx thryptomenoides* common. The soils are yellow loamy sand. Quadrat SR 13 is representative of this vegetation type.

ArEpTs *Acacia resinimarginea* Open Heath with scattered *Eucalyptus pileata* over *Triodia scariosa* Open Grassland

This is another widespread vegetation type occurring on the yellow loamy sand soils, particularly in the central and northern parts of the site. The shrub cover is less dense at 25-40% which has allowed the Spinifex (*T. scariosa*) to grow in higher densities, around 20-25%. The small mallee *Eucalyptus pileata* occurs sporadically throughout this unit. Other common species include *Phebalium filifolium, Homalocalyx thryptomenoides* and *Keraudrenia integrifolia. Callitris preissii* was present as seedlings in some areas but curiously only occurred as old dead plants with no seedlings evident in large areas. The soils are light orange-brown loamy sand. Quadrats SR 2.1, 4, 5 and 7 are representative of this vegetation type.

EpMuTs *Eucalyptus pileata* Open Shrub Mallee over *Melaleuca uncinata* Open Shrubland over *Triodia scariosa* Open Grassland

This vegetation type occurred in the south-east part of the tenement site and was similar to the ArEpTs except that *Acacia neurophylla* was the dominant *Acacia* and several other species not commonly recorded elsewhere on the site such as *Melaleuca eleuterostachya, Hakea francisiana* and *Podolepis capillaris* were present and indicated a transition from the vegetation on the site to that further east. *Acacia neurophylla* was the dominant species in the sandplain heath and shrubland vegetation survey of a part of the IWDF site a short distance to the east (PGV Environmental, 2015). The soils are light orange-red sand. Quadrat SR 15 was representative of this vegetation type.

Eg *Eucalyptus gracilis* Shrub Mallee over *Acacia nigripilosa* subsp. *nigripilosa/Acacia burkittii* Low Shrubland

This vegetation type occurs on harder sandy loam soils on slightly more elevated land in the western and northern parts of the tenement. *Eucalyptus gracilis* is the main tree or mallee species present in densities around 10-40%. *Acacia* species including *A. burkittii* and *A. nigripilosa* subsp. *nigripilosa* are common shrubs as is *Melaleuca uncinata, Alyxia buxifolia, Olearia muelleri* and *Scaevola spinescens.* These areas have a large percentage of bare ground. The soils are hard, red-orange sandy loam. Quadrats SR 2 and 11 are representative of this vegetation type.

EgAaEo *Eucalyptus gracilis* Open Shrub Mallee over *Acacia acuminata/Eremophila oppositifolia* Open Shrubland

This vegetation type occurs at the southern end of the water pipeline route close to the Carina Mine northern pit. The vegetation is located in a slight depression which may lead to slightly moister surface soils after rain. The shrub mallees are up to 4m high and open over an open shrub layer consisting of *Acacia acuminata* and *A. tetragonophylla* as well as *Eremophila oppositifolia, E. maculata* and *Senna artemisioides*. The soils are orange-red sandy loam with ironstone pebbles with a large percentage of bare ground. Quadrat SR 20 is representative of this vegetation type.

Ab *Acacia burkittii* Tall Shrubland

A small band of this vegetation type occurs near the southern end of the water pipeline in a low valley. *Acacia burkittii* is the dominant taller shrub up to 3m high and averaging 20% although it can be denser in places. *Grevillea eriostachya* up to 1.3m is also present. Common smaller shrubs include *Leucopogon* sp. Clyde Hill and *Homalocalyx thryptomenoides*. The soils are orange-red sandy loam with ironstone pebbles at the surface. Quadrat SR 21 is representative of this vegetation type.

ErMuAa *Eucalyptus ?rigidula* Very Open Shrub Mallee over *Melaleuca uncinata/Acacia acuminata* Open Low Heath

This vegetation type occurs on top of a small rise on perhaps the highest part of the water pipeline route between the Carina Mine pit and Mt Dimer Road. *Eucalyptus ?rigidula* (no buds or fruit) commonly occurs as a shrub mallee in very low densities. The shrub layer is dominated by *Melaleuca uncinata* with *Acacia acuminata* and *Senna artemisioides* common. The soils are orange-red sandy loam. Quadrat SR 23 is representative of this vegetation type.

EcAt *Eucalyptus corrugata* Low Woodland over *Acacia tetragonophylla* Tall Open Shrubland

The southwestern part of the tenement is mapped as being in a different Beard vegetation association from the rest of the site. The vegetation confirms this difference with the vegetation consisting of large tracts of typical Goldfields Eucalypt Woodland with *Eucalyptus corrugata* the dominant species up to 8m high and with an open canopy cover of 10-25%. Common understorey species include *Acacia tetragonophylla, Santalum acuminatum, Exocarpos aphyllus, Scaevola spinescens, Acacia colletioides, Phebalium filifolium* and *Austrostipa nitida*. The soils are orange-brown loamy sand. Quadrats SR 10 and 16 are representative of this vegetation type.

EsAt *Eucalyptus salmonophloia* Woodland over *Acacia tetragonophylla* Tall Open Shrubland

This vegetation type also occurs in the southwestern part of the tenement mixed in with the EcAt type. Salmon Gum (*E. salmonophloia*) is sparse and up to 12m high over a tall open shrubland containing similar common species to the EcAt vegetation type such as *Acacia tetragonophylla, Acacia colletioides, Scaevola spinescens* and *Olearia muelleri.* The soils are orange-red sandy loam. Quadrat SR 17 is representative of this vegetation type.

EsEo *Eucalyptus salmonophloia* Woodland over *Eremophila oppositifolia* Open Heath

This species is common at the southern half of the water pipeline route. Superficially this vegetation type looks structurally the same as the EsAt type with Salmon Gum the main species present up to 12m high and 20% cover over an open understorey. However, the understorey composition is quite different and contains Chenopod species (*Atriplex vesicaria, Maireana georgei, Sclerolaena densiflora*) that are absent from the tenement site. *Eremophila* species (*E. oppositifolia, E. pantonii*) are common in the understorey. The soils are orange-red sandy loam. Quadrat SR 22 is representative of this species.

EsalMu *Eucalyptus salubris* var. *salubris* Open Shrub Mallee over *Melaleuca uncinata* Open Shrubland

A small stand of Gimlet (*Eucalyptus salubris* var. *salubris*) occurs on the water pipeline route south of Mt Dimer Road. The Gimlet mallees are up to 5m high and in low density. *Melaleuca uncinata, Senna artemisioides* and *Acacia resinimarginea* are common shrub species and the native grasses *Aristida contorta* and *Austrostipa nitida* occur together. Grass species are very sparse throughout the survey area.

3.4.3 Vegetation Condition

The vegetation condition over the site was assessed using the condition scale adopted in Bush Forever (Table 4). The vegetation was rated as all being in Excellent condition. While there were no weed species recorded on the site the presence of numerous tracks, both old and new, meant that a rating of Pristine was not warranted.

Table 4: Vegetation Condition Rating Scale

Condition	Description
Pristine	Pristine or nearly so, no obvious signs of disturbance.
Excellent	Vegetation structure intact, disturbance affecting individual species and weeds are non-aggressive species.
Very Good	Vegetation structure altered, obvious signs of disturbance. For example, disturbance to vegetation structure caused by repeated fires, the presence of some more aggressive weeds, dieback, logging and grazing.
Good	Vegetation structure significantly altered by very obvious signs of multiple disturbances. Retains basic vegetation structure or ability to regenerate it. For example, disturbance to vegetation structure caused by very frequent fires, the presence of some very aggressive weeds at high density, partial clearing, dieback and grazing.

Condition	Description
Degraded	Basic vegetation structure severely impacted by disturbance. Scope for regeneration but not to a state approaching good condition without intensive management. For example, disturbance to vegetation structure caused by very frequent fires, the presence of very aggressive weeds, partial clearing, dieback and grazing.
Completely Degraded	The structure of the vegetation is no longer intact and the area is completely or almost completely without native species. These are often described as 'parkland cleared' with the flora comprising weed or crop species with isolated native trees or shrubs.

Source: Government of Western Australia, 2000.

3.4.4 Conservation Significance of Flora and Vegetation

Flora

Two Priority 3 species (*Calytrix creswellii* and *Lepidosperma lyonsii*) were recorded in the survey area in low numbers.

Priority 3 species are those that are known from several locations, and the species does not appear to be under imminent threat, or from few but widespread locations with either large population size or significant remaining areas of apparently suitable habitat, much of it not under imminent threat.

Priority species are considered to be under threat but do not have legislative protection under the *Wildlife Conservation Act 1950* or *Environment Protection and Biodiversity Conservation Act 1999*.

Both species were recorded in low numbers and have been recorded in nearby sites (Mt Walton East IWDF site, Mt Walton Access Road and the Carina Mine site). Given the low site coverage in the survey additional populations are likely to occur in the areas that might be cleared and the areas not surveyed outside of the proposed clearing.

Barrett (2007) noted that while *Lepidosperma lyonsii* was a poorly known species it may be more widespread than current herbarium collections suggest.

Another species of *Lepidosperma,* yet to be described, was recorded at several locations throughout the site and is highly likely to occur in numerous locations which will not be impacted by the project in the tenement site.

The other 30 species that were identified as possibly occurring in the survey area were not recorded. Six of those species were identified as possibly occurring due to the expected presence of ironstone included on soil maps on a section of the pipeline route. As it turned out, the survey of the pipeline route did not record any ironstone or ironstone-derived soils or their associated flora species.

Vegetation

The site is located in the Coolgardie 2 COO2 – Southern Cross Biogeographic subregion (DPaW, 2002). The sub-region does not contain any Threatened Ecological Communities. A total of 19 'ecosystems

at risk' occur in the sub-region, most of which occur on hills and ridges. None of the vegetation types in the survey area is listed as an 'ecosystem at risk'.

Most of the vegetation in the survey area belongs to Beard vegetation associations 437 'Shrublands; mixed acacia thicket on sandplain' and association 141 'Medium woodland; York gum, salmon gum and gimlet'. The south-west end of the pipeline route also contains associations 538 'Eucalyptus open woodland/Triodia open hummock grassland' and a small amount of 435 'Acacia sparse shrubland/Cryptandra mixed sparse heath'. All vegetation associations have a Low reservation priority for ecosystems (DPaW, 2002).

4 SUMMARY AND CONCLUSIONS

The Level 2 Flora and Vegetation Survey of the Sandy Ridge Project exploration tenement E16/440 and proposed access roads and water pipeline routes resulted in the following:

- The survey targeted the areas of proposed disturbance, totalling around 276ha of the 959ha development envelope plus 3.7km of a new site access road and 11km for a water pipeline from the Carina Mine site to the south-west;
- The vegetation in the tenement area is mapped as comprising two Beard vegetation associations: Association 437 'Shrublands; mixed acacia thicket on sandplain' and Association 141 'Medium woodland; York gum, salmon gum and gimlet'. The south-west end of the proposed pipeline route contained Beard associations 538 'Eucalyptus open woodland/Triodia open hummock grassland' and a small amount of 435 'Acacia sparse shrubland/Cryptandra mixed sparse heath'. The on-ground survey confirmed the boundaries of the broad associations;
- A total of 97 species from 27 Families and 50 Genera were recorded in the survey. No introduced species were recorded on the site.
- Small populations of two Priority 3 species (*Calytrix creswellii* and *Lepidosperma lyonsii*) were recorded in the tenement and pipeline route respectively. Several populations of an undescribed *Lepidosperma* were also recorded which may have conservation significance. The Priority species and *Lepidosperma* species should not be an impediment to the proposed development as they are highly likely to occur elsewhere in the development envelope and areas surrounding the site;
- None of the other 30 Priority species that were identified as possibly being present in the survey area were recorded. These species therefore will not be impacted by the development;
- A total of 15 vegetation types were described and mapped on the site. The main vegetation types were *Acacia resinimarginea* Open Heath with variations, *Acacia resinimarginea/Eucalyptus pileata/Triodia scariosa* Open Heath and Open Grassland; Mallee shrublands; and *Eucalyptus* woodlands (*E. corrugata, E. salmonophloia, E. salubris*);
- All of the vegetation was considered in Excellent condition;
- No Threatened or Priority Ecological Communities were recorded on the site. No vegetation types listed as an 'ecosystem at risk' in the 2002 WA Biodiversity Audit'. The two Beard vegetation types are listed as Low priority for reservation by DPaW;
- Clearing should attempt to avoid any of the large trees in the southwestern part of the tenement site and along the water pipeline route. The density of the main tall tree species, Salmon Gum and *Eucalyptus corrugata*, should be sufficiently widely spaced to be able to construct low speed access tracks through these areas as well as the alignment of the water pipeline route and any associated maintenance track alongside the pipe. Particular attention should be given to the design of the proposed Accommodation Camp and Class II Waste Disposal Facility to avoid the clearing of tall trees; and
- Any proposed clearing of vegetation outside the area surveyed should be required to have a level 2 flora and vegetation survey over those areas.

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FIGURES

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pgv ENVIRONMENTAL

Tellus Holdings
FLORA AND VEGETATION SURVEY
SANDY RIDGE

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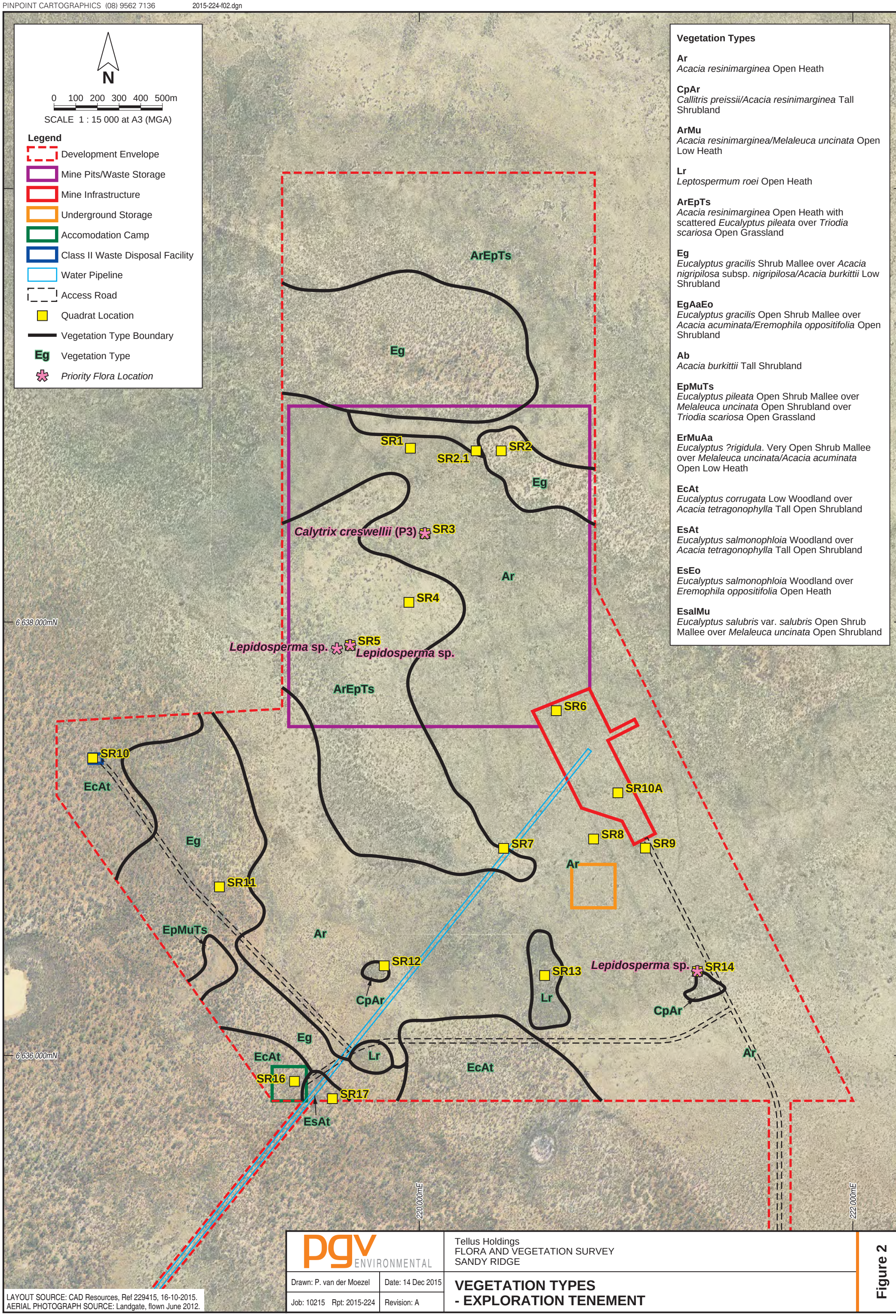
REGIONAL LOCATION

Figure 1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Legend
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Mine Pits/Waste Storage
Mine Infrastructure
Underground Storage
Accomodation Camp
Class II Waste Disposal Facility
Water Pipeline
Access Road
Quadrat Location
Vegetation Type Boundary
Eg Vegetation Type
Priority Flora Location
Vegetation Types
Ar
Acacia resinimarginea Open Heath
CpAr
Callitris preissii/Acacia resinimarginea Tall Shrubland
ArMu
Acacia resinimarginea/Melaleuca uncinata Open Low Heath
Lr
Leptospermum roei Open Heath
ArEpTs
Acacia resinimarginea Open Heath with scattered Eucalyptus pileata over Triodia scariosa Open Grassland
Eg
Eucalyptus gracilis Shrub Mallee over Acacia nigripilosa subsp. nigripilosa/Acacia burkittii Low Shrubland
EgAaEo
Eucalyptus gracilis Open Shrub Mallee over Acacia acuminata/Eremophila oppositifolia Open Shrubland
Ab
Acacia burkittii Tall Shrubland
EpMuTs
Eucalyptus pileata Open Shrub Mallee over Melaleuca uncinata Open Shrubland over Triodia scariosa Open Grassland
ErMuAa
Eucalyptus ?rigidula. Very Open Shrub Mallee over Melaleuca uncinata/Acacia acuminata Open Low Heath
EcAt
Eucalyptus corrugata Low Woodland over Acacia tetragonophylla Tall Open Shrubland
EsAt
Eucalyptus salmonophloia Woodland over Acacia tetragonophylla Tall Open Shrubland
EsEo
Eucalyptus salmonophloia Woodland over Eremophila oppositifolia Open Heath
EsalMu
Eucalyptus salubris var. salubris Open Shrub Mallee over Melaleuca uncinata Open Shrubland
ArEpTs
Eg
SR1
SR2.1
SR2
Eg
Calytrix creswellii (P3)
SR3
Ar
SR4
6 638 000mN
Lepidosperma sp.
SR5
Lepidosperma sp.
ArEpTs
SR6
SR10
EcAt
SR10A
Eg
SR7
SR8
SR9
Ar
SR11
EpMuTs
Ar
SR12
SR13
Lepidosperma sp.
SR14
CpAr
Lr
CpAr
Eg
6 636 000mN
EcAt
Lr
Ar
EcAt
SR16
SR17
EsAt
220 000mE
222 000mE
LAYOUT SOURCE: CAD Resources, Ref 229415, 16-10-2015.
AERIAL PHOTOGRAPH SOURCE: Landgate, flown June 2012.
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Tellus Holdings
FLORA AND VEGETATION SURVEY
SANDY RIDGE
Drawn: P. van der Moezel
Date: 14 Dec 2015
Job: 10215 Rpt: 2015-224
Revision: A
VEGETATION TYPES
- EXPLORATION TENEMENT
Figure 2

Vegetation Types

Ar
Acacia resinimarginea Open Heath

CpAr
Callitris preissii/Acacia resinimarginea Tall Shrubland

ArMu
Acacia resinimarginea/Melaleuca uncinata Open Low Heath

Lr
Leptospermum roei Open Heath

ArEpTs
Acacia resinimarginea Open Heath with scattered *Eucalyptus pileata* over *Triodia scariosa* Open Grassland

Eg
Eucalyptus gracilis Shrub Mallee over *Acacia nigripilosa* subsp. *nigripilosa/Acacia burkittii* Low Shrubland

EgAaEo
Eucalyptus gracilis Open Shrub Mallee over *Acacia acuminata/Eremophila oppositifolia* Open Shrubland

Ab
Acacia burkittii Tall Shrubland

EpMuTs
Eucalyptus pileata Open Shrub Mallee over *Melaleuca uncinata* Open Shrubland over *Triodia scariosa* Open Grassland

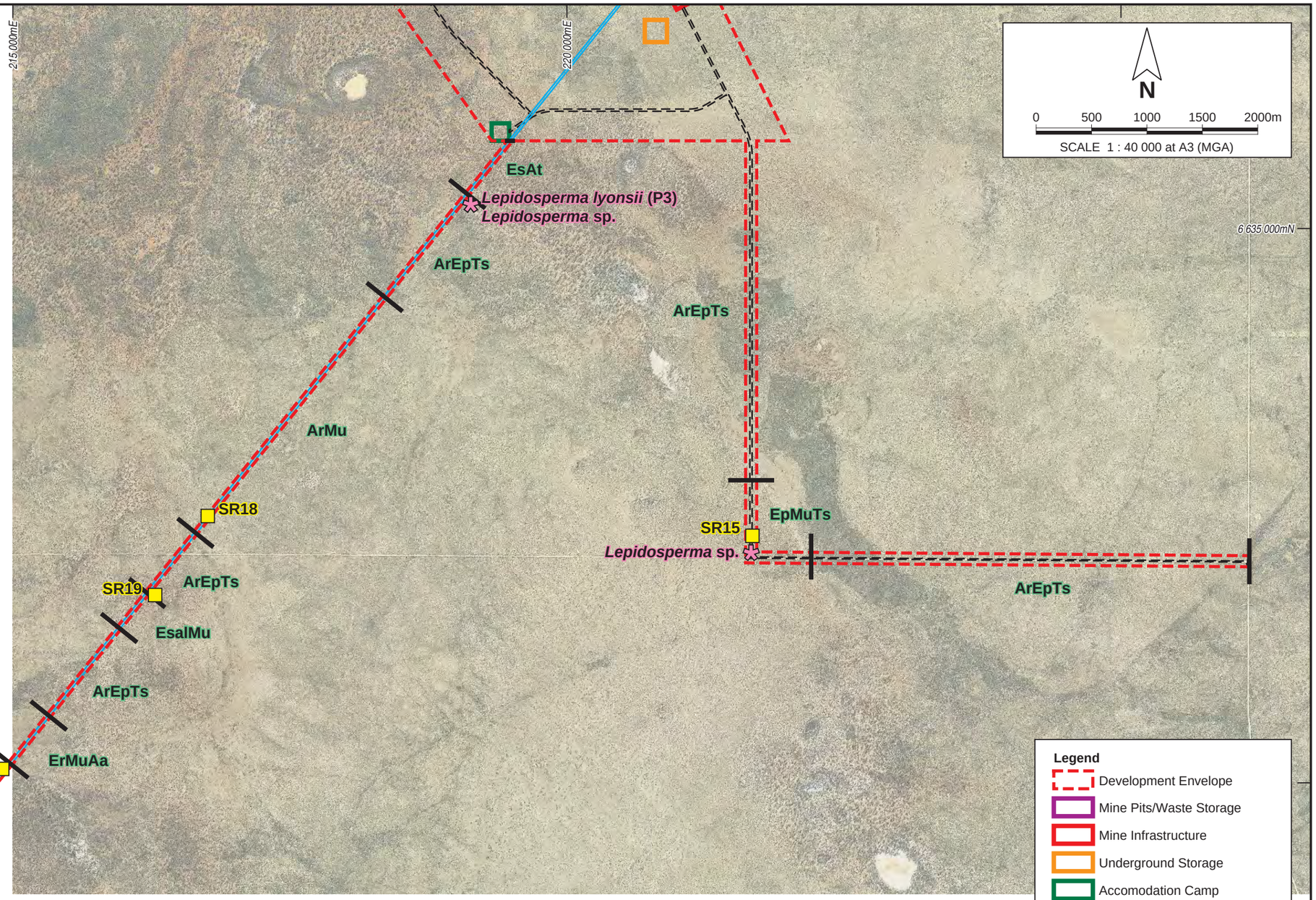
ErMuAa
Eucalyptus ?rigidula. Very Open Shrub Mallee over *Melaleuca uncinata/Acacia acuminata* Open Low Heath

EcAt
Eucalyptus corrugata Low Woodland over *Acacia tetragonophylla* Tall Open Shrubland

EsAt
Eucalyptus salmonophloia Woodland over *Acacia tetragonophylla* Tall Open Shrubland

EsEo
Eucalyptus salmonophloia Woodland over *Eremophila oppositifolia* Open Heath

EsalMu
Eucalyptus salubris var. *salubris* Open Shrub Mallee over *Melaleuca uncinata* Open Shrubland



Legend
- Development Envelope
- Mine Pits/Waste Storage
- Mine Infrastructure
- Underground Storage
- Accomodation Camp
- Class II Waste Disposal Facility
- Water Pipeline
- Access Road
- Quadrat Location
- Vegetation Type Boundary
- Eg Vegetation Type
- *Priority Flora Location*

LAYOUT SOURCE: CAD Resources, Ref 229415, 16-10-2015.
AERIAL PHOTOGRAPH SOURCE: Landgate, flown June 2012.

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FLORA AND VEGETATION SURVEY
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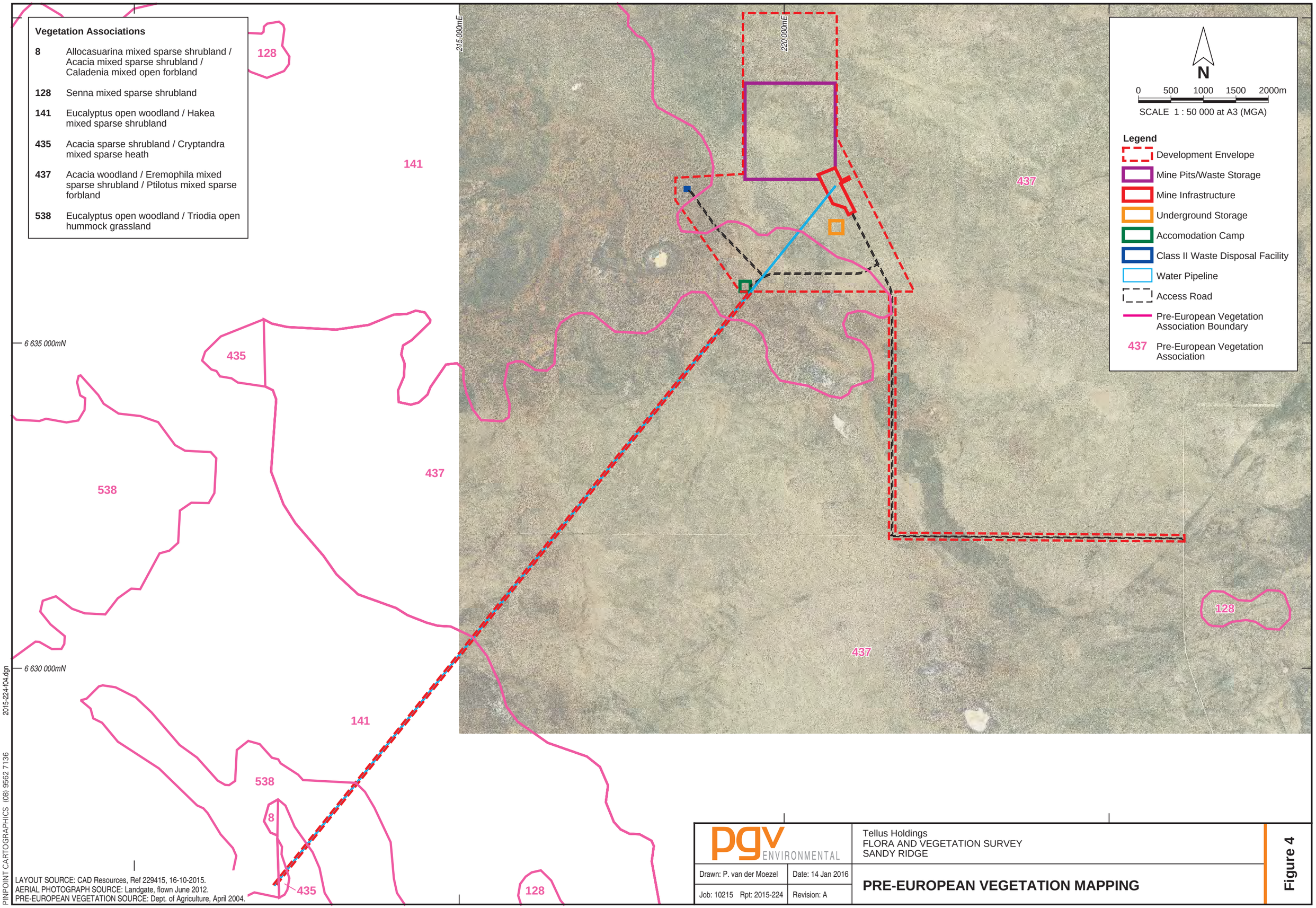
VEGETATION TYPES
- WATER PIPELINE AND ACCESS ROAD

Figure 3



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Tellus Holdings
FLORA AND VEGETATION SURVEY
SANDY RIDGE

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PRE-EUROPEAN VEGETATION MAPPING

Figure 4

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APPENDIX 1

DPaW Database Searches

Taxon	Status	Rank	IUCNCriteria	EPBC	DPaWRegion	DPaWDistrict	Distribution	FloweringPeriod	RecoveryPlan
Acacia cylindrica	3				GOLD,WHTB	KALGOORLIE,CENTRAL WHEATBELT	Southern Cross, Mt Correll, Kulja, Hunt Range, Kalannie, Chiddarcooping N.R., Mollerin N.R., Mt Manning Range, Ennuin Stn.		
Acacia desertorum var. nudipes	3				GOLD,WHTB	KALGOORLIE,CENTRAL WHEATBELT	Ghooli, Southern Cross, Yellowdine, Mt Dimer		
Austrostipa blackii	3				GOLD,MWST,WHTB	KALGOORLIE,GERALDTON,GREAT SOUTHERN,CENTRAL WHEATBELT	Merredin, Dalwallinu, Jaurdi, Widgiemooltha, eastern States, Tutanning Nature Reserve, Beverley, Blue Hills Range, Yandanoo Hills,Mt Manning Range, Barcooting Hill		
Baeckea sp. Jaurdi Station (L.W. Sage & F. Hort 2229)	2				GOLD	KALGOORLIE	Jaurdi Station	Oct	
Banksia arborea	4				GOLD	KALGOORLIE	Koolyanobbing, Die Hardy Range, Jaurdi Stn., Mt Elvire Stn., Diemals Stn., Helena and Aurora Range, Hunt Range, Bungalbin Hill, Mt Jackson, Manning Range	Mar-May, Sept-Oct	
Banksia lullfitzii	3				GOLD,SCST,WHTB	ESPERANCE,KALGOORLIE,GREAT SOUTHERN,CENTRAL WHEATBELT	Southern Cross, Frank Hann N.P., Coolgardie, Mt Manning Range, Ravensthorpe	Mar-May	
Bossiaea celata	3				GOLD	KALGOORLIE	Duri, Boorabbin	Sep,Oct	
Calytrix creswellii	3				GOLD	KALGOORLIE	Helena & Aurora Range,Credo Stn., Mt Manning Range, Wallaroo Rock	Nov-Dec	
Cryptandra polyclada subsp. aequabilis	1				GOLD	KALGOORLIE	Boorabbin	Oct	
Cyathostemon sp. Mt Dimer (C. McChesney TRL 4/72) PN	1				GOLD	KALGOORLIE	Mt Dimer		
Cyathostemon verrucosus	3				GOLD	KALGOORLIE	Bungalbin Hill, Helena & Aurora Ranges, Queen Victoria Rocks, Kalgoorlie, Boorabbin	Sep-Dec,Mar	
Dampiera sp. Jaurdi (D. Angus DA 268) PN	1				GOLD	KALGOORLIE	Jaurdi	Sep	
Daviesia sarissa subsp. redacta	2				GOLD	KALGOORLIE	Boorabbin	Sep	
Elachanthus pusillus	2				GOLD,SCST	ESPERANCE,KALGOORLIE	Orchid Rock, Cocklebiddy, Kalgoorlie, Jaurdi Stn	Oct	
Eremophila caerulea subsp. merrallii	4				GOLD,WHTB	KALGOORLIE,CENTRAL WHEATBELT	Bruce Rock, Jilbadji, Hunt Range, Burra Rock	Aug-Jan	
Eucalyptus exigua	3				GOLD,SCST,WHTB	ESPERANCE,KALGOORLIE,GREAT SOUTHERN,CENTRAL WHEATBELT	Lake Cronin, Hyden, Mt Day, Middle Ironcap, Lake Varley, Narembeen, Benari,Moorine Rock, Yellowdine, Jaurdi Stn., Mt Holland	-	
Eucalyptus formanii	4				GOLD	KALGOORLIE	Mt Jackson, Pigeon Rock, Diemals, Die Hardy Rg, Mt Dimer	Dec-Apr	
Eutaxia actinophylla	3				GOLD,SCST,WHTB	ESPERANCE,KALGOORLIE,CENTRAL WHEATBELT	Norseman, Salmon Gums, Mt Newmont, Bruce Rock, Wallaroo Rock, Mt Willgonarinya	Sep-Dec	
Gastrolobium semiteres	3				GOLD,SCST,WHTB	ESPERANCE,KALGOORLIE,CENTRAL WHEATBELT	Boorabbin Rock, Southern Cross, Koorarawalyee, Disapponitment Rock	Aug-Oct	
Gnephosis intonsa	3				GOLD,SCST,WHTB	ALBANY,ESPERANCE,KALGOORLIE,CENTRAL WHEATBELT	Gibraltar, Boorabbin, Dundas, Ravenshtorpe, North Ironcap, Ora Banda, Lake Cowan, Parker Range	Sep	
Gnephosis sp. Norseman (K.R. Newbey 8096)	3				GOLD,SCST	ESPERANCE,KALGOORLIE	Jaurdi Stn, Norseman	Sep,Oct	
Gompholobium cinereum	3				GOLD,MWST,WHTB	KALGOORLIE,GERALDTON,CENTRAL WHEATBELT	Wongan Hills, Mullewa, Wilroy, Mt Burges, Merredin, Koolyanobbing, Boorabbin, Maya	Sep-Oct	
Goodenia jaurdiensis	2				GOLD	KALGOORLIE	Jaurdi, Helena-Aurora Range	Sep-Oct	
Grevillea erectiloba	4				GOLD	KALGOORLIE	Bungalbin Hill, Mt Jackson, Mt Dimer	Sep	
Grevillea georgeana	3				GOLD	KALGOORLIE	Die Hardy Range, Mt Manning, Mt Correll, Helena and Aurora Range, Bungalbin Hill	Jul	
Haegiela tatei	4				GOLD,MWST,SCST,WHTB	ESPERANCE,KALGOORLIE,GERALDTON,GREAT SOUTHERN	Grass Patch, Lake Lockhart, Lake King, Badja Station, Peak Charles N.P., Lake Grace, Lake Magenta N.R., Lake Lockhart, Lake Cronin, Jaurdi Stn.	-	
Hakea rigida	2				GOLD,WHTB	KALGOORLIE,CENTRAL WHEATBELT	Campion, Bullfinch, Wallaroo Rock, Mt Burges	Sep	
Hemigenia tenelliflora	2				GOLD	KALGOORLIE	Jaurdi	Oct	
Hibbertia lepidocalyx subsp. tuberculata	3				GOLD	KALGOORLIE	Hunt Range, Helena and Aurora Range, Koolyanobbing Range	Jul	
Homalocalyx grandiflorus	3				GOLD	KALGOORLIE	Bungalbin, Comet Vale, Goongarrie Stn., Mt Manning N.R.	Dec	
Lepidium genistoides	3				GOLD,WHTB	KALGOORLIE,CENTRAL WHEATBELT	Walyahmoning Rock, Boorabbin, (Cowcowing), Marvel Loch, (Mukinbudin), Koorda, Ennuin Stn, Merredin	Oct-Dec	
Lepidosperma lyonsii	4				GOLD,WHTB	KALGOORLIE,CENTRAL WHEATBELT	Jaurdi, Karonie, Charles Gardner N.R., Totadgin Conservation Park		
Lissanthe scabra	2				GOLD,WHTB	KALGOORLIE,CENTRAL WHEATBELT	Jaurdi Stn, Marvel Loch, Southern Cross, Frog Rock Nature Reserve	Aug,Sep	
Malleostemon sp. Adelong (G.J. Keighery 11825)	2				GOLD	KALGOORLIE	Adelong Stn, Mt Manning, Johnston Range	Oct	
Mirbelia ferricola	3				GOLD,MWST,SCST	ESPERANCE,KALGOORLIE,GERALDTON	Helena and Aurora Range, Jaurdi Stn, Coorara Soak, Mt Manning N.R, Bremer Range, Koolanooka Hills, Perenjori Hills, Diemals Stn.,	Sep	
Sowerbaea multicaulis	4				GOLD,WHTB	KALGOORLIE,CENTRAL WHEATBELT	Bullfinch, Karroun Hill, Lake Deborah (Bremer Range - Lake Hope, Lake Cronin)	Nov	
Stenanthemum newbeyi	3				GOLD,WHTB	KALGOORLIE,CENTRAL WHEATBELT	Bungalbin Hill, Koolyanobbing, Die Hardy Range, Ennuin Stn, Mt Manning,Helena and Aurora Range, Mt Jackson	Au-Sep,De-Ja	
Stylidium choreanthum	3				GOLD,WHTB	KALGOORLIE,CENTRAL WHEATBELT	Helena & Aurora Range, Ghooli, Southern Cross, Kambalda, Koolyanobbing, Jaurdi Station, Ennuin Stn	Sep-Oct	
Tecticornia flabelliformis	1				GOLD,WHTB	KALGOORLIE,CENTRAL WHEATBELT	Lake Yindarlgooda, Lake Deborah, Widgiemooltha, Eastern States		
Verticordia mitodes	3				GOLD,WHTB	KALGOORLIE,CENTRAL WHEATBELT	Chiddarcooping, Moorine Rock to Mt Holland, Boorabbin NR, bungalbin Hill, Marvel Loch, Bootraan, Koorarawalyee, Wogarl	Dec	
Verticordia stenopetala	3				GOLD,WHTB	KALGOORLIE,CENTRAL WHEATBELT	Mt Holland, Moorine Rock, Queen Victoria Rock, Marvel Loch, Carrabin, Mt Walton, Holleton	Oct	
Xanthoparmelia fumigata	1				GOLD	KALGOORLIE	Boorabbin, South Australia		

FID_	Sheet	NameID	Taxon	Cons_Code	Plant_Des	Site_Descr	Vegetation	Frequency	Notes	Locality
	8284873	16621	Phebalium appressum	1	Shrub, 40 cm tall. Mostly with flower buds, some plants with few white flowers.	Flat. Dry yellow sand. Fire ca 5 years ago.	Open Eucalyptus rigidula mallee over Acacia nigripilosa subsp. nigripilosa, Acacia inaequiloba and mixed shrubs over Triodia.	5 plants seen locally.		Adjacent to the Mount Dimer - Mount Walton Waste Facility track ca 18 km ESE of Mount Dimer
	5642701	5448	Calytrix creswellii	3	Low shrub 20-60 cm.	Yellow-brown sand. Slope.	Allocasuarina/Acacia resinomarginea shrubland-Eucalyptus woodland. Associated species: Acacia resinomarginea, Allocasuarina acutivalvis, A. corniculata, Eucalyptus loxophleba, Euc. transcontinentalis.			Mount Walton Intractable Waste Disposal compound, 100 km NE Koolyanobbing,
	1153536	2009	Grevillea georgeana	3		Banded ironstone.				Mount Dimer, Jaurdi Station
	1362704	2009	Grevillea georgeana	3	Shrub to 2 m high.	On Banded Ironstone.	With Acacia quadrimarginea.			Jaurdi Station, Mount Walton
	6296467	2009	Grevillea georgeana	3	Perennial shrub ca 1.5 m high. Red flowers.	Hill. Crest and slopes of rocky ridge. Skeletal red soil. Banded chert and laterite. Banded ironstone.	Low Woodland B. Acacia/Grevillea thicket with scattered trees and shrubs over shrubs and herbs.	frequent.		Site J1-7. Banded ironstone hill, ca 1 km E on Mount Dimer mine access road from the Jaurdi - Mount Manning track, Jaurdi Station
	7683170	2009	Grevillea georgeana	3		Rocky outcrop. Silica rich. Dry, light brown loam over sheet boulder.	Open Tall Shrubland over moderate Baeckea elderiana dominated low shrubland over rocky outcrops and stony soils. Acacia acuminata, Allocasuarina acutivalvis subsp. acutivalvis, Melaleuca hamata, Baeckea elderiana, Acacia acuminata, Leucopogon breviflorus			Mt Finnerty Project Area, 70 km N of Southern Cross
	8088683	2009	Grevillea georgeana	3	180 cm high.	Flat. Red-brown clay. Low disturbance. Fire > 10 years prior to collection.	Malleostemon roseus, Grevillea zygoloba, Leucopogon breviflorus, Phebalium canaliculatum, Prostanthera grylloana.			Bungalbin - Kooyanobbing
	8589801	2009	Grevillea georgeana	3	Shrub.	Low slope. Ironstone gravel on red sand.	Acacia burkittii, Prostanthera grylloeana, Grevillea obliquistigma, Santalum spicatum, Prostanthera campbellii, Eremophila granitica.			S of Mount Manning, 105 km NE of Southern Cross
	8600694	2009	Grevillea georgeana	3	Perennial shrub to 80 cm high.	Mid slope in mining lease site. Red clay.	Mixed shrubs with low emergent eucalypts. Associated species: Eucalyptus clelandii, Scaevola spinescens, Allocasuarina campestris, Eremophila oppositifolia subsp. angustifolia, Olearia muelleri, Melaleuca leiocarpa.		Reproductive stage: fruit.	Bungalbin, c. 105 km NE of Southern Cross
	8629625	2009	Grevillea georgeana	3	Shrub 2-3 m. Flowering.	Banded Iron formation over BIF.	Eremophila, Banksia arborea.			59 km N-E of Taipan Hill

FID_	Sheet	NameID	Taxon	Cons_Code	Plant_Des	Site_Descr	Vegetation	Frequency	Notes	Locality
	8284946	3666	Labichea eremaea	3	Shrub, 80 cm tall. Yellow flowers.	Undulating sandplain. Dry yellow sand.	Open mallee of Eucalyptus rigidula over Acacia shrubs over Triodia.	1 plant seen.		Adjacent to the Mount Dimer - Mount Walton Waste Facility track ca 21 km ESE of Mount Dimer
	8285055	41785	Melichrus sp. Bungalbin Hill (F.H. & M.P. Mollemans 3069)	3	Small shrub, 30 cm tall. Red/pink flowers.	Flat. Dry yellow orange sand. Fire: ca 5 years ago.	Open shrubland of Acacia resinimarginea with Acacia sibina.	ca 70 plants locally in 50 x 50 m.		Ca 14.5 km S-E of Mount Dimer. Ca 12.7 km N of Mount Walton. Just S of E-W track that runs from old Mount Dimer mine site to the Mount Walton track
	1102257	41785	Melichrus sp. Bungalbin Hill (F.H. & M.P. Mollemans 3069)	3						16 km NE of Yendilberin Hills (NE of Southern Cross)
	1102265	41785	Melichrus sp. Bungalbin Hill (F.H. & M.P. Mollemans 3069)	3						16 km NE of Yendilberin Hills (NE of Southern Cross).
	5645166	6121	Verticordia stenopetala	3	Low shrub.	Yellow sand-gravel over laterite. Slope.	Sparse Eucalyptus transcontinentalis over moderately dense Acacia signata. Associated species: Acacia resinomarginea, Phebalium canaliculatum, Grevillea paradoxa, Astroloma microphyllum, Thryptomene urceolaris.			Mount Walton Retractable Waste Storage Facility, 100 km NE Koolyanobbing,
	6163092	32685	Banksia arborea	4	Tree. Ca 3 m high. Yellow flowers. Fruiting.	Hill. Crest and slopes of rocky ridge. Skeletal red soil. Banded chert and laterite. Banded ironstone.	Low Woodland B. Acacia/Grevillea thicket with scattered trees and shrubs over shrubs and herbs.	locally abundant.		Site J1-7. Banded ironstone hill, ca 1 km E on Mount Dimer mine access road from the Jaurdi - Mount Manning track, Jaurdi Station
	1804243	32685	Banksia arborea	4	Tree, to 3 m, flowers yellow.	Ironstone ridges.		common.		Mount Dimer, S end Hunt Ranges
	6163106	32685	Banksia arborea	4	Tree. Ca 3.5 m high. Yellow flowers. Fruiting.	Hill. Crest and slopes of rocky ridge. Skeletal red soil. Banded chert and laterite. Banded ironstone.	Low Woodland B. Acacia/Grevillea thicket with scattered trees and shrubs over shrubs and herbs.	locally abundant.		Site J1-7. Banded ironstone hill, ca 1 km E on Mount Dimer mine access road from the Jaurdi - Mount Manning track, Jaurdi Station
	8629528	32685	Banksia arborea	4	Tree. Flowering, fruiting, covered in black scale (common at this locality).	Banded Iron formation over BIF.	Grevillea georgeana, Eremophila.			59 km N-E of Taipan Hill

FID_	PopId	Nameid	Taxon	ConsStatus	WARank	PopNumber	SubPopCode	PopStatus	Location	District	Vesting	Purpose 1	Purpose 2	CountDate	Method	MatureCoun	LiveTotal	inFlower
	96399	32685	Banksia arborea	4		9			UCL, Lot 131. Ex Jaurdi Station. Exploration Lease E77/1418. Site J1-7, Banded Ironstone hill ca. 1km E on Mt Dimer mine access Rd from the Jaurdi-Mt Manning Track. [Ca. 5.6km S of Mt Dimer].	KALGOORLIE	NON	UCL	EPL	5/10/1999 0:00		0	0	N
	96359	32685	Banksia arborea	4		14			UCL, Lot 131, Exploration Lease. Ex Jaurdi Station. Mount Dimer, S end of Hunt Range.	KALGOORLIE	NON	UCL	EXL	13/05/1978 0:00		0	0	N
	87651	5448	Calytrix creswellii	3		8			Intractable Waste Storage Site (CR42001), Lot 73. Mt Walton Intractable Waste Disposal compound, 100km NE of Koolyanobbing. [Ca. 49km E of Bungalbin Hill].	KALGOORLIE	RDL	OTH		20/11/1996 0:00		0	0	N
	87640	5448	Calytrix creswellii	3		10			UCL. Ca. 14km SE of Mt Walton Waste Facility. Ca. 18km ENE of Mt Walton, ca. 80km NE of Koolyanobbing.	KALGOORLIE	NON	UCL		23/09/2010 0:00	ACT_IND	348	348	N
	87642	5448	Calytrix creswellii	3		12			UCL. Ca. 11.5km S of Mt Walton Waste Disposal Facility, east of Yendilberin Hills. Ca. 11.5km ENE of Mt Walton. Near north-south track that runs south from the Mt Walton Waste Disposal (not the main access track).	KALGOORLIE	NON	UCL		22/09/2010 0:00	ESTMT	60	60	N
	87643	5448	Calytrix creswellii	3		13			UCL. Ca. 13.5km S of Mt Walton Waste Disposal Facility, east of Yendilberin Hills. Ca. 10.5km ENE of Mt Walton. Near north-south track that runs south from the Mt Walton Waste Disposal (not the main access track).	KALGOORLIE	NON	UCL		22/09/2010 0:00	ESTMT	21	21	N
	85544	2009	Grevillea georgeana	3		17			UCL, Lot 131. Ex-Jaurdi Station. Exploration Lease E77/1418. 5km SW of Mt Dimer. [Just E of Taipan Mine].	KALGOORLIE	NON	UCL	EPL	4/10/1991 0:00	ESTMT	70	70	Y
	85545	2009	Grevillea georgeana	3		18			UCL, Lot 131. Ex-Jaurdi Station. Exploration Lease E77/1418. On Hill NMF 398 in Yendilberin Hills. Site J1-7, banded ironstone hill, ca. 1km E on Mt Dimer Mine Access Rd from the Jaurdi-Mt Manning track.	KALGOORLIE	NON	UCL	EPL	5/10/1999 0:00		0	0	Y
	85546	2009	Grevillea georgeana	3		19			UCL, Lot 131. Ex-jaurdi Station. Exploration Lease E77/1418. Ca. 105km NE of Southern Cross. [Ca. 2.7km S of Mt Dimer]. [Ca. 26.8km E of Bungalbin Hill].	KALGOORLIE	NON	UCL	EPL	22/08/2007 0:00		0	0	N
	85548	2009	Grevillea georgeana	3		20			UCL, Lot 131. Ex-jaurdi Station. Exploration Lease E77/1418. Mount Dimer.	KALGOORLIE	NON	UCL	EPL	7/11/1989 0:00		0	0	N
	85549	2009	Grevillea georgeana	3		21			UCL, Lot 131. Ex-jaurdi Station. Mining Lease M77/1244. Carina Prospect, Yendilberin Hills. [Ca. 14.5km SE of Mt Dimer].	KALGOORLIE	NON	UCL	EPL	30/03/2009 0:00		0	0	Y
	85555	2009	Grevillea georgeana	3		27			UCL, Lot 131, Ex-Jaurdi Station. Exploration Lease E77/1115. Chameleon Prospect, 105km NE of Southern Cross. [Yendilberin Hills]. [Ca. 1.2km N of Mt Walton].	KALGOORLIE	NON	UCL	EXL	29/05/2008 0:00		5	5	N
	85556	2009	Grevillea georgeana	3		28			UCL, Lot 131, Ex-Jaurdi Station. Mt Finnerty Project Area, [105km NE of Southern Cross]. [Ca. 2.3km SE of Mt Walton].	KALGOORLIE	NON	UCL		25/09/2004 0:00		0	0	N
	88113	5811	Homalocalyx grandiflorus	3		12			UCL. Ca. 14km SE of Mt Walton Waste Facility. Ca. 18km ENE of Mt Walton. Ca. 80km NE of Koolyanobbing.	KALGOORLIE	NON	UCL		23/09/2010 0:00	ACT_IND	2	2	N

FID_	PopId	Nameid	Taxon	ConsStatus	WARank	PopNumber	SubPopCode	PopStatus	Location	District	Vesting	Purpose 1	Purpose 2	CountDate	Method	MatureCoun	LiveTotal	inFlower
	88115	5811	Homalocalyx grandiflorus	3		14			UCL. Ca. 13km S of Mt Walton Waste Disposal facility, E of Yendilberin Hills. Ca. 11km ENE of Mt Walton. Near N-S track that runs south of the Mt Walton Waste Disposal facility (not the main access track).	KALGOORLIE	NON	UCL		22/09/2010 0:00	ESTMT	10	10	N
	88116	5811	Homalocalyx grandiflorus	3		15			UCL. Ca. 13.5km S of Mt Walton Waste Disposal facility, E of Yendilberin Hills. Ca. 10.5km ENE of Mt Walton. Near N-S track that runs south of the Mt Walton Waste Disposal facility (not the main access track).	KALGOORLIE	NON	UCL		22/09/2010 0:00	ACT_IND	38	38	N
	86566	3666	Labichea eremaea	3		9			UCL. Ca. 21km ESE of Mt Dimer. Ca. 15km NNE of Mt Walton. Ca. 5km SW of Mt Walton Waste Facility. Near east-west track that runs from Mt Dimer minesite to the Mt Walton track.	KALGOORLIE	NON	UCL		22/09/2010 0:00	ACT_IND	1	1	Y
	96768	36059	Leucopogon sp. Yellowdine (M. Hislop & F. Hort MH 3194)	1		3			UCL. Ca. 13km S of Mt Walton Waste Disposal faciility. E of Yendilberin Hills. Ca. 11km ENE of Mt Walton. Near the N-S track that runs south from the Mt Walton Waste Disposal facility (not the main access track).	KALGOORLIE	NON	UCL		22/09/2010 0:00	ESTMT	30	30	N
	94445	41785	Melichrus sp. Bungalbin Hill (F.H. & M.P. Mollemans 3069) PN	3		19			UCL. Ca. 15.5km SSE of Mt Walton Waste Facility. Ca. 18km ENE of Mt Walton. Ca. 80km NE of Koolyanobbing.	KALGOORLIE	NON	UCL		23/09/2010 0:00	ACT_IND	5	5	N
	94447	41785	Melichrus sp. Bungalbin Hill (F.H. & M.P. Mollemans 3069) PN	3		20			UCL. Ca. 14km SE of Mt Walton Waste Facility. Ca. 18km ENE of Mt Walton. Ca. 80km NE of Koolyanobbing.	KALGOORLIE	NON	UCL		23/09/2010 0:00		2	2	N
	94448	41785	Melichrus sp. Bungalbin Hill (F.H. & M.P. Mollemans 3069) PN	3		21			UCL. Ca. 16km SE of Mt Dimer. Ca. 12.5km NNE of Mt Walton. Near east-west track that runs from Mt Dimer minesite to the Mt Walton track.	KALGOORLIE	NON	UCL		22/09/2010 0:00	ESTMT	600	600	Y
	94449	41785	Melichrus sp. Bungalbin Hill (F.H. & M.P. Mollemans 3069) PN	3		22			UCL. Ca. 14.5km SE of Mt Dimer. Ca. 12.7km N of Mt Walton. Just south of east-west track that runs from Mt Dimer minesite to the Mt Walton track.	KALGOORLIE	NON	UCL		22/09/2010 0:00	ESTMT	70	70	Y
	93376	16621	Phebalium appressum	1		3			UCL. Ca. 18km ESE of Mt Dimer. Ca. 12.5km NNE of Mt Walton. Near E-W track that runs from Mt Dimer minesite to the Mt Walton track [Mt Walton Rd].	KALGOORLIE	NON	UCL		22/09/2010 0:00	ACT_IND	5	5	Y
	88246	6121	Verticordia stenopetala	3		3			UCL, Mount Walton intractable waste storage facility (R 42001), [S of southern boundary of reserve], 100km NE of Koolyanobbing. Shire of Coolgardie.	KALGOORLIE	NON	UCL		8/11/1996 0:00		0	0	N

APPENDIX 2

Species List

SPECIES LIST – Sandy Ridge Project (September 2015)

GYMNOSPERMS

CUPRESSACEAE
Callitris preissii

MONOCOTYLEDONS

ASPARAGACEAE
Thysanotus patersonii

CYPERACEAE
Lepidosperma lyonsii **(P4)**
Lepidosperma sp.
Schoenus hexandrus

HEMEROCALLIDACEAE
Dianella revoluta var. *divaricata*

POACEAE
Aristida contorta
Austrostipa nitida
Triodia rigidissima
Triodia scariosa

XANTHORRHOEACEAE
Xanthorrhoea thorntonii

DICOTYLEDONS

AMARANTACEAE
Ptilotus obovatus
Ptilotus sp.

APOCYNACEAE
Alyxia buxifolia

ASTERACEAE
Calocephalus knappii
Olearia elaeophila
Olearia exiguifolia
Olearia incana
Olearia muelleri
Olearia pimeleoides
Podolepis capillaris
Rhodanthe citrina

BORAGINACEAE
Halgania andromedifolia

BRASSICACEAE
Stenopetalum filifolium

CASUARINACEAE
Allocasuarina acutivalvis subsp. *acutivalvis*
Allocasuarina corniculata

CHENOPODIACEAE
Atriplex vesicaria
Maireana georgei
Sclerolaena densiflora

ERICACEAE
Leucopogon sp. Clyde Hill

EUPHORBIACEAE
Bertya dimerostigma
Beyeria calycina
Beyeria sulcata var. *sulcata*

FABACEAE
Acacia acuminata
Acacia burkittii
Acacia colletioides
Acacia enervia subsp. *enervia*
Acacia kempeana
Acacia multispicata
Acacia neurophylla
Acacia nigripilosa subsp. *nigripilosa*
Acacia resinimarginea
Acacia tetragonophylla
Acacia verricula
Daviesia benthamii subsp. *acanthoclona*
Senna artemisioides

GOODENIACEAE
Coopernookia strophiolata
Scaevola spinescens

LAMIACEAE
Cyanostegia angustifolium
Prostanthera microphylla
Westringia rigida

MALVACEAE
Keraudrenia velutina subsp. *velutina*

MYRTACEAE
Balaustion pulcherrimus
Calytrix birdii
Calytrix creswellii **(P3)**
Calytrix violacea
Eucalyptus gracilis
Eucalyptus corrugata
Eucalyptus kochii subsp. *plenissima*
Eucalyptus leptopoda
Eucalyptus pileata
Eucalyptus ?rigidula
Eucalyptus salmonophloia
Eucalyptus salubris var. *salubris*
Eucalyptus yilgarnensis
Homalocalyx thryptomenoides
Leptospermum roei
Malleostemon peltiger
Malleostemon roseus
Melaleuca calyptroides
Melaleuca cordata
Melaleuca eleuterostachya
Melaleuca laxiflora
Melaleuca uncinata

PROTEACEAE
Grevillea beardiana
Grevillea eriostachya
Grevillea hookeriana subsp. *apiciloba*
Grevillea obliquistigma
Grevillea paradoxa
Grevillea teretifolia
Grevillea zygoloba
Hakea francisiana

RUTACEAE
Phebalium canaliculatum
Phebalium filifolium
Phebalium tuberculosum
Philotheca brucei subsp. *brucei*
Philotheca rhomboidea

SANTALACEAE
Exocarpos aphyllus
Exocarpos sparteus
Santalum acuminatum

SAPINDACEAE
Dodonaea stenozyga

SOLANACEAE
Solanum hoplopetalum

SCROPHULARIACEAE
Eremophila decipiens subsp. *decipiens*
Eremophila ionantha
Eremophila maculata
Eremophila oppositifolia
Eremophila pantonii

STYLIDIACEAE
Stylidium repens

APPENDIX 3

Quadrat Data

QUADRAT SR1

51 219959 E 6638802 N

Vegetation: *Acacia resinimarginea/Allocasuarina acutivalvis* Open Heath

Condition: Excellent
Soil Type: Light yellow-brown loamy sand, pebbly ironstone
Landform: Flat

QUADRAT (20 x 20m)

SPECIES	HEIGHT (m)	COVER (%)
Acacia resinimarginea	1	50
Allocasuarina acutivalvis	1	2
Grevillea paradoxa	0.6	<1
Phebalium canaliculatum	0.5	<1
Phebalium filifolium	0.4	<1
Phebalium tuberculosum	0.3	<1
Aristida contorta	0.3	<1

QUADRAT SR2

51 220378 E 6638790 N

Vegetation: *Eucalyptus gracilis* Shrub Mallee over *Acacia nigripilosa* subsp. *nigripilosa* Low Shrubland
Condition: Excellent
Soil Type: Red-orange sandy loam
Landform: Top of broad ridge

QUADRAT (20 x 20m)

SPECIES	HEIGHT (m)	COVER (%)
Eucalyptus gracilis	4	40
Melaleuca uncinata	1.1	<1
Acacia nigripilosa 2subsp. *nigripilosa*	1	10
Senna artemisioides	1	<1
Phebalium filifolium	0.6	1
Alyxia buxifolia	0.4	<1
Coopernookia strophiolata	0.4	<1
Scaevola spinescens	0.4	<1
Olearia muelleri	0.3	<1
Acacia colletioides	0.3	<1
Triodia scariosa	0.3	<1

QUADRAT SR2.1

51 220262 E 6638790 N

Vegetation: *Acacia resinimarginea* Open Heath over *Triodia scariosa* Open Grassland
Condition: Excellent
Soil Type: Light orange-brown loamy sand
Landform: Upper slope of low dune

QUADRAT (20 x 20m)

SPECIES	HEIGHT (m)	COVER (%)
Acacia resinimarginea	1.2	40
Eucalyptus yilgarnensis	1.2	<1
Eucalyptus kochii subsp. *plenissima*	1	<1
Acacia nigripilosa 3subsp. *nigripilosa*	0.8	1
Phebalium filifolium	0.4	2
Triodia scariosa	0.3	25
Callitris preissii	Dead, no seedlings	

QUADRAT SR3

51 220026 E 6638408 N

Vegetation: *Acacia resinimarginea* Open Heath
Condition: Excellent
Soil Type: Yellow-brown loamy sand
Landform: Flat

QUADRAT (20 x 20m)

SPECIES	HEIGHT (m)	COVER (%)
Acacia resinimarginea	1.1	40
Calytrix creswellii **P3**	0.5	2
Grevillea beardiana	0.5	2
Homalocalyx thryptomenoides	0.4	2
Phebalium filifolium	0.4	<1
Triodia scariosa	0.4	<1
Phebalium canaliculatum	0.3	<1

QUADRAT SR4

51 219952 E 6638091 N

Vegetation: *Acacia resinimarginea* Shrubland over *Triodia scariosa* Open Grassland
Condition: Excellent
Soil Type: Light orange-brown loamy sand
Landform: Flat

QUADRAT (20 x 20m)

SPECIES	HEIGHT (m)	COVER (%)
Acacia resinimarginea	1.1	25
Acacia kempeana	1	<1
Grevillea beardiana	0.6	2
Triodia scariosa	0.3	25
Homalocalyx thryptomenoides	0.3	1
Keraudrenia integrifolia	0.2	<1

QUADRAT SR5

51 219681 E 6637892 N

Vegetation: *Acacia resinimarginea* Shrubland over *Triodia scariosa* Open Grassland
Condition: Excellent
Soil Type: Light orange-brown loamy sand
Landform: Flat

QUADRAT (20 x 20m)

SPECIES	HEIGHT (m)	COVER (%)
Acacia resinimarginea	1.2	30
Xanthorrhoea thorntonii	1	<1
Lepidosperma sp.	0.5	<1
Phebalium filifolium	0.4	<1
Triodia scariosa	0.3	20
Homalocalyx thryptomenoides	0.3	10
Grevillea beardiana	0.3	1
Phebalium tuberculosum	0.3	1
Callitris preissii	Dead, no seedlings	

QUADRAT SR6

51 220632 E 6637591 N

Vegetation: *Acacia resinimarginea* Open Heath
Condition: Excellent
Soil Type: Light orange-brown loamy sand
Landform: Flat

QUADRAT (20 x 20m)

SPECIES	HEIGHT (m)	COVER (%)
Acacia resinimarginea	1.2	40
Grevillea beardiana	0.7	<1
Melaleuca uncinata	0.6	<1
Phebalium filifolium	0.4	4
Phebalium canaliculatum	0.4	2
Homalocalyx thryptomenoides	0.3	10
Triodia scariosa	0.2	<1
Callitris preissii	0.2 (dead shrubs 3m)	<1

QUADRAT SR7

51 220389 E 6636956 N

Vegetation: *Acacia resinimarginea/Eucalyptus pileata* Shrubland over *Triodia scariosa* Open Grassland
Condition: Excellent
Soil Type: Light orange-brown loamy sand
Landform: Flat

QUADRAT (20 x 20m)

SPECIES	HEIGHT (m)	COVER (%)
Eucalyptus pileata	2	2
Exocarpos sparteus	1.8	<1
Hakea francisiana	1.4	<1
Acacia resinimarginea	1.2	25
Triodia scariosa	0.4	25
Phebalium filifolium	0.4	4
Phebalium canaliculatum	0.4	1
Homalocalyx thryptomenoides	0.3	2
Callitris preissii	0.3 (dead shrubs 3m)	<1
Keraudrenia integrifolia	0.2	<1

QUADRAT SR8

51 220804 E 6636999 N

Vegetation: *Acacia resinimarginea* Open Heath
Condition: Excellent
Soil Type: Light orange-brown loamy sand
Landform: Flat

QUADRAT (20 x 20m)

SPECIES	HEIGHT (m)	COVER (%)
Acacia resinimarginea	1.2	40
Phebalium canaliculatum	0.4	<1
Grevillea beardiana	0.4	<1
Homalocalyx thryptomenoides	0.3	25
Phebalium filifolium	0.3	<1
Balaustion pulcherrimum	0.3	<1
Callitris preissii	0.3 seedling	<1
Triodia scariosa	0.2	<1

QUADRAT SR9

51 221043 E 6636957 N

Vegetation: *Acacia resinimarginea* Open Heath
Condition: Excellent
Soil Type: Light orange-brown loamy sand
Landform: Flat

QUADRAT (20 x 20m)

SPECIES	HEIGHT (m)	COVER (%)
Eucalyptus pileata	1.6	1
Acacia resinimarginea	1.2	50
Melaleuca uncinata	0.8	<1
Phebalium filifolium	0.5	4
Phebalium canaliculatum	0.4	<1
Acacia multispicata	0.4	<1
Homalocalyx thryptomenoides	0.3	2
Callitris preissii	0.3 (dead shrubs 3m)	<1

QUADRAT SR10A

51 220916 E 6637212 N

Vegetation: *Acacia resinimarginea* Open Heath
Condition: Excellent
Soil Type: Light orange-brown loamy sand
Landform: Flat

QUADRAT (20 x 20m)

SPECIES	HEIGHT (m)	COVER (%)
Acacia resinimarginea	1.2	40
Eucalyptus pileata	1.2	1
Melaleuca uncinata	1.1	<1
Phebalium canaliculatum	0.5	5
Homalocalyx thryptomenoides	0.3	5
Phebalium tuberculosum	0.3	<1
Leptospermum roei	0.3	<1
Aristida contorta	0.2	<1
Callitris preissii	0.2	<1

QUADRAT SR10

51 218493 E 6637372 N

Vegetation: *Eucalyptus corrugata* Low Woodland over *Acacia tetragonophylla* Tall Open Shrubland
Condition: Excellent
Soil Type: Orange-red sand
Landform: Flat

QUADRAT (20 x 20m)

SPECIES	HEIGHT (m)	COVER (%)
Eucalyptus corrugata	8	25
Eucalyptus gracilis	4	2
Santalum acuminatum	3	<1
Acacia tetragonophylla	2.5	10
Acacia verricula	1.2	<1
Alyxia buxifolia	1.1	1
Exocarpos aphyllus	1.1	<1
Senna artemisioides	1	1
Phebalium filifolium	1	1
Austrostipa nitida	1	<1
Acacia colletioides	0.7	1
Scaevola spinescens	0.4	<1
Olearia muelleri	0.3	1

QUADRAT SR11

51 219078 E 6636778 N

Vegetation: *Eucalyptus gracilis* Very Open Shrub Mallee over *Acacia burkittii* Tall Open Shrubland over *Melaleuca uncinata* Open Shrubland
Condition: Excellent
Soil Type: Red hard loamy sand
Landform: Flat

QUADRAT (20 x 20m)

SPECIES	HEIGHT (m)	COVER (%)
Eucalyptus gracilis	5	10
Acacia burkittii	3	5
Alyxia buxifolia	2.1	1
Melaleuca uncinata	1.8	5
Exocarpos aphyllus	1.8	<1
Senna artemisioides	1.5	1
Allocasuarina corniculata	1.1	<1
Beyeria sulcata subsp. *sulcata*	1.1	<1
Phebalium filifolium	1	1
Scaevola spinescens	0.5	<1
Eremophila pantonii	0.4	<1
Olearia muelleri	0.4	<1
Acacia colletioides	0.3	1

QUADRAT SR12

51 219838 E 6636414 N

Vegetation: *Callitris preissii/Acacia resinimarginea* Tall Shrubland
Condition: Excellent
Soil Type: yellow loamy sand
Landform: Slight rise

QUADRAT (20 x 20m)

SPECIES	HEIGHT (m)	COVER (%)
Callitris preissii	4	5
Acacia resinimarginea	2.5	10
Melaleuca uncinata	2.1	1
Eucalyptus pileata	2	<1
Leptospermum roei	1.5	5
Homalocalyx thryptomenoides	1	15
Phebalium canaliculatum	0.7	1
Triodia scariosa	0.3	1

QUADRAT SR13

51 220578 E 6636369 N

Vegetation: *Leptospermum roei* Open Heath
Condition: Excellent
Soil Type: Yellow loamy sand
Landform: Flat

QUADRAT (20 x 20m)

SPECIES	HEIGHT (m)	COVER (%)
Melaleuca uncinata	2	<1
Leptospermum roei	1.8	50
Grevillea beardiana	1	<1
Phebalium canaliculatum	0.6	<1
Homalocalyx thryptomenoides	0.5	20

QUADRAT SR14

51 221283 E 6636388 N

Vegetation: *Callitris preissii/Acacia resinimarginea* Tall Shrubland
Condition: Excellent
Soil Type: Light yellow-brown loamy sand
Landform: Flat

QUADRAT (20 x 20m)

SPECIES	HEIGHT (m)	COVER (%)
Callitris preissii	3	5
Eucalyptus pileata	2.1	<1
Acacia resinimarginea	1.2	10
Leptospermum roei	1.2	5
Melaleuca uncinata	0.6	<1
Allocasuarina corniculata	0.6	<1
Lepidosperma sp	0.5	<1
Balaustion pulcherrimum	0.4	<1
Grevillea beardiana	0.4	<1
Acacia enervia subsp. *enervia*	0.4	<1
Homalocalyx thryptomenoides	0.3	4
Triodia scariosa	0.2	<1

QUADRAT SR15

51 221674 E 6632228 N

Vegetation: *Eucalyptus pileata* Open Shrub Mallee over *Melaleuca uncinata* Open Shrubland over *Triodia scariosa* Open Grassland
Condition: Excellent
Soil Type: Light orange-red sand
Landform: Flat

QUADRAT (20 x 20m)

SPECIES	HEIGHT (m)	COVER (%)
Eucalyptus pileata	2	25
Acacia neurophylla	1.8	1
Hakea francisiana	1.5	1
Melaleuca uncinata	1.1	5
Melaleuca eleuterostachya	1	1
Phebalium filifolium	0.7	<1
Triodia scariosa	0.3	20
Podolepis capillaris	0.3	<1
Bertya dimerostigma	0.2	1

QUADRAT SR16

51 219424 E 6635881 N

Vegetation: *Eucalyptus corrugata* Low Woodland over *Acacia tetragonophylla* Tall Open Shrubland
Condition: Excellent
Soil Type: Light orange-brown loamy sand
Landform: Flat

QUADRAT (20 x 20m)

SPECIES	HEIGHT (m)	COVER (%)
Eucalyptus corrugata	8	10
Acacia tetragonophylla	3	5
Eremophila decipiens subsp. *decipiens*	2.5	1
Santalum acuminatum	2	<1
Exocarpos aphyllus	2	<1
Scaevola spinescens	1	4
Phebalium filifolium	0.8	<1
Acacia colletioides	0.7	<1
Austrostipa nitida	0.6	<1
Triodia scariosa	0.3	<1
Triodia rigidissima	0.3	<1
Philotheca rhomboidea	0.3	<1
Aristida contorta	0.2	<1

QUADRAT SR17

51 219599 E 6635801 N

Vegetation: *Eucalyptus salmonophloia* Woodland over *Acacia tetragonophylla* Tall Open Shrubland
Condition: Excellent
Soil Type: Orange-red sandy loam
Landform: Flat

QUADRAT (20 x 20m)

SPECIES	HEIGHT (m)	COVER (%)
Eucalyptus salmonophloia	12	10
Acacia tetragonophylla	2.5	10
Santalum acuminatum	1.9	<1
Eremophila decipiens subsp. *decipiens*	1.8	<1
Eremophila pantonii	1.6	<1
Acacia colletioides	1	10
Scaevola spinescens	0.8	5
Senna artemisioides	0.6	<1
Acacia nigripilosa subsp. *nigripilosa*	0.5	<1
Eremophila maculata	0.5	<1
Olearia muelleri	0.3	<1
Triodia scariosa	0.3	<1

QUADRAT SR18

51 216759 E 6632407 N

Vegetation: *Acacia resinimarginea/Melaleuca uncinata* Open Low Heath
Condition: Excellent
Soil Type: Light orange-brown loamy sand with ironstone
Landform: Flat

QUADRAT (20 x 20m)

SPECIES	HEIGHT (m)	COVER (%)
Eucalyptus pileata	2	<1
Acacia resinimarginea	1	25
Acacia kempeana	1	<1
Melaleuca uncinata	0.9	20
Grevillea paradoxa	0.8	<1
Allocasuarina corniculata	0.5	<1
Triodia scariosa	0.4	1
Acacia enervia subsp. *enervia*	0.4	<1
Phebalium filifolium	0.4	<1
Phebalium canaliculatum	0.3	<1
Schoenus hexandrus	0.3	<1
Grevillea beardiana	0.3	<1
Thysanotus patersonii	Climber	<1

QUADRAT SR19

51 216284 E 6631694 N

Vegetation: *Eucalyptus salubris* var. *salubris* Open Shrub Mallee over *Melaleuca uncinata* Open Shrubland
Condition: Excellent
Soil Type: Orange-red sandy loam with ironstone pebbles
Landform: Flat

QUADRAT (20 x 20m)

SPECIES	HEIGHT (m)	COVER (%)
Eucalyptus salubris var. *salubris*	5	10
Melaleuca uncinata	1.1	20
Eremophila ionantha	1	1
Senna artemisioides	0.8	4
Acacia resinimarginea	0.8	2
Acacia tetragonophylla	0.8	<1
Phebalium filifolium	0.6	<1
Austrostipa nitida	0.6	<1
Olearia pimelioides	0.4	<1
Scaevola spinescens	0.3	1
Acacia colletioides	0.2	<1
Aristida contorta	0.2	<1

QUADRAT SR20

51 212191 E 6626740 N

Vegetation: *Eucalyptus gracilis* Open Shrub Mallee over *Acacia acuminata/Eremophila oppositifolia* Open Shrubland
Condition: Excellent
Soil Type: Orange-red sandy loam with ironstone pebbles
Landform: Slight depression

QUADRAT (20 x 20m)

SPECIES	HEIGHT (m)	COVER (%)
Eucalyptus gracilis	4	15
Acacia acuminata	2.5	5
Acacia tetragonophylla	1.7	1
Eremophila oppositifolia	1.1	5
Senna artemisioides	1.1	2
Eremophila maculata	1	<1
Alyxia buxifolia	1	<1
Austrostipa nitida	1	<1
Prostanthera microphylla	0.6	<1
Olearia elaeophila	0.4	<1
Olearia muelleri	0.3	<1

QUADRAT SR21

51 212321 E 6626873 N

Vegetation: *Acacia burkittii* Tall Shrubland
Condition: Excellent
Soil Type: Orange-red sandy loam with ironstone pebbles
Landform: Bottom of low valley

QUADRAT (20 x 20m)

SPECIES	HEIGHT (m)	COVER (%)
Acacia burkittii	3	20
Grevillea eriostachya	1.3	<1
Homalocalyx thryptomenoides	1	25
Prostanthera microphylla	1	<1
Leucopogon sp. Clyde Hill	0.6	5
Senna artemisioides	0.4	<1
Rhodanthe citrina	0.1	<1
Calocephalus knappii	<0.1	<1
Thysanotus patersonii	Climber	<1

QUADRAT S22

51 212796 E 6627468 N

Vegetation: *Eucalyptus salmonophloia* Woodland over *Eremophila oppositifolia* Open Heath
Condition: Excellent
Soil Type: Orange-red sandy loam
Landform: Flat

QUADRAT (20 x 20m)

SPECIES	HEIGHT (m)	COVER (%)
Eucalyptus salmonophloia	12	20
Eucalyptus gracilis	4	<1
Santalum acuminatum	3	<1
Eremophila oppositifolia	1.2	15
Eremophila pantonii	1.1	1
Exocarpos aphyllus	1	<1
Atriplex vesicaria	0.8	2
Senna artemisioides	0.6	1
Alyxia buxifolia	0.5	<1
Olearia muelleri	0.3	<1
Acacia colletioides	0.3	<1
Acacia tetragonophylla	0.2	1
Maireana georgei	0.2	<1
Ptilotus obovatus	0.2	<1
Sclerolaena densiflora	0.1	<1

QUADRAT SR23

51 214904 E 6630126 N

Vegetation: *Eucalyptus ?rigidula* Very Open Shrub Mallee over *Melaleuca uncinata/Acacia acuminata* Open Low Heath
Condition: Excellent
Soil Type: Orange-red sandy loam
Landform: Top of small rise

QUADRAT (20 x 20m)

SPECIES	HEIGHT (m)	COVER (%)
Eucalyptus ?rigidula	4	5
Acacia acuminata	1.2	5
Senna artemisioides	1	2
Eremophila ionantha	1	<1
Allocasuarina acutivalvis	1	1
Melaleuca uncinata	0.8	50
Dodonaea stenozyga	0.7	<1
Phebalium filifolium	0.5	1
Philotheca brucei subsp. *brucei*	0.4	1
Scaevola spinescens	0.4	<1
Callitris preissii	0.3	<1

Geological Evolution Report

TELLUS

SANDY RIDGE PROJECT

WESTERN AUSTRALIA

REGIONAL GEOLOGY and GEOLOGICAL EVOLUTION

Produced for

Tellus Holdings Ltd

Report Number WA16/01

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EXECUTIVE SUMMARY

Introduction

This report summarises the regional and local geology and the geological evolution of Tellus Holding Ltd's Sandy Ridge Project, which is located 120km northeast of Southern Cross in Western Australia. It also discusses potential geological events that might affect the surficial materials within the project area.

Geological Setting

The project is located within the Archean Yilgarn Craton, a crustal block that covers a large part of southern Western Australia. The craton formed between 3000 and 2600 million years ago and its current relatively flat topography largely represents an extremely old Proterozoic erosion surface that has subsequently been modified by weathering, further partial erosion, and local sedimentation, resulting in a complex regolith. The current landforms have been in place for about 250 million years and the Yilgarn Craton has been tectonically stable for ten times that period.

The project area is over a body of weathered granite, which was emplaced about 2700 million years ago.

Project Geology

The project is within a region in which nearly intact deep weathering profiles of 30-50m depth have been retained on broad upland topography. The surficial weathered materials in the project area have been formed over a period of more than 200 million years. The resultant profile typically consists of, from the surface down: sand and gravel, silcrete, kaolinite, saprock, and partly oxidized granite.

Current Weathering and Erosion

Current weathering and erosion in the area is extremely slow. The present surface in the project area has not changed significantly for at least the last 2.6 million years, except for the addition of wind-blown sand, and redistribution of lateritic pebbles.

The minerals constituting the lateritic, silcrete, and kaolinite layers are chemically stable end members of the weathering process and the present semi-arid climate is not conducive to chemical weathering. In addition, the project area contains no active stream channels and is distant from any major drainage system. Consequently, the area is not presently subject to water erosion. Wind erosion is very limited, as the sandplain is well covered with native vegetation.

Future Weathering and Erosion

It is difficult to envisage a scenario under which a significant change to the present minimal rates of erosion or weathering could occur at the project site, within, say, 10 million years.

The Earth is currently in an interglacial period. However, if ice age conditions resume, significant erosion of the silcrete or underlying kaolinised regolith is highly unlikely to occur, as these layers were not affected during any of the previous ice ages over the last 2.6 million years.

In the event of further climate warming, current predictions from the Department of the Environment and the IPCC are for lower rainfall and higher temperatures for the region. Under such conditions there would be no reason to expect increased weathering or erosion.

Potential Geological Hazards

Earthquakes

The project area is in an area of very low earthquake activity and has the lowest possible Earthquake Hazard Rating. No moderate or strong earthquakes have been recorded within 200km of the site over the last 60 years, and the nearest quake in that time period classified as minor or light was centred about 80km away.

Tectonic Movement

The project is within the central portion of the eastern section of the Indo-Australian Tectonic Plate, which is, in general, moving at around 5.6cm per year towards the northeast. If the movement were continued at the same rate, the project area could be expected to approach the present position of the seismically active section of New Guinea in about 60 million years.

Glaciation

There is no evidence that the central portion of the Yilgarn Craton has been subject to glaciation, even during the most recent ice age during the last 70,000 years. The nearest evidence of glaciation is about 300km to the east, where approximately 300-million-year-old glacial sediments lie above the Archaean rocks.

The present north-easterly movement of the Australian continent towards the tropics and away from the South Pole suggests that there is no likelihood of a future glaciation of the area, at least in the next 60 million years.

Igneous Activity

There has not been any igneous activity in the region for over 1000 million years and the most recent volcanic activity in southern WA was 140 million years ago about 525km to the southwest of the project area within the Perth Basin. There is no reason to expect surface or sub-surface volcanic activity in the region during the next 50 million years.

Nearby Mining Activity

The closest current mining activity is at the Mt Walton East Intractable Waste Disposal Facility, which is about 8km to the east-southeast. The mining consists of the excavation of pits into the regolith formed over Archean granite.

Current iron ore open-cut mining is being carried out at Carina, 14km to the southwest, and at Koolyanobbing, about 73km to the southwest. To the east, the nearest operating mines are the Jenana open-cut gold mine 60km to the northeast and the New Galley underground mine 87km to the southeast.

GEOLOGICAL SETTING

The Sandy Ridge Project is located within the Archean Yilgarn Craton that comprises an area of approximately 657 000 km^2 and forms one of the largest intact segments of the Archean crust on Earth (Figure 1). The bulk of the craton is thought to have formed between 3000 and 2600 million years ago, with some gneissic terranes exceeding 3000 million years in age (Anand and Butt, 2010).

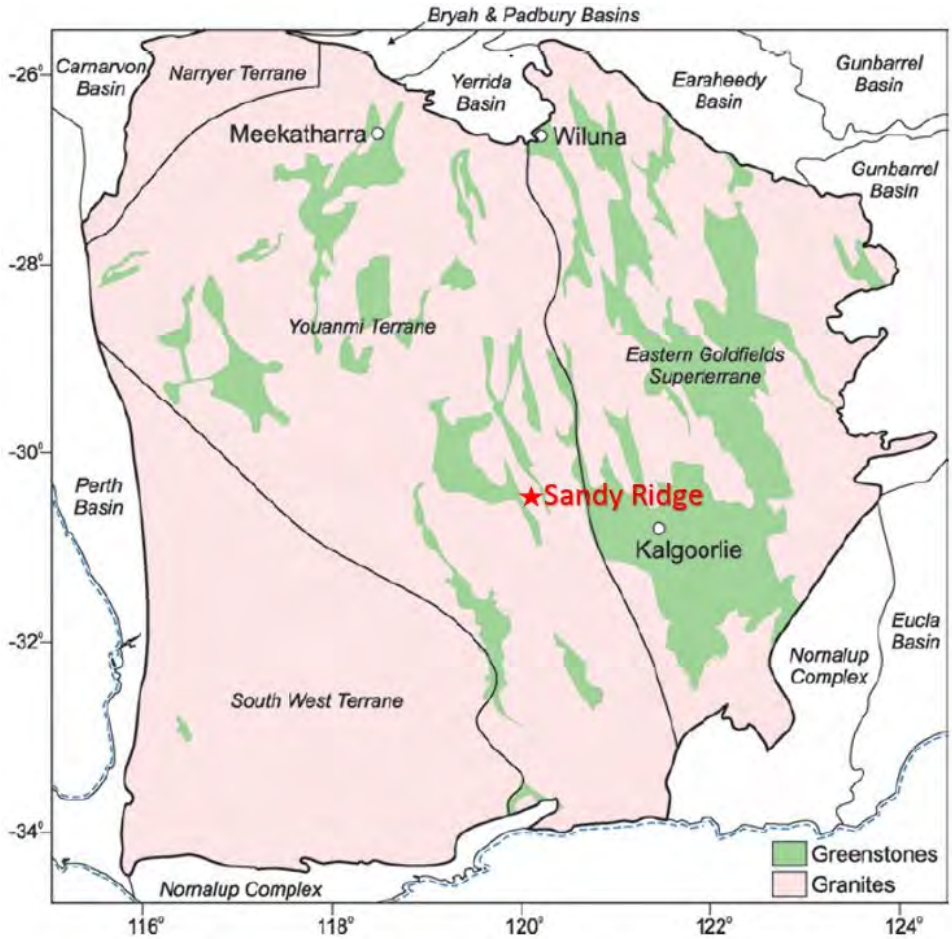

Figure 1 Yilgarn Craton

The surface of the Yilgarn Craton, the Yilgarn Plateau, has low relief and, on a regional scale, probably represents a Proterozoic* erosion surface. This extremely old surface has subsequently been modified by weathering, partial erosion, and sedimentation, resulting in a complex regolith** (Anand and Butt, 2010). Broad landforms have been in place for about 250 million years and the Yilgarn Craton has been tectonically stable for ten times that period.

* The Proterozic is that period of time between approximately 2500 and 540 million years ago.

** The regolith is the combination of weathered rock, soil, and other unconsolidated or cemented material that forms a younger blanket over unweathered bedrock.

GEOLOGICAL HISTORY

Bedrock Geology

The geological history of the project area is relatively simple. It involves the emplacement of a granitic body within the crust about 2700 million years ago (Nelson, 2002). Over the next 2000 million years the overlying rocks were eroded, resulting in a relatively flat landscape, which has been above sea-level for at least the last 540 million years (Figure 2), during which time it has been subject to various weathering events as it has undergone different climatic regimes.

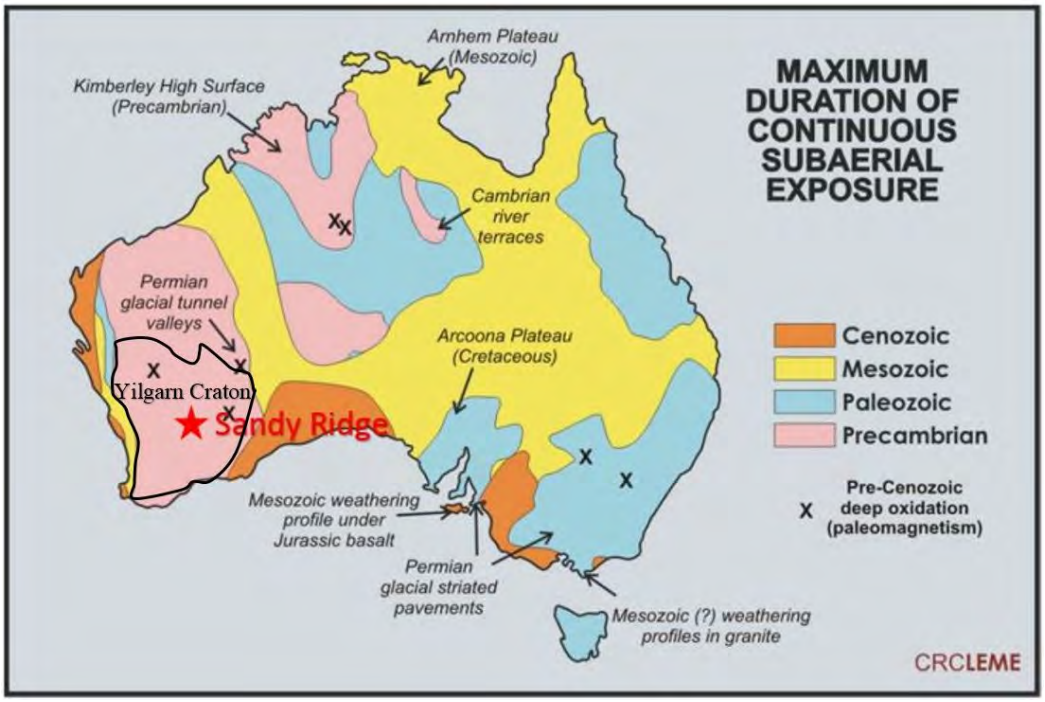

Figure 2 Sandy Ridge Project location within area that has been above sea level for at least 540 million years (from Pillans, 2005)

The regional geology is shown on Figure 3, which displays interpreted bedrock geology. Various granitic bodies are shown in shades of pink, basic volcanic rocks in green, ultrabasic rocks in purple, banded iron formations in grey, and metamorphosed sediments in yellow (Martin *et al*, 2014). The project is located in the centre of a 160km long and 20km wide north-northwest trending granitic body, which intruded older granitic and volcanic rocks.

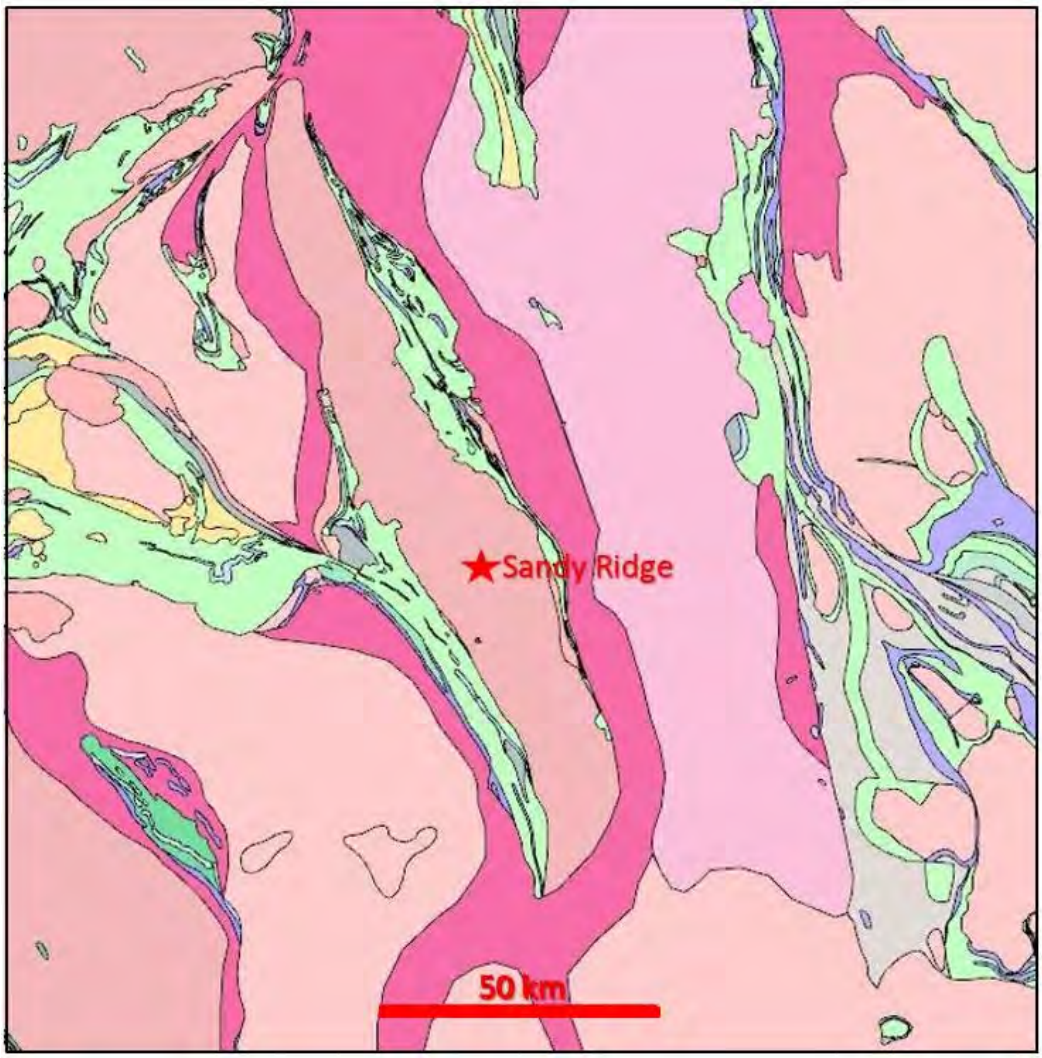

Figure 3 Interpreted bedrock geology of project region (Martin *et al*, 2014)

Regolith Geology

The project is within a region classified as Incipient Etchplain, in which nearly intact deep weathering profiles of 30-50m depth have been retained on broad upland divides (Anand and Paine, 2002). The surficial materials above the fresh granite in the project area have been formed over the last 260 million years (Anand and Butt, 2010). The regolith formation over the Yilgarn Craton is summarised in Figure 4.

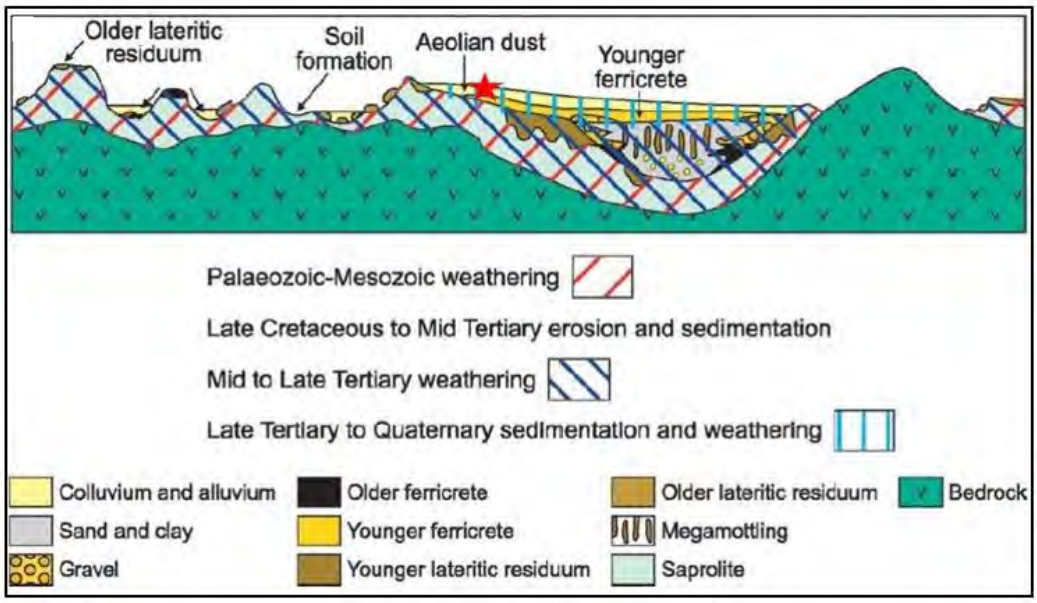

Figure 4 Schematic section showing regolith units over Yilgarn basement – the red star indicates the regolith profile at Sandy Ridge (after Anand and Butt, 2010)

Within the project area the granite has been subjected to various weathering processes, including kaolinisation. A typical profile, is:

- 0-1m: Sand;
- 1-3m: Sandy gravel;
- 3-5m: Silcrete;
- 5-7m: Mottled zone;
- 7-23m: Kaolin;
- 23-27m: Saprock;
- 27m: Oxidized granite; and
- 32m+: Granite

Figure 5, a photograph of chip trays from the air-core drill-hole SRAC204, drilled by Tellus in April 2016, shows a similar lithological profile.

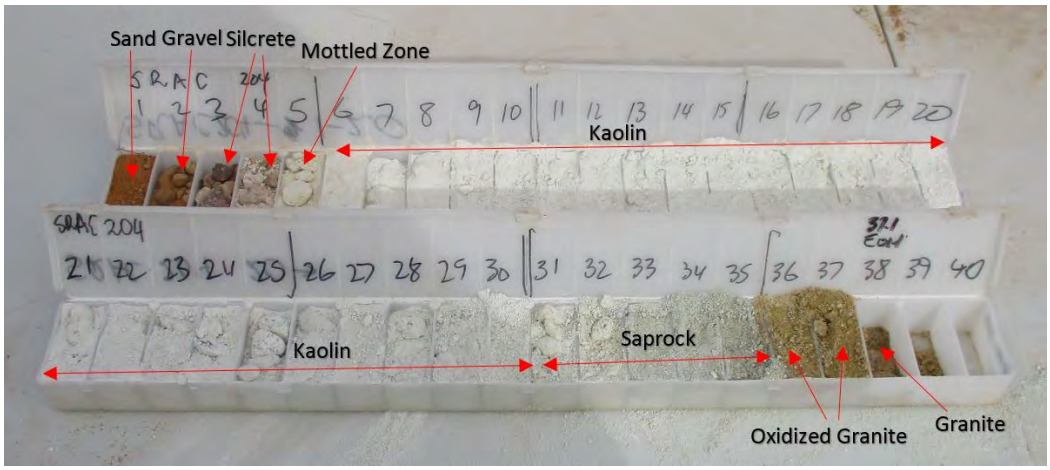

Figure 5 Regolith samples from air-core drill-hole SRAC204

Figures 6 and 7 show a waste disposal pits excavated into the regolith at Mt Walton East, which is 8km to the east-southeast of the project area. The regolith profiles within the two areas are similar.

Figure 6 Pit at Mt Walton East Waste Disposal Facility cut down through lateritic and silcrete layers into the mottled zone (from Dept of Finance, 2016)

Figure 7 Pit at Mt Walton East Waste Disposal Facility cut down through the mottled zone into the kaolinite zone (Dept of Finance, 2013)

The formation of the kaolinised granite and the saprock occurred during two extended periods during which humid and mainly temperate to sub-tropical climates promoted chemical weathering. The first was from the late Permian to the late Cretaceous (from about 260 to 70 million years ago) and the second was through the Eocene to the mid-Miocene (from about 55 to 15 million years ago).

Since the mid-Miocene (ca 15 million years ago) a change to semiarid to arid conditions caused the induration and cementation of the upper regolith by iron oxides, silica, aluminosilicates, or carbonates (Anand and Butt, 2010). At Sandy Ridge these changes caused the formation of the relatively minor mottled zone (caused by the deposition of iron oxides), the silcrete layer (caused by silica cementation), and the pisolitic laterite (caused by iron oxide deposition and cementation). Finally, during the Quaternary Ice Ages, which began about 2.6 million years ago, wind-blown sand formed the final cover.

The laterite, silcrete, and kaolinite are the end products of chemical weathering of the granite from which they have been formed. The major minerals of the unweathered granite in the area are feldspars (ca 65%), quartz (ca 20%), and biotite (ca 10%).

The feldspars weather to form kaolinite, which is stable and resistant to further chemical change. The quartz is resistant to chemical weathering and may form a near surface quartz fragment rich residuum, which may then be cemented silica to form silcrete. The silica has previously been dissolved from other minerals in the weathered rock and transported towards the surface in groundwater. The dissolved iron from the weathered biotite also travels towards the surface, where it is precipitated as iron oxide minerals to form laterite. These minerals: kaolinite, silica, and iron oxides are chemically stable end products that are resistant to further chemical weathering (Anand and Paine, 2002).

Current Weathering and Erosion

Current weathering and erosion in the area is extremely slow.

The present semi-arid climate, with a median annual rainfall of about 250mm and an annual evaporation rate of about 2400mm (Bureau of Meteorology, 2016), is not conducive to chemical weathering, which is active in humid temperate to tropical climates, but much less active in semi-arid and arid climates.

The present surface has not changed for at least the last 2.6 million years, except for the addition of wind-blown sand, and redistribution of lateritic pebbles. The retention throughout the general area of the previously cemented surficial silcrete indicates the lack of erosion.

The project area is situated at an elevation of about 470m in an area of low relief. It contains no active stream channels and no known paleo-channels (Figure 8). It is also distant from any major drainage system (Figure 9). The near horizontal sandy surface and lack of stream channels results in rain water being absorbed into this surface unit, rather than running off with resulting water erosion. Wind erosion is very limited, as the sandplain is well covered with native vegetation.

It is the combination of a virtually flat plateau, cemented surface layers, and semi-arid conditions that creates the stable geomorphology of the area.

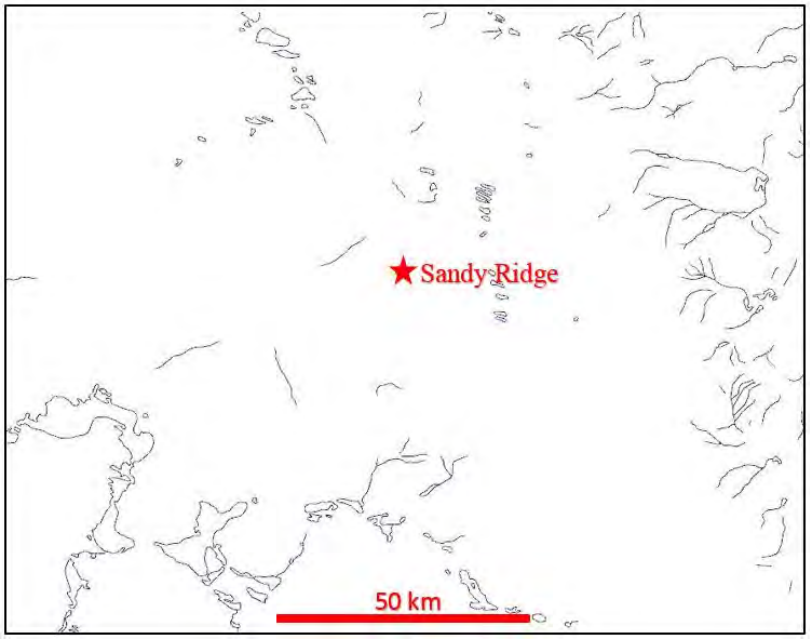

Figure 8 Drainage Map of the Sandy Ridge region (from GSWA GeoVIEW, 2016)

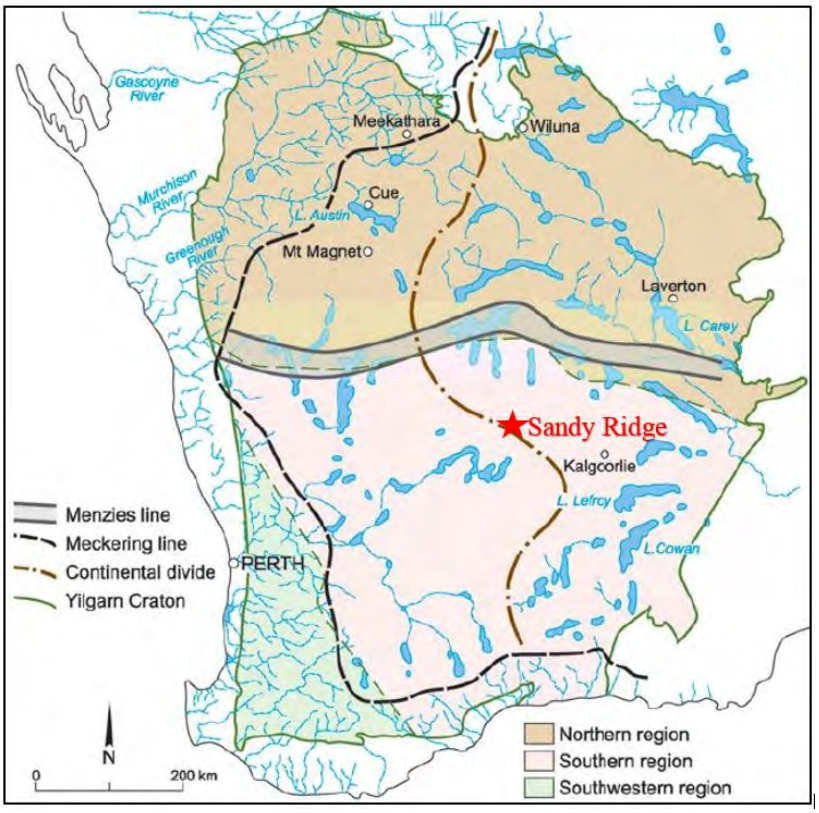

Figure 9 Drainage systems of the southwest of WA (after Anand and Butt, 2010)

Future Weathering and Erosion

It is difficult to envisage a scenario under which a significant change could occur at the project site, within, say, 10 million years, from the present minimal weathering and erosional conditions.

The current landforms at the site must have been in place for about 260 million years, as the regolith, which has formed since this time is still in place, un-eroded; although erosion of this ancient regolith (and deposition of the eroded material) has occurred in other areas of the craton (see Figure 4). The Yilgarn Craton itself has been tectonically stable for ten times that period. Neither mountain building nor continental breakup is considered to be likely to occur in the region.

In broad scale climatic terms, the Earth is currently within an interglacial period, within a larger ice age that began 2.6 million years ago. Should the current ice age continue, then another glacial period can be expected to occur within a few tens of thousands of years. During the previous ice age arid conditions caused vegetation loss and movement of wind-blown sand. However, no significant erosion of the silcrete or kaolinised regolith occurred, probably partly because the sand-stripped surface was resistant to wind erosion owing to its silica and iron cemented nature. The only glaciers on the Australian mainland at this time were in the Snowy Mountains. The location and topography of Western Australia is such that a similar glacial period would not cause glaciation in the region.

On the other hand, if general climate warming occurs, current predictions from the Department of the Environment and the ICCP are that the region would be subject to less rainfall and to warmer temperatures (Dept. of the Environment, 2016; Reisinger *et al*, 2014). Under such conditions there would be no reason to expect either increased weathering or significant erosion.

Earthquake History

The project area is in an area of very low earthquake activity. No moderate or strong earthquakes have been recorded within 200km of the site over the last 60 years, and the nearest quake in that time period classified as minor or light was centred about 80km away.

Figure 10, the southwestern portion of the 2012 Australia Earthquake Hazard Map, shows that the project is situated in an area of the lowest hazard rating in the Australian continent, which itself is an area of relatively low earthquake risk. The contours on the map relate to the size of the maximum expected earthquake generated forces within a 500-year period. The project area is within a region in which this force is predicted to be less than 1% that of gravity (Burbidge, 2012).

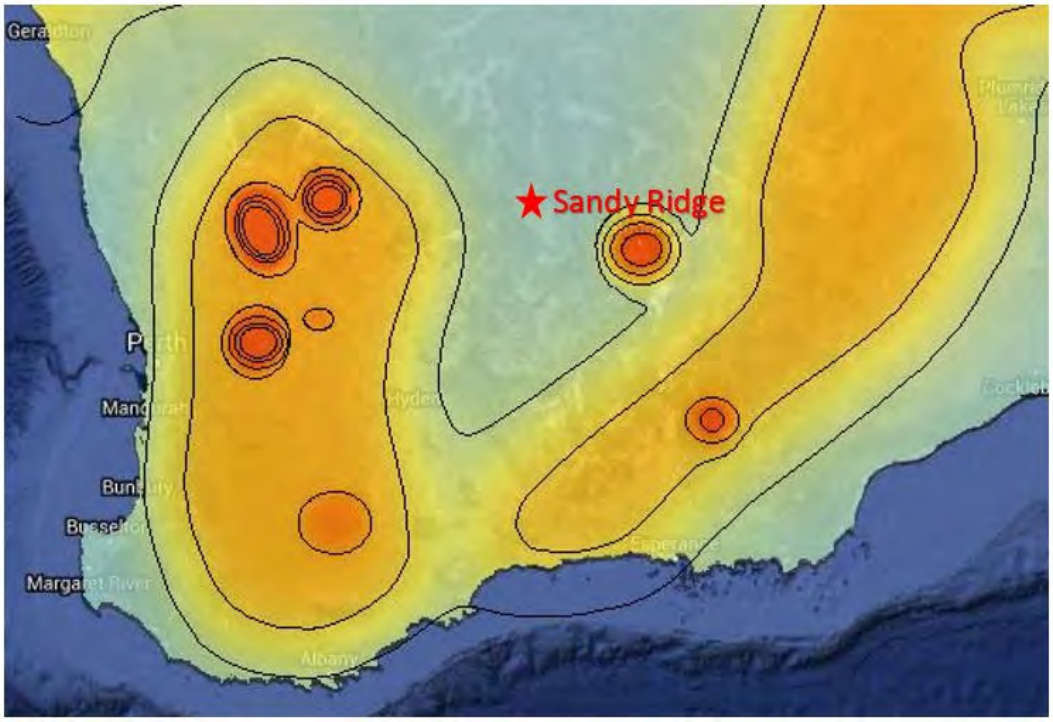

Figure 10 Sandy Ridge Project location in area of low Earthquake Hazard (from Geoscience Australia Earthquake Hazard Map, Burbidge, 2012)

Earthquake strength is measured on a logarithmic magnitude scale; in which each single figure increase corresponds to a ten-fold increase in released energy. Earthquakes are classified in classes ranging from minor to great, depending on their magnitude (Table 1). The common effects of earthquakes of varying magnitude are shown in Table 2.

Table 1 Earthquake Classes (from Michigan Tech, 2016)

Class	Magnitude
Great	8 or more
Major	7 - 7.9
Strong	6 - 6.9
Moderate	5 - 5.9
Light	4 - 4.9
Minor	3 -3.9

Table 2 Earthquake Effects (from Michigan Tech, 2016)

Magnitude	Earthquake Effects
2.5 or less	Usually not felt, but can be recorded by seismograph.
2.5 to 5.4	Often felt, but only causes minor damage.
5.5 to 6.0	Slight damage to buildings and other structures.
6.1 to 6.9	May cause a lot of damage in very populated areas.
7.0 to 7.9	Major earthquake. Serious damage.
8.0 plus	Great earthquake. Can totally destroy communities near the epicentre.

Figure 11 shows the location of earthquakes of Magnitude 3 or greater that have occurred in southern WA in the last 60 years. The cluster to the east-southeast of Sandy Ridge is probably related to destressing of the crust due to the mining activity in the Kalgoorlie area.

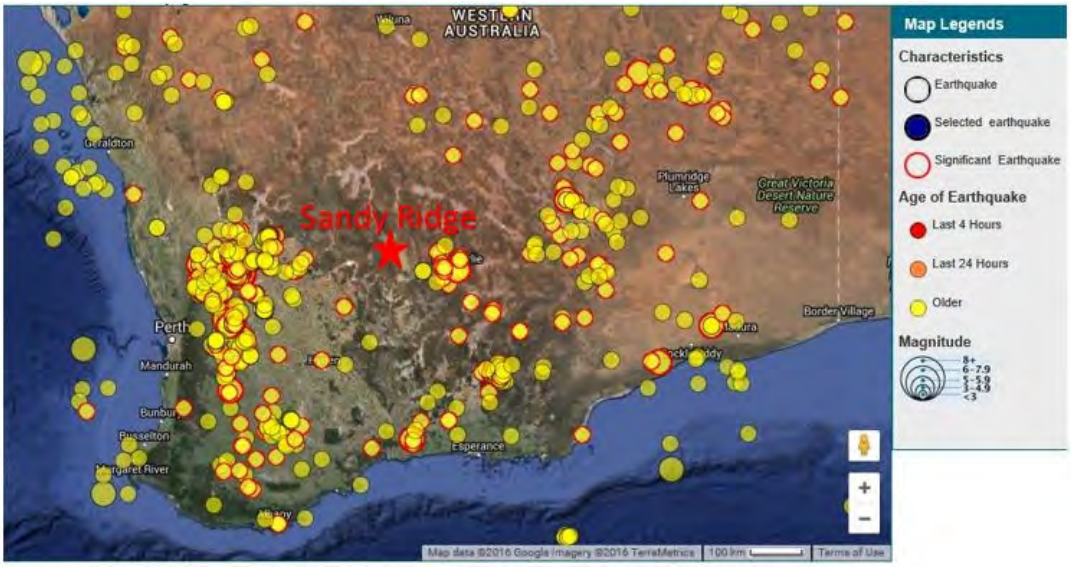

Figure 11 Earthquake locations of Magnitude 3 and greater from 1955 in southern WA (after Geoscience Australia, 2016)

Within 200km of the Sandy Ridge Project the greatest magnitude quake measured 4.7 and the closest (a magnitude 3) occurred about 80km to the southeast (Figure 12). Figure 13 shows the location of earthquakes in the same area classified as less than minor. The closest of these was 20km from the project area.

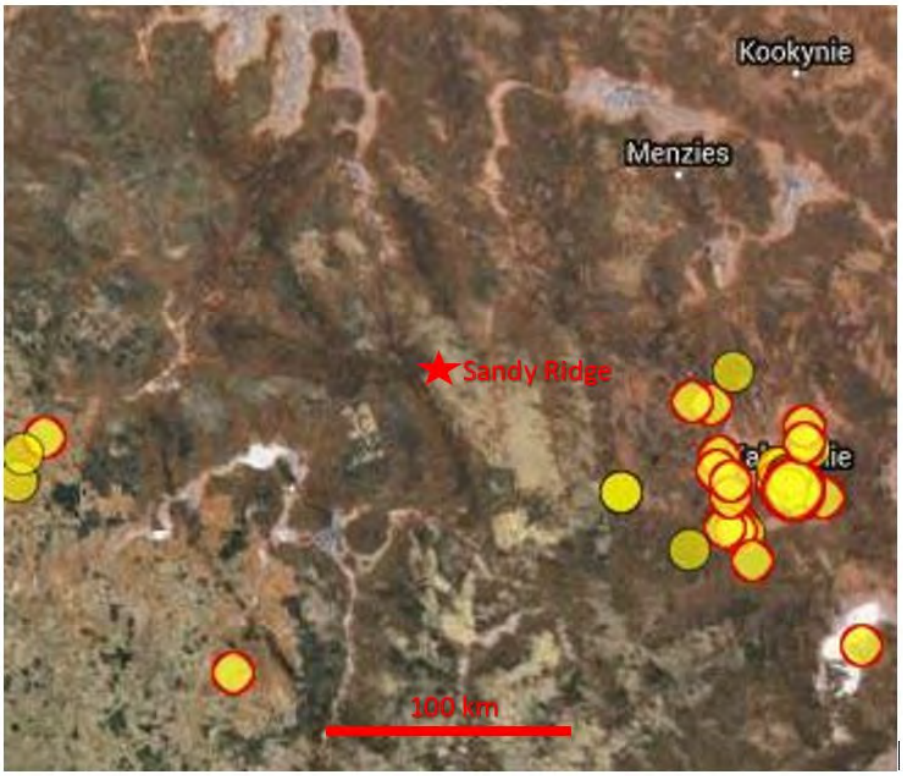

Figure 12 Earthquake locations of Magnitudes 3 to 4.7 from 1955 within approximately 200km of Sandy Ridge Project (after Geoscience Australia, 2016)

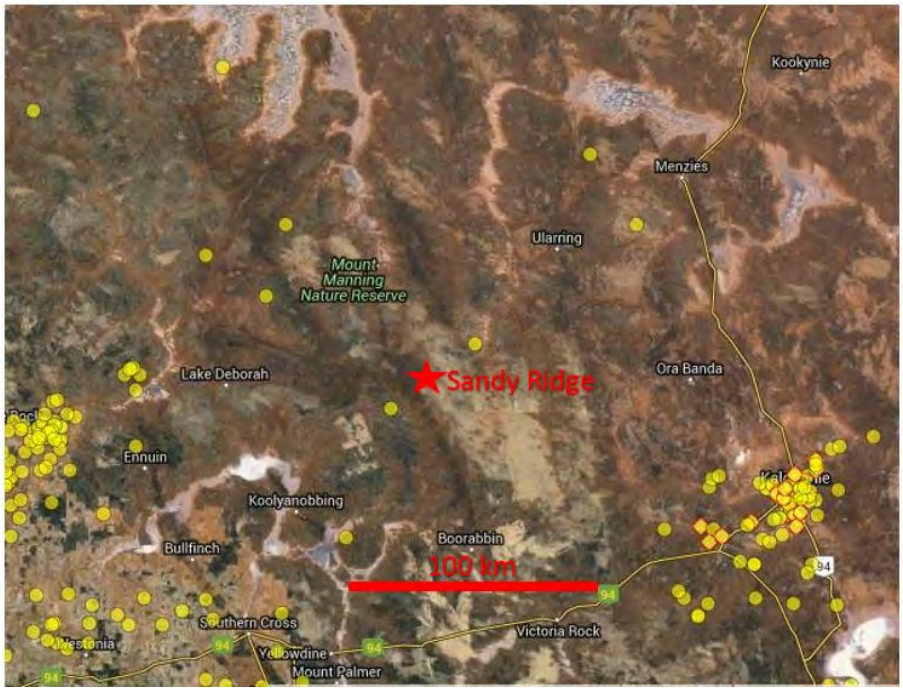

Figure 13 Earthquake locations of Magnitude 2 to 2.9 from 1955 within approximately 200km of Sandy Ridge Project (after Geoscience Australia, 2016)

Tectonic Movement

The Sandy Ridge Project, situated on the Archaean Yilgarn Shield, is within the central portion of the eastern section of the Indo-Australian Tectonic Plate (Figure 14). This eastern section is, in general, moving at around 5.6cm per year towards the northeast (Hammonds, 2012). This rate of movement and the location of the project within a seismically quite portion of a stable shield is very unlikely to cause any significant tectonic activity (uplift, subsidence, or fracturing) in any time frame relevant to the project. However, if the present movement continues at the same rate, the project area can be expected to approach the present position of the seismically active section of New Guinea in about 60 million years.

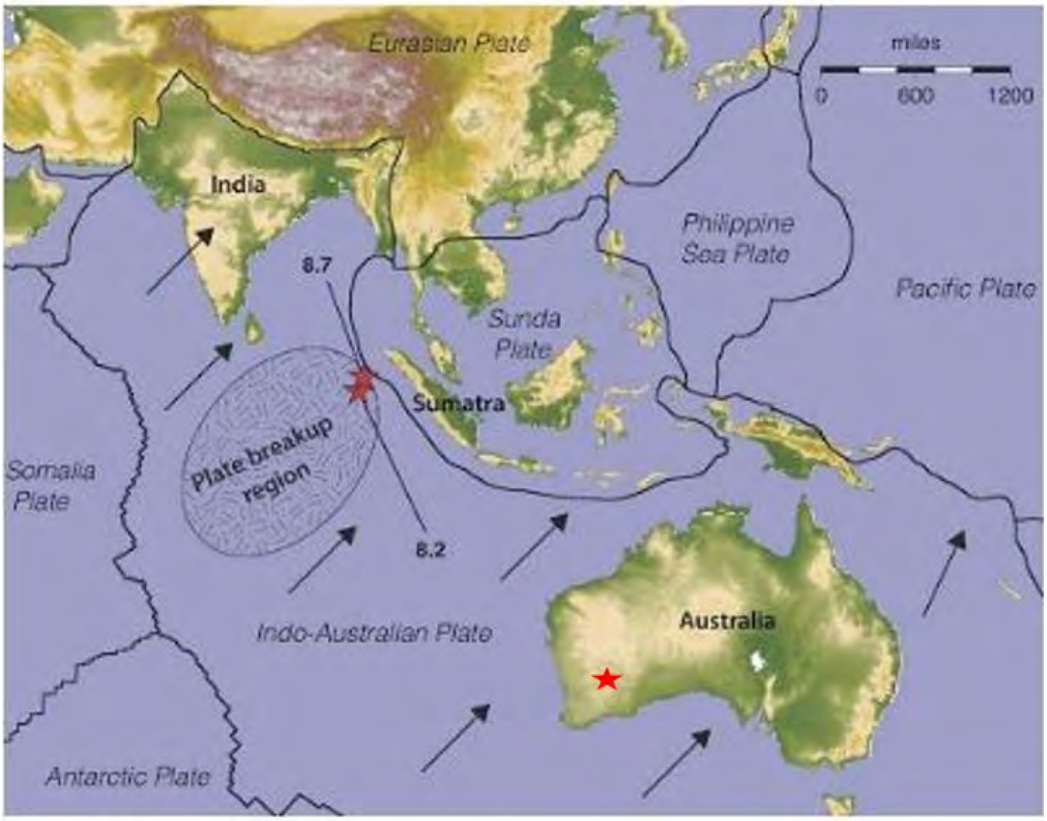

Figure 14 Sandy Ridge Project location within Indo-Australian Plate (after Hammonds, 2012)

Glaciation

There is no evidence that the central portion of the Yilgarn Plateau has been subject to glaciation, even during the most recent Ice Ages of the last 70,000 years, when the only areas in Australia where glaciers were present were the Snowy Mountains and Tasmania (Barrows and Fifield, 2016). The nearest evidence of glaciation is about 300km to the east, near the eastern edge of the craton, where approximately 300-million-year-old glacial sediments of the Paterson Formation lie above the Archaean rocks (Martin *et al*, 2014).

The present north-easterly movement of the Australian continent towards the tropics and away from the South Pole suggests that there is no likelihood of a future glaciation of the area, at least in the next 60 million years.

Igneous Activity

There has not been any igneous activity in the region for over 1000 million years. The Archaean granite that constitutes the bedrock in the project area has been dated at around 2700 million years (Nelson, 2002). A Proterozoic age east-west trending dyke intruded the granitic basement about 20km south of the project area. Similar dykes within the Yilgarn Craton have been dated at ca 2420 million years (Nemchin and Pidgeon, 1998) and at ca 1210 million years (Pidgeon and Nemchin, 2001).

The most recent volcanic activity in southern WA was within the Perth Basin near Bunbury, about 525km to the southwest of the project area. The outpouring of this basalt occurred about 140 million years ago during the breakup of the Gondwana supercontinent (Martin *et al*, 2014).

There is no reason to expect that there will be any sub-surface or surface volcanic activity within this part of the stable craton for at least 50 million years.

Nearby Mining Activity

Operating and proposed mines within the region are shown on Figure 15.

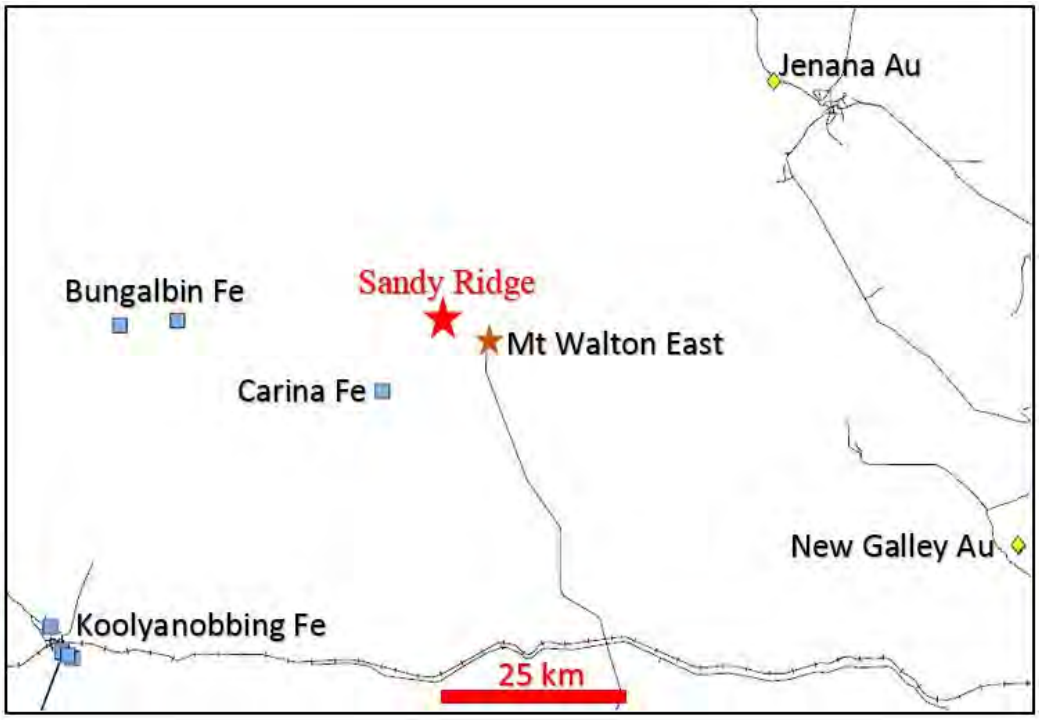

Figure 15 Operating and proposed mines (after GSWA GeoView)

The closest current mining activity is at the Mt Walton East Intractable Waste Disposal Facility, which is about 8km to the east-southeast. It is managed by the Building Management and Works division of the Department of Finance of the Government of

Western Australia. The mining consists of the excavation of pits into the regolith formed over Archean granite (Figures 6 and 7).

Current iron ore open-cut mining is being carried out at Carina, 14km to the southwest, by Polaris Metals NL, which also has a proposed an open-pit at Bungalbin. Iron ore mining is also being carried out at Koolyanobbing, about 73km southwest of Sandy Ridge.

Further east, the nearest operating mines are the Jenana open-cut gold mine 60km to the northeast and the New Galley underground mine 87km to the southeast.

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GLOSSARY

Air-core	A method of drilling by which a sample, often of unconsolidated material, is passed up the inner tube of a drill stem
Archean	The oldest rocks of the Precambrian Era; older than about 2,500 million years
Banded Iron Formation	Chemical sedimentary rock composed mainly of finely alternating layers of silica and iron oxide
Basalt	Dark coloured, fine-grained volcanic rock formed by the cooling of a mafic lava
Basic volcanic	Volcanic rock with a significant content of dark coloured ferromagnesian minerals
Bedrock	Solid rock underlying surficial deposits
Biotite	A dark platy mineral of the mica group
Craton	A part of the earth's crust that has been stable and undeformed**,** except perhaps by faulting, for a long period of time
Cretaceous	The final period of the Mesozoic Era; from about 145 to 66 million years ago
Dyke	A tabular igneous intrusion that cuts across the intruded rocks
Eocene	An epoch of Cenozoic Era, from about 56 to 34 million years ago
Erosion	The action of surface processes (such as water flow or wind) that remove soil, rock, or dissolved material from one location on the Earth's crust, then transport it away to another location
Feldspar	A silicate mineral; formed in igneous and metamorphic rocks; light coloured
Formation	A formal name for an, often sedimentary, rock unit
Glaciation	the process in which land is covered by glaciers, or the effect this process has of eroding the underlying rocks or covering them with glacial sediments

Gneiss	High-grade metamorphic rock composed of alternating bands respectively rich in light and dark coloured minerals
Granite	A light coloured, relatively coarse-grained igneous rock formed at depth beneath the Earth's surface; comprises large sections of continental crust
Greenstone	A field term for metamorphosed mafic and ultramafic igneous rocks
Igneous	Rock formed by solidification of hot mobile material termed magma
Intrusion	A body of igneous rock that invades older rocks
Kaolinisation	The weathering or alteration process in which the clay mineral kaolin is formed
Kaolin or kaolinite	A white clay mineral with the chemical composition $Al_2Si_2O_5(OH)_4$.
Interglacial	A geological interval of warmer global average temperature lasting thousands of years that separates consecutive glacial periods within an ice age. The current interglacial began about 11,700 years ago.
Laterite	An iron oxide-rich rock formed near the Earth's surface by weathering processes
Mesozoic	The era of geological time between about 66 and 250 million years ago
Metamorphic	A rock that has been altered by physical and chemical processes involving heat, pressure, and / or fluids
Miocene	The epoch of geological time within the Cenozoic Era between about 5 and 23 million years ago
Oxidized	A rock that has been exposed to air and water causing its minerals to change by the addition of oxygen (and perhaps carbon and water).
Paleozoic	The era of geological time between about 250 and 540 million years ago
Permian	The period of geological time between about 250 and 300 million years ago
Proterozoic	The eon of geological time between about 540 and 2500 million years ago

Quartz	A mineral composed of silicon and oxygen; forms as hard colourless crystals; a common component of sand.
Quaternary	The period of geological time from about 2.6 million years ago to the present.
Regolith	The surface layer of loose incoherent rock material that lies above “bedrock”; formed by deposition or in-situ weathering.
Saprock	**Saprock** is the first stage of weathering. It consists of partially weathered minerals and as yet unweathered minerals
Sediment	Rock formed by the deposition of solids from water
Seismic	Relating to earthquakes or other vibrations of the earth and its crust.
Silcrete	A cemented surficial rock in which the cement is silica
Silica	The compound SiO_2; quartz is composed of silica
Siliceous	Containing the mineral silica
Silicified	A rock that has been alterated or replaced by silica
Tectonic plate	A slab of the Earth's crust that "floats" and slowly moves on the underlying mantle
Tectonics	Regional scale crustal movements; either shifting the crust as a whole (plate tectonics) or deforming and fracturing it during an episode of tectonism
Terrane	A regional-scale group of rock units
Tertiary	The period of geological time between about 2.6 and 66 million years ago
Ultramafic	Dark-coloured igneous rock containing virtually no quartz or feldspar and composed essentially of ferromagnesian silicates, mainly olivine and pyroxene
Volcanic	Descriptive of rocks originating from volcanic activity
Weathering	The process by which rocks are broken down into small grains and soil by physical or chemical means

DECLARATIONS

This report has been prepared by J. John G. Doepel. Mr Doepel is a Principal Geologist and the Director of Continental Resource Management Pty Ltd ("CRM"). He has over 30 years' experience in the mineral industry as a geologist, including thirteen years as a consultant with CRM. He has carried out exploration on numerous projects, exploring for a wide variety of metals and minerals. He has completed resource estimations for a variety of deposit types including many for industrial minerals. Mr Doepel holds a Bachelor of Science with Honours and a Graduate Diploma in Forensic Science from the University of Western Australia and a Diploma of Teaching from Curtin University. He is a Member of the Geological Society of Australia, of the Australasian Institute of Mining and Metallurgy, and of the Australian Institute of Geoscientists.

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CRM's assessment of the properties included in this report is based upon technical information provided by Tellus. Reference has been made to other sources of information, published and unpublished, including government reports and reports prepared by previous interested parties, where it has been considered necessary. CRM has endeavoured, by making reasonable enquiries, to confirm the authenticity and completeness of the technical data used in the preparation of this report and to ensure CRM had access to all relevant technical and other information.

The statements contained in this report are given in good faith and have been derived from information believed to be reliable and accurate, and supplemented by our own investigations. We have relied upon this information and have no reason to believe that any material facts have been withheld from us. We do not imply that we have carried out any type of audit on the technical, accounting or other records of Tellus, or that our assessment has revealed all of the matters which an audit or more extensive examination might disclose at the date of this report. The conclusions are based on the reference date of the 6th May 2016.

J. Doepel,

6th May 2016

Soils & Materials Characterisation

TELLUS

SANDY RIDGE PROJECT SOIL ASSESSMENT

Tellus Holdings Limited

FINAL REPORT

QUALITY SCIENCE | PRACTICAL OUTCOMES

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EXECUTIVE SUMMARY

The Sandy Ridge project is located approximately 140km north west of Kalgoorlie. The mine is in the proposal stage of development and will extract kaolin clay from the Sandy Ridge kaolin bed for use in industrial applications. Landloch was engaged by Tellus Holdings Ltd to undertake an assessment of the soil of the Sandy Ridge project.

The Project resides on the metagranites of the Southern Cross Granite-Greenstone Terrane, and lies between Youanmi greenstone belts. These rocks are deeply weathered and this has formed a well leached kaolinized zone under a lateritic duricrust. Regionally, the lateritic duricrust can be nodular and grade into ferruginous mottled clays and can be up to 4m thick. A combination of geology and geomorphology exert the main controls over the soils found at Sandy Ridge and two main types have developed; Red Sandy Duplexes and Deep Yellow Sands.

The Red Sandy Duplex soils are reddish brown sands with a neutral pH over alkaline sandy clay loam B horizons. The soil is massively but weakly structured. The soil has very low salinity levels ($EC_{1:5}$<0.17dS/m) but does have an exchangeable sodium percent (ESP) of 7.6% in the more clay rich (20%) B horizon, which may be a dispersion risk. The surface stone mantle consists of infrequent gravel to rock-sized particles of varying abundance of what appears to be the underlying ferricrete hardpan.

The Deep Yellow Sands have strongly acid pH throughout their profile. Exchangeable Aluminium may be mobile at the lower pH levels and may be toxic to vegetation, and thus the Deep Yellow Sands should be used with caution. There is little pedological development and the textures are sands at the surface 5cm and loamy sand throughout the lower profile which was greater than 1.5m in depth. The material appears to be free draining, which is probably a major factor in the differences in relatively sparse vegetation of this soil type compared to the more complex vegetation associated with the Red Sandy Duplexes. The soils have very low salinity levels ($EC_{1:5}$ 0.02-0.03dS/m) and there are few surface coarse fragments.

Details on soil management for available quantities, stripping, and handling techniques are contained within this report.

1 INTRODUCTION

1.1 Overview

Landloch has been engaged by Tellus Holdings Ltd to undertake a baseline soil assessment of the proposed Sandy Ridge Project (The Project). The Project encompasses a mining area consisting of waste pit, mine infrastructure (workshop, offices, etc), accommodation camp, connecting haul roads, and Class II waste disposal facility.

The Sandy Ridge Project is in the pre-approval stage and is therefore required to undertake baseline environmental and other studies. The baseline soil assessment will be used as part of the approval process, as well as in preparation of the mine closure plan in accordance with the Environmental Protection Agency (EPA) and Department of Mines and Petroleum (DMP) *Guidelines for Preparing Mine Closure Plans* (EPA/DMP 2015).

The purpose and scope of the baseline soil assessment is to provide information on the properties of the undisturbed soil resource of the project area, including an indication of any adverse properties such as salinity, dispersion, and poor structure. The tasks to be completed for the baseline soil assessment include:

- A review of publically available information relating to the soils and landforms of the Sandy Ridge project area;
- A field survey of the soils of the Sandy Ridge project area, including sampling of soils and description of soil profiles;
- Physical and chemical characterisation of selected soil samples;
- Interpretation of the physical and chemical soil test results;
- Mapping of the approximate functional undisturbed soil boundaries and estimation of available soil volumes;
- Production of a report that outlines the assessment method, provides the results of the field assessment and soil test results and their interpretation, provides the mapping, and broadly details the implication of these in terms of landform rehabilitation and mine closure planning.

1.2 Project background

The Sandy Ridge Project is located approximately 140km north west of Kalgoorlie (Figure 1). The mine will extract kaolin clay from the Sandy Ridge kaolin bed for use in industrial applications. The Project is situated on exploration tenement E16/440 (59km^2 in extent), of which there is a development envelope of 875ha (Figure 2) comprising disturbance features of the mine pit (37ha), infrastructure (11.8ha), accommodation camp (2.5ha), and a Class II waste disposal facility (0.26ha), and underground storage area (4ha). The proposed disturbance area is approximately 6.4% of the development envelope.

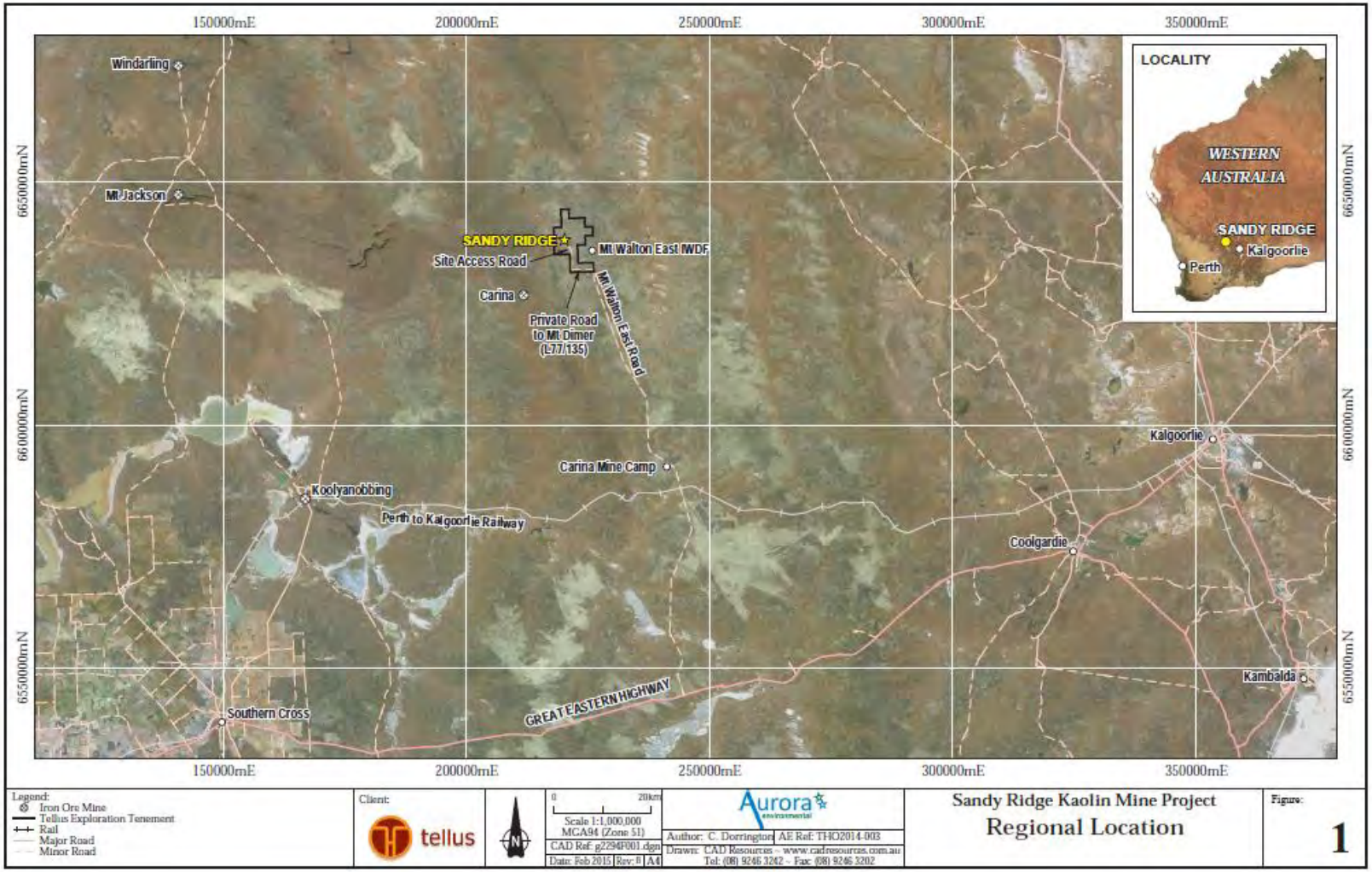


Figure 1: Location of the Sandy Ridge Project. (Source: Aurora Environmental)

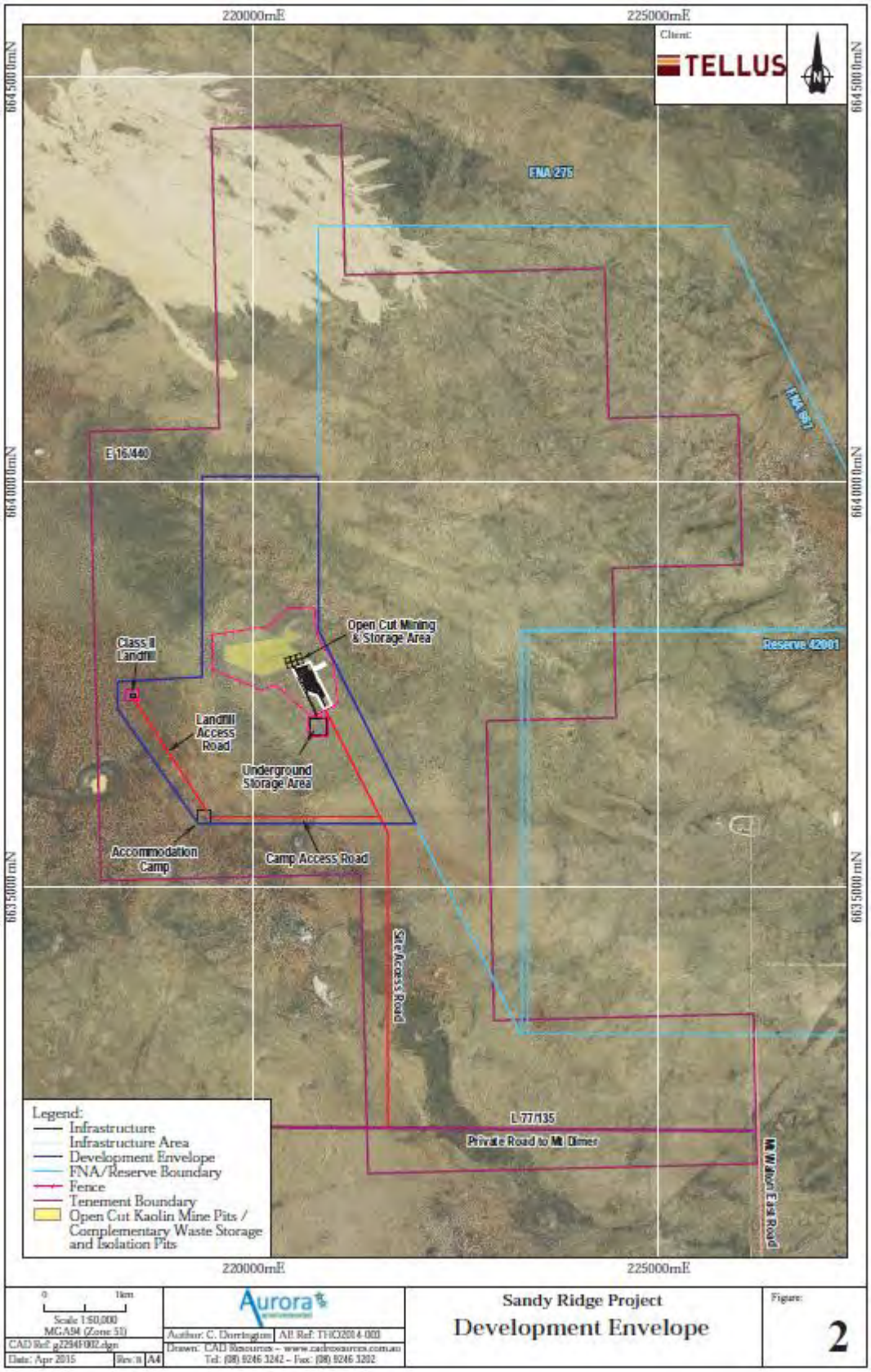


Figure 2: Development envelope of the Sandy Ridge Project. (Source: Aurora Environmental)

1.3 Existing environment

1.3.1 Climate

The climate of the Sandy Ridge site is described as semi-desert Mediterranean. The mean annual rainfall is low and occurs mainly from January to July with the driest months being late spring to early summer. The winter months are cool with very hot summers (Table 1).

Table 1: Mean monthly rainfall and daily maximum temperature for weather stations near to the proposed Sandy Ridge site (BOM 2015).

Month	Mean Monthly Rainfall* (mm)	Mean Daily Maximum Temperature^ (°C)
January	37.6	33.3
February	25.8	32.3
March	25.4	29.4
April	25.3	24.9
May	21.6	20.3
June	33.7	16.9
July	32.8	16.1
August	19.5	18.1
September	20.9	22.0
October	13.7	25.1
November	16.3	29.3
December	12.9	32.3
	265.8 (MEAN ANNUAL)	**25.0** (DAILY AVERAGE)

* Koolyanobbing (#12227) ^ Coolgardie (#012018)

1.3.2 Geology

The Project resides on the metagranites of the Southern Cross Granite-Greenstone Terrane, and lies between Youanmi greenstone belts. The porphyritic granitic rocks are intruded by quartz veins and dolerite dykes. This bedrock has been extensively weathered and laterised. Most of the bedrock is covered by Tertiary and Quaternary alluvial, colluvial, and Aeolian deposits.

Weathering of the Archaean aged granites led to the formation of the kaolin deposit. These rocks are deeply weathered and this has formed a well leached kaolinized zone under a lateritic duricrust. Regionally, the lateritic duricrust can be nodular and grade into ferruginous mottled clays and can be up to 4m thick (Abeysinghe *et al.* 2002).

1.3.3 Geomorphology, soil, and vegetation

The Project falls within the Norseman (266) soil landscape mapping zone (Tille 2006). The landforms of the area consist of very low relief undulating plains and low rises. Small rocky hills and ridges can be found on the granitic terrain. The plains can host salt lakes, claypans, and some silcrete duricrusts.

The soils of the gently sloping areas can be Yellow sandy earths and Yellow loamy earths, with some Yellow deep sands. The slightly more hilly terrain can have Red loamy earths, Red shallow loams, or Calcareous loamy earths. The main vegetation type is Salmon gum/redwood/merit/red mallee/gimlet woodland with acacia/casuarina thickets (and some mulga shrublands and spinifex grasslands (Tille 2006).

2 SOIL ASSESSMENT METHODOLOGY

2.1 Regulatory requirements

The Department of Mines and Petroleum (DMP) requires an assessment of soils that are the subject of Mining Proposals. Analysis of both topsoil and subsoil layers is required and should "identify possible adverse parameters such as low or high pH, high salinity, nutrient/trace element deficiencies, poorly structured soils, dispersive or sodic soils and potentially hazardous compounds" (DMP 2011). The impacts of proposed mining activities on soil properties, and any topsoil management plan that is developed should include consideration of:

- Topsoil and subsoil characteristics in relation to plant growth;
- Harvestable topsoil and subsoil volumes;
- Estimated volumes of topsoils and subsoils required for rehabilitation;
- Stockpile dimensions (footprint) and their location on mine site plans;
- Harvest, preservation, and redeployment methodologies; and
- Proposed field trials relating to soil depth requirements, suitability for plant growth, and amendment and fertiliser requirements.

DMP provides guidance on the minimum set of soil parameters that should be measured as part of the development of Mining Proposals (DMP 2011). This set includes:

- Soil pH;
- Soil salinity (Electrical Conductivity [EC]);
- Particle size distribution (texture is used as a surrogate by Landloch except where potentially dispersive soils are encountered);
- Emerson dispersion test;
- Total Phosphorus (Total P);
- Total Nitrogen (Total N);
- Available P (as phosphate); and
- Nitrate N.

These parameters specified by DMP are broadly consistent with normal assessments of soil quality and address most of the major soil properties affecting plant growth. Although specified by the DMP, Landloch does not test for Nitrate N. This is because Nitrate N is highly variable in soils and will vary with soil depth, time of sampling, and rainfall/soil moisture. The soil samples also require very careful collection and handling protocols. It is for these reasons that Landloch does not test for this parameter at the assessment stage.

2.2 Assessment methodology

2.2.1 Survey scale

Broad area project feasibility and land resource inventory studies are typically conducted at a 1:100,000 map scale which as a minimum, requires one soil pit for every 100ha (McKenzie *et al.* 2008). At this medium scale, this required the description of four soil pits. It should be noted that this survey density refers to the entire development envelope, of which 93.6% will not be disturbed. The location of the four soil pits was placed as close as practical to the proposed disturbance features to obtain a more accurate description of the soils to be disturbed.

Although a soil map (and assessment of the soils mapped) will be provided for the entire E16/440 exploration tenement, the greatest confidence will be associated with the mapping area within the development envelope. The rest of the soil map covering other areas within the E16/440 exploration tenement has been inferred from information gathered from the disturbance envelope mapping and therefore should be regarded as having a lower confidence level.

2.2.2 Preliminary desktop review

A preliminary desktop review of available information relevant to this assessment was conducted from publically available sources. The information sources included:

- Technical Bulletins from the Department of Agriculture (WA);
- Geological maps from Geological Survey (WA), and Geoscience Australia; and
- Online journal articles.

The review of soil, geology, land systems, and vegetation attributes (summarised in Section 1) was used to develop an understanding of the soils likely to be encountered and their location within the landscape. Soil description pits were allocated for each land system and used to describe the different soils found in each location.

2.2.3 Field assessment

A one day field inspection was conducted by Landloch staff on the 22nd of April 2015. The purpose of the field trip was to record data on soils and soil profiles, and to collect soil samples. These data were used to validate the information collated as part of the desktop review. Soils data were recorded from soil pits. The data recorded consisted of general observations of the landscape and land surfaces, and detailed descriptions of the soils and soil profiles. These data were supplemented with laboratory analysis of selected soil samples.

Description of soil profiles and landscape characteristics was conducted in accordance with McDonald *et al* (1998), and soils were classified according Isbell (1996). Broad colour names are those of Isbell (1996) while more detailed colour descriptions were defined using the Munsell Soil Colour Charts. Field pH was measured using the paste calorimetric method described by Raupach and Tucker (1959).

Soil pits were excavated within the development envelope. The soil pits were constructed using a 1.8 tonne excavator to dig to a maximum depth of 1.5m. Areas of hardpan material were

encountered below the surface in sections of the development envelope, and consequently some pits were excavated to the depth of refusal which was shallower than 1.5m. The soil pit sampling sites were numbered sequentially as they were collected during the field inspection.

At each soil pit location, observations of the topography and surface condition included:

- Location (GPS);
- Aspect and slope;
- Elevation;
- Geomorphology;
- Vegetation;
- Drainage;
- Surface condition; and
- Coarse fragment percentage.

Soils descriptions within each soil pit included:

- Depth;
- Horizonation;
- Colour;
- Field texture;
- Coarse fragment percentage;
- Structure;
- Fabric;
- Consistence; and
- Permeability.

The information collected during the pit descriptions was used to draw estimated boundaries of the different soils on hard copy maps. Locations of the soil pits are shown in Figure 3.

2.2.4 Soil characterisation

During the field visit soil samples were collected for laboratory analysis. Samples were collected from the A horizon (surface) and subsurface (B, C, or R horizon) for every soil pit. The samples were returned to Landloch's Perth laboratory and an initial assessment on all samples was made by in-house tests for field pH, electrical conductivity, colour, and texture. From the initial assessment, a representative selection of each soil type (approximately 50% of the samples) were sent to a National Association of Testing Authorities (NATA) accredited soils laboratory for more detailed assessment. This approach is consistent with the *Australian Soil Survey Guidelines* (McKenzie *et al* 2008). The soil material analysed for chemical and physical properties was labelled with a sample number corresponding to the soil pit from which the sample was sourced.

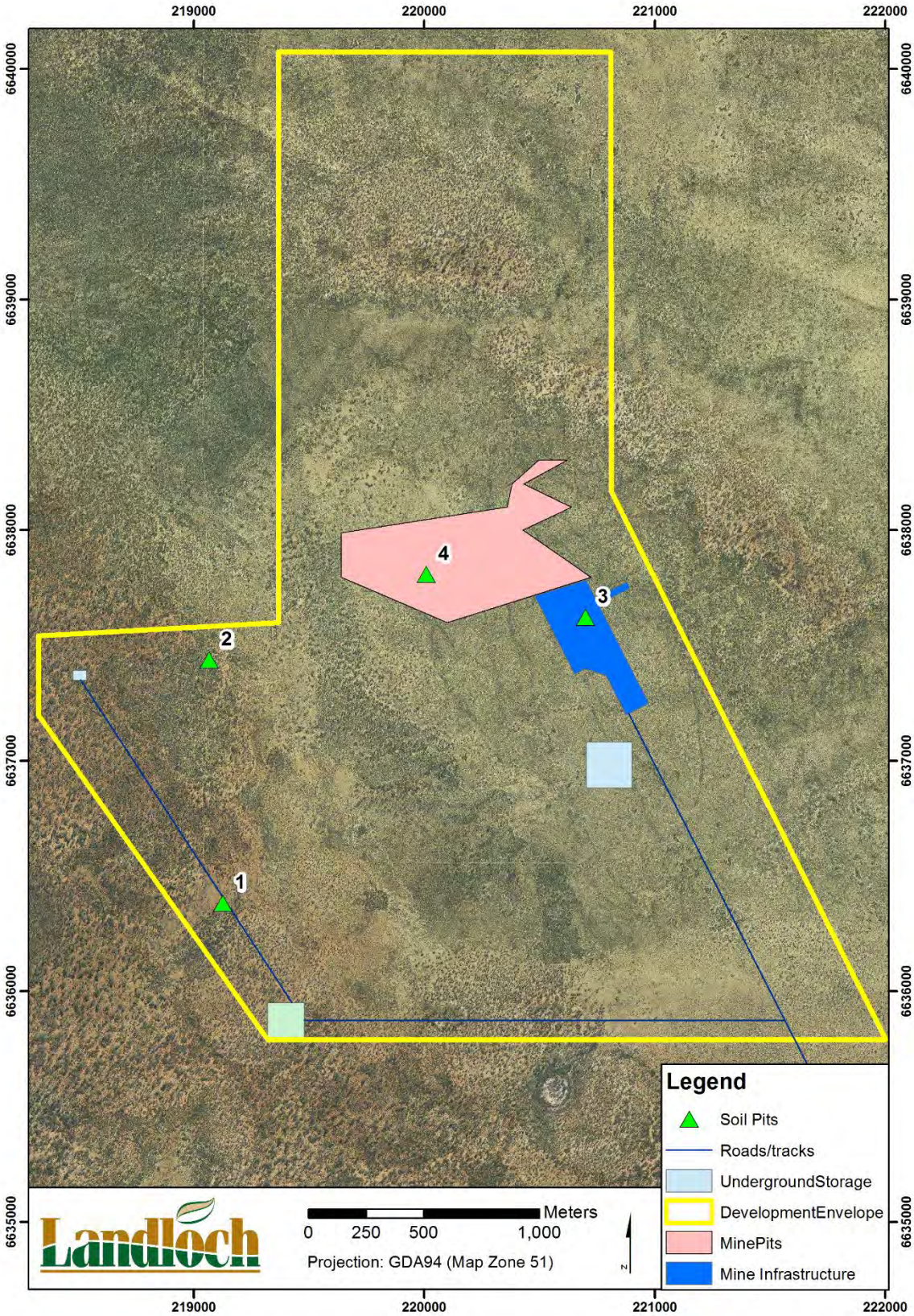


Figure 3: Soil pit locations in relation to proposed infrastructure at the Sandy Ridge Project.

Surface soils were assessed for the following properties:

- Soil $pH_{1:5}$;
- Electrical Conductivity ($EC_{1:5}$);
- Particle size distribution (gravel, sand, silt, clay);
- Total N;
- Total P;
- Available (Colwell) P and K;
- Available Sulphur (KCl);
- Exchangeable cations (Ca^{2+}, Mg^{2+}, Na^{+}, K^{+} and Al^{3+});
- Effective Cation Exchange Capacity;
- Available trace elements (Cu, Zn, Mn, and Fe);
- Organic Carbon; and
- Emerson class number.

The subsoils were assessed for the following properties:

- Soil $pH_{1:5}$;
- Electrical Conductivity ($EC_{1:5}$);
- Particle size distribution (gravel, sand, silt, clay);
- Exchangeable cations (Ca^{2+}, Mg^{2+}, Na^{+}, K^{+} and Al^{3+}); and
- Effective Cation Exchange Capacity.

Test details are contained in Appendix A.

3 RESULTS

3.1 Soils of the Sandy Ridge Project

A combination of geology and geomorphology exert the main controls over the site's soils. The main soil type is a Deep Yellow Sand that is associated with the higher relief areas in the north east of the development envelope and the greater exploration tenement (Figure 4). The Deep Yellow Sands are most likely the result of recent aeolian and alluvial movement of eroded sand from the weathered granites of the area that form a very low dune system. The Red Sandy Duplexes are much shallower soils in the south western section of the development envelope. They are red in colour and are only around 0.3m deep over a tightly packed laterite ferricrete that is pale in colour. The areas associated with the Red Sandy Duplexes are lower in the landscape and it is speculated that these are areas of broad through-going drainage and consequently are areas of net erosion.

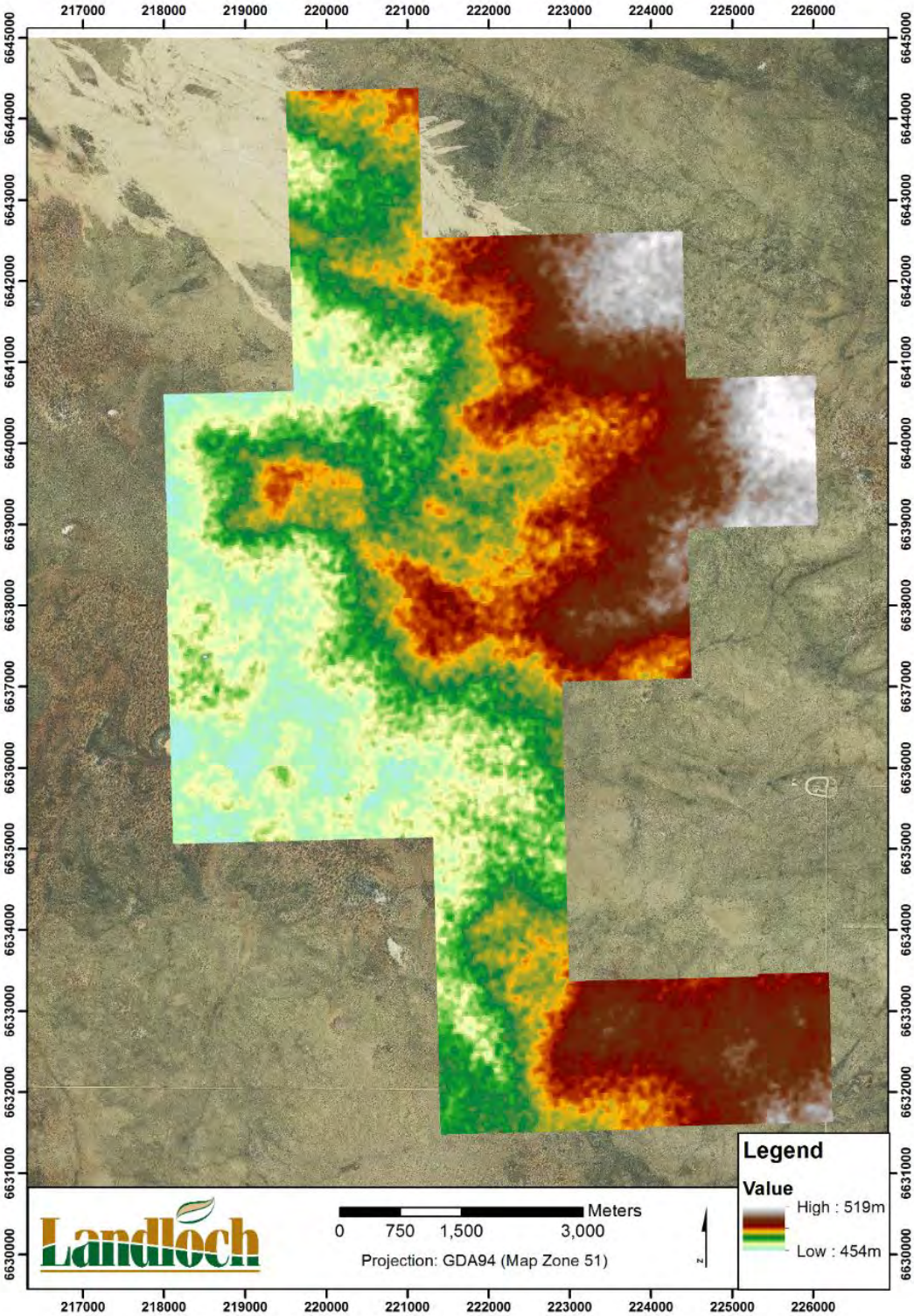


Figure 4: Elevation of the Sandy Ridge Mine exploration area.

Vegetation communities associated with the soil types also differed. The Red Sandy Duplexes supported a multi-storied plant community with gum trees, acacias, and ground cover species (Figure 5A). The Deep Yellow Sands on the other hand supported mainly low scrub with scattered mulga that appeared dead due to fire damage (Figure 5B).

A B

Figure 5: A) Vegetation communities on the Red Sandy Duplexes, and B) vegetation associated with the Deep Yellow Sands.

The demarcation of the two soil types was defined by the soil pits, vegetation mapping, and also supported by the Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) ferrous iron index as shown in Figure 6. The higher index values (i.e., brighter colours) correspond to the lower lying drainage areas, indicating that in this area where there is a lower level of sandy aeolian material over the laterite regolith. The Sandy Ridge soils are shown in Figure 7, with the soils in the exploration tenement (denoted by EXP) mapped at a lower confidence level than the soils within the development envelope (DEV).

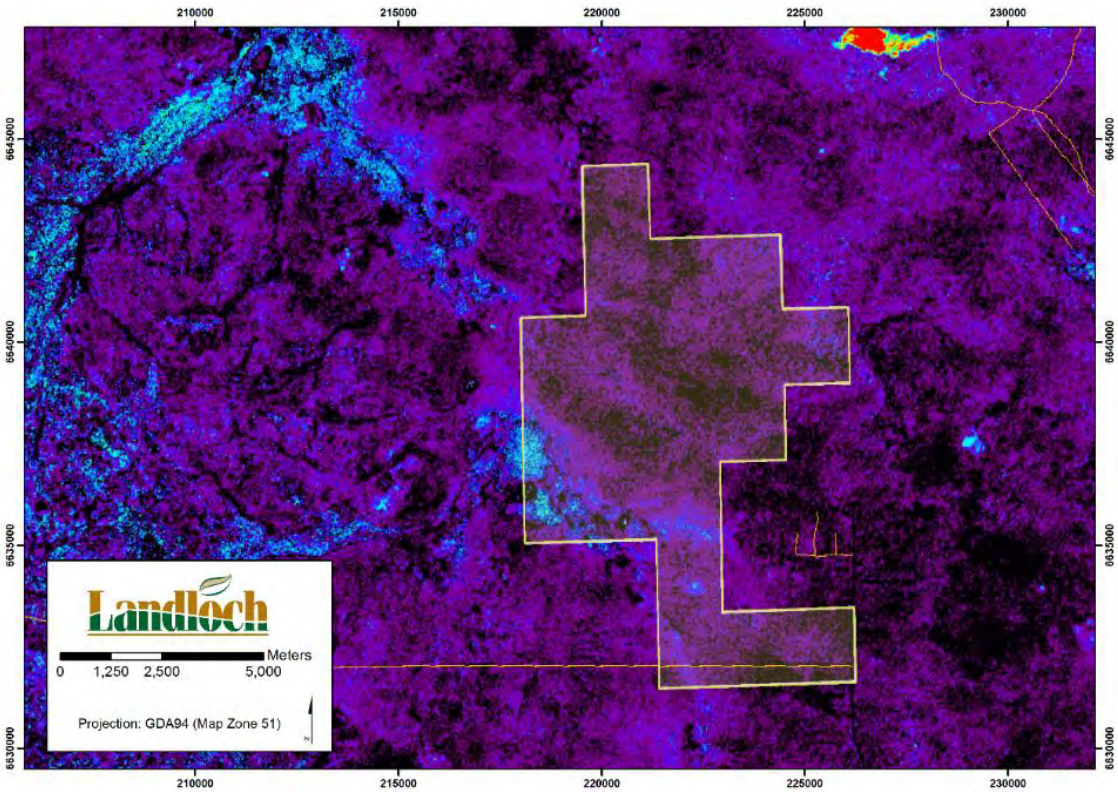


Figure 6: ASTER ferrous iron index for the Sandy Ridge Site (ASTER 2015).

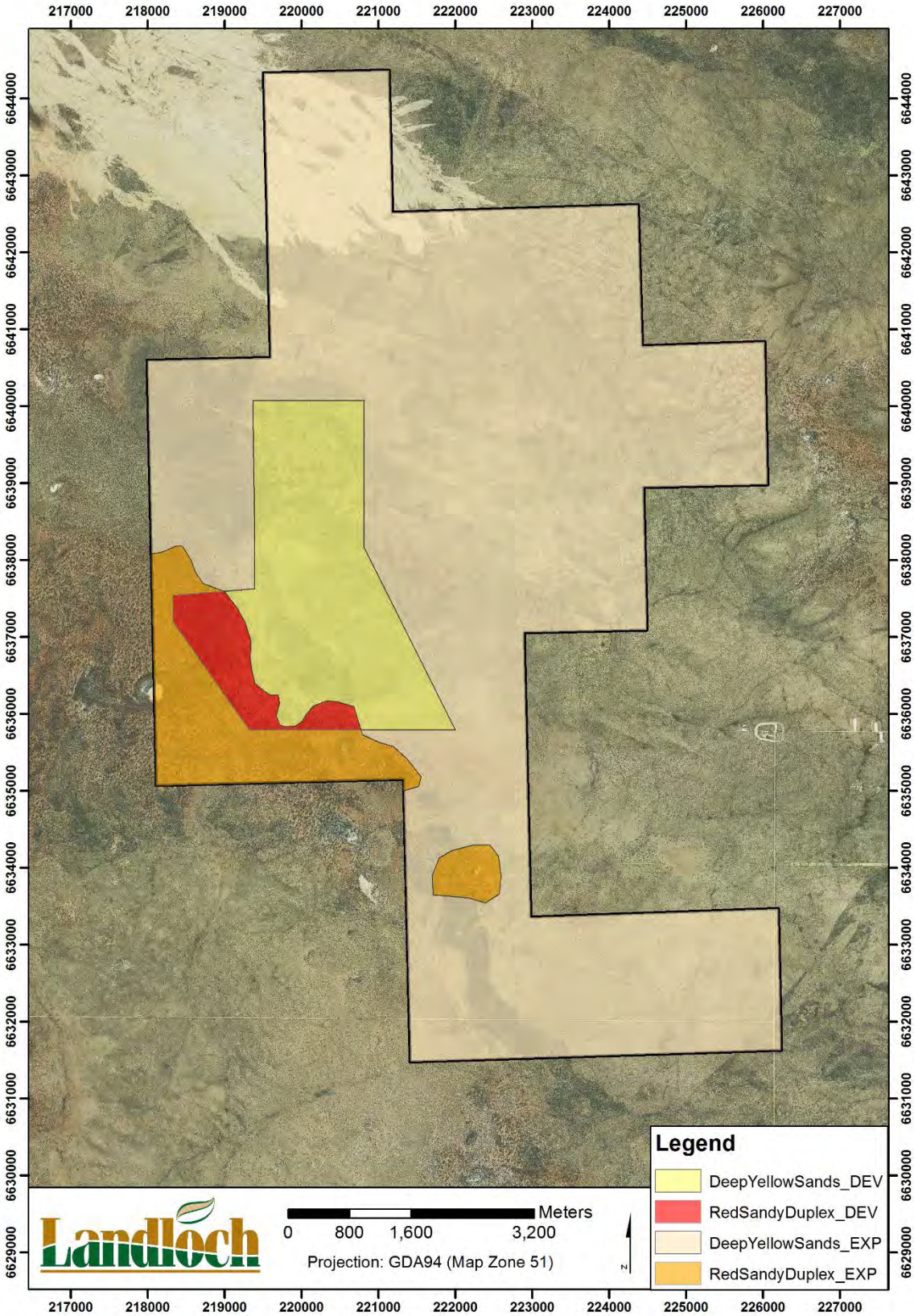


Figure 7: Map of the soil types found at the Sandy Ridge Project. Note that soils in the exploration tenement (EXP) are inferred and have a lower confidence level than the soils mapped in the development envelope (DEV).

3.1.1 Red sandy duplex soils

The Red Sandy Duplex soil is associated with the lower lying sections of the site. Although they are gently sloping areas, they appear to be areas of net soil loss and consequently the soil profile overlying the laterite is shallow (0.2-0.3m). Figure 8 is an example of the maximum depth to which the excavator could dig.

Figure 8: Shallow depth of refusal of an excavated soil pit in the Red Sandy Duplex soil.

The Red Sandy Duplex soil can be divided into an A and B horizon that overlie the hardpan layer. The A_1 horizon has a thickness of ~5cm, A_2 horizon has a thickness of ~15cm, and the B_2 horizon was deeper than 20cm. The surface (A_1) horizon has a visibly platy massive structure indicating an alluvial influence. The subsurface (A_2) horizon was slightly lighter in colour and had a larger sub-rounded massive structure (Figure 9). In both cases, the massive structure is weak, and breaks down when disturbed. The subsurface (B_2) horizon was tightly packed and displayed a smaller crumb structure. Figure 8 shows a section of the excavated pit with sections of the white hardpan showing through. This was initially thought to be a calcrete layer in the field, but the white rocky material did not fizz when subjected to hydrochloric acid and hence is not calcareous (Table 2).

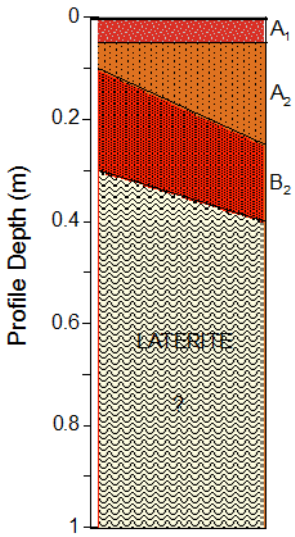
Figure 9: Red Sandy Duplex soil showing a massive platy surface structure and white laterite hardpan layer.

Although there is a similar appearance between the A and B horizons, they differ in texture and pH. Broadly, the Red Sandy Duplex soils are reddish brown sands with a neutral pH over alkaline sandy clay loam B horizons. The soil is massively but weakly structured. The soil has very low salinity levels ($EC_{1:5}$<0.17dS/m) but does have an exchangeable sodium percent (ESP) of 7.6% in the clay B horizon. The surface stone mantle consists of infrequent gravel to rock-sized particles of varying abundance of what appears to be the underlying ferricrete hardpan material (Figure 10).

Figure 10: Red Sandy Duplex soil surface coarse fragments.

Table 2: Characteristics of the Red Sandy Duplex soils.

Property	Inspection Site Description
Brief description	Shallow dark red/brown sand over sandy clay loam
Extent	146ha (Development), 419.2ha (Exploration)
Soil samples	Pit 1, Pit 2
Gradient	Gently undulating
Soil Landscape	Norseman
Soil classification	Petroferric Kandosol
Surface coarse fragments	0–20% abundance, sub-angular pebbles to small rocks
Surface condition	Soft to moderate
*Permeability**	Moderate (surface), slow (subsurface)
*Water repellent**	No
*Drainage**	Sheet wash and low relief drainage lines
Soil depth (cm)	**Soil Profile Description**
0–5	A_1 Dark red-brown (2.5YR-2.5/4), weakly structured, sand, <5% coarse pebble fragments, pH 7 (field)
5-20	A_2 Dark red (2.5YR-3/6), weakly structured, loamy sand, <2% coarse pebble fragments, pH 7 (field)
20-30	A_2 Dark red (10R-3/6), weakly structured, sandy clay loam, <2% coarse pebble fragments, pH 8 (field)
>30	Very hard pale laterite/ferricrete of unknown depth



* Glossary of terms contained in Appendix B.

3.1.2 Deep yellow sands

The Deep Yellow Sands are associated with the higher elevation areas of low sandy dune systems of the site. The soil depth was greater than 1.5m and easy excavation was only stopped due to the HS&E requirements of the soil pit dimensions. There is only minor variation throughout the profile in terms of colour, texture, and pH (Figure 11), but for the purposes of this report the subsurface layer has been termed a B horizon on the basis of containing slightly higher clay and lower organic matter content than the A horizon (Table 3).

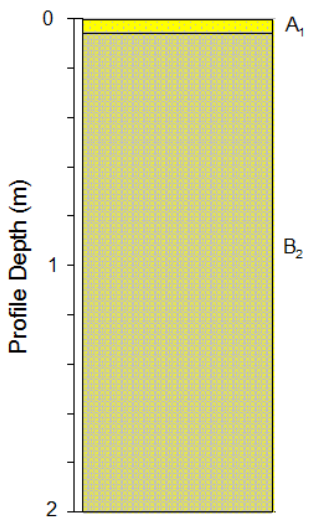
Figure 11: Deep Yellow Sand soil pit showing little change in characteristics with depth.

The Deep Yellow Sands have strongly acid pH throughout their profile. There is little pedological development with soil depth and the greatest influence appears to be where deposition/erosion has occurred. The textures are sands at the surface 5cm and loamy sand throughout the lower profile. The soils have very low salinity levels ($EC_{1:5}$ 0.02-0.03dS/m) and there are few surface coarse fragments (Figure 12). The material appears to be free draining, which is probably a major factor in the differences in vegetation between this soil type and the Red Sandy Duplexes. As water availability is often the main limiting factor in vegetation growth in the arid regions, the low permeability of the Red Sandy Duplex hardpan and lower landscape position would account for the greater density and variety of vegetation associated with this soil type.

Figure 12: Deep Yellow Sand surface coarse fragments.

Table 3: Characteristics of the Deep Yellow Sands.

Property	Inspection Site Description
Brief description	Deep yellow acidic sand
Extent	726.6ha (Development), 4,641.6ha (Exploration)
Soil samples	Pit 3, Pit 4
Gradients	Flat to gently undulating
Soil Landscape	Norseman
Soil classification	Yellow Orthic Tenosol
Surface coarse fragments	<2%
Surface condition	Soft
Permeability	Moderate to high
Water repellent	No
Drainage	Surface sheet
Soil depth (cm)	**Soil Profile Description**
0–5	A_1 yellow red (7.5YR-6/6), massive, sand, few coarse fragments, pH ~4.5 (field)
>15	B_2 Dark red (7.5YR-7/6), massive, loamy sand, few coarse fragments, pH ~4.5 (field)



3.2 Laboratory analysis

3.2.1 Soil analysis results

Laboratory results are shown in Table 4, and are interpreted against industry standards using references such as *Interpreting Soil Test Results* (Hazelton and Murphy, 2011), and against Landloch's database of soil characterisation data. For soil chemistry, much of the descriptive criteria within industry standards was developed for the agricultural industry, which focuses on exotic crops that have very specific chemical and nutrient requirements. So when soil fertility results are described as 'very low,' it is important to note that the native vegetation in the Sandy Ridge Project Area have adapted to low nutrient status conditions. For reference, an agricultural guide has been included in Appendix C.

It should also be noted that results listed in Table 4 are for soils from a selection of soil pits. It is therefore prudent to consider the results as an indication of the nature of the site's undisturbed soils. Although adequate at the proposal stage, further testing will be required if the project is approved to gain a more detailed understanding of the soils for long term storage and use to rehabilitate mine infrastructure at closure.

Table 4: Chemical and physical soil test results for the Sandy Ridge Project.

Analyses		Unit	Sample ID					
			Red Sandy Duplexes			*Deep Yellow Sands*		
			Pit 2-1	*Pit 2-2*	*Pit 2-3*	*Pit 4-1*	*Pit 4-2*	*Pit 4-3*
			5cm	*20cm*	*30cm*	*5cm*	*20cm*	*50cm*
$pH_{1:5}$		*pH units*	7.00	7.06	8.89	4.92	4.37	4.21
Electrical Conductivity ($EC_{1:5}$)		*dS/m*	0.02	0.02	0.17	0.03	0.02	0.02
Total Nitrogen		*mg/kg*	205	104	249	232	206	470
Total Phosphorus		*mg/kg*	<75	<75	<75	<75	<75	<75
Organic Carbon		*%*	0.47	0.20	0.28	0.73	0.41	0.17
Plant Available Nutrients	*Phosphorus - Colwell*	mg/kg	13.8	5.4	5.1	5.9	3.6	3.5
	Potassium - Colwell	mg/kg	218	28.2	208	44.3	22.6	46.7
	Sulphur - KCl	mg/kg	4.1	3.8	8.3	8.5	11.8	26.0
	Copper – DTPA	mg/kg	0.34	*	*	0.32	*	*
	Iron – DTPA	mg/kg	7.3	*	*	25.1	*	*
	Manganese – DTPA	mg/kg	2.3	*	*	0.9	*	*
	Zinc – DTPA	mg/kg	0.2	*	*	0.2	*	*
Exchangeable Cations	*Calcium*	meq/100g	2.49	2.18	9.52	0.92	0.62	0.51
	Magnesium	meq/100g	0.46	0.71	3.38	0.25	0.15	0.13
	Potassium	meq/100g	0.33	0.36	1.75	0.31	0.34	0.26
	Sodium	meq/100g	0.14	0.10	1.20	0.14	0.13	0.09
	Aluminium	meq/100g	0.04	0.01	0.02	0.06	0.36	0.37
	Effective Cation Exchange Capacity	meq/100g	3.5	3.4	15.9	1.7	1.6	1.4
	Exchangeable Sodium Percentage	%	4.1	2.9	7.6	8.4	7.9	6.4
Particle Size Distribution of Fine Fraction	*Coarse Sand 0.2-2.0mm*	%	70.4	67.3	49.2	70.3	68.9	57.7
	Fine Sand 0.02-0.2mm	%	26.5	29.6	29.1	23.8	22.5	33.8
	Silt 0.002-0.02mm	%	0.4	0.4	0.4	2.2	0.4	2.2
	Clay <0.002mm	%	2.7	2.7	21.3	3.6	8.2	6.3
Dispersion Index		*Class*	3	3	2	7	6	6

NB: $EC_{1:5}$: Electrical conductivity as measured in a 1:5 soil water solution
$pH_{1:5}$: Soil pH as measured in a 1:5 soil water solution
Exchangeable cations expressed as a ratio of the cation concentration and the ECEC.

ECEC: Effective Cation Exchange Capacity
Clay <0.002 mm, Silt 0.002–0.02 mm, Fine sand 0.02–0.2 mm, Coarse sand 0.2–-2.0 mm, Gravel >2.0 mm
* Below detection limit

4 DISCUSSION

4.1 Soil chemistry results

4.1.1 Material $pH_{1:5}$ and salinity ($EC_{1:5}$)

The materials' pH and electrical conductivity (EC) were measured using a 1 part soil to 5 parts deionised water solution. The pH of the Red Sandy Duplex soils was neutral at the surface and alkaline (8.9) at depth, while the Deep Yellow Sands are strongly acid (4.2-4.9).

Acid soils can inhibit plant growth due to aluminium toxicity, and the threshold at which aluminium is mobilised and becomes increasingly toxic to vegetation is considered to be <5.0. The highest exchangeable Al result (33.6%) for the Deep Yellow Sand subsoil (Pit 4-3) expressed as a percent of the effective cation exchange capacity (ECEC), indicates that aluminium may be mobile in these soils. Therefore, sandy subsoils should be managed with some caution.

Both soil types have very low salinity levels $EC_{1:5}$ values (<0.17dS/m), most likely due to free salt having been washed through the sandy profile in the Deep Yellow Sands and the location of the Red Sandy Duplex soils in low relief drainage areas. The EC results are not be expected to inhibit native vegetation growth.

4.1.2 Effective cation exchange capacity and exchangeable cations

The ECEC is a measure of a materials' ability to adsorb and hold cations, and can be used in conjunction with clay content to indicate clay mineralogy[1]. The ECEC values measured for the Red Sandy Duplex soils was <3.5meq/100g in the A horizon and 15.9meq/100g for the B horizon where clay content was 21.3%. When considered in conjunction with clay content, the ECEC values indicate that the dominant clay type will be a 1:1 class (such as kaolin), typical of highly weathered soils. Kaolinitic soils tend to have low nutrient status and are not reactive (shrink and swell when wet). The Deep Yellow Sand had a very low ECEC of only <1.7meq/100g consistent with low clay content and low organic matter.

4.1.3 Exchangeable sodium percentage and structural stability

The exchangeable sodium percentage (ESP) value of a material is an indicator of clay dispersion potential. Materials with an appreciable dispersive clay fraction tend to be prone to tunnel erosion, hardsetting, and are prone to high levels of runoff and surface erosion.

The typical threshold value for soils of concern is an ESP >6%. However, whether or not a material will actually disperse is a function of complex interactions between exchangeable cation concentrations, salinity, and clay content. The Red Sandy Duplex soil had an ESP values above this threshold in the B horizon, low salinity, and a moderate clay contents (~20-27%), meaning that dispersion risk for this soil is significant. The ESP of the Deep Yellow Sand is greater than 6%, but the low clay content would indicate that the risk of clay dispersion is low.

[1] All samples were washed of dissolved salts prior to testing for exchangeable cations and ECEC.

4.1.4 Emerson test

The Emerson dispersion test is a simple method to determine the behaviour of soil aggregates when rapidly wet by water. It is an indicator of clay dispersion potential. Class 1 is highly dispersive and Class 8 is highly aggregated in water (Figure 13). A classification range for the Red Sandy Duplex soils that includes values of 2 and 3 indicates that there is a risk of dispersion, especially in the B horizon with a higher clay content. The Deep Yellow Sands had Emerson test results of 5 to 7, indicating that the dispersion risk is low.

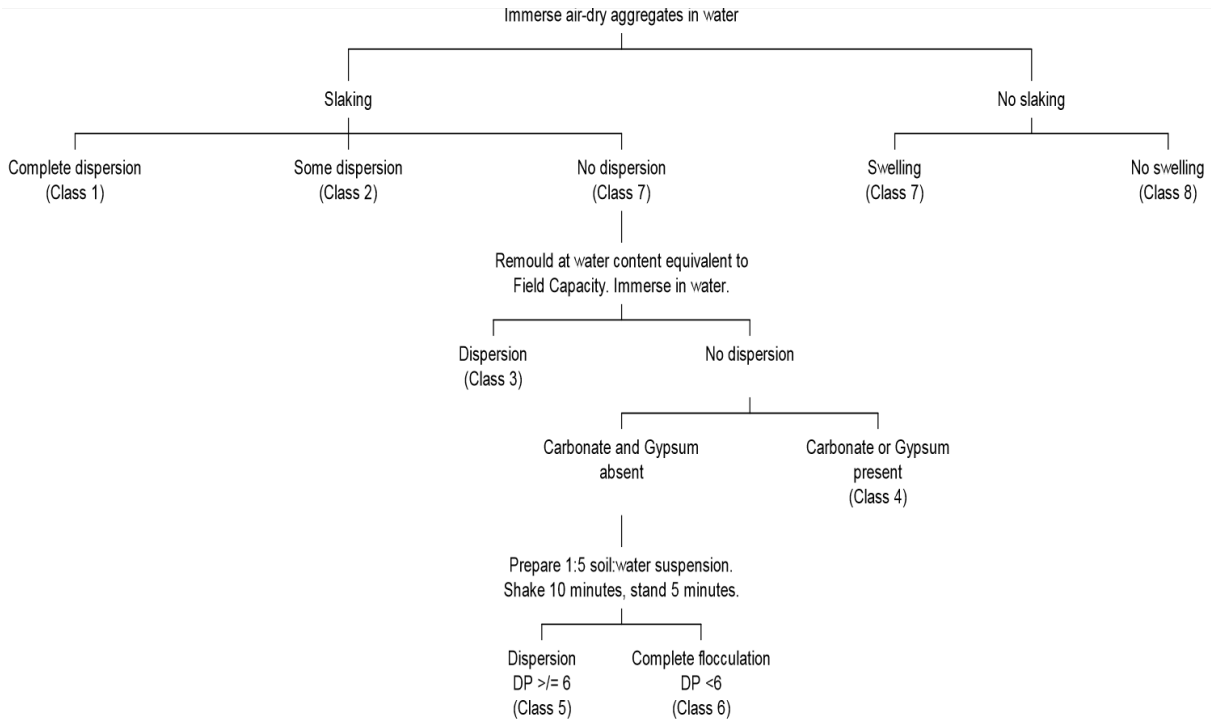


Figure 13: The Emerson classification system of soil based on its dispersion in water (Australian Standards 1997).

4.1.5 Fertility

The arid zone soils of the Western Region are characterised by their low fertility (Bettenay 1983). This reflects their deep weathering, strong leaching, overgrazing, low rainfall and little input of organic material.

All the soils assessed in this report had very low nutrient status for total N, total P, plant-available P, plant available K, and organic C (Table 4). The exception was the surface soil sample for the Red Sandy Duplex; the plant available P for this soil was low.

For the arid Goldfields region, these macro and micro nutrient results are typical. Only species that are adapted to this low nutrient environment should be re-established to ensure long term self-sustainability.

Much of arid zone soil fertility is stored in the biomass, thus disturbance of these soils by vegetation clearing and stripping is likely to reduce the nutrient status of the soils (to even lower levels) and as such, irrespective of their inherent low fertility, it is likely that application of

amendments will be required during rehabilitation activities to increase the likelihood of successful of vegetation establishment.

4.1.6 Summary of soil properties

From the analysis results and observations of the different soil types in the field, it can be broadly stated that:

- Both soils within the development envelope have low fertility (which is normal for an arid zone soil) and are poorly structured and would present an erosion risk if used on the sloping constructed surfaces of features such as waste dumps or the batters of mining voids,
- The main limiting soil factor for the Red Sandy Duplex will be the elevated ESP in the subsoil,
- The main limiting factors for the Deep Yellow Sand will be the potential acidity and aluminium toxicity (especially the subsoils),
- The Red Sandy Duplex subsoils will require amendment of their dispersion potential in order for them to be used in rehabilitation,
- The Deep Yellow Sands subsoils (>20-30cm), and soils recovered from this soil layer may require amendment with lime prior to use at the surface in rehabilitation.

As these conclusions are based on a limited number of samples, continual monitoring of the stockpiled soil's physical and chemical properties is advised during the construction and operation phase.

5 SOIL MANAGEMENT

5.1 Available soil resource

5.1.1 Soil extent and volumes

Ideally topsoils should be stripped to a depth of 10cm so as to selectively harvest the soil containing the highest amounts of seed, biological activity, and fertility. However, for the purposes of calculating the recoverable volumes of soil material, the stripping depth is assumed to be 30cm, allowing for 10cm of topsoil and 20cm of subsoils to be recovered. The estimation of recoverable soil materials is made with the following assumptions:

- Topsoil and subsoil will be stripped from all locations where land disturbance will occur; and
- A planar surface was used to calculate the soil type areal extents.

The disturbance types and areas were provided by Aurora Environmental (Table 5), and the soil map (Figure 6) was used to partition the disturbance area by soil type. The mining pit and infrastructure will disturb the Deep Yellow Sands, while the accommodation camp and Class II waste storage facility will disturb the Red Sandy Duplex soils. GIS software was used to calculate the disturbance area of the roads and tracks to the two soil types. Road corridor disturbance width is assumed to be 20m, and the extent is from the Mt Dimer access road turn off to the Class II waste facility and the entrance to the mining infrastructure area.

Table 5: Disturbance areas by soil type for the Sandy Ridge project.

Disturbance Type	Area (ha)	
	Deep Yellow Sands	Red Sandy Duplex
Mine Pit and waste disposal	37.2ha	
Mine infrastructure	11.8ha	
Accommodation camp		2.5ha
Class II waste facility		0.26ha
Underground storage area	4ha	
Roads and tracks (av. 20m wide)	12.8ha	5.5ha
TOTALS	65.8ha	8.26ha

Therefore the soil extents within the disturbance area are:

- Red Sandy Duplex – 8.26ha
- Deep Yellow Sand – 65.8ha

The Sandy Ridge Project recoverable topsoil volumes based on a strip depth of 10cm are:

- 8,260m^3 of Red Sandy Duplex
- 65,800m^3 of Deep Yellow Sand

The Sandy Ridge Project recoverable subsoil volumes based on a strip depth of 20cm are:

- 16,520m^3 of Red Sandy Duplex
- 131,600m^3 of Deep Yellow Sand

5.1.2 Identification of soil useful for rehabilitation

Both soil types are poorly structured and have a high percentage of sand. This means that they will be susceptible to erosion, and may not be stable if placed on sloping land surfaces. The usefulness of the soils for rehabilitation will depend on how they are managed during the life of the operation, including their use as part of a final landform design.

Landloch would encourage the further stripping of a third depth increment of the Deep Yellow Sand from the 50-150cm depth profile. The properties of this material did not vary greatly with depth and this third depth increment could be used as a layer to place on top of backfilled pit waste before the placement of the subsoil and soils during rehabilitation.

Landloch would also encourage the stripping of the hard laterite layer below the 30cm depth from the Red Sandy Duplex soils. It appears that there will not be any significant volumes of competent rock generated during the mining process, and so this will be a scarce resource on site and could be used in targeted areas of high erosion risk. Although the laterite is not ideal, it did appear to be somewhat resistant to weathering when on the soil surface (Figure 9). While the laterite could potentially be a useful resource for rehabilitation from an erosion point of view, it would require further assessment as a plant growth medium.

Any tree or scrub debris pushed over before soil stripping should also be preserved. Landloch has used these materials previously to design an erosionally resistant surface for very sandy materials. When correctly used, it not only prevents surface water concentration, but also reduces wind erosion and provides organic material, seed trapping areas, and fauna habitat.

5.2 Soil handling

Ideally, stripping and stockpiling of soils should be avoided where possible, and if stripped, soils should be directly respread to areas prepared for rehabilitation rather than stockpiled. This is because stockpiling of soils can lead to compaction, nutrient depletion, and loss of seed stock and soil microfauna. However, direct respreading is not always achievable, and stockpiles are often constructed as part of mining operations. If soil stripping and stockpiling are to be conducted, the following principles should be applied.

5.2.1 Soil stripping

Topsoil stripping to the recommended depth of 30cm should be performed at a time of year when the soil seed bank is highest. This is likely to be just after the wetter months. However, soil should not be handled when wet, as this tends to increase compaction. Care also needs to be taken to avoid stripping soils when weed infestation is high.

Inevitably, some degradation of soils will occur during stripping and other soil handling activities, with different types of machinery causing different levels of soil degradation. The use of scrapers for soil stripping is not recommended. The *Mine Rehabilitation* handbook, that forms part of a series produced by the *Leading Practice Sustainable Development Program for the Mining Industry* (DITR 2006) confirms this recommendation by stating that, *"…combined use of a front-end loader, truck and bulldozer for the removal, transport, and spreading of topsoil is the best combination to reduce compaction".*

5.2.2 Soil stockpiling

Stockpiling soils can cause structural degradation (particularly of the soil at the bottom of the stockpile) and loss of soil biota (DITR 2006). Compaction caused by stockpiling may be largely removed by soil respreading during rehabilitation works (particularly for sandy soils), but the soil biota cannot be replaced without intervention.

Some studies have suggested that much of the loss of soil organic carbon occurs during stripping and stockpile construction (Visser *et al* 1984), and this is particularly likely in sandy soils in arid zones for which rates of organic matter loss can be relatively rapid. For example, Dalal and Mayer (1986) found that the half-life of organic carbon in the surface layer of a tilled sandy loam was only 0.6 year, whereas organic carbon in clay soils was found to have a half-life of up to 12 years.

It is commonly recommended that topsoil stockpiles should be no deeper than 1.0m (DME 1996), though information providing a basis for that recommendation is limited[2]. It is generally considered that stockpiling topsoils deeper than 1.0m tends to kill the topsoil seed bank and, to

[2] Interactions between soil texture, environment (particularly rainfall) and vegetation type have yet to be addressed in a logical framework.

a lesser extent, degrade the structure of the soil at the bottom of the stockpile (Keipert *et al* 2002). This would largely negate the properties of topsoil that are advantageous to rehabilitation activities. However, at a mine site close to Laverton, WA where rainfall is relatively low, the soil moisture content of the stockpiles was consistently low and seed reserves within the stockpile were not encouraged to germinate. The dry conditions within deeper stockpiles therefore enabled the preservation of the seed bank until it was respread. It has also been shown that stockpiles with a height of 2.0m had greater seed survival than 4.0m deep stockpiles (S. Lowe *pers. comm.*).

However, deeper soil stockpiles may potentially decrease the already low soil nutrients and soil microbial populations by creating anaerobic conditions at depth (Abdul-Kareem and McRae 1984). Therefore, where topsoil is stockpiled to greater depths, additional seed and fertiliser may be required to counter the reduction in soil seed bank and soil microbial propagules caused by stockpiling.

If soils are to be stockpiled for longer than 12 months, they should be actively fertilised and seeded to:

- reduce erosion risk;
- maintain and accumulate soil organic matter levels; and
- increase soil seed banks.

Fertiliser application rates for stockpiles should be determined based on the results of field trials. The species seeded should be fast growing, and ideally leguminous to provide some nitrogen input to the soil, though care should be taken to avoid introducing weeds, and to avoid undue distortion of the natural diversity and abundance of species present in the soil seed bank. The low fertility of the available soils however may limit species selection to the locally adapted communities.

For best preservation of the soil seed bank and biota, the topsoil stockpiles should be flat-topped or slightly domed. Slight doming of the topsoil reduces the risk of waterlogging, though this is unlikely to be a significant issue at this site. Encouraging water entry will make more water available to plants and minimise the risk of erosion and sediment movement from the stockpile.

Subsoils are generally sandy and do not contain seed, and respreading is likely to remove any compaction caused by stockpiling. The Deep Yellow Sands in particular could be stockpiled to greater depths; up to 4.0m. Indications are that the Red Sandy Duplex subsoils have a high clay content and consequently stockpiling should be managed the same way as topsoils.

Stockpiling subsoil to greater depth also provides clear delineation between subsoil and topsoil stockpiles, reducing the risk that topsoils and subsoils will be mixed. As for topsoil stockpiles, subsoil stockpiles should be built to maximise water entry.

All soil stockpiles should be monitored for erosion (wind and water) and weed infestations. Control of weeds in stockpiled soil is likely to be more cost effective than controlling infestations once the soil is respread. Weeds can be controlled by planting species that will outcompete the weeds, or by spraying herbicides.

5.2.3 Soil respreading

Once the soil has been respread and directly prior to seeding, the final topsoil surface will require light ripping to break any surface crusting. Landloch has observed surface sealing greatly impacting on germination rates, and a site-specific seeding strategy should be developed based on the specific rehabilitation material.

5.2.4 Soil amendments

The nutrient status of the soils is very low and the native vegetation is adapted to grow in this environment. However from a rehabilitation perspective, it is recommended to replace or supplement the nutrients lost through disturbance to encourage rapid establishment of vegetation.

The precise nature of these nutrient additions will in part be determined by the success of the soil stockpiling strategies outlined above. If done successfully, the topsoil can be spread containing a seed bank of target species and adequate nutritional levels to ensure good germination and growth. Soil stockpile monitoring (soil characterisation) before spreading should be undertaken to determine the nutrient status of the material. Levels should be at least comparable to those found in undisturbed soils.

Application of fertiliser to the topsoil is recommended based on the predicted low nutrient status of the bare soils in the stockpiles and the loss of nutrients caused by the removal of vegetation and disturbance of the soil. Likely fertiliser requirements are not high, and rates and types should be based on soils data for stockpiled materials.

It should be noted that the application of an immobile element such as P (as is likely to be needed) to the surface of soils that are high in iron oxide may not be successful, as the P is likely to be immobilised in the shallow surface layer and would therefore seldom be accessible to plant roots. Therefore, incorporation of fertiliser into the soil profile rather than simply applying it to the surface is strongly recommended.

The results have indicated that there may be a dispersion risk with the Red Sandy Duplex soils, particularly the clay subsoils. For this reason it would be recommended that gypsum should be added to stabilise the Red Sandy Duplex subsoils. Indicative rates would be approximately 2-5t/ha and is calculated assuming it is incorporated into a soil depth of 30cm. Amendment of the Deep Yellow Sands and the Red Sandy Duplex topsoils is not required.

A potential amendment programme could target the following:

- reducing the dispersion risk of the Red Sandy Duplex subsoils,
- increasing the pH of the Deep Yellow Sands, and
- increasing the fertility of both soil types.

Such a programme could be implemented by following these steps:

- conduct soil sampling to assess the variability and chemical nature of the surface soils,
- design a soil amendment programme based on the soil test results,
- strip surface vegetation from the disturbance areas,
- apply soil amendments to the de-vegetated areas, and
- strip the soil materials, thus mixing the soil amendments into the soil to be stockpiled.

5.2.5 Soil monitoring protocols

If topsoil is to be stockpiled, it will require monitoring for changes in its physical and chemical condition. Monitoring should occur at a minimum of every 12 months and should record:

- Surface condition and erosion;
- Nutrient status, pH, and EC; and
- Seed germination rates.

The monitoring protocols should form part of the site-wide rehabilitation monitoring strategy so that if monitoring shows deterioration of the topsoil resource, this will trigger actions to address the issues.

5.2.6 Tree debris

Tree debris is often overlooked in soil assessments but can be an important resource for mine site rehabilitation. There are significant amounts of trees, shrubs, brush, and grasses across the site that could be recovered (Figure 4). The surface vegetation should be stripped separately from the topsoil, and also stored separately. The tree debris (trunk diameters greater than ~10cm) can then be used as erosion protection for stockpiled soil material, and the trees, shrubs, brushes, and grasses, will add seed, nutrients, and organic carbon to the soil.

5.3 Implications for mine closure design

Successful rehabilitation outcomes require detailed and careful planning that typically not only reduces environmental risk, but also minimises the actual cost of rehabilitation activities. Unlike iron ore mining activities, there will not be large waste landforms to rehabilitate at the Sandy Ridge Project as the waste will be backfilled into the pit. However, mine planners must still design for an erosionally stable surface at closure, and Landloch has seen throughout WA's arid zone that sandy material is quite erodible even at low gradients. Surface water control will be key for erosional stability of the final land landform surface. Of particular importance will be the avoidance of landform designs that act to concentrate runoff. Also of importance will be the interface between the backfilled waste materials and the growth medium placed above it. The behaviour and character of the waste materials from mining operations will impact the design of the rehabilitated surface. It would be expected that the kaolin wastes would have a very low permeability and potentially hard setting. This could potentially create an impermeable layer beneath free draining sand material creating a subsurface drainage pattern and changing the hydrology of the area. Root penetration into this layer by taller woody species may also inhibit growth.

Soil management during operations and rehabilitation activities will also be important. It is possible, through poor management of soil and waste resources to cause rehabilitation failure where success was very achievable. This risk exists for Sandy Ridge in the stripping, storage, and placement of soils. Careful planning and management of the soil resource will ensure this goal is met in the most efficient and cost effective manner.

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APPENDIX A. ANALYSIS METHODS USED ON TOPSOILS AND SUBSOILS

Soil Analyses	Abbreviation	Units	Methodology	Reference
pH	pH	na	1:5 soil:water	Rayment & Lyons (2011)
Electrical Conductivity	EC	dS/m	1:5 soil:water	Rayment & Lyons (2011)
Exchangeable Cations	Ex (Ca^{2+}, Mg^{2+}, Na^{+}, K^{+}, Al^{3+})	meq/100 g	NH_4Cl	Rayment & Lyons (2011)
Dispersion Potential	NA	Value 1–8	Emerson Index	Australian Standard (1980)
Total Nitrogen	Total N	mg/kg	Kjeldahl	Rayment & Lyons (2011)
Total Phosphorous	Total P	mg/kg	Nitric/Perchloric	Rayment & Lyons (2011)
Available Phosphorous	Av P	mg/kg	Colwell	Rayment & Lyons (2011)
Available Potassium	Av K	mg/kg	Colwell	Rayment & Lyons (2011)
Available Sulfur	Av S	mg/kg	KCl-40	Rayment & Lyons (2011)
Organic Carbon	OC	%	Walkley–Black	Rayment & Lyons (2011)
Micro Nutrients	Cu^{2+}, Mn^{2+}, Zn^{2+}, Fe	mg/kg	Diethylamine triamine pentaacetic adic (DTPA)	Rayment & Lyons (2011)
Particle size distribution (% of clay, silt and sand)	PSD	%	Hydrometer	Rayment & Lyons (2011)
Phosphorous Buffer Index	PBI	na	PBI_{+ColP}	Rayment & Lyons (2011)
Effective Cation Exchange Capacity	*ECEC*	meq/100g	NH_4Cl	Rayment & Lyons (2011)
Exchangeable Sodium Percentage	*ESP*	%	NH_4Cl	Rayment & Lyons (2011)

Note: Not all tests were conducted on each sample. Subsoil samples were not subjected to fertility analyses.

APPENDIX B. GLOSSARY OF TERMS

Acidic	A soil property expressed by a pH that is less than 7.0 in soil/water suspension.
Active gully	Gully is actively eroding: walls, head and/or bed are unstable.
Aggregate	Unit of soil structure consisting of primary soil particles held together by cohesive forces or by secondary soil materials such as iron oxides, silica or organic matter. Aggregates may be natural, such as peds, or formed by tillage, such as crumbs and clods. See ped. Macro-aggregates are more than 250 µm in diameter and micro-aggregates are less than 250 µm.
Alluvial fan	Fan shaped deposit of alluvium (silt etc) at the mouth of a stream or gully where flows flatten out and sediment is able to fall out the flow.
Alluvium	Sediment (sand, clay, silt etc) deposited by flowing water.
Alkaline	A soil property expressed by a pH that exceeds 7.0 in soil/water suspension.
Ameliorant	A substance used to improve the chemical or physical properties of a soil. For example, gypsum to improve aggregate stability and soil structure, lime to increase pH levels.
Armouring	The accumulation of coarse (rocky) particles at the soil surface due to preferential removal of finer size fractions.
ASWAT test	'Aggregate stability in water' test – developed by Field *et al.* (1997) to assess the stability of a soil.
Biota	Soil biology – eg. earthworms, fungi and algae.
Bulk density (BD)	Ratio of the mass or weight of dry soil to its volume or bulk. Usually shown as grams per cubic centimetre. Is a measure of soil porosity and can be used to measure compaction. A high bulk density has a low porosity and is usually hardest and compacted.
Bund	An impervious embankment of earth that forms part or all of the perimeter or barrier to retain or exclude something such as water.
Cation exchange capacity (CEC)	Measure of the capacity of a soil to hold the major cations (i.e. the amount of exchange sites on negatively charged clay particles and organic matter in a soil). The major cations include calcium, magnesium, sodium, potassium and aluminium. It is also a measure of the potential fertility of the soil.

Compaction	The process whereby soil density is increased as a result of tillage, stock trampling or vehicular traffic. Compaction can lead to lower soil permeability and poorer soil aeration resulting in increased erosion hazard and poorer plant productivity. Deep ripping and conservation tillage can alleviate the condition.
Consolidation	Refers to increases in soil bulk density and cohesive strength that occur as a consequence of repeated wetting and drying under natural conditions.
Crust	See surface crust.
Degradation	Decreasing functionality and sustainability of a landscape.
Dispersive soil	Soils that are structurally unstable and disperse in water into basic particles (such as sand, silt and clay). Dispersive soils tend to be highly erodible and present problems for successfully managing earthworks.
Drainage	Refers to to the rapidity and extent of water removal from the soil profile or site. Drainage is distinct from *permeability* which refers to the rate at which water moves internally through a soil profile.
Electrical conductivity (1:5 soil:water) (EC_w)	A measure of the conduction of electricity through a soil water extract (1:5 soil:water). The value can reflect the amount of salt in a soil extract or the salinity of soil and water. Measured in DeciSeimens per metre (dS/m).
Emerson Aggregate Test	Also referred to as the slaking test – an aggregate or ped of soil is placed into distilled or rain water and assessed for slaking and dispersion characteristics. Describes the inherent stability of a soil.
Erodibility	Refers to the rate of detachment and/or movement of soil in response to some erosive force. The exact definition of erodibility varies from model to model, depending on the types of erosive forces considered. Equally, the units of erodibility may seem somewhat counter-intuitive, but are a function of the units used in calculating erosive forces. Some models, such as the Water Erosion Prediction Project (WEPP), use different erodibility factors for different erosion process.
Exchangeable cations	Cations that can be exchanged in the soil complex for or by other cations.
Exchangeable sodium percentage (ESP)	A measure of exchangeable sodium in relation to other exchangeable cations. Soils with a high ESP are typically unstable and, therefore, have high erodibility.
Gully erosion	Removal of soil in a narrow path by water erosion to considerable depths, typically deeper than 0.5 m.

Gypsum	A naturally occurring soft crystalline material, which is a hydrated form of calcium sulphate ($CaSO_4.H_2O$). Usually, gypsum contains approximately 23% calcium and 18% sulphate. It is used to amend soil structure and reduce crusting in hard setting clay soils. Gypsum also acts to replace exchangeable sodium attached to clay particles with exchangeable calcium, reducing clay dispersion and sodicity.
Hardsetting	Condition of a soil where the surface is dry, hard and compacted with no apparent pedal development. These soils are not disturbed or indented by pressure of the forefinger. These harder setting soils tend to result in high runoff.
Headwall	Vertical wall at the beginning/top of a gully.
Horizons	Horizons refer to the horizontal organisation of the soil profile. An individual horizon will have physical and chemical characteristics that differ from the one above or below it. The A horizon consists of one or more mineral horizons that have organic accumulations but lower clay content then the underlying horizon. The B horizon is a mineral layer that has a concentration of clay/Fe/Al, a structure differnet and stronger colours to the A horizon, and is the horizon of maximum pedological development. The C horizon is dominated by partially weathered rock and little pedological development. The R horizon consists of hard rock.
Hydraulic conductivity	The flow of water through soil per unit of energy gradient. For practical purposes, it may be taken as the steady-state percolation rate of a soil when infiltration and internal drainage are equal, measured as depth per unit.
Infiltration	The movement of water through the soil surface. Soils with a high infiltration capacity allow more rain to enter the soil than those with a low infiltration capacity. Runoff will occur when the rate of rainfall exceeds the soil's infiltration capacity. Surface soil structure and texture are important determinants of the infiltration capacity of a soil.
Interrill erosion	Describes the detachment and movement of particles by the combined action of raindrops and shallow overland flows. When a drop impacts the flow, the resulting turbulence ejects particles up into the flow, and the particles remain in the flow for a period of time, during which the particle travels some distance in the direction of flow. In the absence of raindrop impact, such shallow flows have little or no erosive capacity.
KPI	Key Performance Indicator.
Leaching	Removal in solution of soluble minerals and salts as water moves through the profile.

Macropores	Spaces/voids in soil fabric, generally <2 mm in diameter produced by soil biota, roots, coarse-grained particles, spaces/cracks in the soil structure.
Mass wasting	Mass wasting occurs when a block of soil collapses by soil topple/soil fall/circular slip.
Micro nutrients	An element/nutrient required by plants for growth but only in small/minute quantities.
Nutrient availability	A general expression which refers to the ease with which plants can absorb a particular nutrient from the soil – depending on factors such as solubility.
Ped	An individual, natural soil aggregate. See aggregate.
Permeability	The characteristic of a soil which governs the rate at which water moves through it. It depends on soil texture, soil structure, the presence of compacted or dense soil horizons and the size and distribution of pores in the soil.
pH_w	Measure of soil acidity and alkalinity in 1:5 soil:water on a scale of 0 (extremely acidic) to 14 (extremely alkaline). A pH of 7 is neutral.
Porosity	Degree of pore space in a soil i.e. the percentage of the total space between solid particles.
Remnant vegetation	Native vegetation remaining after widespread clearing has taken place.
Resources	Components that contribute to the functionality and production of a landscape such as water, soil, nutrients and seed.
Rill erodibility	The rate of detachment in a rill per unit of effective shear stress.
Rill erosion	An erosion process on sloping land; small channels of only several centimetres in depth are formed.
Runoff	That portion of precipitation or irrigation on an area that does not infiltrate, but instead is discharged from the area over the surface of the soil.
Salinity	A measure of the total soluble salts in a soil that can hinder plant growth.
Scour	Occurs where the shear (flow sliding/frictional forces) and wrenching forces (flow eddies – turbulent forces) imposed by the flow are greater than the resistant forces of the material of the channel bed.
Seedbed	Soil layer that affects and supports the germination and emergence of seeds.
Sheet erosion	Removal of the upper layers of soil by overland flow, often accelerated by raindrop splash.

Shear strength	The maximum strength of soil at which point significant plastic deformation or yielding occurs due to an applied shear stress. There is no definitive "shear strength" of a soil as it depends on a number of factors affecting the soil at any given time.
Slaking	Partial breakdown of soil aggregates in water due to the swelling of clay and the expulsion of air from pore spaces within the aggregate. These aggregates may subsequently disperse.
Sodic soil	Soil containing sufficient exchangeable sodium (commonly greater than six per cent) to adversely affect soil structure. Sodic soils tend to have poor drainage and have a tendency to disperse.
Sodium adsorption ratio (SAR)	Proportion of sodium cation (Na^+) held in the soil relative to that of calcium and magnesium.
Soil	Soil is a natural body consisting of layers (soil horizons) of mineral constituents of variable thicknesses, which differ from the parent materials in their morphological, physical, chemical, and mineralogical characteristics.
Soil instability	The tendency of soil to break down into smaller granules or individual particles in contact with water as a result of poor chemical or physical conditions or mechanical disturbance. These soils are prone to formation of surface seals, crusts, and erosion.
Soil organic matter	The organic fraction, plant and animal residues, of the soil. **Soil organic carbon** is the organic fraction of the soil exclusive of undecayed plant and animal residues.
Soil profile	Vertical section of the soil from the soil surface down through the layers of soil (eg. topsoil, subsoil) including the parent material.
Soil texture	Proportion of soil particles of different sizes – silt, clay and sand in a soil. It can also be influenced by the presence of organic matter and the clay type. The particle composition of a soil can dictate the behaviour and inherent characteristics of that soil.
Structure	Describes the way the soil particles are arranged to form soil peds. Peds are units of soil structure that are separated from each other by natural planes of weakness. They differ from clods which are formed as a result of soil disturbance such as ploughing.
Subsoil	Layer of soil underneath the topsoil, usually has higher clay content, denser and stronger in colour. In most cases it is a poor medium for growth without the topsoil layer. If exposed, can be quite erosive.

Subsoiling	Deep ploughing into the subsoil (similar to subsoil shattering).
Surface crusting (surface sealing)	The arrangement of dispersed clay particles in the immediate soil surface layers, making a crust that is comparatively impermeable to water. This typically occurs due to raindrop impact on bare soil. The potential for runoff and erosion are increased.
Swelling clay (shrink-swell)	Process that occurs when interacting clay platelets move apart due to the absorption of water molecules between clay platelets.
Tension crack	A crack that develops on gully wall, sidewalls and above tunnel erosion indicating imminent failure or collapse: often the result of undercutting, caving or tunnelling.
Topsoil	Original surface layer of mineral soil containing material that is usually darker, more fertile and better structured than the underlying layers.
Tunnel erosion	Tunnelling is an insidious form of sub-surface erosion, resulting as the name suggests in a tunnel through sub-surface soil layers. Tunnel erosion is caused by the movement of excess water through dispersive (usually sodic) subsoil.
Undercutting	Undercutting occurs where the flow in the main gully channel undercuts the sidewall, often leading to mass wasting.
Water repellent soils	Soils that are resistant to wetting (from a dry state). It is a condition usually associated with sandy surface horizons caused by an organic coating on sand grains
WEPP	Water Erosion Prediction Project – erosion simulation software.

APPENDIX C. SOIL TEST PARAMETERS AND CLASSIFICATION

Test Parameter		Units	Classification				
			Very low	Low	Medium	High	Very high
$EC_{1:5}$		*dS/m*	0.15	0.15-0.45	0.45-0.9	0.9-2	>2
Total N		*mg/kg*	500	500-1500	1500-2500	2500-5000	>5000
Total P		*mg/kg*	50	50-200	200-500	500-1000	>1000
Available P		*mg/kg*	<10	10-20	20-40	40-100	>100
Available K		*mg/kg*	<391	391-782	782-1955	1955-3910	>3910
Organic C		%	<0.5	0.5-1.5	1.5-2.5	2.5-5	>5
Trace elements	Copper	*mg/kg*	<0.1	0.1-0.3	0.5-5	5.-15	>15
	Manganese	*mg/kg*	<1	1-2	2-50	50-500	>500
	Zinc	*mg/kg*	<0.3	0.3-0.8	0.8-5	5-15	>15

$pH_{1:5}$	*pH Units*
Extremely acid	<4.5
Very strongly acid	4.5-5
Strongly acid	5.1-5.5
Medium acid	5.6-6
Slightly acid	6.1-6.5
Neutral	6.6-7.3
Mildly alkaline	7.4-7.8
Moderately alkaline	7.9-8.4
Strongly alkaline	8.5-9
Very strongly alkaline	>9

Exchangeable sodium percent (ESP)	%
Non-sodic	<6
Sodic	6-14
Strongly sodic	>15

(Source: Hazelton and Murphy, 2011, and Bruce and Rayment, 2004.)

Characterisation of the clay capping material from the Sandy Ridge Mine Site

Tellus Holdings Ltd

FINAL REPORT

December, 2015

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EXECUTIVE SUMMARY

The Sandy Ridge Project ('The Project') is proposed to be operated by Tellus Holdings Ltd ('Tellus') located approximately 140km north west of Kalgoorlie. Part of the development facility will include the storage and isolation of hazardous and intractable waste in mine voids that will be capped with a 2m thick layer of compacted kaolinised granite cap (KGC) material. Tellus are seeking an initial assessment of the physical and chemical nature of the KGC material with the aim of identifying any potential risks of using the KGC on the surface.

Six representative samples of the KGC material was supplied to Landloch by Tellus representing different locations and depths. The samples were sourced from RC drill chips and therefore no particle size analysis was conducted.

The pH of the samples is typically neutral to slightly acidic, with the exception of one sample result of 5.8. The salinity results were low, with one exceptional result of 1.17dS/m. The effective cation exchange capacity indicated that the KGC is strongly weathered and low in organic material. All materials had exchangeable sodium percents above the 6% threshold with one result at 34%. Overall, the main structure-related risk based on these results is that of hardsetting rather than dispersion.

The plant available water results were low and range from 7 to 18%. While this is a low figure, to put it in context the natural sandy topsoils would have a PAW around the 5 – 10%. The saturated hydraulic conductivity results are very low with a range of only 0.26 – 1.2mm/hr. This would indicate that the material will not readily allow infiltration but that it will rather runoff.

The metal levels for the Sandy Ridge material are generally very low, with most results (As, Ba, Be, B, Cd, Co, Cu, Pb, Mn, Se, and Hg) below detection level. The exception are the results for Cr, Ni, Va, and Zn, but all are well below the environmental investigation trigger levels.

1 INTRODUCTION

The Sandy Ridge Project ('The Project') is proposed to be operated by Tellus Holdings Ltd ('Tellus') and is located approximately 140km north west of Kalgoorlie. The proposed mine will extract kaolin clay from the Sandy Ridge kaolin bed for use in industrial applications. The Project is situated on exploration tenement E16/440 (59km^2 in extent), of which there is a development envelope of 1004.2ha (Figure 1) comprising various mining infrastructure such as mine pits, offices and workshops, and an accommodation camp.

Part of the development facility will include the storage and isolation of hazardous and intractable waste in mine voids. The facility will receive waste that will be placed in the excavated clay strata, backfilled, and capped with several metres of impermeable clay. Further clean backfill will be used to bring the level of the pit up to ground surface, following which a 2m thick layer of compacted kaolinised granite cap (KGC) material will be placed over the cell.

Tellus are seeking an initial assessment of the physical and chemical nature of the KGC material as this capping layer. The initial assessment will identify any potential risks of using the KGC as an exposed cap as well as any other advantageous characteristics that may assist in the rehabilitation of the site.

2 BACKGROUND

2.1 Geology and materials

The Project resides in the central eastern portion of the Achaean Yilgarn Block comprising granitic rocks and greenstone belts. The granite domes are deeply weathered and the generalised stratigraphy is (from the surface):

- Alluvial and colluvial sands – yellow quartz sand over red nodular clayey sand (~1.5m thick)
- Silcrete – kaolinitic clay indurated with silica to form a hardcap over deeper strata (~3m thick)
- Kaolinitic clay – weathered granite forming soft white clay strata (~15m thick)
- Granitoid basement – variable regional depth below surface from 3.5 to 47m (Department of Finance 2014).

Waste storage and isolation will be hosted within the kaolinitic clay layer and this excavated kaolinised granite material will form the capping material. It is this material that is the focus of this report (i.e. KGC material).

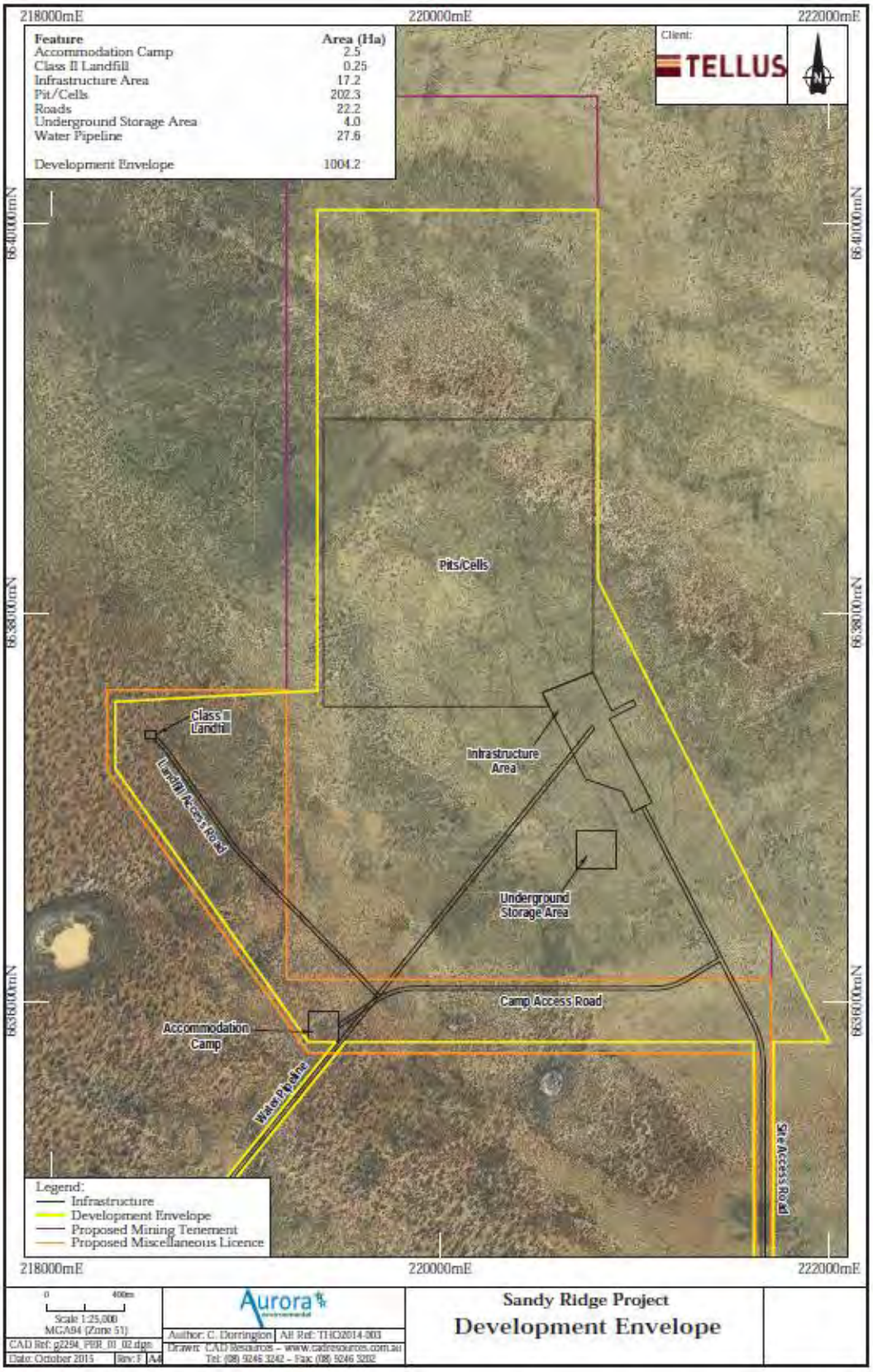

Figure 1: Development envelope of the Sandy Ridge Project. (Source: Aurora Environmental)

2.2 Characteristics required by the regulators

The Department of Mines and Petroleum (DMP) states in their guidelines for mining proposals that waste landforms should be designed to ensure that the final structure is safe, stable, and sustainable. The guidelines go on to state that, 'management strategies should be based on material characteristics, encapsulation of hostile materials, (and) designing long term stability…' (DMP 2006). Specifically, the DMP require characterisation data on material properties focussing on adverse characteristics – tests should identify hazards associated with pH, salinity, sodicity, nutrient/trace deficiencies, metals, and structure.

The intended use of the KGC material is to provide a permanent surface seal over the encapsulated wastes. As such no detailed plant nutrition analysis was conducted. The DMP sometimes requires information on acid generation potential, but this is typically associated with metalliferous mineralised rock waste and the KGC material does not present a risk in this area.

3 SAMPLES AND ANALYSIS

Six representative samples of the KGC material was supplied by Tellus to Landloch. The samples were selected based on information from drill logs and represent different spatial locations and depths from the likely kaolinised clay strata. The details are:

- TC1^ – SRAC007 drill depth 7-8m*
- TC2 – SRAC008 drill depth 7-8m
- TC3 – SRAC021 drill depth 5-14m
- TC4 – SRAC022 drill depth 18-31m
- TC5 – SRAC037 drill depth 11-12m
- TC6 – SRAC043 drill depth 9-10m

^ Landloch code. * Tellus drill log code and details

As the samples are RC drilling materials, the particle size distribution (PSD) analysis is expected to be of little use. The details of the full chemical and physical tests undertaken on the six samples are listed in Table 1.

Table 1: Complete list of chemical and physical tests undertaken on six drill samples from the Sandy Ridge kaolinitic clay strata.

Chemical Analytes	Physical Analytes
Material $pH_{1:5}$	Particle size distribution (Rock, gravel, sand, silt, clay)
Material $EC_{1:5}$ (salinity)	Plant available water
Exchangeable cations (Ca^{2+}, Al^{3+}, Mg^{2+}, Na^{+}, K^{+})	Saturated hydraulic conductivity
Cation exchange capacity	Emerson dispersion index
Exchangeable sodium percentage	
Total Metals (NEPM Suite)	

3.1 Threshold values: plant growth

As a guide, threshold values adopted in the discussion are shown in Table 2. These values are based on Landloch's experience with assessing soil characteristics for the WA Goldfields.

Table 2: Indicative guide to chemical analysis.

Property	Value
pH	5.5 – 9.0 (pH > 9.5 or < 5.0 requiring specific management)
$EC_{1:5}$	< 2.0 dS/m (EC >4.0 dS/m requiring specific management)
ESP	< 6 %, (ESP >10% requiring specific management. Materials with CEC <3 meq/100g and Na < 0.3 meq/100g were not considered of concern.

3.2 Total metals standards

The Assessment Levels for Soil, Sediment and Water (DEC 2010) provides a range of trigger levels for total metals in soils, and is based on the National Environment Protection Measure standards (NEPM 2011). The trigger levels range from ecological investigation levels (EIL) to health investigation levels (HIL) for industrial premises (Table 3).

It is typical to use HIL-F level (industrial) when assessing total metal levels in the disturbed areas such as a mine site. However, the EIL level is the most appropriate for a green field site undergoing preliminary material characterisation so as to readily identify any potential risks in using the KGC material on the surface.

The Chromium levels reported here are for Total Chromium. This is a cost effective method for the initial assessment, as hexavalent (VI) and trivalent (III) Chromium are both analysed. *The Assessment Levels for Soil, Sediment and Water* (DEC 2010) does not provide a trigger level for Total Chromium in soil, although it does for sediment (low trigger value 80mg/kg). The Chromium III EIL trigger level will be adopted for this report.

Levels in exceedance of the EIL levels are highlighted in red in the results (Tables 3). The full laboratory report is contained in Appendix A.

Table 3: Trigger levels for metals for health investigation levels and ecological investigation levels (DEC 2010).

	Ecological Investigation Levels	Health Investigation Levels			
		A[1]	D	E	F
	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)
Metals/Metalloids					
Antimony, Sb	-	**31[12]**	-	-	**410[12]**
Arsenic, As	20[8]	100[8]	400[8]	200[8]	500[8]
Barium, Ba	**300[8]**	**15,000[12]**	-	-	**190,000[12]**
Beryllium, Be	-	20[8]	80[8]	40[8]	100[8]
Cadmium, Cd	3[8]	20[8]	80[8]	40[8]	100[8]
Chromium[2] (Cr III)	**400[8]**	**120,000[8]**	**480,000[8]**	**240,000[8]**	**600,000[8]**
Chromium[2] (Cr VI)	**1[8]**	100[8]	400[8]	200[8]	500[8]
Cobalt, Co	50[9]	100[8]	400[8]	200[8]	500[8]
Copper, Cu	**100[8]**	1,000[8]	4,000[8]	2,000[8]	5,000[8]
Lead, Pb	**600[8]**	300[8]	1,200[8]	600[8]	1,500[8]
Manganese, Mn	500[8]	1,500[8]	6,000[8]	3,000[8]	7,500[8]
Methyl mercury[3]	-	10[8]	40[8]	20[8]	50[8]
Mercury (inorganic), Hg	1[8]	15[8]	60[8]	30[8]	75[8]
Molybdenum, Mo	40[9]	390[12]	-	-	**5100[12]**
Nickel, Ni	60[8]	600[8]	2,400[8]	600[8]	3,000[8]
Tin, Sn	50[10]	**47,000[12]**	-	-	**610,000[12]**
Vanadium, V	50[8]	**550[12]**	-	-	**7,200[12]**
Zinc, Zn	200[8]	7,000[8]	28,000[8]	14,000[8]	35,000[8]

4 RESULTS

The results from the full chemical and physical testing is shown in Tables 4 and 5.

This section of the material characterisation report containing the results of the full chemical and physical tests on the subset of samples is primarily concerned with examining the wastes from a risk perspective based on its use as a surface cap.

The metal results will be used as initial indicators of any potential hazards associated with the KGC if used on the surface for a medium period of time.

Table 4: Chemical and physical test results for the Sandy Ridge kaolinitic clay material.

Property		Units	TC1	TC2	TC3	TC4	TC5	TC6
pH		pH units	6.72	6.91	6.59	6.51	5.75	6.59
Electrical Conductivity		dS/m	0.48	0.40	0.74	1.17	0.19	0.60
Exchangeable Cations	Calcium	meq/100g	0.69	0.74	0.72	0.55	0.49	0.71
	Magnesium	meq/100g	1.43	1.64	1.29	0.77	1.28	1.03
	Potassium	meq/100g	0.23	0.30	0.14	0.08	0.11	0.08
	Sodium	meq/100g	0.50	1.39	0.31	0.13	0.91	0.13
	Aluminium	meq/100g	0.01	0.01	0.01	0.01	0.01	0.01
	Effective Cation Exchange Capacity	meq/100g	2.8	4.1	2.5	1.5	2.8	2.0
	Exchangeable Sodium Percentage	%	17.4	34.1	12.5	8.40	32.4	6.49
Particle Size Distribution	Coarse Sand 0.2-2.0mm	%	50.3	33.2	49.1	39.0	46.3	39.4
	Fine Sand 0.02-0.2mm	%	32.6	37.4	22.3	38.3	24.9	38.8
	Silt 0.002-0.02mm	%	13.8	28.1	10.8	16.4	14.5	18.4
	Clay <0.002mm	%	3.2	1.3	17.7	6.3	14.3	3.4
Plant Available Water		%	14	18	7	12	10	16
Dispersion Index		Class	6	6	6	6	6	6
Saturated Hydraulic Conductivity		mm/hr	0.46	0.26	1.20	0.29	0.50	0.45

Table 5: Total metals values for the Sandy Ridge kaolinitic clay material.

Property		Units	TC1	TC2	TC3	TC4	TC5	TC6
Total Metals	Arsenic	mg/kg	<5	<5	<5	<5	<5	<5
	Barium	mg/kg	<10	<10	<10	<10	<10	<10
	Beryllium	mg/kg	<1	<1	<1	<1	<1	<1
	Boron	mg/kg	<50	<50	<50	<50	<50	<50
	Cadmium	mg/kg	<1	<1	<1	<1	<1	<1
	Chromium*	mg/kg	7	4	3	5	<2	<2
	Cobalt	mg/kg	<2	<2	<2	<2	<2	<2
	Copper	mg/kg	<5	<5	<5	<5	<5	<5
	Lead	mg/kg	<5	<5	<5	<5	<5	<5
	Manganese	mg/kg	<5	<5	<5	<5	<5	<5
	Nickel	mg/kg	3	2	<2	2	<2	<2
	Selenium	mg/kg	<5	<5	<5	<5	<5	<5
	Vanadium	mg/kg	<5	10	<5	<5	<5	<5
	Zinc	mg/kg	<5	<5	8	20	<5	7
	Mercury	mg/kg	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1

* Total Chromium

4.1 Material pH and salinity

The material pH was measured using a solution of one part soil to five parts deionised water by weight ($pH_{1:5}$). Electrical conductivity was also measured using a 1:5 soil solution ($EC_{1:5}$).

The pH of the samples is typically neutral to slightly acidic. The exception is TC5 with a more acidic pH of 5.8. The salinity of the Sandy Ridge kaolinitic clay materials was low, with the exception of TC4 with a result of 1.17dS/m. The pH of TC5 and EC result of TC4 are at levels that might impact the germination of seedlings and would require amendments if the KGC was to be used as a final surface cover, but as it will ultimately be a subsurface layer these results are not unusual in an arid zone context.

4.2 Effective cation exchange capacity (ECEC)

The ECEC[1] is a measure of a material's ability to adsorb and hold cations. The ECEC results are low (TC2 the highest with 4.1meq/100g) and this would indicate that the KGC is strongly weathered and low in organic material.

4.3 Exchangeable sodium percent (ESP) and Emerson stability index

The exchangeable sodium percentage (ESP) value of a material is an indicator of clay dispersion potential. Materials with an appreciable dispersive clay fraction (typically greater than 10%) tend to be prone to tunnel erosion, hardsetting, and are prone to high levels of runoff and surface erosion. The typical threshold value for soils of concern is an ESP >6%. However, whether or not a material will actually disperse is a function of complex interactions between exchangeable cation concentrations, salinity, and clay content. For the purposes of this report, materials are defined as dispersive when they have the following characteristics:

- ESP >6%, and
- Clay content >10%, and
- ECEC >3meq/100g, and
- Na concentration >0.3meq/100g.

All of the Sandy Ridge KGC samples have ESP values greater than 6%, with TC2 having the highest result at 34%. Overall, four of the six samples have exchangeable Na concentrations greater than 0.3meq/100g, five out of six have an ECEC less than 3meq/100g, and four of the six samples have low clay content. When these factors are considered together, TC3 and TC5 are likely to be most prone to tunnelling. This being said, the plans to construct a domed structure that does not encourage water to pond will significantly reduce the risks of tunnel erosion. Therefore, the main structure-related risk based on these results is that of hardsetting rather than dispersion.

[1] All samples were washed of dissolved salts prior to testing for exchangeable cations and ECEC.

The Emerson stability index for all samples indicate that dispersion is a low risk. This is likely due to a combination of low clay content, low Na concentrations, and low ECEC.

4.4 Particle size distribution (PSD) of fine fraction

The laboratory results show that the clay content of the material is dominated by sands, with an appreciable silt fraction and low clay content (TC3 and TC5 do have slightly higher clay contents). A simple hand texture indicates that the clay content is much higher than indicated by these results. This may be due to the presence of an appreciable silt fraction that tends to behave like clays in a hand texture.

4.5 Plant available water (PAW) and saturated hydraulic conductivity

Plant available water is the measure of water held in the soil matrix that is available to plants. It is typically expressed as a percent and is the difference between a soil that has been drained by gravity (~33kPa soil suction) and a dry soil at plant permanent wilting point (1,500kPa soil suction). The results are low and range from 7 to 18%. While this is a low figure, to put it in context the natural sandy topsoils would have a PAW around the 5 – 10%.

The saturated hydraulic conductivity is the ability of a saturated material to transmit water through its pore matrix, and is measured in mm/hr. Lower the saturated hydraulic conductivity values will result in high runoff during rainfall events that can cause erosion. Materials with low saturated hydraulic conductivity values will also tend to pond water for longer.

The saturated hydraulic conductivity results for the Sandy Ridge site are very low with a range of only 0.26 – 1.2mm/hr. This would indicate that the material will not readily allow infiltration but that it will rather runoff. The materials are 'packed' into the test vessels at Landloch for the saturated hydraulic conductivity measurement by compacting the material with a hammer in a dry state. It may be worth investigating the utility of rolling and watering the material during construction to achieve an impermeable barrier.

4.6 Total metals

The metal levels for the Sandy Ridge material are generally very low, with most results (As, Ba, Be, B, Cd, Co, Cu, Pb, Mn, Se, and Hg) below detection level. The exception are the results for Cr, Ni, Va, and Zn, but all are well below EIL trigger levels. It should be noted that the Chromium result was for Total Chromium, and while the results were low (≤7mg/kg), the proportion comprised of Cr VI is not known. The material can be further analysed for Chromium species if required.

5 DISCUSSION

There is a low risk of contamination of the surrounding environment if the KGC material from the Sandy Ridge operation is used as a capping layer on the waste cells. The material has no properties from a contamination perspective that would present a risk to

the surrounding environment. The results indicate that the material properties are generally pH neutral and EC levels are low, but may vary to slightly acidic and saline. Landloch would also view this risk as negligible as:

- The EC and pH values recorded for the KGC is well within the range of other natural surface soils that Landloch has examined within the WA Goldfields region,
- The KGC will eventually be a subsurface layer covered by topsoil and will not be within the active rooting zone of most ground cover plant species, and
- The properties that could be described as deleterious for optimal plant growth can be easily amended as part of a comprehensive rehabilitation plan.

Some properties however do have implications for the long term erosional stability, in particular its potentially hardsetting nature and low saturated hydraulic conductivity. The combination of these two properties means that when used on the surface any rainfall event will rapidly be conducted into runoff that will erode the fine textured KGC material, even though it will be constructed at low gradients. These properties will also have implications when the KGC is covered by soil at final rehabilitation. The natural topsoils are very sandy (Landloch 2015) and will have a high infiltration rate. A high permeability material over a very low permeable material will create saturation of the surface soils that could potentially lead to tunnelling, slumping, slipping of the soil from the underlying KGC material, and rill development.

Further works should view the IWDF construction methods and the rehabilitation plans together to assess if a highly compacted KGC layer would be the most practical solution to limiting water ingress to the underlying intractable waste and the long term rehabilitation of the site. Factors to consider are the low rainfall, high soil evaporation rates, and erodibility of the site's KGC material and sandy topsoils. Long term erosion modelling can combine these factors to examine the most effective method to manage water infiltration and erosion of the surface cover materials.

6 CONCLUSION

Based on the results of this material characterisation study, the implications are:

- The KGC material is relatively benign in terms of its chemical nature. Some samples were slightly acidic and saline, but most trended towards neutral and non-saline.
- Analysis of the NEPM metal suite showed most were below detection limits, and any metals detected were well below the lowest trigger levels (EIL) for site contamination studies.
- The KGC material is fine textured, has low permeability, and may potentially be hardsetting, indicating that it will potentially erode when placed on the surface, and encourage failure of the soil layer when covered in natural sandy topsoils.
- Landloch would encourage further investigations to parameterise the KGC materials and topsoils for their erosional characteristics to examine strategies to optimise the closure goals of preventing the leaching of water to the underlying wastes and providing a long term rehabilitation cover that is safe, erosionally stable, and ecologically self-sustainable.

REFERENCES

Department of Environment and Conservation (DEC) (2010) *Contaminated Sites Management Series. Assessment Levels for Soil, Sediment and Water*, Department of Environment and Conservation Version 4, February 2010.

Department of Mines and Petroleum (DMP) (2006) *Guidelines for mining proposals in Western Australia*, Department of Mines and Petroleum, February 2006.

Landloch (2015) *Sandy Ridge Project Soil Assessment*, Tellus Holdings Limited. Report 22nd June, 2015.

National Environment Protection Measure (NEPM) (2011) *Schedule B1: Guideline on investigation levels for soil and groundwater*, National Environment Protection Measure, April 2011.

APPENDIX A. LABORATORY REPORT (METALS)

ALS Environmental

CERTIFICATE OF ANALYSIS

Work Order	: EP1512559	Page	: 1 of 4
Client	: LANDLOCH	Laboratory	: Environmental Division Perth
Contact	: Brendan Roddy	Contact	: Customer Services EP
Address	: PO BOX 5175 SOUTH LAKE WESTERN AUSTRALIA 6164	Address	: 10 Hod Way Malaga WA Australia 6090
E-mail	: ----	E-mail	: ALSEnviro.Perth@alsglobal.com
Telephone	: +61 08 9494 2835	Telephone	: +61-8-9209 7655
Facsimile	: +61 08 9417 3744	Facsimile	: +61-8-9209 7600
Project	: Tellus - Sandy Ridge	QC Level	: NEPM 2013 Schedule B(3) and ALS QCS3 requirement
Order number	: ----	Date Samples Received	: 31-Jul-2015 14:40
C-O-C number	: ----	Date Analysis Commenced	: 03-Aug-2015
Sampler	: Dylan O'Riley	Issue Date	: 11-Aug-2015 07:26
Site	: ----		
		No. of samples received	: 6
Quote number	: ----	No. of samples analysed	: 6

This report supersedes any previous report(s) with this reference. Results apply to the sample(s) as submitted.

This Certificate of Analysis contains the following information:

- General Comments
- Analytical Results

NATA

WORLD RECOGNISED ACCREDITATION

NATA Accredited Laboratory 825

Accredited for compliance with ISO/IEC 17025.

Signatories

This document has been electronically signed by the authorized signatories indicated below. Electronic signing has been carried out in compliance with procedures specified in 21 CFR Part 11.

Signatories	*Position*	*Accreditation Category*
Canhuang Ke	Metals Instrument Chemist	Perth Inorganics

RIGHT SOLUTIONS | RIGHT PARTNER

Page	: 2 of 4
Work Order	: EP1512559
Client	: LANDLOCH
Project	: Tellus - Sandy Ridge

ALS

General Comments

The analytical procedures used by the Environmental Division have been developed from established internationally recognized procedures such as those published by the USEPA, APHA, AS and NEPM. In house developed procedures are employed in the absence of documented standards or by client request.

Where moisture determination has been performed, results are reported on a dry weight basis.

Where a reported less than (<) result is higher than the LOR, this may be due to primary sample extract/digestate dilution and/or insufficient sample for analysis.

Where the LOR of a reported result differs from standard LOR, this may be due to high moisture content, insufficient sample (reduced weight employed) or matrix interference.

When sampling time information is not provided by the client, sampling dates are shown without a time component. In these instances, the time component has been assumed by the laboratory for processing purposes.

Key : CAS Number = CAS registry number from database maintained by Chemical Abstracts Services. The Chemical Abstracts Service is a division of the American Chemical Society.
LOR = Limit of reporting
^ = This result is computed from individual analyte detections at or above the level of reporting
ø = ALS is not NATA accredited for these tests.

Page : 3 of 4
Work Order : EP1512559
Client : LANDLOCH
Project : Tellus - Sandy Ridge

ALS

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Client sample ID	TC1 SRAC0010	TC2 SRAC008	TC3 SRAC021	TC4 SRAC022	TC5 SRAC037
			Client sampling date / time	31-Jul-2015 08:30	31-Jul-2015 08:30	31-Jul-2015 08:30	31-Jul-2015 08:30	31-Jul-2015 08:30
Compound	CAS Number	LOR	Unit	EP1512559-001	EP1512559-002	EP1512559-003	EP1512559-004	EP1512559-005
				Result	Result	Result	Result	Result
EA055: Moisture Content								
^ Moisture Content (dried @ 103°C)	----	1	%	5.0	2.7	9.7	9.0	8.3
EG005T: Total Metals by ICP-AES								
Arsenic	7440-38-2	5	mg/kg	<5	<5	<5	<5	<5
Barium	7440-39-3	10	mg/kg	<10	<10	<10	<10	<10
Beryllium	7440-41-7	1	mg/kg	<1	<1	<1	<1	<1
Boron	7440-42-8	50	mg/kg	<50	<50	<50	<50	<50
Cadmium	7440-43-9	1	mg/kg	<1	<1	<1	<1	<1
Chromium	7440-47-3	2	mg/kg	7	4	3	5	<2
Cobalt	7440-48-4	2	mg/kg	<2	<2	<2	<2	<2
Copper	7440-50-8	5	mg/kg	<5	<5	<5	<5	<5
Lead	7439-92-1	5	mg/kg	<5	<5	<5	<5	<5
Manganese	7439-96-5	5	mg/kg	<5	<5	<5	<5	<5
Nickel	7440-02-0	2	mg/kg	3	2	<2	2	<2
Selenium	7782-49-2	5	mg/kg	<5	<5	<5	<5	<5
Vanadium	7440-62-2	5	mg/kg	<5	10	<5	<5	<5
Zinc	7440-66-6	5	mg/kg	<5	<5	8	20	<5
EG035T: Total Recoverable Mercury by FIMS								
Mercury	7439-97-6	0.1	mg/kg	<0.1	<0.1	<0.1	<0.1	<0.1

Page : 4 of 4
Work Order : EP1512559
Client : LANDLOCH
Project : Tellus - Sandy Ridge

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Client sample ID	TC6 SRAC043	----	----	----	----
			Client sampling date / time	31-Jul-2015 08:30	----	----	----	----
Compound	CAS Number	LOR	Unit	EP1512559-006	------	------	------	------
				Result	Result	Result	Result	Result
EA055: Moisture Content								
^ Moisture Content (dried @ 103°C)	----	1	%	8.4	----	----	----	----
EG005T: Total Metals by ICP-AES								
Arsenic	7440-38-2	5	mg/kg	<5	----	----	----	----
Barium	7440-39-3	10	mg/kg	<10	----	----	----	----
Beryllium	7440-41-7	1	mg/kg	<1	----	----	----	----
Boron	7440-42-8	50	mg/kg	<50	----	----	----	----
Cadmium	7440-43-9	1	mg/kg	<1	----	----	----	----
Chromium	7440-47-3	2	mg/kg	<2	----	----	----	----
Cobalt	7440-48-4	2	mg/kg	<2	----	----	----	----
Copper	7440-50-8	5	mg/kg	<5	----	----	----	----
Lead	7439-92-1	5	mg/kg	<5	----	----	----	----
Manganese	7439-96-5	5	mg/kg	<5	----	----	----	----
Nickel	7440-02-0	2	mg/kg	<2	----	----	----	----
Selenium	7782-49-2	5	mg/kg	<5	----	----	----	----
Vanadium	7440-62-2	5	mg/kg	<5	----	----	----	----
Zinc	7440-66-6	5	mg/kg	7	----	----	----	----
EG035T: Total Recoverable Mercury by FIMS								
Mercury	7439-97-6	0.1	mg/kg	<0.1	----	----	----	----

ALS Environmental

QA/QC Compliance Assessment for DQO Reporting

Work Order	: **EP1512559**	Page	: 1 of 4
Client	: **LANDLOCH**	Laboratory	: Environmental Division Perth
Contact	: Brendan Roddy	Telephone	: +61-8-9209 7655
Project	: Tellus - Sandy Ridge	Date Samples Received	: 31-Jul-2015
Site	: ----	Issue Date	: 11-Aug-2015
Sampler	: Dylan O'Riley	No. of samples received	: 6
Order number	: ----	No. of samples analysed	: 6

This report is automatically generated by the ALS LIMS through interpretation of the ALS Quality Control Report and several Quality Assurance parameters measured by ALS. This automated reporting highlights any non-conformances, facilitates faster and more accurate data validation and is designed to assist internal expert and external Auditor review. Many components of this report contribute to the overall DQO assessment and reporting for guideline compliance.

Brief method summaries and references are also provided to assist in traceability.

Summary of Outliers

Outliers : Quality Control Samples

This report highlights outliers flagged in the Quality Control (QC) Report.

- **NO Method Blank value outliers occur.**
- **NO Duplicate outliers occur.**
- **NO Laboratory Control outliers occur.**
- **NO Matrix Spike outliers occur.**
- **For all regular sample matrices, NO surrogate recovery outliers occur.**

Outliers : Analysis Holding Time Compliance

- **NO Analysis Holding Time Outliers exist.**

Outliers : Frequency of Quality Control Samples

- **NO Quality Control Sample Frequency Outliers exist.**

Baseline Radiation & Metals Report

TELLUS

Baseline Radiation and Metals Report E 16/440, M16/540 Sandy Ridge February 2016

Prepared by
David Jenkins
Terra Search
Perth

Executive Summary

This report details the baseline knowledge on the radiation and Metal content at Tellus Holdings Sandy Ridge Kaolinite and storage facility. All available public and proprietary geophysical and geochemical data has been examined by Principal Geologist David Jenkins to determine the background levels of metals and naturally occurring radioactive materials (NORM).

There is a large Kaolinite resource defined within the tenement. The well developed kaolinite zone is within the weathered portion of the granitic bedrock. Regional Magnetics indicate a large consistent basement and drilling to date has not identified any other significant lithologies, alteration or mineralisation in the area. There has been extensive analysis of drilling chips completed by Tellus Holdings over a suite of 24 elements. No elevated metals values have been returned and the likelihood of any localised enrichment with in the area is considered low.

Regional radiometrics shows a low background of radiation present in the area. The geology in the area is considered unlikely to produce significant accumulations of Uranium or Thorium with Potassium being the dominant radioactive species. The nearest uranium accumulations identified within the Western Australian Department of Mines mineral occurrence database are calcrete uranium occurrences that form in saline paleochannels and playa lake sediments. The nearest is low level mineralisation approximately 80km away at Lake Eva. There is no evidence of significant paleochannel development in the Sandy Ridge area. There are no significant Thorium accumulations in the region to the knowledge of the Author. Regional sampling of the granite shows the uranium content to be consistently at or below 11ppm. This is considered too low to contribute to any significant secondary surficial uranium enrichment. It is the authors opinion that the radiation levels in the project area are low.

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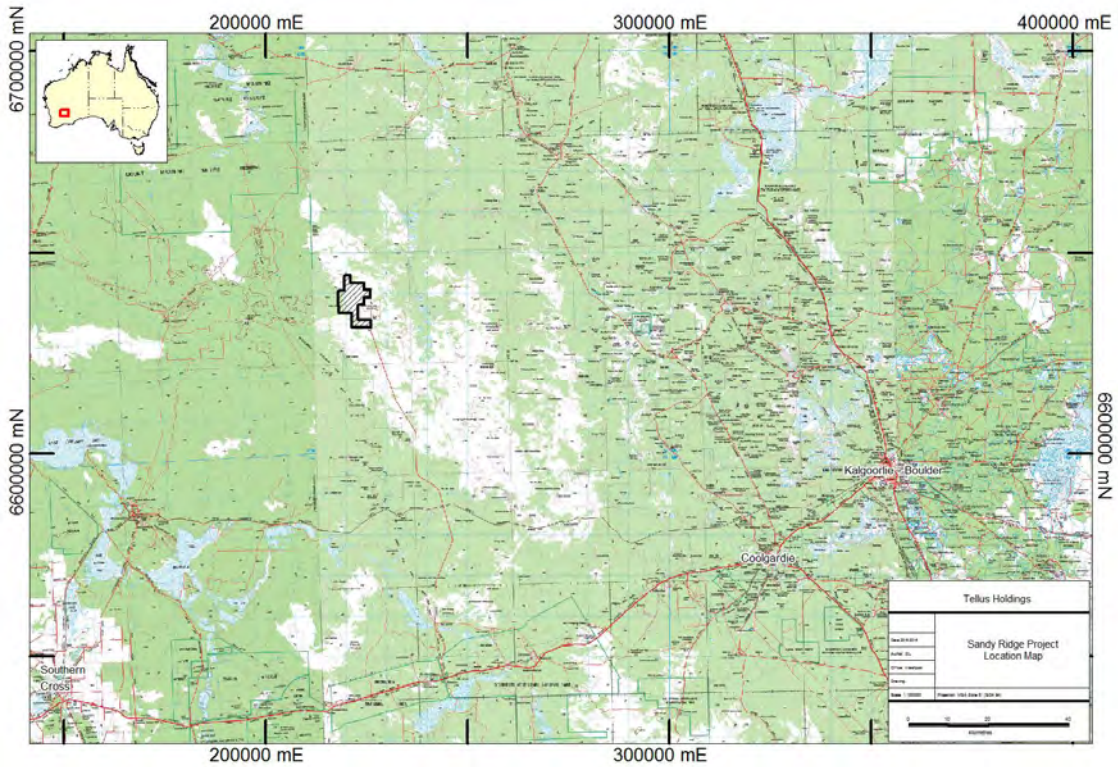
1. Introduction

Terra Search has been commissioned by Tellus Holdings to review the baseline knowledge of the radiation and metals content within their Sandy Ridge project. Terra Search has completed two extensive drilling programs within the area and have a strong understanding of the geology and geochemistry in the area. The tenement E16/440 within the Sandy Ridge project area totals an area of approximately 59.3km2.



2. Location and Access

The tenement can be accessed by travelling 90km north along the Mt. Walton Road from the Great Eastern Highway. After travelling 90km north there is a left turn onto the Mt. Dimer Road heading west. 4.5km down the Mt. Dimer road is a turnoff to the north, which is the access road to tenement E16/440 project area.

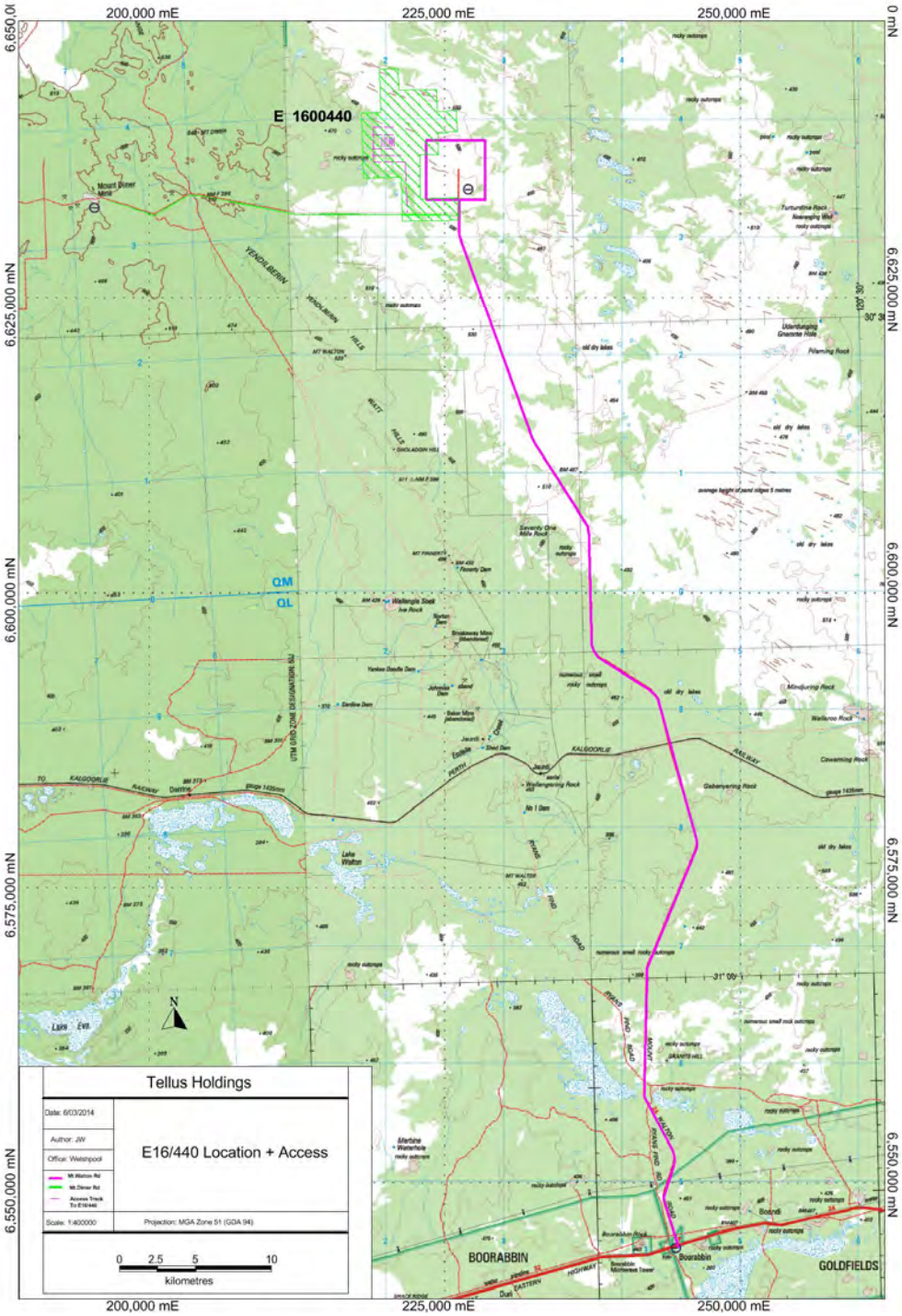


Figure 1 Sandy Ridge Location and Access

3. Tenure

E16/440 was granted to Tellus Holdings on the 23rd of January 2013. The E16/440 tenement consists of 20 subblocks with a combined area of 59.3km². The tenement is graticular (Fig 3). A mining lease M16/540 has been applied for covering 8.32km².

BID Map	Graticular Block	Sub Block
SH5109	6946	q,v,w,x
SH5109	7017	e,k,p
SH5109	7018	a,b,c,d,f,g,h,l,m,r,w,x,y

Table 1 Graticular Blocks E16/440

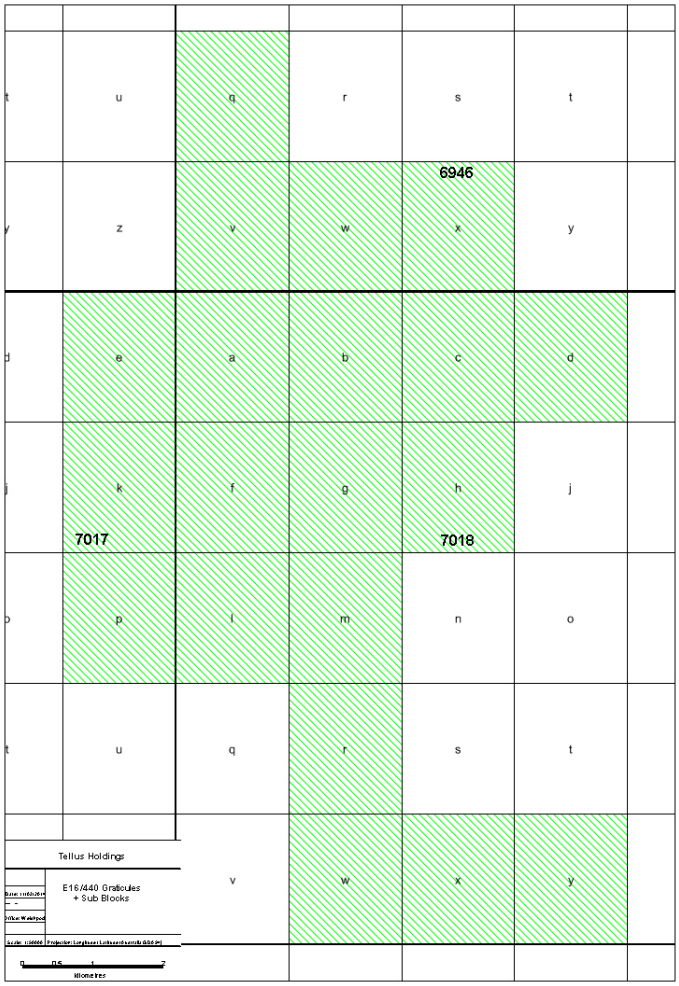


Figure 2 Graticules and Sub Blocks

4. Geology

Regional Geology

The project area lies in the central eastern portion of the Yilgarn Craton, a tectonically stable, ancient craton comprising linear to arcuate north-west trending belts of greenstone and local gneissic rocks intruded by granitoid rocks of Archaean age. Overlying all these rock units are alluvial, colluvial, aeolian or lacustrine deposits of Cainozoic age. Some of the surficial sediments and the basement rocks (except where outcropping), are deeply weathered and lateritised. The Archaean rocks are generally poorly exposed.

The granitoids occur in plutons and linear belts and are mainly equigranular to foliated adamellites, with subordinate granites, paragneiss and orthogneiss. Locally they are intruded by quartz veins, pegmatites and aplites (Fig 4).

The Cainozoic sediments are generally thin and variable, except in the palaeodrainages, where sediments of Eocene age infill incised palaeochannels. The remaining surficial sediments comprise locally-developed alluvial, colluvial, aeolian, occasional lacustrine and hydrochemical deposits of Late Cainozoic age.

In the vicinity of the Sandy Ridge area, Archaean monzogranites of the Yilgarn Granites Supersuite is the bedrock. Deep weathering of the feldspathic and ferromagnesian minerals within the granite has resulted in the formation of kaolinite. Flanking these rocks are similarly aged metamorphosed mafic dominant granite-greenstones of the Youanmi Terrane – Southern Cross Domain. Also present within the area are sedimentary siliciclastic rock, including metamorphosed sandstone, siltstone, shale and chert. Weathering of the monzogranite generally extends to a maximum depth of 30 m, although it is closer to 40 m within the study area. The weathering profile on the granitoids generally comprises a ferruginous laterite at the surface, underlain by kaolinitic clay in which most rock structures and textures have been obliterated. This then grades downward into a zone of weathered rock with identifiable rock textures and structures in which joints are clay filled.

Project Geology.

The geology of the project area is consistent across the tenement with an Archaean monzogranite bedrock present throughout, below sands, residual soils and laterite (Fig 5). Minor mafic dykes of likely Proterozoic age are also present but are thin and of little significance, with only one dyke intersected in all drilling to date. The granite has been weathered to a depth of between 30-40m across the drilled area with a strong kaolinitised clay zone above the granite saprock. A silcrete layer is common with a lateritic residuum present in most cases. Typical drillchip trays of 2 drillholes are shown in figure 3.

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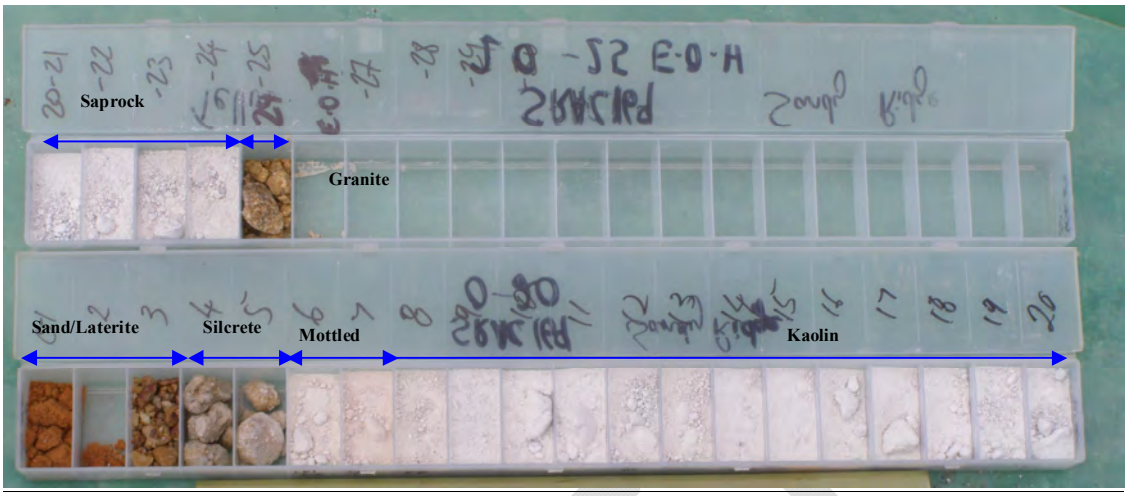

Figure 3 Chip tray for SRAC169

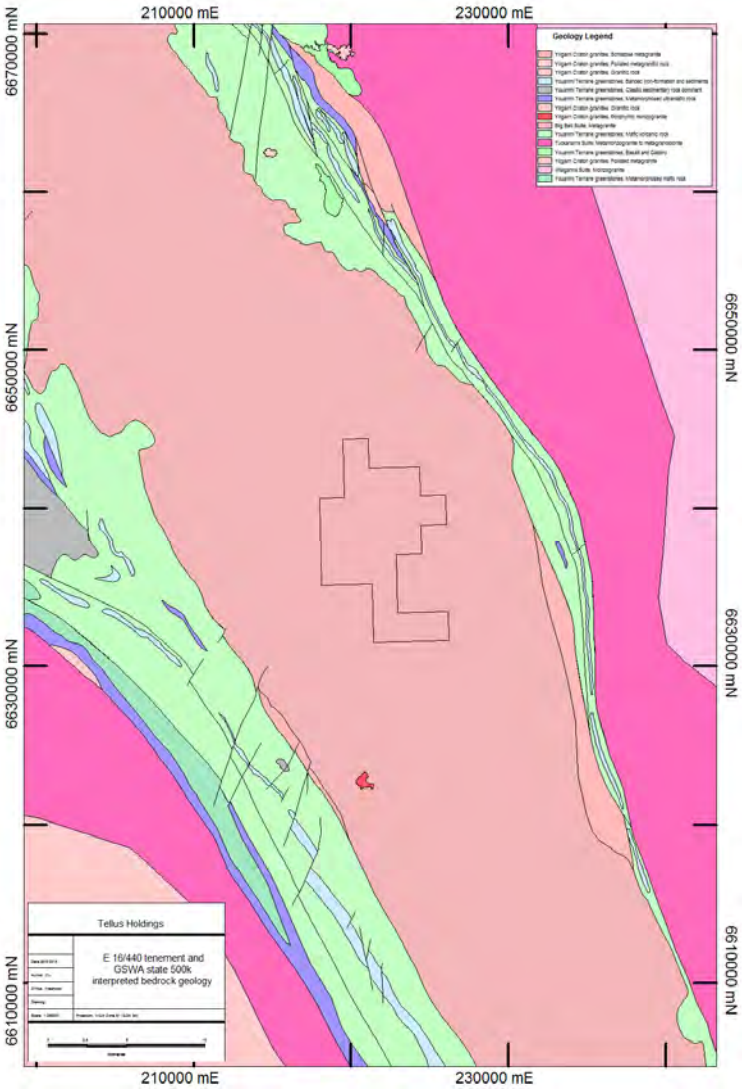

Figure 4 Regional Geology E 16/440

No veining or alteration has been encountered and the kaolinitisation is considered to be a weathering product and not a hydrothermal process. There is little cover across the area and no significant paleochannel development. No strong aquifers were encountered in the drilling.

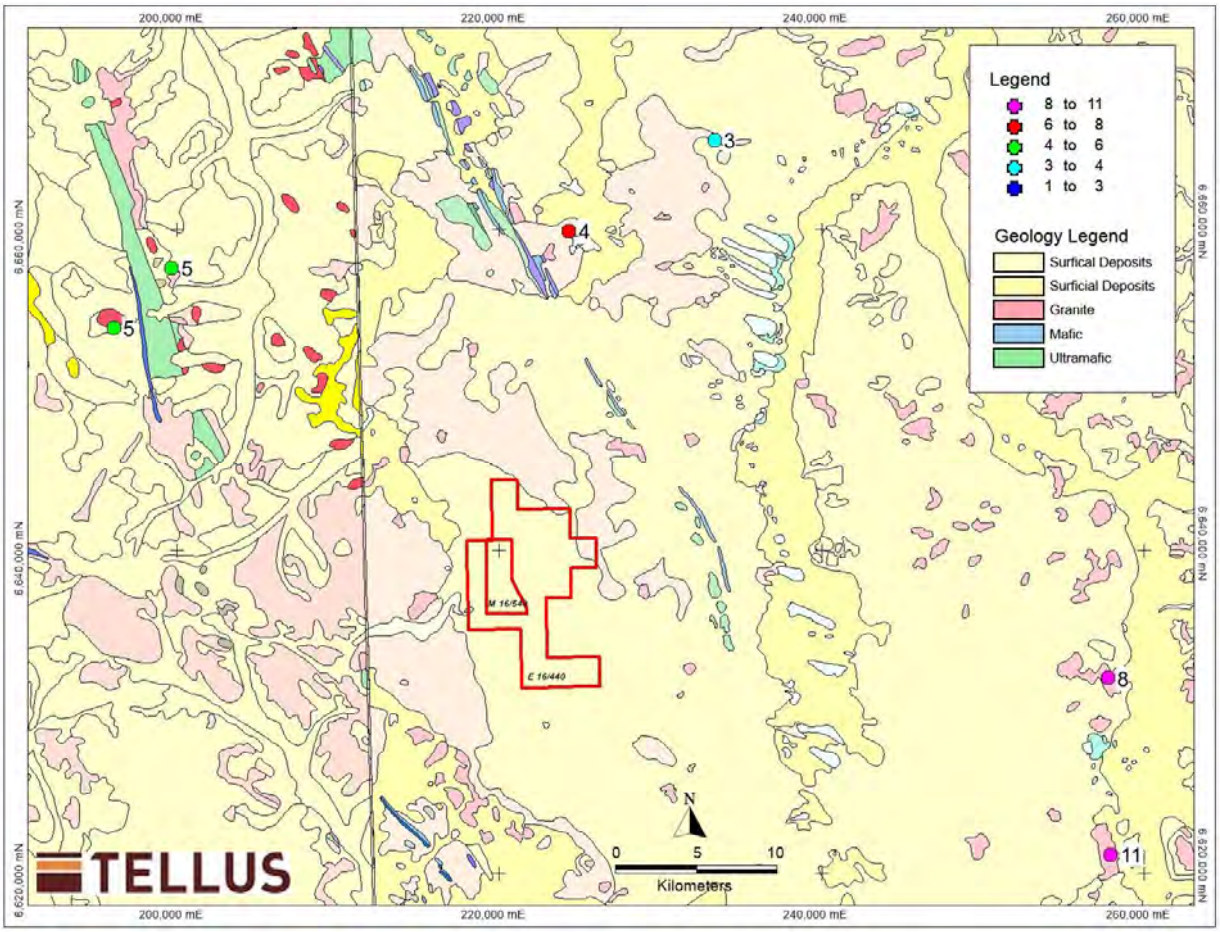

Figure 5 Regional surface geology with OZCHEM Geochemical data Uranium values in ppm

5. Baseline Radiation levels

The area has no known Naturally occurring radioactive material (NORM). The nearest known uranium prospects within the Department of Mines and Petroleum databases are some 80km to the south east at Lake Eva and 100k to the west at Lake Marmion (http://www.dmp.wa.gov.au/Minerals/Mines-and-Mineral-Deposits-2283.aspx). An airborne magnetics and radiometrics survey was flown in 1997 by World Geoscience Corporation for Stockdale Prospecting. The survey specifications are detailed below:

SURVEY SPECIFICATIONS

AIRCRAFT - VH-MEH ROCKWELL SHRIKE COMMANDER AC500S

MAGNETOMETERS - Geometrics G-822A Cesium
RESOLUTION - 0.001 nanotesla
CYCLE RATE - 0.1 second
SAMPLE INTERVAL - 7.8 metres

SPECTROMETER - 256 channel PGAM-1000
VOLUME - 33.56 litres
CYCLE RATE - 1.0 second
SAMPLE INTERVAL - 78 metres

DATA ACQUISITION - Picodas PDAS-1000
- 11 CHANNEL RMS GR33A

FLIGHT LINE SPACING - 250 metres
FLIGHT LINE DIRECTION - 090 - 270 degrees
TIE LINE SPACING - none flown
TIE LINE DIRECTION - none flown degrees

This survey is the most detailed survey available for the area. The magnetics show a stable response across the area consistent with the geological interpretation of a stable granite basement (Fig 6).

The Radiometrics is similarly low across the tenement with no significant anomalies in the Uranium and Thorium wavelengths and values on the low end of radiometric response (Fig 7). The uranium/Thorium Ratio is used to highlight any uranium enrichment zones within an area. As can be seen in Figure 7b, there is no significant variation in this ratio across the area indicating that uranium levels are likely to be at the background levels of the monzogranite body.

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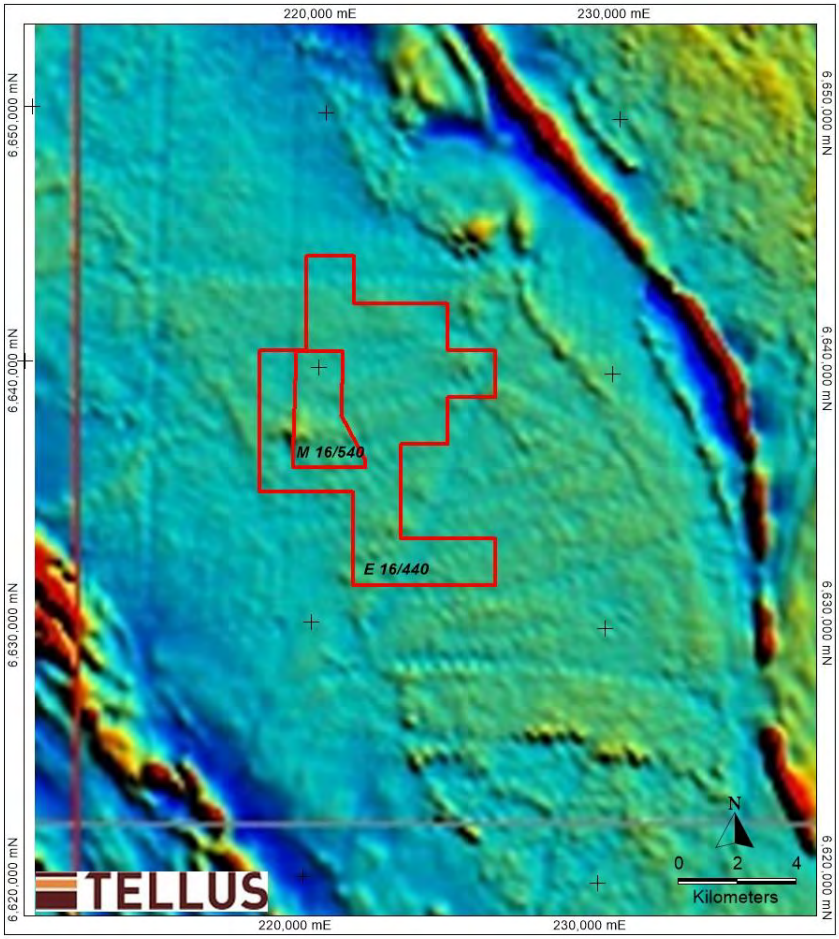

Figure 6 Regional Magnetics

Rock chip sampling of the granite outcrop in the region, available from Geoscience Australia's OZCHEM database, has returned a maximum of 11ppm Uranium and Thorium (Fig 5). None of the samples are within the tenement area itself. This level of background is considered within the lower range of typical values for a granite terrain. The main mechanism for concentration of NORM within the region is surficial concentrations in paleochannels and playa lakes in a saline environment. The lack of any paleochannels or lacustrian environments in the project area would preclude such a concentration.

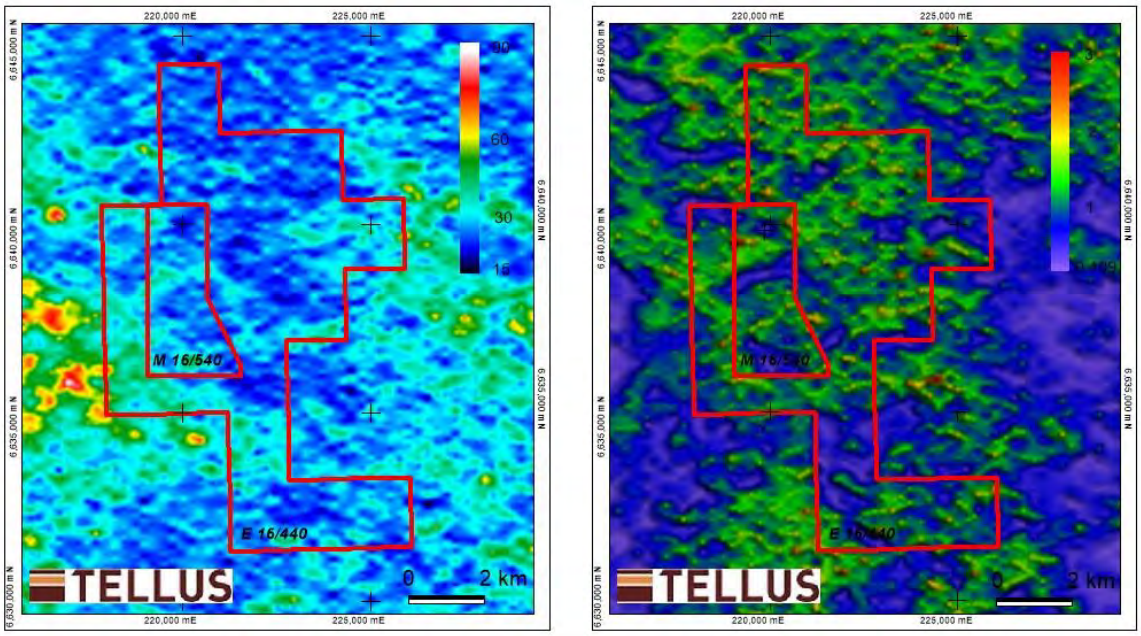

Figure 7 Radiometric response a) Uranium channel (LHS) b) Uranium/Thorium Ratio (RHS)

It is the authors opinion that the radiation levels in the project area are low.

6. Baseline Metals levels

The geology of the project area is dominated by granites which tend to be low in metal content compared to more mafic rocks. There has been extensive analysis of the exploration drilling at Sandy Ridge with a total of 312 assays available from the 2015 drilling program (Fig 10). These assays were processed at Nagrom using XRF for Fe2O3, SiO2, Al2O3, TiO2, MnO, CaO, P, S, MgO, Zn, LOI, K2O, Sn, V, Cr, Co, Ni, Cu, As, Pb and Ba. Thirty-two of the assays were QAQC samples which provide a high level of confidence in the data. These assays were completed on composite samples from the Kaolinite zone. The statistics of the compositing exercise are displayed in Table 11 below. The data from previous drilling was not considered as a more limited suite of elements were analysed for.

Table 2 Statistics of the Composite Samples

Property	Value
Number of composites for assay	280+32 duplicates
Average meters per composite	4.2 m
Maximum meters per composite	6 m
Minimum meters per composite	2 m
Maximum number of composites per hole	5

Table 3 shows the statistical data for the full suite of analysed elements. The maximum

values are low for all of the contaminant elements and the distribution statistics show a remarkable consistency across the site. These low levels are as expected for the geological environment in the project area. The overlying laterite zones will have some secondary enrichment of some elements. Given the low levels these are unlikely to be of concern although direct assay of same of this material could be undertaken.

Table 3 Statistical analysis of the 24 elements analysed

Attribute	Fe2O3	SiO_2	Al_2O_3	TiO_2	MnO	CaO	P	Na_2O
Count	312.0000	312.0000	312.0000	312.0000	312.0000	312.0000	312.0000	312.0000
Min	0.0758	45.9580	30.0240	0.0680	0.0005	0.0100	0.0005	0.0060
Max	2.8300	55.5170	39.3360	0.9910	0.0170	0.0700	0.0450	0.3990
Mean	0.6474	48.1276	37.0629	0.4032	0.0016	0.0272	0.0077	0.0990
Std Dev	0.3629	1.5494	1.5175	0.1593	0.0019	0.0095	0.0084	0.0564
Variance	0.1317	2.4006	2.3027	0.0254	0.0000	0.0001	0.0001	0.0032
Attribute	S	MgO	Zn	LOI_{1000}	K_2O	Sn	V	Cl
Count	312.0000	312.0000	312.0000	312.0000	312.0000	312.0000	312.0000	312.0000
Min	0.0005	0.0100	0.0005	8.9000	0.0550	0.0005	0.0005	0.0005
Max	0.0310	0.2880	0.0130	13.9000	4.7660	0.0050	0.0060	0.3150
Mean	0.0078	0.0588	0.0021	12.9436	0.5555	0.0008	0.0017	0.0740
Std Dev	0.0063	0.0389	0.0019	0.7735	0.7370	0.0007	0.0013	0.0566
Variance	0.0000	0.0015	0.0000	0.5982	0.5431	0.0000	0.0000	0.0032
Attribute	Cr	Co	Ni	Cu	As	Pb	Ba	Sr
Count	312.0000	312.0000	312.0000	312.0000	312.0000	312.0000	312.0000	312.0000
Min	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005
Max	0.0120	0.0030	0.0220	0.0020	0.0020	0.0330	0.0970	0.0110
Mean	0.0010	0.0005	0.0010	0.0005	0.0005	0.0038	0.0099	0.0016
Std Dev	0.0013	0.0001	0.0022	0.0001	0.0001	0.0047	0.0151	0.0017
Variance	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0002	0.0000

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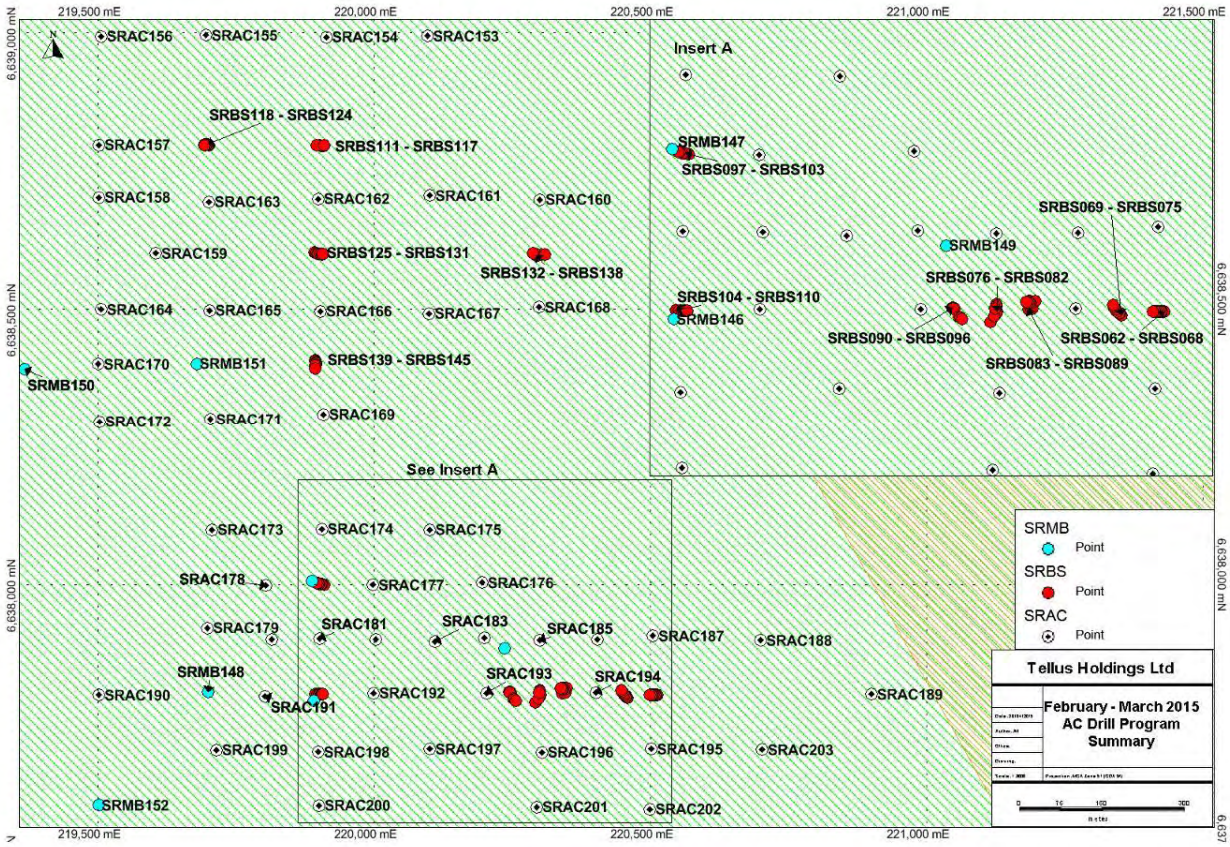

Figure 8 Distribution of drilling data used for the calculation of baseline metal contents

7. Conclusions

The Sandy Ridge project has remarkable geological consistency across the investigated area. Radiation and Metal levels have been examined using publicly available regional geological, geophysical and geochemical data. Baseline metals level have also been quantified in the kaolinitic zone using the drilling data collected by Tellus.

The results of this investigation are that radiation levels are low across the region and metal levels are also low. It should be noted that the laterite zone present above the kaolinite zone in a majority of the area may have elevated metal levels compared with the kaolinite zone and may require specific testing during future investigations, although the levels are not expected to be of concern.

DRAFT

Landform Evolution Modelling

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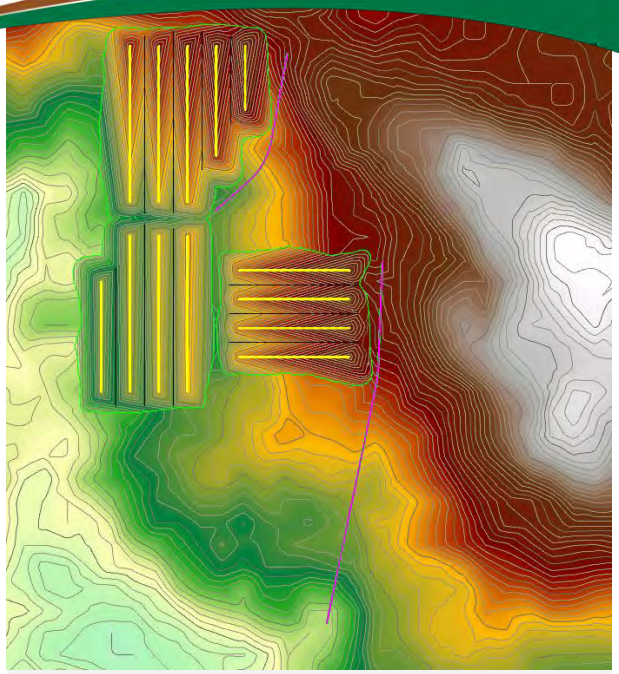

SANDY RIDGE LANDFORM EVOLUTION MODELLING

Tellus Holdings Limited

February 2016

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1 INTRODUCTION

The Sandy Ridge Project (the Project) is proposed to be developed by Tellus Holdings Ltd (Tellus) and is located approximately 140km north west of Kalgoorlie. The proposed mine will extract kaolin clay from the Sandy Ridge kaolin bed for use in industrial applications. The Project is situated on exploration tenement 16/440 (59km^2 in extent), of which there is a development envelope of 1,004ha (Figure 1) comprising various mining infrastructure such as a mine pit, offices and workshops, and an accommodation camp (Figure 2).

Part of the development will include the storage and isolation of hazardous and intractable waste in mine voids (herein referred to as 'cells').These cells will be located in the pit/cell area identified in Figure 2. The waste facility will receive waste that will be placed in the excavated mine voids, backfilled, and capped with 3 metres of impermeable clay (Figure 3). Further backfill, approximately 4m, will be used to bring the level of the cell up to ground surface, where a 2m thick layer of compacted kaolinised granite cap (KGC) material will be domed to provide a permanent cover before placement of a topsoil cover and final rehabilitation.

Tellus are seeking long-term (10,000 years) landform evolutionary modelling to assess the erosion of the landform. This assessment will identify the safe and stable erosional limits of using the KGC material in the proposed designs. Based on the results of the material characterisation and long term erosion modelling, the design may be revised following new recommendations.

1.1 Purpose

The purpose of the clay cap is to prevent water ingress into the cells. An assessment of the capping material's erosion potential is required to ensure the design integrity over the very long term. This report details the studies undertaken by Landloch to assess the current design and provide recommendations on erosion-related aspects of the design. The overarching aim is to ensure that the Sandy Ridge cells are safe, stable, and non-polluting feature for the long term.

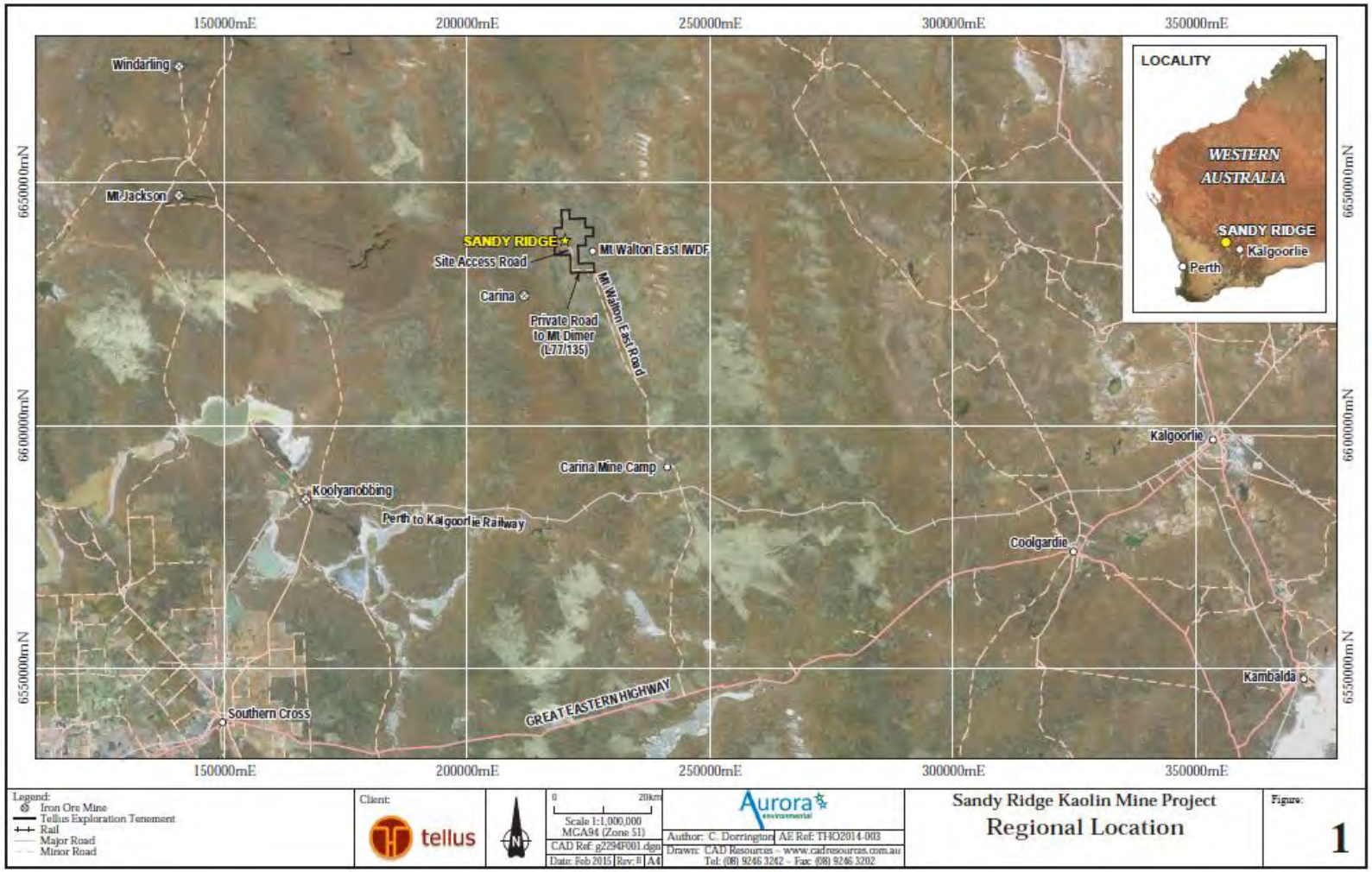

Figure 1: Location of the Sandy Ridge Project. (Source: Aurora Environmental)

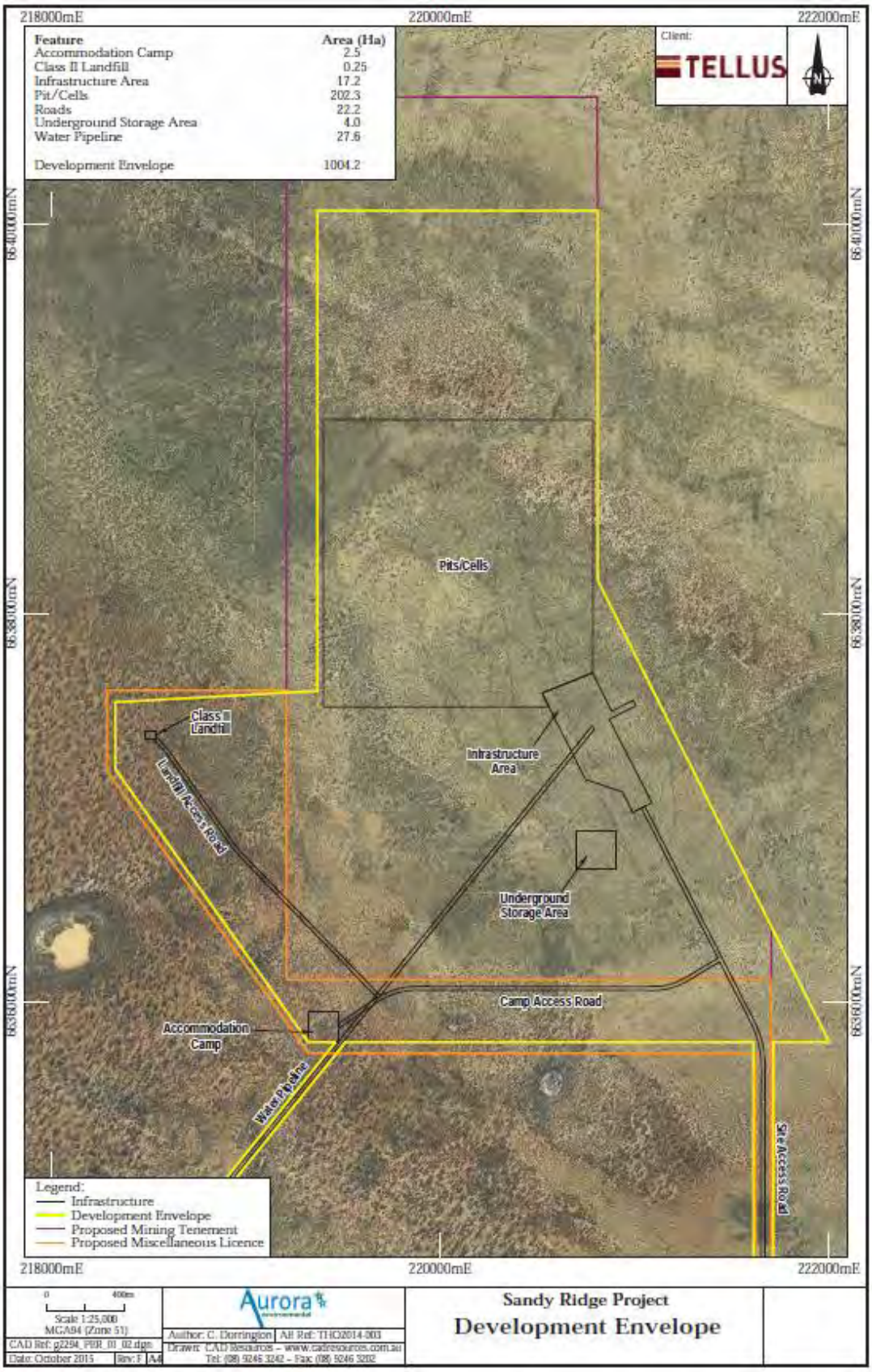

Figure 2: Development envelope of the Sandy Ridge Project. (Source: Aurora Environmental)

Figure 3: Example of placing intractable waste into the excavated clay slot at the Mt Walton IWDF (Dept. of Finance, 2014).

1.2 Proposed waste facility design

The cell will be excavated to ensure that there is at least a 5m separation distance between the base of the cells and the granite basement. The waste will be stored between 8-23m below ground level. Once waste is placed within the zone, the remaining void space will be backfilled with sand and a 3m compacted KGC layer will be placed above it. A mixed laterite/silcrete/clay/sand layer will be compacted to bring the waste facility up to surface level (~4m layer depth). The final surface layer will be a compacted domed kaolinised granite cap (KGC) up to 100m wide with a very low gradient (5%). A conceptual design showing the vertical layering of waste and materials is shown in Figure 4. The kaolin clay cap will remain in place for geological time. Following subsidence monitoring of the cap, a deep layer of topsoil will be replaced and vegetated. The purpose of the design is to prevent water entering the backfilled pit or waste leachate escaping from the base and entering aquifers.

Details of the Sandy Ridge conceptual design is shown in Figure 5. Multiple cells are proposed to be constructed, in rows. The final landform will comprise of three groups of cells which will be approximately 100m wide, 650m long, approximately 5m high, with low batter gradients of 5% (3°). Temporary operational bunds will be constructed on the eastern side to divert water during mining operations and have an expected life of ~25 years.

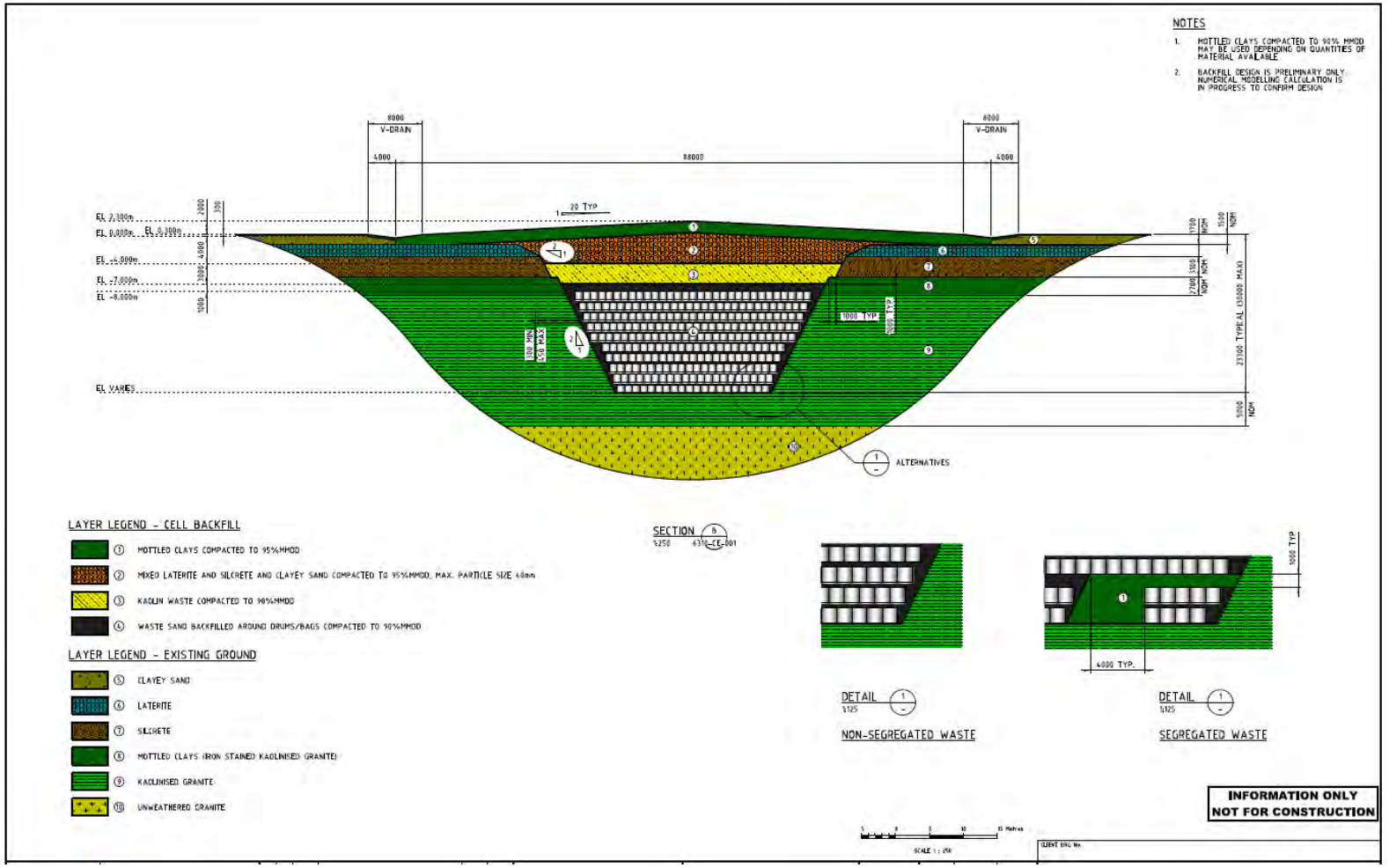

Figure 4: Conceptual design of the waste facility (Source: Tellus Holdings Ltd).

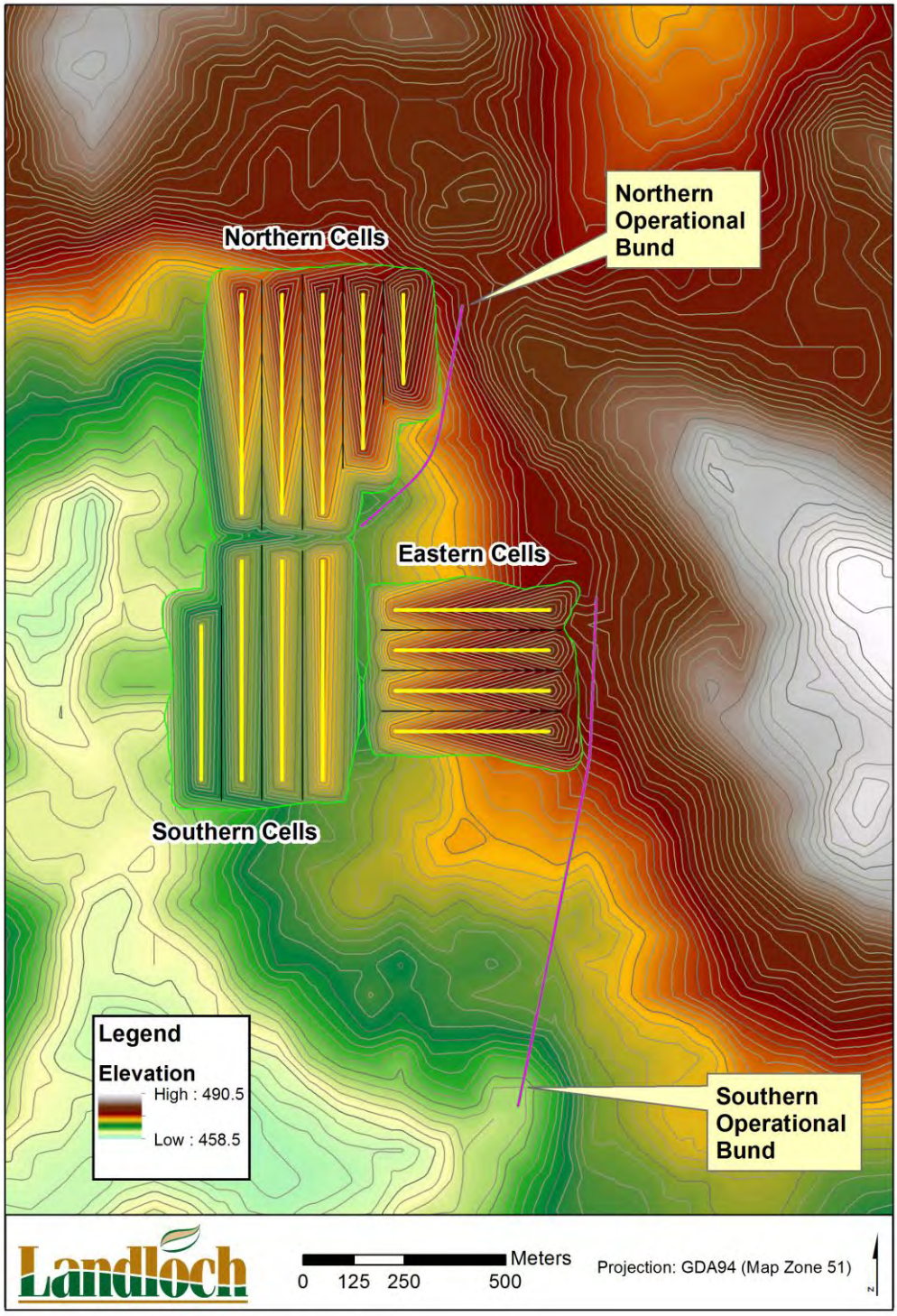

Figure 5: Proposed layout of the Sandy Ridge waste facility cells.

2 SCOPE

Tellus are seeking an assessment of the proposed design. Specifically, Tellus wants to assess the long term (10,000 years) behaviour and performance of landforms and associated containment systems, including waste cell capping systems, modelled under the prevailing climate, including landform evolution modelling. This study will:

- Assess the design in terms of its erosional stability,
- Assess the operational bunds,
- Identify high risk features of the design, and
- Make recommendations for design improvements.

The works completed include:

1. Chemical and physical testing of bulk samples of the topsoil and KGC material.
2. Erodibility studies of the topsoil and KGC material using simulated rain and overland flow studies.
3. Derivation of Water Erosion Prediction Project (WEPP) erosion model (Flanagan and Livingston 1995) and SIBERIA landform development model (Willgoose *et al.* 1989, Willgoose *et al.* 1991) parameters from data collected during the erodibility studies.
4. Assessment of erosion potential of batters constructed from topsoil and KGC material using WEPP erosion model. This included determination of constraints to achievable batter height and gradient.

3 MATERIALS

The main materials of Sandy Ridge have been previously assessed by Landloch. This included an assessment of the natural topsoils extent and properties (Landloch 2015a), and a chemical characterisation of the clay capping material (Landloch 2015b). These reports informed selection of the main materials considered in this study. They are:

1. **Topsoil (TE1)** – in the pits/cells area the main topsoil is a deep yellow sandy material. This topsoil is assumed to constitute the surrounding catchment of the pits/cells and the material that will be used to cover the KGC caps for final closure. Landloch travelled to site and collected the bulk samples of the topsoil for characterisation in the previous Landloch (2015) report.
2. **KGC (TE4)** - comprising of a composite of two samples, SRBS116 and SRBS117 from exploration drilling. Each sample is a blend of drill core material from 6 - 8m, 9 - 10m, and 12 - 31m and these two samples were in turn mixed to form the TE4 sample characterised in this report. The KGC material was supplied to Landloch by Tellus.

4 LANDFORM DESIGN METHODOLOGY

4.1 Overview

For this project, two models were used; WEPP and SIBERIA. The WEPP model was used to estimate long term erosion rates of the materials at typical batter configurations from

the design shown in Figure 5. The SIBERIA landform evolution model was used to assess the long term erosional durability of the waste facility design, and also assess the operational bunds. Material characterisation, model description and calibration are described below.

4.2 Determination of baseline properties

The fine components (<2mm diameter) of both the Sandy Ridge KGC and topsoil were assessed for the following chemical and physical characteristics:

- Soil $pH_{1:5}$;
- Electrical Conductivity ($EC_{1:5}$);
- Total N;
- Total P;
- Available (Colwell) P and K;
- Available Sulphur (KCl);
- Available trace elements (Cu, Zn, Mn, and Fe);
- Exchangeable cations (Ca^{2+}, Mg^{2+}, Na^{+}, K^{+} and Al^{3+});
- Exchangeable Sodium Percentage;
- Effective Cation Exchange Capacity;
- Particle size distribution of the fine material (sand, silt, clay);
- Saturated hydraulic conductivity;
- Organic Carbon; and
- Emerson class number.

These properties were used to:

- define the plant growth potential of the soil;
- identify any hazards posed using these materials in rehabilitation designs; and
- enable parameterisation of the WEPP model.

5 MATERIAL CHARACTERISATION

5.1 Baseline soil and KGC properties

Baseline soil and KGC data are provided in Table 1. Overall, the results support Landloch's previous studies (Landloch 2015a, 2015b) of the soil and KGC. In these studies the soil is a sandy, acidic, non-saline, low nutrient, slightly sodic material. The KGC is a sandy silt, neutral, low salinity, very low nutrient, sodic material.

Table 1: Baseline soil and KGC data.

Analyses	Unit	TE1 (Soil)	TE4 (KGC)
$pH_{1:5}$ in water	pH units	5.6	6.52
Electrical Conductivity ($EC_{1:5}$)	dS/m	0.03	0.17
Total Nitrogen	mg/kg	310	72.5

Total Phosphorus		mg/kg	31.8	65.9
Organic Carbon		%	0.64	<0.05
Plant Available Nutrients	Phosphorus - Colwell	mg/kg	9.2	7.9
	Potassium - Colwell	mg/kg	407	101
	Sulphur - KCl	mg/kg	3.9	17.9
	Copper – DTPA	mg/kg	0.4	0.35
	Iron – DTPA	mg/kg	26.2	3.6
	Manganese – DTPA	mg/kg	1.08	0.25
	Zinc – DTPA	mg/kg	0.16	0.19
Exchangeable Cations	Calcium	meq/100g	1	0.58
	Magnesium	meq/100g	0.23	1.39
	Potassium	meq/100g	0.16	0.20
	Sodium	meq/100g	0	0.81
	Aluminium	meq/100g	0.07	0.00
	Effective Cation Exchange Capacity	meq/100g	1.53	2.99
	Exchangeable Sodium Percentage	%	11.0	27.2
Particle Size Distribution of Fine Fraction (<2mm)	Coarse Sand 0.2-2.0mm	%	70.4	39.5
	Fine Sand 0.02-0.2mm	%	23.9	36.2
	Silt 0.002-0.02mm	%	3.3	18.8
	Clay <0.002mm	%	2.4	5.5
Emerson Class		Class	6	8
Saturated hydraulic conductivity		mm/hr	13.4	0.15

5.1.1 pH and salinity

The pH of the surface soil is acidic as expected. Previous results show that the deep yellow sand soils increase in acidity with depth. The KGC is slightly acidic and this result is replicated from many different depth levels analysed at Sandy Ridge.

Both the soil and the KGC have very low salinity values, with both having $EC_{1:5}$ values <0.17dS/m. Only one KGC sample previously analysed had a high salinity value, but this was the exception. Surface soils and the KGC material pH and salinity levels would not be expected to greatly inhibit plant growth.

5.1.2 Fertility

Both materials have very low nutrient levels, in particular the KGC material but this is expected. Rehabilitation plans should include a provision for soil amendment to increase the establishment of vegetation.

5.1.3 Exchangeable cations and dispersion

The Exchangeable Sodium Percentage (ESP) for the soil and KGC are above the 6% threshold (11% and 27% respectively). Although these materials would be defined as sodic, the likelihood of dispersion occurring from the topsoil would be low. It has a very low ECEC and very low clay content. Hence the high ESP value (calculated using the

ECEC value) hides the fact that very low concentrations of sodium actually exist on the soil exchange surfaces. Further, there is very low clay contents (2.4%) and therefore if clay dispersion was to occur, it would have very little impact on the structure of the material as a whole.

The KGC contains similar ECEC values and clay contents. The most significant risk posed by the presence of a potentially dispersive soil with elevated silt contents is the formation of hardset surfaces. Hardset soils are prone to increased runoff and erosion, and vegetation germination and establishment are adversely affected. A very hardset (and cracked) surface was observed by Landloch after the KGC material was packed into the test plots and underwent several wet/dry cycles (Figure 6). Agricultural gypsum could be added to the KGC to mitigate this risk during rehabilitation.

While surface cracking was observed, these pores quickly sealed during rainfall simulation leading to a very low saturated hydraulic conductivity result. This in combination with the low height of the waste facility caps would not constitute a high risk of these features tunnelling.

Figure 6: Kaolinised granite capping material in a Landloch test plot before rainfall simulation.

5.1.4 Saturated hydraulic conductivity

Both materials were packed into test funnels to determine their saturated hydraulic conductivity (KSat). As expected the sandy topsoil had the highest average value of 13.4mm/hr. Rockwater (2015) reported that the sandy soils can have an infiltration rate as high as 720mm/day.

The KSat results for the KGC material were very low. Landloch repeated the experiment by packing the funnels in layers with moist clay and compacting each layer to replicate the anticipated earth works practices of constructing the KGC cap by watering and rolling in layers. Landloch could not achieve any infiltration of water into this material.

6 COMPUTER SIMULATIONS AND RESULTS

6.1 Computer simulation of runoff and erosion from waste facility batters

6.1.1 The WEPP model

The WEPP model was developed by the United States Department of Agriculture to predict runoff, erosion, and deposition for hillslopes.

WEPP is a simulation model with a daily input time step, although internal calculations on days when rainfall occurs uses shorter time steps. Plant and soil characteristics important to erosion processes are updated every day. When rainfall occurs, those plant and soil characteristics are considered in determining the likelihood of runoff. If runoff is predicted to occur, the model computes sediment detachment, transport, and deposition at points along the slope profile.

The erosion component of the WEPP model uses a steady-state sediment continuity equation as the basis for the erosion computations. Soil detachment in interrill areas is calculated as a function of the effective rainfall intensity and runoff rate. Soil detachment in rills is predicted to occur if the flow hydraulic shear stress is greater than the soil's critical shear stress, and when the sediment load of the flow is below its transport capacity. Deposition in rills is computed when the sediment load is greater than the capacity of the flow to transport it.

All WEPP model simulations completed by Landloch uses a 100-year stochastic climate sequence for Kalgoorlie-Boulder developed from observed daily and sub-daily data from nearby weather stations.

6.1.2 Climate file

Climate sequences are needed to simulate runoff and soil loss with the WEPP model. For each day of simulation, the WEPP model requires ten daily weather variables:

- Precipitation (mm),
- Precipitation duration (hr),
- Peak storm intensity,
- Time to storm peak,
- Average minimum temperature,
- Average maximum temperature,
- Dew point temperature,
- Solar radiation,
- Wind speed, and
- Wind direction.

Of these, the four rainfall-related variables (underlined in list above) are of particular importance because previous studies have shown that predicted runoff and erosion are most sensitive to these rainfall variables (Nearing et al. 1990; Chaves and Nearing 1991).

For most sites around the world, complete historical weather data on these variables are not available. To use the WEPP model for runoff and erosion prediction, synthetic weather sequences that statistically preserve the mean and variations in the historical observations are required.

CLIGEN is a stochastic weather generator that can be used to provide WEPP model climate input files. CLIGEN has been extensively assessed for a wide range of climates in Australia, and it was found that CLIGEN was most suitable to provide the required climate input for the WEPP model to predict runoff and erosion in Australia (Yu 2003).

Daily climate data for Kalgoorlie-Boulder were sourced from the Australian Bureau of Meteorology (BoM). Rainfall intensity (6-minute pluviograph) data were also sourced from the Bureau of Meteorology for Kalgoorlie-Boulder.

Using the two data sets, the following parameter values were computed and used to develop the synthetic climate sequence for Sandy Ridge:

- Mean daily rainfall on wet days for each month,
- Standard deviation and skewness coefficient of daily rainfall for each month,
- Probability of a wet day following a dry day for each month,
- Probability of a wet day following a wet day for each month,
- Mean daily max. temperature for each month,
- Standard deviation of daily max. temperature for each month,
- Mean daily min. temperature for each month,
- Standard deviation of daily min. temperature for each month,
- Mean maximum 30-min rainfall intensity for each month, and
- Probability distribution of the dimensionless time to peak storm intensity.

These parameter values were assembled to create a CLIGEN parameter file for the site. Wind data (used to calculate soil evaporation) were not synthesised by CLIGEN because Priestley-Taylor's method for estimating the potential evaporation will automatically be used by the WEPP model. A 100-year climate sequence was generated using CLIGEN version 5.1 (Yu 2002).

6.1.3 Determination of WEPP model erodibility parameters

Although the concept of "erodibility" is broadly understood, its precise meaning can vary considerably within the framework of some erosion prediction models. The WEPP model (Flanagan and Livingston 1995) was used in assessing the erosion potential of landform designs for the Sandy Ridge Project. Within the WEPP model, erodibility is described via a number of specific parameters:

- Interrill erodibility (K_i);
- Rill erodibility (K_R);
- Critical shear for rill initiation (τ_c); and
- Effective hydraulic conductivity (K_e).

The WEPP model erodibility parameters for the KGC and topsoil surfaces were derived from data collected using laboratory-based experimental methods involving the application of:

- Simulated rain and measurement of runoff rate and sediment in runoff to obtain estimates of K_i and K_e; and
- Concentrated surface water flows to obtain estimates of K_R and τ_c.

Interrill erosion was measured by applying a simulated rain event with known rainfall intensity to simulation plots 0.75m wide and 0.75m long (Figure 7). The rainfall simulator configuration used in this report is described in Loch et al. (2001). Rill erosion was measured by applying overland flow to simulation flumes 0.4m wide and 2.0m long (Figure 8).

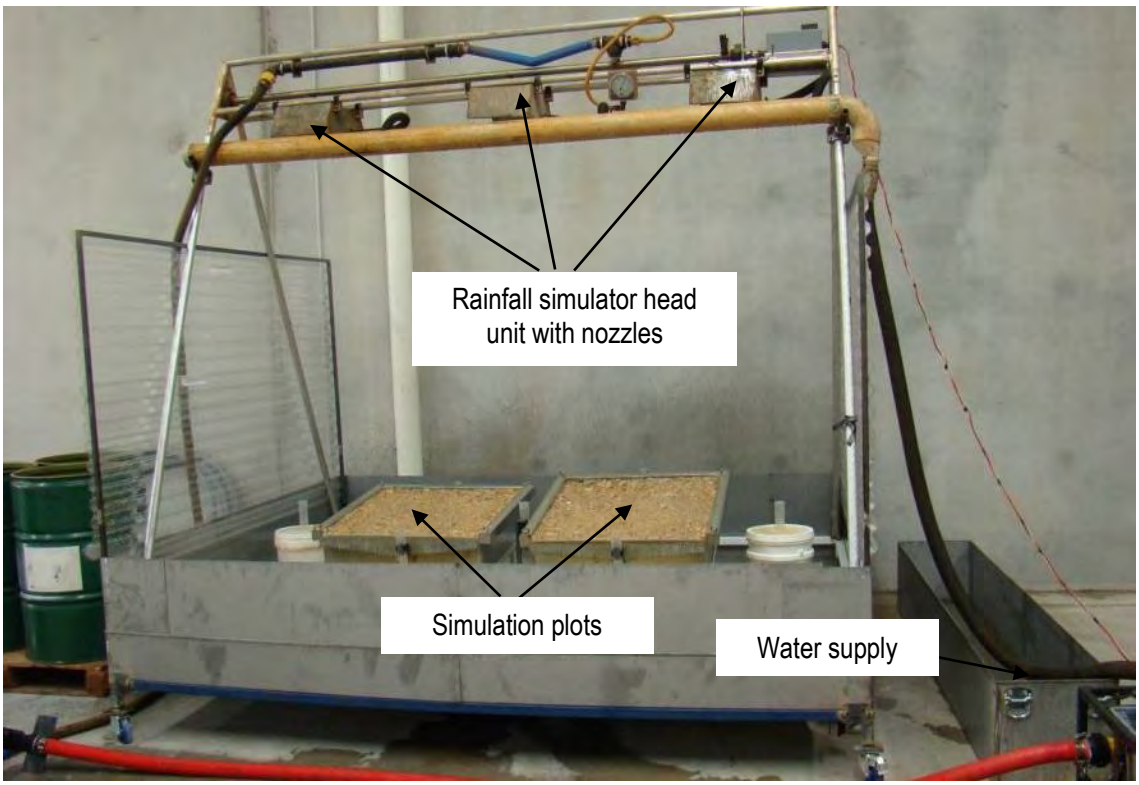

Figure 7: Laboratory-based rainfall simulator installation.

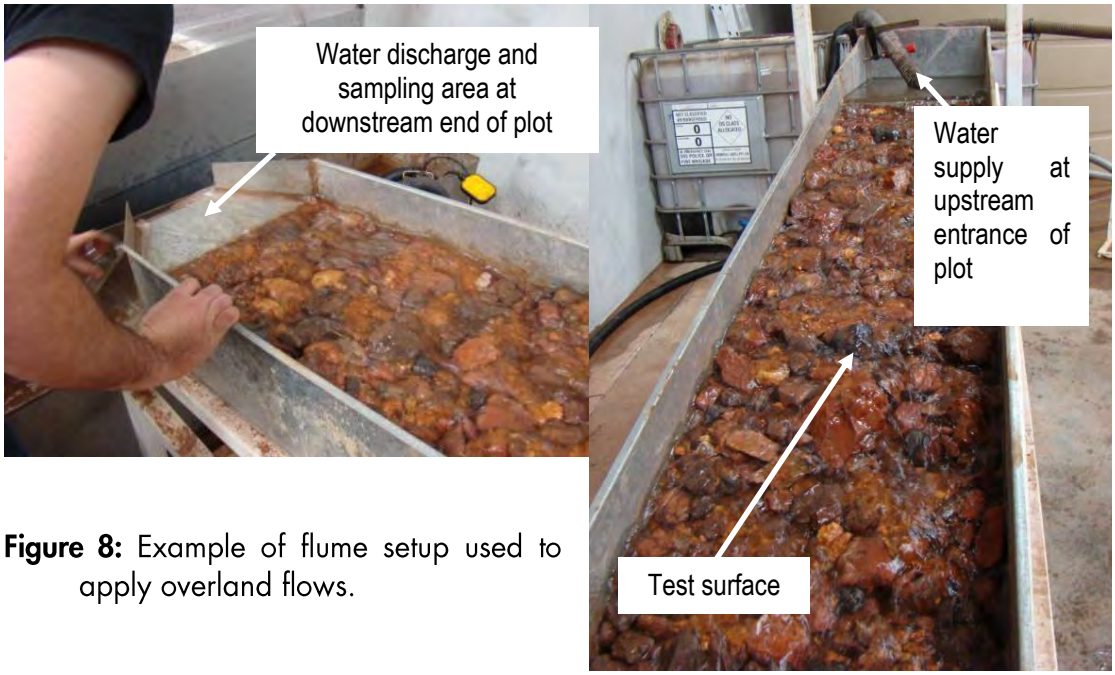

Figure 8: Example of flume setup used to apply overland flows.

6.1.4 Sediment properties

Estimates of erosion rates are sensitive to the particle size and density distributions of the eroded sediment. This is particularly true for situations in which erosion is strongly limited by sediment transport capacity such as can occur for cohesionless soils such as sands.

The version of the WEPP model available for general use has been coded to estimate sediment properties solely on the basis of input soil particle size data. However, Landloch has access to a version of the WEPP model not generally available that specifically allows input of detailed sediment particle size and density data. Consequently, this modified version of the model can more accurately predict erosion and has been applied in this study.

Settling columns (Figure 9) were used to develop equivalent sand size distributions for the sediment (Loch 2001). This approach is particularly useful as it integrates both particle size and density into a single testing parameter, and can be readily entered into the WEPP model.

Consequently, several samples of the rain-impacted surface of all samples were taken using sampling and handling methods described by Loch (1994).

Figure 9: Landloch's automated settling columns deployed on site in support of field based rainfall simulation.

6.1.5 WEPP model erodibility parameters

The WEPP model erodibility parameters derived by laboratory testing are provided in Table 2.

Within the WEPP model, effective hydraulic conductivity (K_e) is derived through analysis of a material's steady infiltration rate and runoff rates. The effective hydraulic conductivity values measured are high for the sandy topsoil in comparison to the KGC material. A higher hydraulic conductivity value will mean that runoff and erosion potential for the topsoil will be lower than that of the KGC material.

Interrill erodibility (K_i) describes the detachment and movement of particles by the combined action of raindrops and shallow overland flows. K_i values for the topsoil were slightly higher than for the KGC material.

Critical shear is an important property of material erodibility and describes the force of flowing water necessary to initiate rills. Both the soils and KGC material have very low values, similar to that of agricultural soils.

The rill erodibility (K_R) results for the two materials are similar. The relatively high K_R results combined with low critical shear means that little force is required within concentrated flows to initiate rilling, and that once initiated, detachment rates within rills will be high.

Table 2: WEPP model parameters derived from laboratory testing.

Parameter	Unit	TE1 (Soil)	TE4 (KGC)
Effective hydraulic conductivity, K_e	mm/h	39	6
Interrill erodibility, K_i	kg.s/m^4	1,177,986	823,302
Rill erodibility, K_R	s/m	0.0015	0.0012
Critical shear, τ_c	Pa	2.5	2.7

6.1.6 Definition of 'acceptable' erosion

The concept of 'acceptable' erosion is widely mentioned, but it appears to have little relevance to minesite rehabilitation. An acceptable erosion rate has been defined as a rate of erosion such that land productivity was not reduced, and is therefore of greatest relevance to agricultural situations. The definition ignores the pronounced temporal variations in erosion rates evident in arid regions and gives no information on the way in which that erosion may develop and impact on a landform over the long-term. In practice, rilling in one year may well develop into gullies in subsequent years if the erosion continues to incise the soil surface at a reasonably high rate at the same place. Alternatively, a rill may become armoured, and erosion rates reduce through time. To date, there is no methodology for assessing what is an acceptable erosion rate for rehabilitated lands.

With those issues in mind, Landloch's approach to landform design aims to create slopes on which rilling will be minimal or absent. Such slopes will have little potential to become heavily gullied, and any interrill erosion that occurs will be relatively insignificant relative to potential rates of erosion by rilling that could develop on long, steep, slopes. If rilling and gullying is avoided, the slope should be sustainable. (Surfaces eroded by interrill erosion typically become armoured in any case.)

Landloch has considerable experience in modelling erosion, and assessing erosion processes and rates in the field. In the WA Goldfields area, landforms designed with a predicted average erosion rate (averaged over the whole slope) less than **5t/ha/y**, together with a predicted maximum erosion rate at any point on the slope less than **10t/ha/y** exhibit a low tendency to rill.

These erosion threshold values were adopted as acceptable for this report. To date, observations made by Landloch on several sites indicate that this erosion threshold definition has produced batters with low rilling potential that have been consistent with rehabilitation success (DRET 2009).

6.1.7 WEPP model assumptions

Each material was used in several simulations of runoff and erosion. The typical waste facility batter configuration is 5m high with a 3° gradient. A slightly higher configuration of 7m high and 4° was simulated, along with a range of hypothetical 5m and 10m high batter sections was also run to compare the materials. All batters considered had a linear profile shape and did not contain berms. No allowance was made for vegetation effects on erosion. This is consistent with cover levels in the arid zone as vegetation tends to be

too low to effectively contribute to reducing erosion of steep batter slopes. No allowance was made for water from upslope areas to discharge onto the batter slopes.

6.1.8 WEPP model input conditions considered within simulations

WEPP model simulations were conducted on the two materials using the following model settings:

a) Rill spacing was set at 5 m. This will allow for some conservatism in the WEPP model erosion predictions.
b) Surface roughness was set at 3cm for all materials, consistent with the value used when calibrating the model runoff predictions using the rainfall simulator infiltration data. A roughness of 3cm is equivalent to a surface with elevations changes of ~0.2m (i.e. small rip lines).
c) The climate file used is based on the current climatic conditions and variations due to global warming were not considered.

6.1.9 WEPP modelling results

The WEPP model was run for the waste facility slopes of 5m and slope gradients of 3°, with some other hypothetical batter configurations also modelled. The results are given in Table 3. Cells shaded green indicate batter configurations that are at or below the defined erosion threshold levels. Cells shaded red indicate batter configurations that are above the defined erosion threshold levels.

Table 3: WEPP model results for the Tellus soil and KGC materials for a range of lineal batter configurations.

Batter Configuration			Long-term Annual Erosion Predictions (t/ha/y)			
			TE1 (Soil)		TE4 (KGC)	
Height (m)	Gradient (°)	Footprint (m)	Avg	Peak	Avg	Peak
5	3	95	0.17	0.21	4.22	6.85
5	4	71	0.3	0.37	5.58	9.26
5	5	57	0.41	0.54	6.55	11
7	3	134	0.17	0.2	5.09	7.83
7	4	100	0.29	0.35	6.63	10.5
7	5	80	0.42	0.52	7.97	12.9
10	10	57	1.18	1.53	17.15	28.4
10	15	37	1.65	2.31	18.45	31
10	18	31	1.79	2.58	18.66	31.5

6.1.10 Tellus topsoil

The results show that the sandy topsoil is within acceptable erosion limits for all batter configurations considered. The result is due to the relatively high effective hydraulic conductivity (K_e) value measured for the soil (Table 2). In this arid environment, there are not enough rainfall events of sufficient magnitude to generate runoff and transport the material off the batter.

6.1.11 Tellus KGC

Tellus KGC was modelled at the same configurations as the topsoil. The results were a contrast to the soil in that it eroded above the acceptable thresholds at all but the lowest gradient and height. This is attributable to a very low K_e resulting in many events that caused surface flows that readily detached material from the batter.

6.1.12 Summary

The results of the WEPP modelling indicate that:

- Batters constructed of KGC will erode at rates above the acceptable erosion thresholds for all but the lowest gradient (3°) and height (5m) configuration considered.
- Batters constructed of topsoil are more erosionally stable due to the high effective conductivity that prevents surface flows and the consequent erosion, but a suitable substrate would need to be provided.

6.2 Computer simulations of 3D landform evolution

6.2.1 The SIBERIA model

Long-term simulations (hundreds or thousands of years) of the impacts of erosion on a constructed landform can only be done using landform development models, of which the SIBERIA model (Willgoose *et al.* 1989, Willgoose *et al.* 1991) is the most developed and accepted.

The SIBERIA model is a 3-dimensional topographic model that predicts the long-term development of channels and hillslopes in a catchment on the basis of runoff, erosion, and deposition. The location and speed with which rills and gullies develop are controlled by a channelisation function. The SIBERIA model does not input actual rainfall or material erodibility parameters. Rather, the input parameters define this channelisation function that is related to both runoff and soil erodibility (Willgoose *et al.* 1989) and must be derived for each particular material at each particular site.

The SIBERIA model solves for two variables:

1. Elevation, from which slope geometries are determined, and
2. An indicator function that determines where channels exist.

Channel growth is governed by an activation threshold that is dependent on discharge and slope gradient. When the activation threshold is exceeded, a channel is predicted to develop. In this way, it is possible for a modelled surface to initially have no gullies, and for channels to develop when the activation threshold is exceeded.

The SIBERIA model has been successfully applied to explain aspects of geomorphology of natural landforms (Willgoose 1994) and has been extensively used in the context of mining, and subjected to extensive validation. In general, the validation work indicates that, provided the model is adequately calibrated, SIBERIA predictions of landform development appear to be reasonable (Hancock *et al.* 2000, Hancock *et al.* 2002, Hancock *et al.* 2003, Willgoose *et al.* 2003). In addition, Hancock (2004) notes that rates of erosion predicted by the SIBERIA model for a catchment in the Northern Territory

compared favourably with estimates of erosion derived using the caesium-137 method. As the two methods used completely independent input information, the agreement is particularly significant.

The SIBERIA model has been widely used for assessment of the development of constructed landforms on a range of mine sites across Australia and overseas (Willgoose 1995, Willgoose and Riley 1993, Boggs *et al.* 2000, Hancock *et al.* 2003, Hancock and Willgoose 2004, Hancock 2004, Mengler *et al.* 2004, Hancock and Turley 2006). The model is equally applicable to any climatic regime as its input parameters are derived by calibration to runoff and erosion data. Input parameters can be derived from output from the WEPP model using methods developed by Landloch in consultation with the developers of SIBERIA.

6.2.2 The SIBERIA model input parameters

The SIBERIA model predicts the long-term average change in elevation of a point by predicting the volume of sediment lost from a node. The rate of sediment transport through a node (q_s in units of m^3/y) is determined by the equation:

$$q_s = \beta_1 \times q^{m_1} \times S^{n_1} \qquad 1)$$

where β_1 is the sediment transport rate coefficient, q is discharge (m^3/y), m_1 is the discharge exponent, S is the slope (m/m), and n_1 is the slope exponent. The SIBERIA model does not directly model runoff, but uses sub-grid effective parameterisation which relates discharge to area draining through a point as:

$$q = \beta_3 \times A^{m_3} \qquad 2)$$

Where β_3 is the coefficient between discharge and area, A is area (m^2), and m_3 is the exponent of the area in discharge.

To run the SIBERIA model, the parameters β_1 , m_1, n_1, β_3, and m_3 are usually needed. However, if the batter area to be modelled is identical to the batter for which erosion data is available for calibration, m_3 and β_3 can be taken as 1.0 and a value of 1.5 for n_1 can be adopted for situations where slope gradient does not affect slope erodibility (Willgoose pers. comm.). Where steeper slopes are subject to greater armouring, the exponent n_1 may be as low as 0.7 (Evans *et al.* 1998). Therefore, the two key parameters that require derivation are β_1 and m_1.

Effectively, the β_1 parameter could be described as an erosion rate parameter, as it primarily controls the rate of sediment movement. The m_1 parameter could be described as primarily controlling slope length responses. However, in practice, there is interaction between all of the parameters with the result that an almost infinite number of parameter sets will all show the same rate of erosion though some aspects of the pattern of erosion that is predicted will vary. For this reason, fixed values of n_1 and m_3 are adopted where possible, reducing the difficulty of deriving parameter values.

6.2.3 Derivation of the SIBERIA model input parameters from laboratory data

Input parameters for the SIBERIA model are typically derived by fitting the model equations to time series data of runoff and erosion. However, in most instances, sufficiently long series of these data is not available for landforms of interest. Therefore, in consultation with the model developers, Landloch has developed an alternative approach for developing the required input parameters. The general approach applied is to:

a) Make laboratory or field based measurements on materials to derive calibrated WEPP model parameters.
b) Run the WEPP model to generate data sets of runoff and erosion for batter slopes and materials of interest using long (100 years), site specific climate sequences.
c) Analyse the WEPP model output to derive the required SIBERIA model input parameters.

6.2.4 Derived SIBERIA model input parameters

The derived SIBERIA model parameters are provided in Table 4.

Table 4: SIBERIA model parameters derived from laboratory testing.

Parameter	TE1 (Soil)	TE4 (KGC)
m_1	0.9821	0.9739
β_1	0.00155	0.032147

6.2.5 SIBERIA model assumptions

The SIBERIA model is used in this study to primarily focus on the long term erosional stability (10,000 years) of the waste facility. It has also been used to examine the durability of the operational bunds. The assumptions used for the long term landform evolution of the waste facility are:

- To ensure the best possible resolution, the eastern cells were used to assess the long term erosional response of the waste facility design.
- The SIBERIA model was calibrated with the topsoil (TE1) material parameters.
- The eastern cells are assumed to be rehabilitated and therefore are covered in a deep layer of topsoil. This simulation does not include the 0 – 10 year inspection phase were the KGC caps are left exposed.
- No vegetation was assumed on the waste facility. The observed native vegetation growing on the sandy topsoils were dispersed shrubs with single stems. The assumption of no vegetation adds a level of conservancy to the model results.
- The SIBERIA model simulated the long term runoff and erosion of the eastern cells for a 10,000 year period, and land surface evolution changes were captured at 50, 100, 250, 500, 750, and 1,000 year periods, and then every 1,000 years to 10,000 years.

To examine the durability of the operational bunds (life ~25 years), the SIBERIA model used the following assumptions:

- A sub-catchment was delineated that was contributing to the northern cells that was bordered by the northern operational bund (Figure 5).
- The SIBERIA model was calibrated with the KGC material parameters.
- The operational bunds were assumed to be constructed from the KGC material.
- The contributing catchment was assumed to be the KGC material, so that a 'worst case' scenario could be modelled as the KGC has a low infiltration rate and therefore in the arid Sandy Ridge climate, would more readily conduct flows from rainfall events onto the operational bunds.
- As the operational bunds are a relatively narrow feature and the SIBERIA model has input grid size limitations, the bund's width (but not height) was increased so that the feature was able to be delineated within the available cell size, and to also include the contributing catchment.
- SIBERIA simulated the long term runoff and erosion of the waste facility operational bunds for a 1,000 year period, and land surface evolution changes were captured at 50, 100, 150, 200, 300, 400, 500, 750, and 1,000 year periods.

As the SIBERIA model is calibrated to WEPP parameters, SIBERIA uses the same climate assumptions as described in Section 6.1.2.

6.2.6 SIBERIA model results: waste facility long term landform evolution

The results for the 10,000 year landform evolution model runs of the eastern cells using the SIBERIA model are shown in Figure 10. The results show that there is predicted to be relatively little change to the waste facility surface over the simulation period. There has been surface lowering along the cell batters, but this is typically less than 200mm. The material has been eroded from the individual cell batter slopes and deposited in between the cells with maximum deposition values of 500mm. This deposition can be seen in cross section A-A shown in Figure 10. The cross section is shown in Figure 11. The profile shows the deposition of material in between the cells and toe of slope, but no discernible changes to the waste facility batters or cell height.

The most significant surface change has occurred along the western side in between the individual cells and indicated by the arrows in Figure 10, and these small gullies are termed 'north,' 'middle', and 'south.' After the 10,000 year model run, the maximum erosion results (i.e., the greatest reduction in the Z value between the original surface and final simulation) is 412mm for the northern gully, 536mm for the middle gully, and 697mm for the southern gully. This appears to be caused by water flow from the cell batters into the mid lines, and then from the mid lines draining towards the west.

The Sandy Ridge topsoil is a sandy material that has a high infiltration rate and in combination with the arid climate, there are very few events that lead to any significant runoff. Where runoff does occur, the gentle batter gradients ensure flow velocities are low and does not entrain material and form significant rilling. If the sheeting of topsoil over the KGC material for rehabilitation is >1m, then it would be anticipated that even the small gully development will not intersect the clay capping material below.

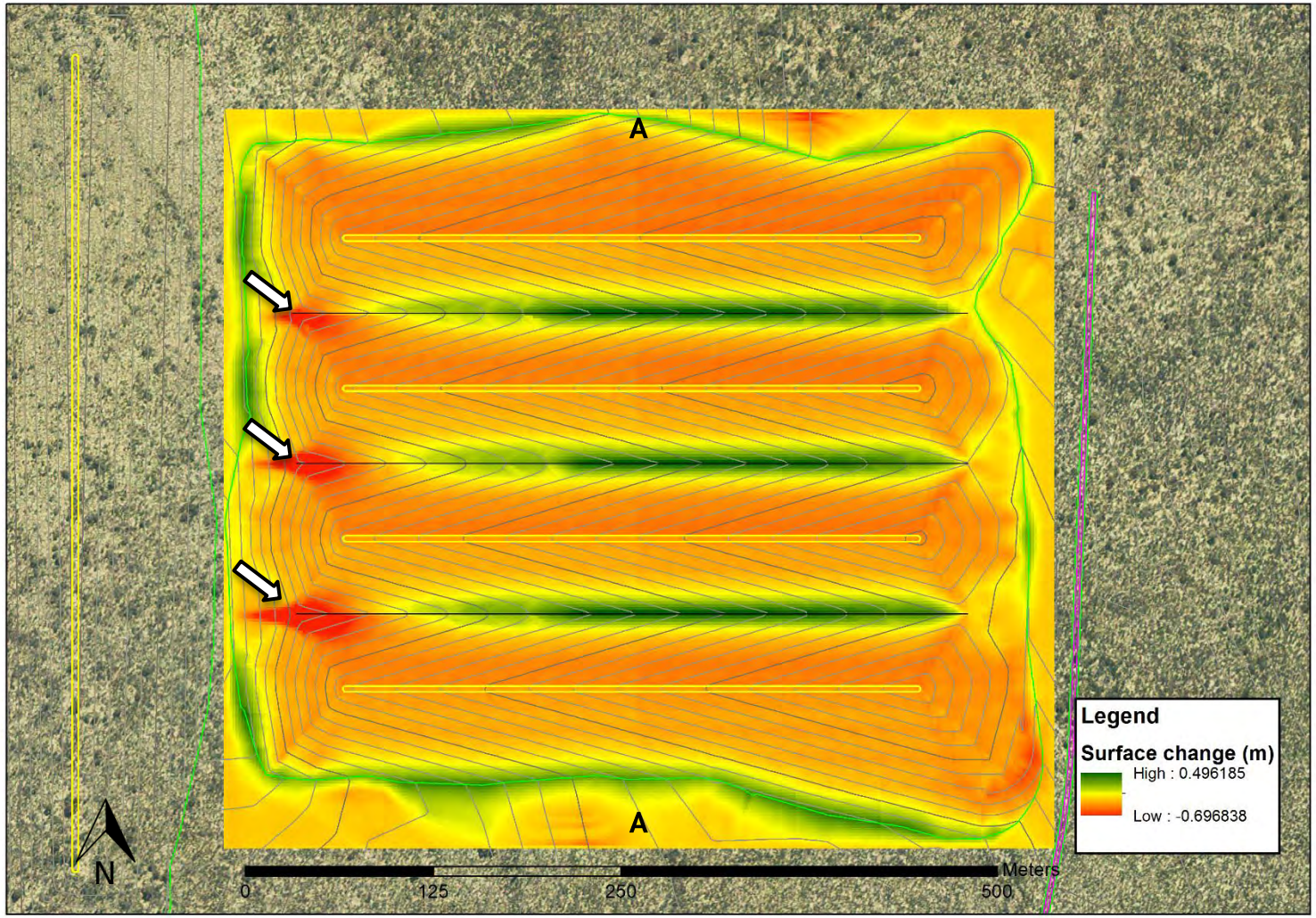

Figure 10: SIBERIA model 10,000 year results for long term landscape evolution of the eastern cells.

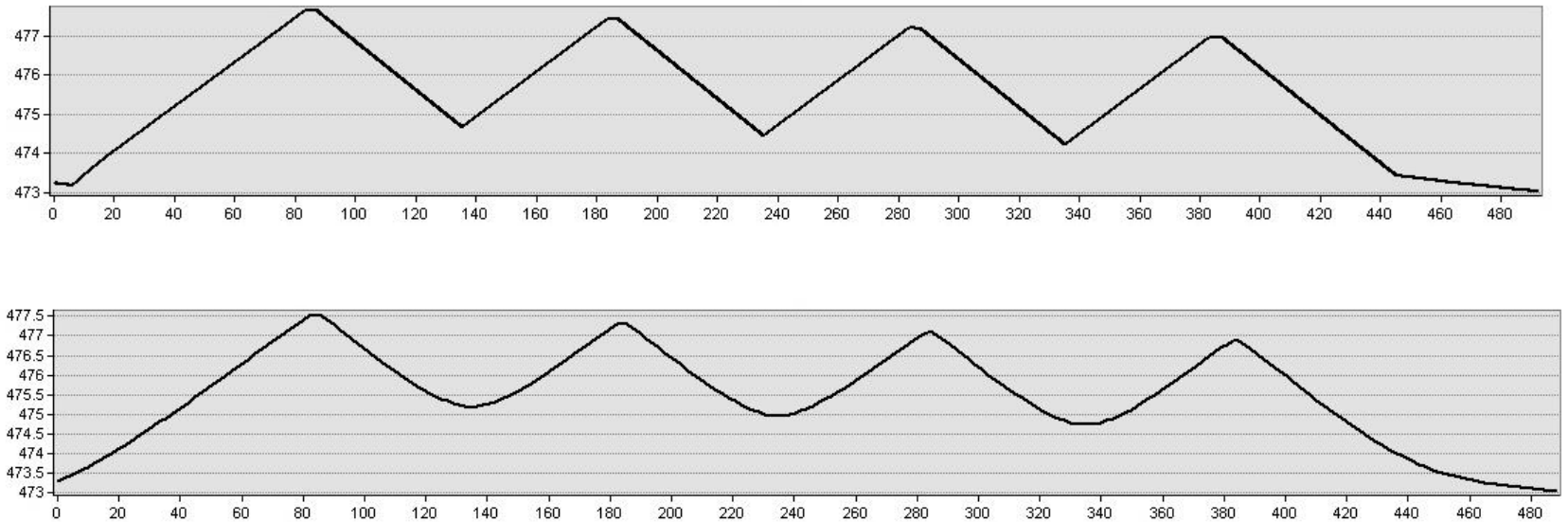

Figure 11: SIBERIA model results cross section for the original surface (top) and 10,000 year simulation (bottom). Axes in meters.

6.2.7 SIBERIA model results: operational bunds

The results are shown in Figure 12 for a 200 year period of simulation. The cross sections show that the KGC flood bunds lose their shape relatively quickly and halve in elevation over 50 years. As was identified in the original hydrology report, the flood bunds are to intercept potential surface flows of around 20cm. The bunds appear to be functional from this point of view for around the 100 year period, but then have eroded to a point where they will not be able to intercept flows of this magnitude. As seen on the cross sections, the width of the flood bunds is much greater than is proposed in the waste facility designs. It is only the mass of material that remains once the batter angles have been decreased over the shorter term that keeps these features distinguishable on the landscape over the longer period. As the bunds are only intended to function for ~20 years, the model results would indicate that they would remain functional for this period but Tellus operational staff may need to inspect and repair them during the mining operations. There may also be an implication for closure as the operational bunds will most likely erode to a point where they are indistinguishable from the natural surface over the much longer term.

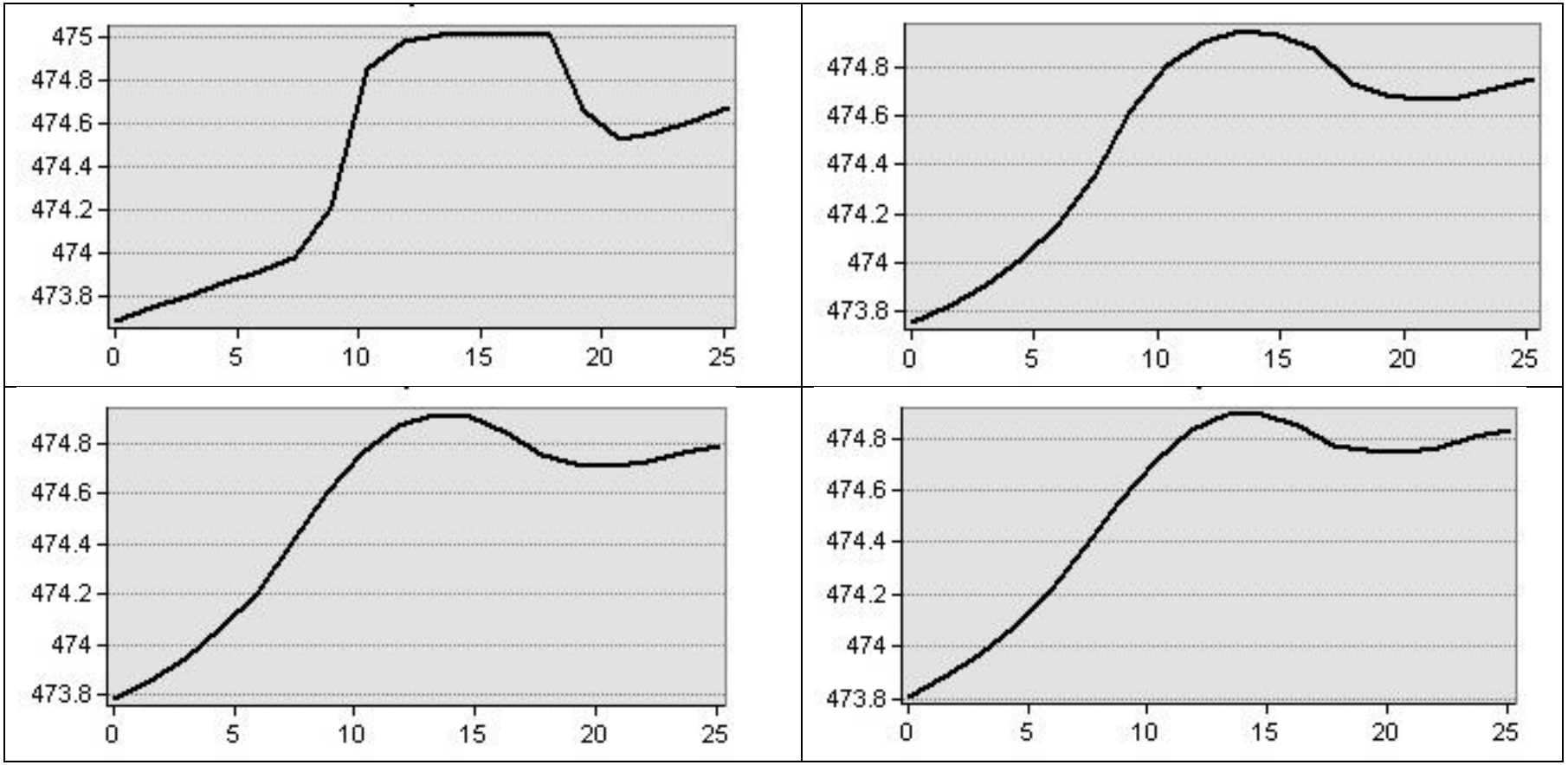

Figure 12: SIBERIA model results for the flood bund cross section for year 0 (top left), 50 years (top right), 100 years (bottom left), and 150 years (bottom right). Horizontal axis in meters, vertical axis in centimetres.

7 DISCUSSION

7.1 Model limitations

The WEPP model has been widely used and is well understood. Landloch has been using this model since 1998 and has been constantly developing methods for improved calibration and model accuracy, the most recent example being the acquisition of a modified version that allows incorporation of material particle size and destiny into erosion prediction. Landloch has also been conducting work on WEPP model validation by comparing simulation results with field erosion plot data, and there has been good agreement between the two data sets (Howard and Roddy 2012). The WEPP model, when run in hillslope mode, is not suited to modelling very complex landscapes (e.g., dissected) or for landscapes with permanent rivers or gullies as these processes are not simulated within the model. However, the WEPP model is well suited to erosion simulation on waste landform batters.

The SIBERIA model's main limitation is that it evolves the landscape constantly through the period of simulation at a rate equal to the long-term erosion rates. It does not consider erosion caused by individual events. Consequently the model is best suited for landscape evolution studies over long periods and not focussed on single events or short periods of time. As with all models, calibration is important and the SIBERIA model is most reliably calibrated from WEPP model output that in turn was derived from measurements made on the specific materials.

It should be noted that no model is currently able to adequately represent physical processes in conjunction with erosion, such as long term physical and chemical weathering of materials, vegetation and actual climatic changes, and bush fires.

7.2 Climate sensitivity

The original scope of works presented to Landloch from Tellus was to investigate the erosional stability of the waste facility for a range of climatic events. Using the most extreme climate change emission scenario of RCP 8.5[1], ~30% of the models predict a wetter climate; ~70% predict little change or a dryer climate for Australia's arid interior as shown in Table 4 (Whetton *et al.* 2012). A detailed climate change assessment of the Pilbara found the largest increase to annual rainfall estimated is an extra 24 to 30mm/yr for RCP 8.5. There was also a corresponding increase in potential evaporation of 77mm/yr for the same scenario (Charles *et al.* 2015). Assuming that an increase to annual rainfall of 24-30mm/yr did occur and the hypothetical result was a doubling of the waste cell long term erosion rate, this would mean that the erosion rate is an order of magnitude lower than Landloch's threshold of acceptable erosion.

[1] Representative Concentration Pathway of 8.5Wm^2 in 2100, with a CO_2 equivalent of 1370ppm, and temperature anomaly of 4.9°C (Riahi *et al.* 2011).

Table 4: Predicted changes to annual rainfall and mean surface temperatures from 48 Australian climate change models for the arid interior.

		Annual Mean Surface Temperature (C)			
		Slightly warmer <0.5°	Warmer 0.5 - 1.5°	Hotter 1.5 - 3°	Much hotter >3°
Annual Rainfall (%)	Much wetter >15			3	4
	Wetter 5 to 15			1	7
	Little Change -5 to 5				11
	Drier -15 to -5				9
	Much Drier < -15			1	12

7.3 Modelling results and the current proposed design

From the material characterisation of the topsoil and the KGC, the long term erosion modelling using WEPP, landscape evolution modelling using SIBERIA, the following points are made in relation to the current proposed waste facility design:

- The topsoil and KGC material's fine particle size distribution, low critical shear, and high interrill and rill erodibility indicate that both materials are prone to erosion.
- The topsoil's high saturated conductivity however means that rainfall will infiltrate and may not be converted to runoff (as is the case for the KGC) and therefore produces less erosion events than the KGC material.
- The predicted erosion of topsoil is below the threshold of acceptable erosion for 10m high landform with linear batters up to 20°, whereas erosion of the KGC material is only below this threshold at low height (<5m) and gradient (<4°) configurations.
- The proposed waste facility design of 5m high cells with 3° batters covered with a deep layer of topsoil is erosionally stable over the very long term due to the permeability of the topsoil, arid climate, and a gently sloping design. The model results indicate that the topsoil layer should be at least 1m thick.
- The KGC material will be suitable for the construction of operational bunds (life ~20 years) provided they are inspected and maintained as necessary.

7.4 Potential design modifications

7.4.1 Cover design

The SIBERIA model results show that there is some direction of flows into the between cell areas, which are then conveyed to the cell outlets where the greatest surface

lowering occurs (Figure 10). The following design modification are suggested to potentially improve the waste facility design and may to be considered for further work.

7.4.2 Cover materials

The present design calls for each cell to be capped with KGC and left exposed to allow for subsidence inspections. The modelling results show that the KGC material is hardsetting and erodible, and this can be observed on the caps of previous stockpiles of kaolin where the material rills and delivers fine material out into the receiving environment (Figure 13).

In low rainfall arid zones where the evaporation rate is high, there are rarely (if any) rainfall event that would wet the soil profile deeper than ~500mm (assuming a soil porosity of 30% and a 150mm storm event) (R. Loch *pers. comm*). This is combined with the Mt Walton study stating that there is currently no water tables in the area (Dept. of Finance 2014), and that there may be 8 to 23m of compacted KGC material between the waste and the ground surface. Rather than designing impermeable above ground caps that are likely to erode, change surface hydrology, require follow up rehabilitation for closure, and costly earth works to compact and construct, some potential alternatives may use the available materials' inherent properties to achieve design aims and closure goals.

Figure 13: KGC stockpile in Western Australia with eroded fine material indicated by the arrow.

7.4.2.1 Store and release cover

As it is unlikely that surface water will penetrate to significant depth, the use of an impermeable cap may not be required. It may be better to design a cover that will store any rainfall, make it available for plants, and hold the moisture for evaporation. The design would:

- Follow the proposed design for the deeper layers,
- Place KGC into the top part of the pit (machine trafficked, not compacted) so that a low dome is formed above the ground surface,
- The KGC material is amended to prevent hard setting,
- 500mm of topsoil is placed over the KGC material, fertilised, and seeded (Figure 14).

The advantages of a cover would be that it would not place an erodible material on the surface for a long period of time. It would reconstitute the natural topsoil so that it could hold moisture and allow the regeneration of native plants. It would also mean more efficient earth works to construct (i.e., no compaction in thin layers) and eliminate the necessity to return in a decade to complete the rehabilitation. The other advantage is that it would avoid constructing a texture contrasting profile where a highly permeable material is placed over a highly impermeable material. The drainage pattern of a natural texture contrast soil is shown in Figure 15. There is a potential for subsurface drainage to be initiated after final rehabilitation that would lead to the erosion of the surface material. A store and release cover would seek to minimise the hard contact of the KGC with the sandy topsoil.

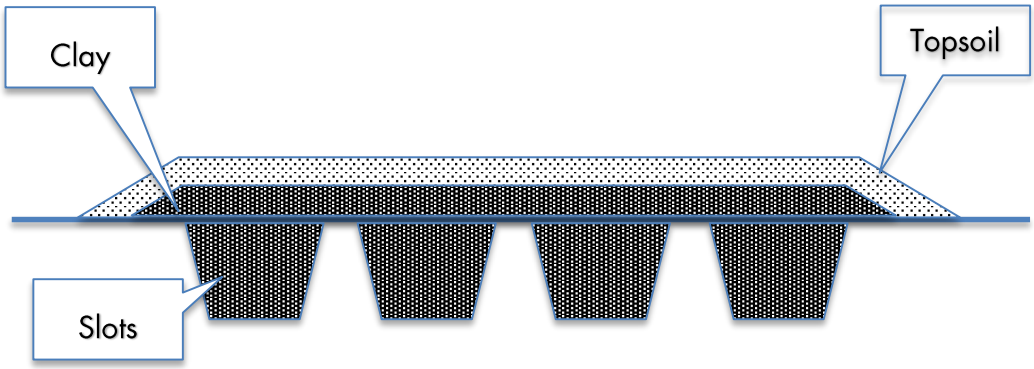

Figure 14: Store and release cover system.

Figure 15: Texture contrast soil (sand over clay) and the subsurface drainage pattern (green dye).

7.4.2.2 Re-established drainage surface

A modification to the store and release design would be to reinstate the previous natural surface as practically as possible. This would require the KGC material to be backfilled to within ~1m of the surface, with sandy topsoil used to bring the level up to the original RL (Figure 16). Settlement of the materials would have to be factored in, but the advantages of the design would be a very low relief/low erosion surface that would store and release water but that matches the aesthetics of the surrounding areas. Vegetation would also be re-established to further aid the stability of the surface, mimicking the present catchment function/erosional stability due to low relief and broad sheet wash drainage patterns.

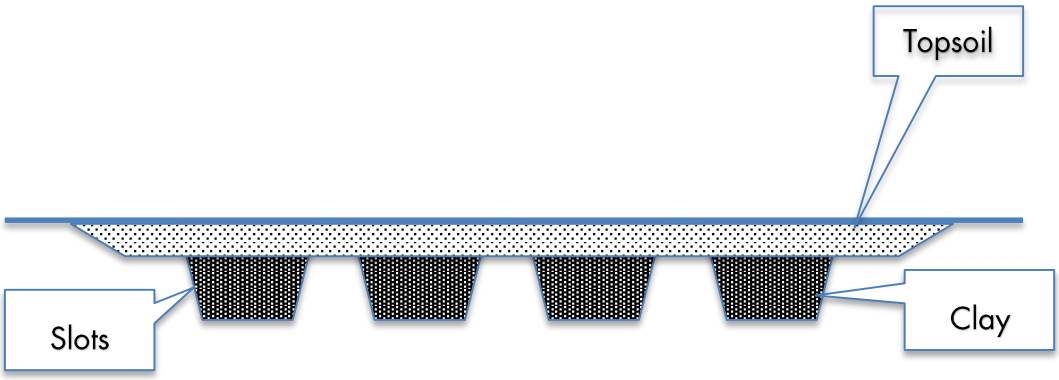

Figure 16: Reinstated natural surface cover system.

7.5 Further works

As the WEPP and SIBERIA models are now calibrated, these could be rapidly run to examine any modifications to the current waste facility design (such as doming the capping layer) and assessing changes to the mining plan. Also of value would be to confirm the water movement into the near-surface subsoil material using soil water balance modelling. This modelling can examine the water movement through a profile of different materials and could compare the effectiveness of the proposed KGC caps against any store and release design.

This report did not explore the impacts of wind erosion. This may potentially be a factor in placing sandy topsoil over 5m thick KGC caps in a low relief arid environment. The correct use of tree debris will likely be important in minimising the wind's surface contact with the reinstated topsoil (Figure 17).

Topsoil and KGC material amendment and fertilisation (to encourage the rapid development of native vegetation) has not been detailed in this report. Amendment and fertilisation rates and application techniques could be recommended based on existing material characterisation data.

Field trial plots would also be beneficial to validate model results, assess the placement of sandy topsoil over clay, and trial wind erosion and vegetation establishment strategies.

Figure 17: Example of using tree debris on a freshly reinstated sandy topsoil on a waste dump to minimise wind erosion in Western Australia.

8 CLOSING

The long term landform evolution modelling indicates that the rehabilitated waste facility at Sandy Ridge is erosionally stable over the very long term. Landloch has identified some potential improvements for the proposed waste facility design. These primarily involve eliminating the flow concentrating features, and examining alternatives to the capping layer design that may best work with the natural materials to ensure a long term erosionally stable surface and support the reestablishment of native vegetation.

Erosion potential for the main materials from the Sandy Ridge Project have been assessed. The assessment is based on:

- Consideration of the prevailing climate and its erosivity.
- Known factors critical for stability of natural and disturbed surfaces.
- Assessment of the variability of materials found on site.
- Characterisation of the erodibility of the typical surface materials present.
- Computer simulations of runoff and erosion on the range of typical slopes.
- Consideration of the role of rock on erosion potential.
- Issues relating to measured sediment characteristics.

Consequently, the results are based on site data and its interpretation using well-validated procedures.

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Terrestrial Fauna Surveys

TELLUS

Level 1 Vertebrate Fauna Assessment for the Sandy Ridge Project

Version 4. July 2016

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Front Cover: Tawny Frogmouth – *Podargus strigoides* (one was flushed from a tree during the field assessment)

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EXECUTIVE SUMMARY

Tellus Holdings Limited (Tellus) has undertaken a preliminary drilling program to assess the mineralisation on part of its tenement (E16/440) in the Shire of Yilgarn. Tellus proposes to develop a kaolin mine with complimentary storage and waste isolation facilities at its Sandy Ridge Project. The Sandy Ridge Project is approximately 140km north-west of Kalgoorlie and 75km north-east of Koolyanobbing, WA.

A Level 1 fauna assessment was undertaken to provide an indication of the vertebrate fauna assemblage (reptiles, amphibians, small mammals and birds) on and in the vicinity of the project area so that potential impacts on the fauna might be adequately assessed, to assess whether the proposed impact area supports active Malleefowl mounds and to assess the impact and environmental risks associated with the proposed development on the fauna assemblage.

There were two broad fauna habitats present in the project area; an open eucalypt woodland with an open understorey of shrubs over ephemeral grasses or scattered spinifex on red sandy clay soils, and a moderately dense to dense sand plain shrubland varying in height from 0.5-1.8m on yellow sandy soils. The project area contains a few vehicle tracks and there has been some exploration drilling and associated access tracks in the proposed mine pit and infrastructure development areas. Other than this disturbance, the habitat is in very good to excellent condition.

Because of the two broad fauna habitat types and the limited disturbance to the area, the fauna assemblages are likely to be intact and diverse, except for the impact of feral predators. There is a low possibility that Major Mitchell's Cockatoo, Western Rosella and Woma are potentially in the project area. However, the proposed impact area is small (~52ha), so the probability of significantly impacting on any of these species is very low. The project area was searched for Malleefowl tracks and mounds and none were found. Therefore there is a very low probability of impact on this species.

Other conservation significant species that are potentially in the project area include the Rainbow Bee-eater, Fork-tailed Swift, Peregrine Falcon, Crested Bellbird, Bush Stone-curlew, Australian Bustard and the Central Long-eared Bat. These aerial species will readily move into adjacent areas when vegetation clearing commences and the mine becomes operational, so any impacts on these species when considered in a bioregional context will be very low. Vegetation clearing will result in the loss of numerous small vertebrates in the project area and indirect impacts such as a reduction or loss of activity areas and closure of burrows, habitat fragmentation, increased presence of feral predators, road deaths and unnatural noises, vibrations, artificial light sources and vehicle and human movement in an area may force animals into adjacent areas.

To mitigate and minimise impacts on vertebrate fauna it is recommended that:

- information on protecting fauna and reporting deaths and sightings of Malleefowl and other conservation significant species should be incorporated into the project induction program;
- all areas disturbed during exploration are rehabilitated as soon as practical after they are no longer required;
- where possible, access routes are aligned to existing roads, tracks and other barriers or follow the boundaries of broad-scale vegetation associations in the area;
- pets are not permitted on the project;
- all waste and rubbish be contained in bins and regularly removed from the project or placed in landfill;
- feeding of native fauna is prohibited;
- a log of all on-site drill holes is maintained detailing when they were capped, how and by whom; and
- a fauna management plan is prepared and implemented for the life of the project.

1 INTRODUCTION

1.1 Background

Tellus Holdings Limited (Tellus) has undertaken a preliminary drilling program to assess the mineralisation on part of its tenement (E16/440) in the Shire of Yilgarn. Tellus proposes to develop a kaolin mine with complimentary storage and waste isolation facilities at its Sandy Ridge Project.

The Sandy Ridge Project is located approximately 140km north-west of Kalgoorlie and 75km north-east of Koolyanobbing, WA (Figure 1). The assessed project area included all the area with purple and blue boundaries in inset A, within the blue boundary in inset B and within the green boundary in inset C in Figure 2 ('project area').

1.2 Project objectives and scope of works

Terrestrial Ecosystems was commissioned by Tellus to undertake a Level 1 fauna assessment which will be included with environmental approval documentation when seeking to develop the project as a kaolin mine. The purpose of this fauna assessment was to provide information to enable an assessment of potential impacts from the proposed development activity on the vertebrate fauna assemblage that could be present in the project area. The methodology broadly follows that described in the Environmental Protection Authority (EPA) Position Statement No. 3: *Terrestrial Biological Surveys as an Element of Biodiversity Protection* (EPA 2002), Guidance Statement No. 56: *Terrestrial Fauna Surveys for Environmental Impact Assessment in Western Australia* (EPA 2004) and the *Technical Guide – Terrestrial Vertebrate Fauna Surveys for Environmental Impact Assessment* (EPA / DEC 2010).

The objectives of this fauna assessment were to:

- provide an indication of the vertebrate fauna assemblage (reptiles, amphibians, small mammals and birds) on and in the vicinity of the project area so that potential impacts on the fauna might be adequately assessed;
- assess whether the proposed impact area supports active Malleefowl mounds; and
- assess the impact and environmental risks associated with the proposed development on the fauna assemblage.

To achieve these objectives, Terrestrial Ecosystems has:

- reviewed Terrestrial Ecosystems fauna survey database [includes WA Museum and Department of Parks and Wildlife (DPaW) records] to identify potential vertebrate fauna within the project area and surrounds;
- reviewed DPaW listed Threatened and Priority species as recorded in NatureMap that are likely to occur in the project area and surrounds;
- searched the Commonwealth government's on-line database to identify fauna species of national environmental significance that are protected under the *Environment Protection and Biodiversity Conservation Act 1999* (*EPBC Act 1999*) potentially occurring in the project area and surrounds;
- reviewed previous fauna surveys conducted in the region;
- undertaken a one day reconnaissance survey of the project area, which included a search for Malleefowl tracks and mounds; and
- provided a discussion of the likelihood of *EPBC Act 1999* and *Wildlife Conservation Act (1950)* listed species being present in the project area.

2 EXISTING ENVIRONMENT

2.1 Southern Cross IBRA subregion

The project area is located in the Coolgardie (COO2 – Southern Cross) Interim Biogeographic Regionalisation for Australia (IBRA) sub-region. The Southern Cross subregion is characterised as a weathered plain comprising gently undulating uplands dissected by broad valleys with bands of low greenstone hills. The subregion contains a diverse eucalypt woodland (*Eucalyptus salmonophloia, E. salubris, E. transcontinentalis, E. longicornis, E. leptopoda, E. platycorys, E. scyphocalyx*) and low heaths (*Allocasuarina corniculata*, *Callitris preissii*, *Melaleuca uncinata*, *Acacia beauverdiana*; Cowan et al. 2002).

2.2 Climate

Chart 1 shows the average mean monthly maximum and minimum temperatures and rainfall for Southern Cross, the closest weather station. Temperatures are highest in December – February. Most rain comes in mid winter. Winter rain is the result of low pressure cells that move in an easterly direction from the south-west of the state, whereas, summer rain is often from thunderstorms that move in from either the west or the north-west.

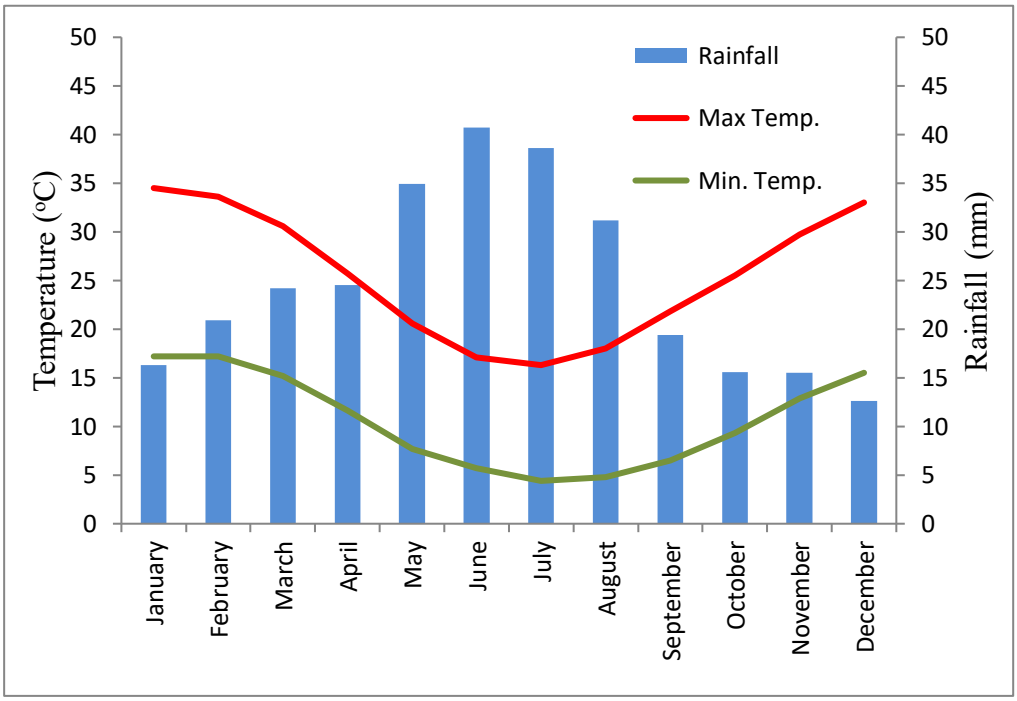

Chart 1. Mean monthly maximum and minimum temperatures and rainfall for Southern Cross

2.3 Land use history

The dominant land uses in this bioregion are pastoralism, crown reserves and mining. Mining is evident in many areas around Southern Cross, Yellowdine and Koolyanobbing, with numerous small abandoned mines and open shafts throughout the Yilgarn landscape. Many of the larger trees in the bioregion were removed decades ago to support the mining and power generation industries and these trees have often not been replaced by replanting programs.

2.4 Previous biological surveys in the region

The frogs, reptiles, mammals and birds in the vicinity of the project area have been previously surveyed. Surveys in the vicinity of the project area that have been reviewed as part of this assessment include:

Bell, D. T., Bell, R. C. and Loneragan, W. A. (2007) Winter bird assemblages across an arid gradient in south-west Western Australia. *Journal of the Royal Society of Western Australia,* 90, 219-227.

Dell, J. and How, R. A. (1985) Vertebrate fauna. In Dell; J; How; RA; Newbey K.R. and Hnatiuk RJ. The Biological Survey of the Eastern Goldfields of Western Australia Part 3; Jackson - Kalgoorlie. *Records of the Western Australian Museum*, Supplement No 23, pp. 39-66.

Dickman, C.R., Henry-Hall, N.J., Lloyd, H. and Romanow, K.A. (1991) A survey of the terrestrial vertebrate fauna of Mount Walton, western goldfields, Western Australia. *Western Australian Naturalist*, 18, 200-206.

Ecologia Environmental Consultants (2001) *Koolyanobbing Expansion Project - Fauna Assessment Survey*. Unpublished report for Portman Iron Ore Limited, Perth.

Ecologia Environmental Consultants (2003) *Koolyanobbing Expansion Project - Transport Corridor Fauna Assessment Survey*. Unpublished report for Portman Iron Ore Limited, Perth.

Lyons, M.N. and Chapman, A. (1997) *A Biological Survey of the Helena and Aurora Range; Eastern Goldfields Western Australia*. Unpublished report for Environment Australia, Canberra.

McKenzie, N.L. and Rolfe, J.K. (1995a) Vertebrate fauna. In: Keighery GJ, McKenzie NL and Hall NJ. The Biological Surveys of the Eastern Goldfields of Western Australia. Part 11 Boorabbin-Southern Cross Study Area. *Records of the Western Australian Museum*, Supplement No. 49, pp 31-65.

Ninox Wildlife Consulting (2008) *Interim Report on the first field survey of the Carina Prospect, Yilgarn Iron Ore Project*. Unpublished report for Polaris Metals NL, Perth.

Ninox Wildlife Consulting (2009b) *Interim report on the first field survey of the Chamaeleon Prospect, Yilgarn Iron Ore Project*. Unpublished report for Polaris Metals NL, Perth.

Ninox Wildlife Consulting (2009a) *A Fauna Survey of the Carina Prospect; Yilgarn Iron Ore Project*. Unpublished report for Polaris Metals NL, Perth.

In addition, unpublished data from Jason Fraser's PhD project on the sand plain north of Bungalbin Hill and Western Australian Museum records contained in Terrestrial Ecosystems' fauna survey database have also been used.

The Dell and How (1985) fauna survey data are from a Western Australian Museum (WAM) survey of the Jackson-Kalgoorlie area which was part of the Eastern Goldfields biological regional survey. Their survey sites were to the north of the project area. The Dickman et al. (1991) data are from a survey near Mt Walton which is less than 10km from the project area in similar habitat. The Ecologia Environmental Consultants (2001, 2003) data for the Koolyanobbing project areas are for sites to the south-west of the project area. Some of the habitat types surveyed were similar to those in the project area. The Lyons and Chapman (1997) data for the Helena and Aurora Range includes survey sites on the sand plain that are similar to those in the project area. The McKenzie and Rolfe (1995a) data from the Boorabbin-Southern Cross survey, which was part of the Eastern Goldfields biological regional surveys, is for an area to the east and south-east of the project area. Much of the habitat surveyed was similar to that in the project area; therefore these data provide a good representation of the fauna likely to be encountered in the project area. The Ninox Wildlife Consulting (2008, 2009b, a) surveys for Carina and Chamaeleon are just to the south of the project area and Jason Fraser's data are for areas to the north-west of the project area and include habitat similar to that in the project area. Prof. H. Recher provided access to his bird survey data for areas around Yellowdine which were useful when commenting on the potential impacts on conservation significant bird species.

The location of survey sites associated with these fauna surveys are shown in Plate 1.

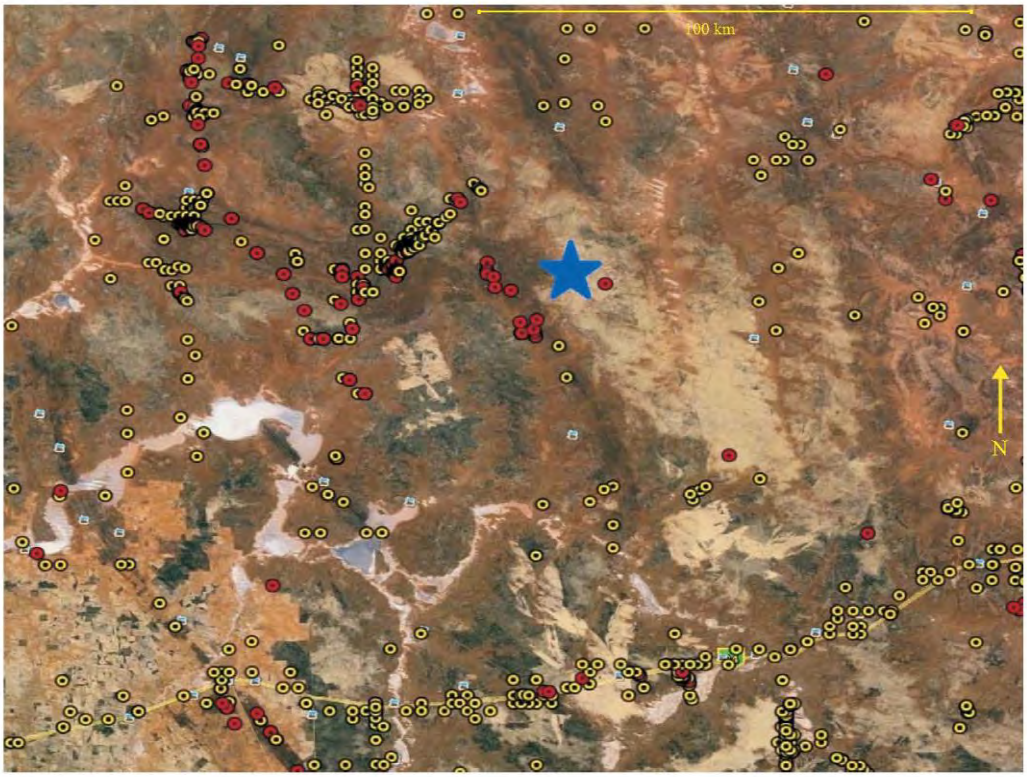

Plate 1. Location of regional survey sites and individual fauna records available in Terrestrial Ecosystems' fauna survey database. Survey sites shown as red dots with a black centre, individual records as yellow dots and the project area as a blue star.

2.5 Great Western Woodlands

The Sandy Ridge project area is part of the Great Western Woodlands (Watson et al. 2008, pp. vi) that is being promoted by the Wilderness Society because the area contains the 'largest and healthiest temperate woodland remaining on our planet'. The Wilderness Society argued the fauna and flora diversity in the area has evolved with the landscape during an unbroken biological lineage stretching back 250 million years.

There is pressure from numerous conservation groups for the preservation of the Great Western Woodlands, and it is likely that the DPaW will progressively become more involved in the protection of this areas.

3 METHODOLOGY

3.1 Database searches

A review of the *EPBC Act 1999* Threatened Species Database was undertaken to identify species of conservation interest to the Commonwealth Government. The search coordinates were 30.33549ºS and 120.10354ºE with a 100km buffer (Appendix C). In addition, a point search of the Terrestrial Ecosystems' fauna survey database was used to develop an appreciation of the vertebrate fauna assemblages in the vicinity of the project area. The DPaW threatened and priority species database was searched within the vicinity of the project area via the records in NatureMap to identify threatened species of interest to the DPaW. The search areas varied but were chosen to allow for similar habitat types so that representative fauna assemblages were collated.

Other more general texts were also used to provide supplementary information on vertebrates in the bioregion, including; Tyler *et al.* (2000) for frogs; Storr *et al.* (1983, 1990, 1999, 2002) and Thompson and Thompson (2006) for reptiles; Johnstone and Storr (1998, 2004) for birds, and Van Dyck and Strahan (2008) for mammals.

Collectively these sources of information were used to create lists of species expected to utilise the project area and similar habitats in the vicinity of the project area. It should be noted that these lists will include species that have been recorded in the subregion but are possibly vagrants and they will not generally be found in the project area due to a lack of suitable habitat (e.g. wetland and water birds). Vagrants can be recorded almost anywhere. Many of the bird, mammal, reptile and amphibian species have specific habitat requirements that may be present in the subregion but not in a particular subsection of the subregion because of a lack of suitable habitat. Also, the ecology of many species is often not well understood and it can sometimes be difficult to indicate those species whose specific habitat requirements are not present in subsection of the subregion, again because of differences in habitat. As a consequence many species will be included in the lists produced from database searches but will not be present in the actual project area.

3.2 Reconnaissance survey

The project area was visited in 22 April 2015 as part of the preparation of this assessment. The purpose of the reconnaissance survey was to determine fauna habitats and habitat condition.

The project area was searched on foot and in an all-terrain vehicle (ATV) for evidence of malleefowl, conservation significant fauna and to record fauna habitat types and their condition. Malleefowl is listed as Vulnerable under the *EPBC Act 1999* and a Schedule 1 species under the WA *Wildlife Conservation Act (1950)* and government regulators typically wish to know whether malleefowl are present, and if so, how abundant and where they are located in a project area.

Searches for Major Mitchells Cockatoo and Western Rosella nests can only be done during the breeding season and are not normally included in a Level 1 vertebrate fauna assessment. A trapping program is required to determine the presence of Chuditch and it is difficult to determine the presence of Woma and Carpet Pythons, as they are seldom seen in targeted searches and are normally recorded incidentally during a Level 2 vertebrate fauna survey and at night.

The reconnaissance survey was undertaken by zoologists; Dr Scott Thompson and Andrew Hide.

3.3 Fauna habitat assessment

A fauna habitat assessment was undertaken for the project area. This field assessment had two foci:

- assessing fauna habitat types and their condition; and
- assessing the possible presence of, and recording evidence of, conservation significant fauna so that mitigation and management strategies might be implemented to reduce potential impacts.

Zoologists stopped at multiple locations within the project area and recorded a suite of data about the fauna habitat and its condition. This information included a description of the habitat structure, habitat condition,

landform, soils and vegetation and time since last fire. The following data were recorded at each location as part of the habitat assessment:

Observer's name
Coordinates of the location as UTM (WGS 84)
Fire history – options
> 5 years
1-5 years
< 1 year
Landform – options

Beach	Lake / lake edge
Clay plain	Lower slope
Cliff	Mid slope
Creek line	Ridge
Dam	River
Drainage line	Rocky outcrop / breakaway
Dune crest	Salt lake
Dune slope	Sand dune
Dune swale	Sand plain
Escarpment	Stony plain
Flat	Swamp
Gorge	Undulating
Gully	Upper slope
Intertidal / mangrove	Wetland
	Water hole

Habitat quality – options

- *High quality fauna habitat* – These areas closely approximate the vegetation mix and quality that would have been in the area prior to any disturbance. The habitat has connectivity with other habitats and is likely to contain the most natural vertebrate fauna assemblage.
- *Very good fauna habitat* - These areas show minimal signs of disturbance (e.g. grazing, clearing, fragmentation, weeds) and generally retain many of the characteristics of the habitat if it had not been disturbed. The habitat has connectivity with other habitats and fauna assemblages in these areas are likely to be minimally effected by disturbance.
- *Good fauna habitat* – These areas showed signs of disturbance (e.g. grazing, clearing, fragmentation, weeds) but generally retain many of the characteristics of the habitat if it had not been disturbed. The habitat has connectivity with other habitats and fauna assemblages in these areas are likely to be affected by disturbance.
- *Disturbed fauna habitat*– These areas showed signs of significant disturbance. Many of the trees, shrubs and undergrowth are cleared. These areas may be in the early succession and regeneration stages. Areas may show signs of significant grazing, containing weeds or have been damaged by vehicle or machinery. Habitats are fragmented or have limited connectivity with other fauna habitats. Fauna assemblages in these areas are likely to differ significantly from what might be expected in the area had the disturbance not occurred.
- *Highly degraded fauna habitat* – These areas often have a significant loss of vegetation, an abundance of weeds, and a large number of vehicle tracks or are completely cleared. Limited or no fauna habitat connectivity. Fauna assemblages in these areas are likely to be significantly different to what might have been in the area pre-disturbance.

*Habitat structur*e - options

Upper stratum

Tall open woodland	Scattered tall trees
Tall woodland	Scattered trees
Open woodland	Scattered low trees
Woodland	Low closed forest
Open forest	Low open forest
Closed forest	Low woodland
Tall closed forest	Low open woodland
Tall open forest	

Middle stratum

Shrubland	Open heath

Tall shrubland	Low closed heath
Tall open shrubland	Low open heath
Low shrubland	Tall closed scrub
Scattered low shrubs	Tall open scrub
Low open shrubland	Scattered tall shrubs
Scattered tall shrubs	Open shrubland
Closed heath	Scattered shrubs
Lower stratum	
Closed hummock grassland	Closed tussock grassland / sedgeland / herbland
Mid-dense hummock grassland	Tussock grass land / sedgeland / herbland
Hummock grassland	Open tussock grassland / sedgeland / herbland
Open hummock grassland	Scattered tussock / grasses / sedges / herbs
Scattered hummock grassland	Very open tussock grassland / herbland
Soil Type – options	
Sand	Clay loam
Loamy sand	Silty clay loam
Clayey sand	Clay
Sandy loam	Rock
Loam	Peat / organic
Silty loam	Stony
Sandy clay loam	
Soil Colour –options	
Black	Red
Brown	White
Grey	Yellow
Orange	
Surface stones - options	
None	Boulders (>250mm)
Pebbles (0-50mm)	Rocks
Cobbles (51-250mm)	
Potential for conservation significant species to be found in the area	
Yes	
No	
Impact of clearing on conservation significant species – options	
Low	Moderate - high
Low - moderate	High
Moderate	Extreme
Translocation of conservation significant fauna required:	
No	
Yes	

3.3.1 Report preparation

This report has been prepared by Drs Scott and Graham Thompson, both of whom have substantial field fauna survey experience and are familiar with the fauna habitats in the vicinity of the project area.

3.4 Limitations

This fauna risk assessment is based on information contained in the Commonwealth Government's *EPBC Act 1999* Threatened Species database and other published and unpublished fauna survey data for the bioregion and a reconnaissance survey. It is acknowledged that multiple surveys conducted in different seasons, repeated over several years are necessary to fully appreciate the fauna assemblage in the project area.

The EPA *Guidance for Assessment of Environmental Factors: Terrestrial Fauna Surveys for Environmental Impact Assessment in Western Australia, No. 56* (2004) suggested that fauna surveys may be limited by many variables. Limitations associated with each of these variables are assessed in Table 1.

Table 1. Fauna survey limitations and constraints

Possible limitations	Constraint (yes/no); significant, moderate or negligible	Comment
Competency and experience of the consultant carrying out this assessment	No	The environmental scientists that undertook the field survey and prepared this assessment are familiar with the vertebrate fauna of this bioregion and are experienced in these types of assessments.
Scope	No	All aspects of the scope of works have been addressed.
Proportion of fauna identified, recorded and/or collected	No	Not applicable.
Accuracy of previous survey work	Yes, negligible	Terrestrial Ecosystems has reported fauna survey data recorded by various authors, but is not in a position to vouch for the accuracy of this information. It is acknowledged that the taxonomy of Western Australian vertebrates is continually being revised and the nomenclature of some of the species listed in the appendices may have changed since publication by the authors.
Sources of information	Yes, negligible	Vertebrate fauna information was available from on-line databases and unpublished and published reports of surveys conducted in the bioregion in a variety of habitat types. Many of these surveys employed a low level of trapping effort which significantly impacts on the capacity of these data to represent the fauna assemblages in the areas surveyed.
Timing/weather/ season/ cycle	No	Weather was suitable for a site visit.
Disturbances which affected results of the survey	No	The project area contained tracks and there was evidence of recent exploration activity in some areas. This minor level of disturbance has been taken into account in this assessment.
Intensity of survey effort	No	Not applicable.
Resources	No	Adequate resources were available.
Remoteness and/or access problems	No	There was a vehicle access track to some sections of the project area. Other sections of the project area were searched on foot or by ATV. Access was not a limitation or constraint.
Availability of contextual information on the region	No	There is a substantial quantity of fauna survey data available for the Southern Cross IBRA bioregion.

Negligible = less than 20%.

4 RESULTS

4.1 Fauna habitats

There were two broad habitats available in the project area. These are an open eucalypt woodland with an open understorey of shrubs over ephemeral grasses or scattered spinifex on red sandy clay soils; and a moderately dense to dense sand plain shrubland varying in height from 0.5-1.8m on yellow sandy soils.

The areas outlined in purple and blue in inset A of Figure 2 are a moderately dense to dense sand plain shrubland and the areas outlined in blue and green in insets B and C of Figure 2 are an open eucalypt woodland with an open understorey of shrubs over ephemeral grasses or scattered spinifex on red sandy clay soils. Plates 2-5 provide an indication of the habitat types available and Appendix D has many more images.

Plate 2. Open Eucalypt woodland over shrubs and ephemeral grasses

Plate 3. Open Eucalypt woodland over shrubs and scattered spinifex

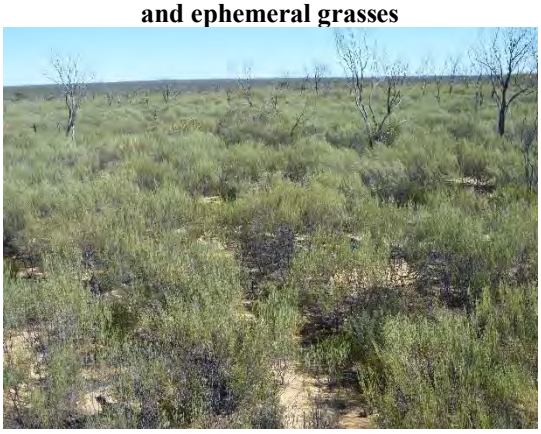

Plate 4. Sand plain shrubland (low)

Plate 5. Sand plain shrubland (high)

4.2 Fauna habitat condition

The project area contains a few vehicle tracks and there has been some exploration drilling and associated access tracks in the project area. Other than this disturbance, the habitat in the project area is in very good to excellent condition.

Appendix D provides the results of the fauna habitat assessment. These data and images indicate the range of fauna habitats present in the project area.

There was evidence of fox activity in the project area but no cat or dog tracks were observed. A large area adjacent to the project area has been burnt >5 years ago, however, there was no evidence that the project area had been recently burnt.

The open woodland of tall eucalypts contained trees with hollows suitable as nesting sites for Major Mitchell's Cockatoo, Western Rosellas and other birds and arboreal mammals.

4.3 Malleefowl

The project area was searched for Malleefowl mounds and tracks. Malleefowl are predominantly a ground dwelling species and walk a considerable distance each day foraging for insects and seeds. Their tracks are distinctive, and in areas of soft sand or on sand tracks their presence is often easily detected. No Malleefowl mounds or tracks were observed during the site visit.

4.4 Bioregional vertebrate fauna

Appendix A provides a summary of the fauna survey data that are available in the vicinity of the project area. There are appreciable differences in the recorded fauna assemblages within and among fauna surveys shown in Appendix A. These differences are partially due to the low survey effort often deployed and they also reflect variations in soils and vegetation as well as temporal variations in the fauna assemblages.

Tables 2-5 provide a list of vertebrate species potentially found in the vicinity of the project area that have been compiled based on the fauna survey reports listed in section 2.4.

Table 2. Birds potentially found in the vicinity of the project area

Family	Species	Common Name
Accipitridae	*Hamirostra melanosternon*	Black-breasted Buzzard
	Accipiter fasciatus	Brown Goshawk
	Accipiter cirrocephalus	Collared Sparrowhawk
	Aquila audax	Wedge-tailed Eagle
	Hieraaetus morphnoides	Little Eagle
Anatidae	*Chenonetta jubata*	Australian Wood Duck
	Anas gracilis	Grey Teal
Aegothelidae	*Aegotheles cristatus*	Australian Owlet-nightjar
Podargidae	*Podargus strigoides*	Tawny Frogmouth
Casuariidae	*Dromaius novaehollandiae*	Emu
Charadriidae	*Vanellus tricolor*	Banded Lapwing
Turnicidae	*Turnix varius*	Painted Button-quail
	Turnix velox	Little Button-quail
Columbidae	*Phaps chalcoptera*	Common Bronzewing
	Ocyphaps lophotes	Crested Pigeon
Alcedinidae	*Todiramphus pyrrhopygius*	Red-backed Kingfisher
Meropidae	*Merops ornatus*	Rainbow Bee-eater
Cuculidae	*Chalcites basalis*	Horsfield's Bronze-Cuckoo
	Chalcites osculans	Black-eared Cuckoo
	Cacomantis pallidus	Pallid Cuckoo
	Cacomantis flabelliformis	Fan-tailed Cuckoo
Caprimulgidae	*Eurostopodus argus*	Spotted Nightjar
Falconidae	*Falco cenchroides*	Nankeen Kestrel
	Falco berigora	Brown Falcon
	Falco longipennis	Australian Hobby
	Falco peregrinus	Peregrine Falcon
Megapodiidae	*Leipoa ocellata*	Malleefowl

Family	Species	Common Name
Otididae	*Ardeotis australis*	Australian Bustard
Rallidae	*Fulica atra*	Eurasian Coot
Acanthizidae	*Calamanthus cautus*	Shy Heathwren
	Calamanthus fuliginosus	Striated Fieldwren
	Pyrrholaemus brunneus	Redthroat
	Smicrornis brevirostris	Weebill
	Gerygone fusca	Western Gerygone
	Acanthiza robustirostris	Slaty-backed Thornbill
	Acanthiza chrysorrhoa	Yellow-rumped Thornbill
	Acanthiza apicalis	Inland Thornbill
	Aphelocephala leucopsis	Southern Whiteface
	Acanthiza uropygialis	Chestnut-rumped Thornbill
Artamidae	*Artamus personatus*	Masked Woodswallow
	Artamus cinereus	Black-faced Woodswallow
	Artamus cyanopterus	Dusky Woodswallow
	Artamus minor	Little Woodswallow
	Cracticus torquatus	Grey Butcherbird
	Cracticus nigrogularis	Pied Butcherbird
	Cracticus tibicen	Australian Magpie
	Strepera versicolor	Grey Currawong
Campephagidae	*Coracina maxima*	Ground Cuckoo-Shrike
	Coracina novaehollandiae	Black-faced Cuckoo-Shrike
	Lalage sueurii	White-winged Triller
Climacteridae	*Climacteris rufa*	Rufous Treecreeper
Corvidae	*Corvus coronoides*	Australian Raven
	Corvus bennetti	Little Crow
	Corvus orru	Torresian Crow

Family	Species	Common Name
Estrildidae	*Taeniopygia guttata*	Zebra Finch
Eupetidae	*Cinclosoma castanotum*	Chestnut Quail-thrush
	Cinclosoma castaneothorax	Chestnut-breasted Quail-thrush
Hirundinidae	*Cheramoeca leucosterna*	White-backed Swallow
	Hirundo neoxena	Welcome Swallow
	Petrochelidon nigricans	Tree Martin
Maluridae	*Malurus splendens*	Splendid Fairy-wren
	Malurus leucopterus	White-winged Fairy-wren
	Malurus lamberti	Variegated Fairy-wren
	Malurus pulcherrimus	Blue-breasted Fairy-wren
Meliphagidae	*Certhionyx variegatus*	Pied Honeyeater
	Lichenostomus virescens	Singing Honeyeater
	Lichenostomus leucotis	White-eared Honeyeater
	Lichenostomus flavicollis	Yellow-throated Honeyeater
	Lichenostomus cratitius	Purple-gaped Honeyeater
	Lichenostomus ornatus	Yellow-plumed Honeyeater
	Lichenostomus plumulus	Grey-fronted Honeyeater
	Purnella albifrons	White-fronted Honeyeater
	Manorina flavigula	Yellow-throated Miner
	Acanthagenys rufogularis	Spiny-cheeked Honeyeater
	Anthochaera carunculata	Red Wattlebird
	Epthianura tricolor	Crimson Chat
	Epthianura albifrons	White-fronted Chat
	Glyciphila melanops	Tawny-crowned Honeyeater
	Lichmera indistincta	Brown Honeyeater
	Melithreptus brevirostris	Brown-headed Honeyeater
Monarchidae	*Grallina cyanoleuca*	Magpie-Lark
	Anthus novaeseelandiae	Australasian Pipit

Family	Species	Common Name
Nectariniidae	*Dicaeum hirundinaceum*	Mistletoebird
Neosittidae	*Daphoenositta chrysoptera*	Varied Sittella
Pachycephalidae	*Pachycephala inornata*	Gilbert's Whistler
	Pachycephala pectoralis	Golden Whistler
	Pachycephala rufiventris	Rufous Whistler
	Colluricincla harmonica	Grey Shrike-thrush
	Oreoica gutturalis	Crested Bellbird
Pardalotidae	*Pardalotus striatus*	Striated Pardalote
Petroicidae	*Microeca leucophaea*	Jacky Winter
	Petroica goodenovii	Red-capped Robin
	Melanodryas cucullata	Hooded Robin
	Eopsaltria griseogularis	Western Yellow Robin
	Drymodes brunneopygia	Southern Scrub-robin
Pomatostomidae	*Pomatostomus superciliosus*	White-browed Babbler
Rhipiduridae	*Rhipidura fuliginosa*	New Zealand Fantail
	Rhipidura albiscapa	Grey Fantail
	Rhipidura leucophrys	Willie Wagtail
Podicipedidae	*Tachybaptus novaehollandiae*	Australasian Grebe
	Poliocephalus poliocephalus	Hoary-headed Grebe
Cacatuidae	*Calyptorhynchus banksii*	Red-tailed Black-Cockatoo
	Lophochroa leadbeateri	Major Mitchell's Cockatoo
	Eolophus roseicapillus	Galah
	Nymphicus hollandicus	Cockatiel
Psittacidae	*Glossopsitta porphyrocephala*	Purple-crowned Lorikeet
	Polytelis anthopeplus	Regent Parrot
	Platycercus icterotis xanthogenys	Western Rosella
	Barnardius zonarius	Australian Ringneck
	Psephotus varius	Mulga Parrot

Family	Species	Common Name
	Melopsittacus undulatus	Budgerigar
	Neophema elegans	Elegant Parrot

Family	Species	Common Name
Strigidae	*Ninox novaeseelandiae*	Southern Boobook
Tytonidae	*Tyto alba*	Barn Owl

Table 3. Mammals potentially found in the vicinity of the project area

Family	Species	Common Name
Bovidae	*Capra hircus*	Goat
Camelidae	*Camelus dromedarius*	Dromedary
Canidae	*Canis lupus*	Dingo/dog
	Vulpes vulpes	Red Fox
Felidae	*Felis catus*	House Cat
Molossidae	*Austronomus australis*	White-striped Freetail Bat
	Mormopterus planiceps	Southern Freetail-bat
Vespertilionidae	*Chalinolobus gouldii*	Gould's Wattled Bat
	Chalinolobus morio	Chocolate Wattled Bat
	Nyctophilus geoffroyi	Lesser Longeared Bat
	Nyctophilus major	Western Longeared Bat
	Scotorepens balstoni	Inland Broadnosed Bat
	Vespadelus baverstocki	Inland Forest Bat
	Vespadelus regulus	Southern Forest Bat
Dasyuridae	*Antechinomys laniger*	Kultarr
	Ningaui ridei	Wongai Ningaui
	Ningaui yvonneae	Mallee Ningaui
	Pseudantechinus woolleyae	Woolley's False Antechinus

Family	Species	Common Name
	Sminthopsis crassicaudata	Fat-tailed Dunnart
	Sminthopsis dolichura	Little Long-tailed Dunnart
	Sminthopsis gilberti	Gilbert's Dunnart
	Sminthopsis granulipes	White-tailed Dunnart
	Sminthopsis hirtipes	Hairy-footed Dunnart
Burramyidae	*Cercartetus concinnus*	Southwestern Pygmy Possum
Macropodidae	*Macropus fuliginosus*	Western Grey Kangaroo
	Macropus robustus	Wallaroo or Euro
	Macropus rufus	Red Kangaroo
Leporidae	*Oryctolagus cuniculus*	European Rabbit
Tachyglossidae	*Tachyglossus aculeatus*	Short-beaked Echidna
Muridae	*Mus musculus*	House Mouse
	Notomys alexis	Spinifex Hopping Mouse
	Notomys mitchellii	Mitchell's Hopping Mouse
	Pseudomys albocinereus	Ash-grey Mouse
	Pseudomys bolami	Bolam's Mouse
	Pseudomys hermannsburgensis	Sandy Inland Mouse

Table 4. Amphibians potentially found in the vicinity of the project area

Family	Species	Common Name
Limnodynastidae	*Neobatrachus albipes*	White-footed Trilling Frog
	Neobatrachus kunapalari	Kunapalari Frog
	Neobatrachus pelobatoides	Humming Frog
	Neobatrachus sutor	Shoemaker Frog
Myobatrachidae	*Pseudophryne guentheri*	Crawling Toadlet
	Pseudophryne occidentalis	Western Toadlet

Table 5. Reptiles potentially found in the vicinity of the project area

Family	Species	Common Name
Agamidae	*Ctenophorus adelaidensis*	Southern Heath Dragon
	Ctenophorus cristatus	Bicycle Dragon
	Ctenophorus fordi	Mallee Sand Dragon
	Ctenophorus isolepis	Crested Dragon
	Ctenophorus maculatus	Spotted Military Dragon
	Ctenophorus ornatus	Ornate Crevice Dragon
	Ctenophorus reticulatus	Western Netted Dragon
	Ctenophorus salinarum	Salt Pan Dragon
	Ctenophorus scutulatus	
	Moloch horridus	Thorny Devil
	Pogona minor	Bearded Dragon
	Tympanocryptis cephalus	Pebble Dragon
Boidae	*Antaresia stimsoni*	Stimson's Python
	Aspidites ramsayi	Woma
	Morelia spilota imbricata	Carpet Python
Carphodactylidae	*Nephrurus stellatus*	
	Underwoodisaurus milii	Barking Gecko
Diplodactylidae	*Crenadactylus ocellatus*	Clawless Gecko
	Diplodactylus granariensis	
	Diplodactylus pulcher	
	Lucasium maini	
	Lucasium stenodactylus	
	Oedura reticulata	
	Strophurus assimilis	Goldfields Spiny-tailed Gecko
	Strophurus elderi	
	Strophurus intermedius	
	Strophurus wellingtonae	
Elapidae	*Acanthophis antarcticus*	Southern Death Adder
	Brachyurophis fasciolata	
	Brachyurophis semifasciata	
	Demansia psammophis	
	Echiopsis curta	Bardick
	Furina ornata	Moon Snake
	Neelaps bimaculatus	Black-naped Snake
	Parasuta gouldii	
	Parasuta monachus	
	Pseudechis australis	Mulga Snake
	Pseudonaja affinis	Dugite

Family	Species	Common Name
	Pseudonaja mengdeni	Gwardar
	Pseudonaja modesta	Ringed Brown Snake
	Simoselaps bertholdi	Jan's Banded Snake
	Simoselaps semifasciata	
	Suta fasciata	Rosen's Snake
Gekkonidae	*Gehyra purpurascens*	
	Gehyra variegata	
	Heteronotia binoei	Bynoe's Gecko
	Rhynchoedura ornata	Beaked Gecko
Pygopodidae	*Aprasia repens*	
	Delma australis	
	Delma butleri	
	Delma nasuta	
	Lialis burtonis	
	Pygopus lepidopodus	Common Scaly Foot
	Pygopus nigriceps	
Scincidae	*Cryptoblepharus buchananii*	
	Ctenotus atlas	
	Ctenotus brooksi	
	Ctenotus leonhardii	
	Ctenotus mimetes	
	Ctenotus pantherinus	Leopard Skink
	Ctenotus schomburgkii	
	Ctenotus uber	
	Ctenotus xenopleura	
	Cyclodomorphus melanops	Slender Blue-tongue
	Egernia depressa	Pygmy Spiny-tailed Skink
	Egernia formosa	

Family	Species	Common Name
	Egernia richardi	
	Eremiascincus pallidus	Western Sand-swimming Skink
	Hemiergis initialis	
	Lerista gerrardii	
	Lerista kingi	
	Lerista macropisthopus	
	Lerista picturata	
	Lerista rhodonoides	
	Liopholis inornata	
	Menetia greyii	
	Morethia adelaidensis	
	Morethia butleri	
	Morethia obscura	
	Tiliqua occipitalis	Western Bluetongue
	Tiliqua rugosa	
Typhlopidae	*Anilios australis*	
	Anilios bicolor	
	Anilios bituberculatus	
	Anilios hamatus	
Varanidae	*Varanus giganteus*	Perentie
	Varanus gouldii	Bungarra or Sand Monitor
	Varanus tristis	Racehorse Monitor

4.5 Conservation significant fauna species

Species listed under the *EPBC Act 1999* or the *Wildlife Conservation Act (1950)* as being of conservation significance or are listed in the DPaW Priority and Threatened Species list and potentially in the vicinity of the project area are shown in Table 6.

Conservation significant fauna are protected by the Commonwealth *EPBC Act 1999*, and this list includes species covered by international treaties such as the Japan-Australia Migratory Bird Agreement (JAMBA) and China-Australia Migratory Bird Agreement (CAMBA) and the Western Australia (WA) *Wildlife Conservation Act (1950)*. The WA *Wildlife Conservation Act (1950)* provides for the publishing of the *Wildlife Conservation (Specially Protected Fauna) Notice* that lists species under multiple categories. In addition, DPaW maintains a list of fauna that require monitoring under five priority headings based on DPaW's knowledge of their distribution, abundance and threatening processes (Appendix B). The *EPBC Act 1999* and *Wildlife Conservation Act (1950)* imply legislative requirements for the management of anthropogenic impacts to minimise the effects of disturbances on species and their habitats. Priority species have no statutory protection, other than the DPaW wishes to monitor potential impacts on these species. Environmental consultants and proponents of developments are encouraged to avoid and minimise impacts on these species. Definitions of the significant fauna under the *WA Wildlife Conservation Act (1950)* are provided in Appendix B.

4.5.1 Significant fauna species recorded or predicted for the project area

Four Threatened species of fauna and two migratory species of birds were identified under the *EPBC Act 1999* as potentially occurring in the project area. There are 11 Schedule species listed under the WA *Wildlife Conservation Act (1950)* and 11 priority species listed on the DPaW's Priority Fauna List that potentially occur in the project area. The following is an assessment of the likelihood of each of the species listed in Table 6 being found in the project area.

Table 6. Species that are potentially found in the vicinity of the project area and that are listed as being of conservation significance under state or commonwealth government legislation or with DPaW.

Species	Status under the Wildlife Conservation Act / DPaW	Status under the EPBC Act	Comment on potential impact that vegetation clearing will have on conservation significant species
Myrmecobius fasciatus Numbat	Schedule 1	Vulnerable	Not recently recorded in the vicinity of the project area, so it is unlikely to be present in the project area. Impact potential very low.
Calyptorhynchus latirostris Carnaby's Black-Cockatoo	Schedule 1	Endangered	Not recently recorded in the vicinity of the project area, so it is unlikely to be present in the project area. Impact potential very low.
Leipoa ocellata Malleefowl	Schedule 1	Vulnerable	Potentially in the vicinity of the project area, but it was not recorded during the reconnaissance survey. Unlikely to be in the proposed disturbance area. Impact potential very low.
Dasyurus geoffroii Chuditch	Schedule 1	Vulnerable	Not recently recorded in the vicinity of the project area, so it is unlikely to be present in the project area. Impact potential very low.
Merops ornatus Rainbow Bee-eater	Schedule 3	Migratory	It has been recorded in numerous fauna surveys in the vicinity of the project area and could therefore be seen and breed in the project area. However, these birds will readily move out of the area if disturbed, so there is unlikely to be a significant impact. It could potentially breed in the sandy areas. Impact potential low.
Apus pacificus Fork-tailed Swift	Schedule 3	Migratory	The the Fork-tailed Swift may infrequently be seen in the vicinity of the project area, but is unlikely to be impacted as it is predominantly an aerial species and will readily move away from a disturbance. Impact potential very low.
Platycercus icterotis xanthogenys (Mallee) Western Rosella	Schedule 1		Could be found in the eucalypt woodland. It would readily move to adjacent undisturbed areas once vegetation clearing commences. Impact potential very low in a regional context.
Lophochroa leadbeateri Major Mitchell's Cockatoo	Schedule 4		Major Mitchell's Cockatoo could be in the general area. It would readily move to adjacent undisturbed areas once clearing commences. Impact potential very low in a regional context.
Falco peregrinus Peregrine Falcon	Schedule 4		The Peregrine Falcon may infrequently be observed in the project area, however, vegetation clearing is unlikely to have a significant impact on this species as there are plenty of similar habitats in adjacent areas and it will readily move from a disturbance area. Impact potential very low.
Aspidites ramsayi Woma	Schedule 4		Possibly in the project area, but based on the size of the areas to be disturbed, the impact potential is very low in a regional context.
Morelia spilota imbricata Carpet Python	Schedule 4		Not recently recorded in the vicinity of the project area, so it is unlikely to be present in the project area. Impact potential very low in a regional context.

Species	Status under the Wildlife Conservation Act / DPaW	Status under the EPBC Act	Comment on potential impact that vegetation clearing will have on conservation significant species
Acanthophis antarcticus Southern Death Adder	Priority 3		Unlikely to be in the project area. Impact potential very low in a regional context.
Hylacola cauta whitlocki Shy Heathwren	Priority 4		Could be found in the project area, however, it would readily move to adjacent undisturbed areas once clearing commences. Overall potential for impact is low, however, there may be localised impacts if a nest was disturbed.
Pseudomys occidentalis Western Mouse	Priority 4		Not recently recorded in the vicinity of the project area, so it is unlikely to be present in the project area. Impact potential very low.
Oreoica gutturalis Crested Bellbird	Priority 4		The Crested Bellbird could be seen in the project area, however, the clearing of vegetation in a section of the project area is unlikely to have a significant impact on this species. If present it will move to more suitable habitat in adjacent areas once vegetation clearing commences. Impact potential very low.
Burhinus grallarius Bush Stone-curlew	Priority 4		Very low possibility that it is in the general area and will readily move to an adjacent area if disturbed. Impact potential very low in a regional context.
Nyctophilus(timoriensis) sp. 1 Central Long-eared Bat	Priority 4		The project area is on the north-western boundary of its known distribution so it is potentially present in the area. The proposed clearing of vegetation in the project area is unlikely to have a significant impact on this species as it will readily move when disturbed, and they are likely to be in a similar abundance in adjacent areas. Impact potential very low.
Ardeotis australis Australian Bustard	Priority 4		Could occasionally be present. The proposed clearing of vegetation in the project area is unlikely to have a significant impact on this species as it will readily move when disturbed, and they are likely to be in a similar abundance in adjacent areas. Impact potential very low.
Charadrius rubricollis Hooded Plover (western subspecies)	Priority 4		Unlikely to be seen in the project area due to a lack of suitable habitat. Impact potential very low.
Calamanthus camestris montananellus Rufous Fieldwren	Priority 4		It was not reported in any of the other surveys in the vicinity of the project area, so it is unlikely to be present in the project area. Will readily move to an adjacent area if disturbed so impact potential is very low.
Macropus irma Western Brush Wallaby	Priority 4		Unlikely to be in the project area and if it was, it is unlikely that vegetation clearing will significantly impact on this species because it can easily move to adjacent undisturbed areas once clearing commences. Impact potential very low.
Isoodon obesulus fusciventer Quenda	Priority 5		Unlikely to be in the project area and if it was, it is unlikely that vegetation clearing will significantly impact on this species because it can easily move to adjacent undisturbed areas once clearing commences. Impact potential very low.

4.5.2 Conservation significant species and potential impact on species of conservation significance

Numbat (*Myrmecobius fasciatus*) - Schedule 1 under the *Wildlife Conservation Act (1950)* and Vulnerable under the *EPBC Act 1999*.

Numbats were once present across southern semi-arid and arid Australia, including parts of NSW, SA and southern NT, as well as the south-west of Western Australia. In Western Australia, there are small residual populations at Dryandra and Perup, with recent translocations at Boyagin Nature Reserve, Tutanning Nature Reserve, Batalling block and Karroun Hill Nature Reserve (Friend 2008). Numbats are essentially solitary, forage during the day in winter and in the early morning and late afternoon in summer.

There is a very old record of a Numbat being found south of the project area, however, it is highly unlikely that they are now present in the project area. Therefore there is a very low possibility of impacting on this species.

Carnaby's Black-Cockatoo (*Calyptorhynchus latirostris*) – Schedule 1 under the *Wildlife Conservation Act (1950)* and Endangered under the *EPBC Act 1999*.

Carnaby's Black-Cockatoo (*Calyptorhynchus latirostris*) is a large, pied, cockatoo. Garnett et al. (2011) and the DSEWPaC (2011) reported that Carnaby's Black-Cockatoo inhabits the south-west of Western Australia, from Kalbarri to as east on the south coast as Esperance. It breeds inland and moves to the coastal areas when chicks have fledged (Saunders et al. 1985). Carnaby's Black-Cockatoos are highly gregarious, usually seen in trios, small parties or large flocks (up to 5000 birds; Perry 1948). These flocks usually contain males, females and immature birds.

In some locations, breeding populations have decreased or become locally extinct (Saunders 1986, Saunders and Ingram 1987). For example, in the Coomallo Creek area north of Perth, Black-Cockatoos laid 74 clutches in 1973, 75 in 1974, 82 in 1975 but only 20 in 1994 and 19 in 1996 (Saunders and Ingram 1987). Saunders (1986) reported finding 13 nests at Manmanning in 1969 but by 1977, the species had stopped breeding in the area. Saunders (1990) reported failed nestings due to predation by a cat, galahs broke Carnaby's Black-Cockatoo eggs and took over nests, while other adult birds were killed by vehicles and Wedge-tailed Eagles (*Aquilla audax*).

Carnaby's Black-Cockatoos are partly migratory and partly sedentary (Higgins 1999). In the drier regions of their geographic range where most of the native vegetation has been cleared (e.g. wheatbelt), Carnaby's Black-Cockatoos are postnuptial migrants (Saunders 1980, Saunders and Ingram 1995). After breeding, individuals in these areas migrate to feed in higher rainfall areas including the Swan Coastal Plain, and to a lesser extent, forests dominated by *E. marginata* (Jarrah), *C. calophylla* (Marri) and *E. diversicolor* (Karri; Saunders 1980).

Garnett et al. (2011) estimated there were between 10,000 and 60,000 birds in the population.

Carnaby's Black-Cockatoo breed between July and November mostly in eucalypt woodland (Saunders 1980, 1986). Carnaby's Black-Cockatoo nest in tree hollows that are created by fire, fungi, termites or old age, with hollows between 2.5 and 12m above the ground (Saunders 1979, Higgins 1999). Hollows are large, ranging from 10 to over 250cm in depth (Higgins 1999). These hollows are usually in live or dead smooth-barked *Eucalyptus salmonophloia* (Salmon Gum) or *Eucalyptus wandoo* (Wandoo). However, Carnaby's Black-Cockatoo will also nest in *E. longicornis* (Red Morrell), *E. loxophleba* (York Gum), *E. gomphocephala* (Tuart), *E. rudis* (Flooded Gum), *E. salubris* (Gimlet), *E. occidentalis* (Swamp Yate) and *C. calophylla* (Higgins 1999, Cale 2003). When breeding, they most often forage in the surrounding shrubland and kwongan heath (Higgins 1999). Eggs are laid on a mat of wood chips chewed from the sides of the hollow. Clutches are 1-2, but most often only one chick is raised. Incubation takes 29 days, and only the female incubates and broods (Johnstone and Kirkby 2011). Initially the female will return to the nest mid-morning to feed the chick, but after about 2-3 weeks both parents leave in the early morning and return late evening.

Young remain with their parents until the parents return to the breeding area in the following year (Saunders 1980). Immature birds probably do not move into the breeding areas until they are ready to breed, although little is known of the movements of immature Carnaby's Black-Cockatoo until they are ready to breed (Saunders 1977).

Saunders (1980) reported Carnaby's Black-Cockatoo at Coomallo Creek (breeding area) foraged mostly on native plants, with the only exception being *Erodium* sp.. Higgins (1999) reported the habitat of Carnaby's Black-Cockatoo was uncleared or remnant woodlands dominated by *Eucalyptus*, particularly *E. wandoo* and *E. salmonophloia* and often in shrubland or kwongan heathland dominated by *Hakea*, *Dryandra*, *Banksia* and *Grevillea* and seasonally in *Pinus* plantations and less often in *C. calophylla*, *E. diversicolor* or *E. marginata*.

The project area is outside the eastern fringe of their normal geographic distribution (Johnstone and Storr 1998), however, Davies (1966) reported Carnaby's Cockatoo as far east as Norseman, but this was a rare occurrence and given the recently reported reduction in the population and contraction in its range (Department of Sustainability Environment Water Population and Communities 2012), it is unlikely to be seen this far east again. Terrestrial Ecosystems' assessment is that they are unlikely to be present in the vicinity of the project area.

Malleefowl (*Leipoa ocellata)* - Schedule 1 under the *Wildlife Conservation Act (1950)* and Vulnerable under the *EPBC Act 1999*.

Malleefowl are relatively large, mostly terrestrial birds that tend to be sedentary, nesting in the same general area year after year (Frith 1962a, Priddel and Wheeler 2003). Density of the birds is generally highest in areas of higher rainfall and on more fertile soils (Frith 1962a, Copley and Williams 1995, Benshemesh 2007) and where shrub diversity is greatest (Woinarski 1989). Malleefowl are now primarily found in semi-arid and arid shrublands and low woodlands dominated by mallee (*Eucalyptus* sp.) in the more temperate areas (Frith 1962b, a). Grazed areas generally have lower densities (Benshemesh 2007).

A sandy or gravelly substrate and abundance of leaf litter are requirements for the construction of the birds' incubator mounds (Frith 1959, 1962a). Jones and Goth (2008) indicated malleefowl mounds were 60-90cm high and 3.7m wide, however, there is considerable variability in the size, which is often influenced by how often the mound has been used. Malleefowl frequently use already constructed mounds instead of building a new mound each year (Priddel and Wheeler 2003). Malleefowl that reuse an existing mound tend to rake more material from the surrounding area each year on to the existing mound, with the consequence that some of the older mounds are higher than 100 cm and wider than 5m. Density of the canopy cover is an important feature associated with high breeding densities (Frith 1962a, Benshemesh 2007) and it is this dense mallee vegetation that can make ground searches for malleefowl mounds difficult.

Malleefowl have been recorded in other fauna surveys in the vicinity of the project area (Appendix A), however, no evidence (e.g. tracks or mounds) of Malleefowl were found in the project area. It is therefore Terrestrial Ecosystems' assessment that the project area does not contain active Malleefowl mounds, although it is possible that Malleefowl are in the general area.

Chuditch (*Dasyurus geoffroii*) – Schedule 1 under the *Wildlife Conservation Act (1950)* and Vulnerable under the *EPBC Act 1999*.

The Chuditch is the largest carnivorous marsupial in Western Australia (WA). It is usually active from dusk to dawn. Formally known from over 70% of Australia, the Chuditch now has a patchy distribution throughout the Jarrah forest and mixed Karri/Marri/Jarrah forest of south-west WA and other isolated areas (Serena and Soderquist 2008). Chuditch are solitary animals for most of their life and den in hollow logs, burrows, culverts, etc and have also been recorded in tree hollows and rock cavities. Chuditch are opportunistic feeders, and forage primarily on the ground at night. Their diet can include other mammals, birds, lizards, bird and reptile eggs but the majority is a mixture of large invertebrates (e.g. spiders, scorpions and crickets; Serena and Soderquist 2008).

The Terrestrial Ecosystems fauna survey database has historical records of a Chuditch west of the project area. They have been recorded in similar habitat around Forrestania, but there are no recent records in the vicinity of the project

area. Based on the available data it is Terrestrial Ecosystems assessment that Chuditch is unlikely to be found in the project area as it is now outside its known geographical distribution.

Rainbow Bee-eater (*Merops ornatus*) - Migratory under the *EPBC Act 1999*.

The Rainbow Bee-eater is widespread during late spring and summer in the southern section of WA, particularly in sandy areas that have access to water. This migratory bird inhabits open woodlands and forests, semi-arid scrub, grasslands but avoids dense forests (Morcombe 2003). This species was recorded in numerous fauna surveys in the vicinity of the project area (Appendix A), and could therefore be seen and breed in the Sandy Ridge project area if conditions were suitable. However, these birds will readily move out of the area if disturbed, so there is unlikely to be a significant impact. It could potentially breed in the sandy areas.

Fork-tailed Swift (*Apus pacificus*) - Migratory under the *EPBC Act 1999* and Schedule 3 under the W*ildlife Conservation Act (1950)*.

The Fork-tailed Swift breeds in north-east and mid-east Asia and winters in Australia and New Guinea. It arrives in the Kimberley in late September and in central and southern WA in November and leaves in late April. The Fork-tailed Swift may be an infrequent visitor to the area although it has not been recorded in previous surveys. This swift is found in a variety of habitats from rainforest to semi-desert and is often recorded ahead of a major summer storm (Morcombe 2003).

It is Terrestrial Ecosystems' assessment that the Fork-tailed Swift may infrequently be seen in the vicinity of the project area, but is unlikely to be impacted by the proposed mine as it is predominantly an aerial species and will readily move away from a disturbance.

Western Rosella (*Platycercus icterotis xanthogenys*) – Priority 4 with DPaW.

The mallee form of the Western Rosella is found mostly in Eucalypt and Casuarina woodland and shrublands, especially Wandoo, Flooded Gums and Salmon Gums. This species was sighted by McKenzie and Rolfe (1995b) during the Boorabbin-Southern Cross biological survey, but it was not seen in any of the other fauna surveys around the Sandy Ridge project area (Appendix A). Based on his surveys around Yellowdine, Prof. H. Recher (pers. comm.) suggested that this species is sparse throughout the Great Western Woodland and they probably nested in the woodlands. Johnstone and Storr (1998) indicate that the project area is north of its known distribution, so it is unlikely to breed in the project area. Given that the proposed clearing represents a very small fraction of similar habitat in the area, it is Terrestrial Ecosystems' assessment that the proposed clearing in the project area is unlikely to have a significant impact on this species.

Major Mitchell's Cockatoo (*Lophochroa leadbeateri*) – Schedule 4 under the *Wildlife Conservation Act (1950)*

Major Mitchell's Cockatoo's geographic distribution includes some of the semi-arid and arid zones of Australia. It has a disjunct geographic distribution in WA with a population in the semi-arid area east of Geraldton to include Lake Moore and Lake Barlee. Major Mitchell's Cockatoo is most often seen high in the branches of Salmon Gums (*Eucalyptus salmonophloia*) and other large eucalypts, in heavily timbered creek-lines or roadside verges in various parts of the WA wheatbelt. Major Mitchell's Cockatoo breeds in the hollows of large eucalypts (Rowley and Chapman 1991). It is scarce throughout most of WA and the primary cause for its decline is land clearing for agriculture and subsequent fragmentation of remaining habitat. There is a small population that is seen around Southern Cross, and they are frequently seen north of Southern Cross. Based on numerous surveys around Yellowdine, Prof. H Recher (pers. comm.), suggested that they forage in the agricultural areas and the kwongan.

The most significant potential impact on this species would be the removal of trees that contained nests with eggs or chicks. However, there is no evidence to indicate that it nests in the vicinity of the project area. Clearing of trees outside of the breeding period (August – October) will minimise the potential impact on this species. It is Terrestrial Ecosystems' assessment that the proposed vegetation clearing in the project area is unlikely to have a significant impact on this species.

Peregrine Falcon (*Falco peregrinus*) – Schedule 4 *Wildlife Conservation Act (1950)*.

The Peregrine Falcon is uncommon, although widespread throughout much of Australia excluding the extremely dry areas and has a wide and patchy distribution. It favours hilly or mountainous country and open woodlands and may be an occasional visitor to the project area. Nesting sites include ledges along cliffs, granite outcrops and quarries, hollow trees near wetlands and old nests of other large bird species (Johnstone and Storr 1998). There is no evidence to suggest any change in status in the last 50 years. Peregrine Falcons were recorded during numerous fauna surveys in the bioregion (Appendix A), so they are in the area.

It is Terrestrial Ecosystems' assessment that the Peregrine Falcon may infrequently be observed in the project area, however, vegetation clearing is unlikely to have a significant impact on this species as there are plenty of similar habitats in adjacent areas and it will readily move from a disturbance area.

Woma (southern form: *Aspidites ramsayi*) – Schedule 4 under the *Wildlife Conservation Act (1950)*.

This python was once common in a crescent shaped distribution from Shark Bay through the wheatbelt to Kitchener. The Western Australian Museum has records of them being caught in the vicinity of the Great Eastern Highway from around Southern Cross and east toward Coolgardie (Thompson and Thompson 2006). The published literature indicates it is now only found around Shark Bay and east of Kalgoorlie.

Terrestrial Ecosystems is aware of another small population on the sand plain near the project area, in habitat similar to that in the project area. It is therefore potentially in the project area in low numbers, but because of the abundance of similar habitat in adjacent areas, any impacts on this species are unlikely to be significant in a regional context.

Carpet Python (*Morelia spilota imbricata*) - Schedule 4 under the *Wildlife Conservation Act (1950)*.

The Carpet Python is a large snake found across the south-west of WA, north to Geraldton and Yalgoo, and east of Kalgoorlie, Fraser Range and Eyre (Thompson and Thompson 2006, Browne-Cooper 2007). It inhabits forest, heath or wetland areas and shelters in hollow logs or in branches of large trees. It feeds on a variety of vertebrates including small mammals and reptiles. Carpet Python assemblages are generally found in low numbers and are dispersed across a relatively large area, except during the breeding season when aggregations have been recorded.

There are old records in Terrestrial Ecosystems fauna survey database of Carpet Pythons being found in the vicinity of the project area. However, they have not been found during any recent surveys (see Appendix A), so if they are present, then its numbers are likely to be very low. Given its wide distribution and the abundance of similar habitat in adjacent areas, any impacts on this species are unlikely to be significant in a regional context.

Southern Death Adder (*Acanthophis antarcticus*) – Priority 3 with DPaW

The Southern Death Adder is a very cryptic snake that is found from the Darling Range, central wheatbelt and from Esperance across the Nullarbor Plain to the South Australian border (Cogger 2014). It is rarely caught in fauna surveys and only opportunistically encountered on roads and in undisturbed bushland at night. Jason Fraser caught a single specimen north of Bungalbin Hill on the sand plain, in habitat similar to that in the project area. They are rarely encountered in the Southern Cross bioregion, and therefore unlikely to be seen in the project area.

Shy Heathwren (*Hylacola cauta whitlocki*) – Priority 4 with DEC.

The Shy Heathwren is a small ground species that is found in the semi-arid interior of WA, including much of the southern wheatbelt. Its habitat includes dense shrub and heathlands in the understorey of eucalypt woodlands, often on sandy soils. Johnstone and Storr (2004) recorded it as locally moderately common or common, but generally scarce or uncommon and patchily distributed, and reported that the project area is within its geographic distribution.

The Shy Heathwren was recorded during surveys by McKenzie and Rofle (1995) and Lyons and Chapman (1997) and could be expected across the region, however, it is likely to be confined to very specific habitats.

Given that the proposed land clearing represents a very small fraction of similar habitat in the area, it is Terrestrial Ecosystems' assessment that the proposed clearing in the project area is unlikely to have a significant impact on this species. If it is in the area then it will move once vegetation clearing commences.

Western Mouse (*Pseudomys occidentalis*) is classified as Priority 4 under the WA Wildlife Conservation Act 1950.

Kitchener and Chapman (1977) described the Western Mouse's preferred habitat as tall shrub land with mallee eucalypts and a heath understorey on a substrate of gravelly loam. Van Dyck and Strahan (2008) reported its geographic distribution to being confined to unburnt areas on sandy clay loam or sandy loam in dense vegetation.

There is a very old record of the Western Mouse in the vicinity of the project area in the DPaW's threatened and priority species database, however, it has not been recorded in any of the more recent surveys, so it is Terrestrial Ecosystems' view that it is unlikely to be in the project area. Potential impacts on this species are therefore likely to be very low.

Crested Bellbird (*Oreoica gutturalis gutturalis*) – Priority 4 with DPaW

Johnstone and Storr (2004) reported the geographic distribution for the Crested Bellbird to include the greater part of WA. Its preferred habitat is scrub and thickets (but not near edges). In the south-west of WA it is found mostly in wooded areas, including open Banksia scrub and heathland. It has been recorded in numerous fauna surveys in the bioregion (Appendix A). It is Terrestrial Ecosystems' assessment that the Crested Bellbird could be seen in the project area.

It is Terrestrial Ecosystems' assessment that the proposed clearing of vegetation in a section of the project area is unlikely to have a significant impact on this species. If the Crested Bellbird is in the area then it will move to more suitable habitat in adjacent areas and will not be significantly impacted on by small scale vegetation clearing.

Bush Stone-curlew (*Burhinus grallarius*) – Priority 4 species with DPaW

The Bush Stone-curlew is a large bird that is often found in lightly wooded areas (Johnstone and Storr 1998). The Bush Stone-curlew demonstrates some site fidelity but its home range appears quite large. There are no records of the Bush Stone-curlew in any of the other fauna surveys in the vicinity of the project area, however, it is a very cryptic species and often not recorded in surveys when present in the area. It is Terrestrial Ecosystems' view that the Bush Stone-curlew may be seen infrequently in the project area, but will readily move away from a disturbance and is unlikely to be impacted by the proposed development.

Central Long-eared Bat (*Nyctophilus (timorensis*) sp.) – Priority 4 with DPaW

This species is probably the species referred to by Churchill (2008) as the Central Long-eared Bat (*Nyctophilu*s sp. 1). This species is distributed across the southern and central wheatbelt, southern part of the Great Victoria Desert and the Nullarbor coast. The project area is on the north-western boundary of its known distribution. It roosts in tree cavities, foliage and under loose bark.

It is Terrestrial Ecosystems' assessment that the proposed clearing of vegetation in the project area is unlikely to have a significant impact on this species as it will readily move when disturbed, and they are likely to be in a similar abundance in adjacent areas.

Australian Bustard (*Ardeotis australis*) – Priority 4 with DPaW

The Australian Bustard is a large, long-lived, sexually dimorphic bird with males standing 110-120cm tall and females 80-90cm tall with large birds weighing up to 10kg (Ziembicki 2010). It is widely distributed on mainland Australia except for most of Victoria and eastern NSW. This bird has a broad habitat preference for open areas ranging from grassland and treeless plains, savannah, croplands, golf courses and airfields. Is partially

migratory/nomadic moving around the Australian continent is search of resources (Ziembicki 2010). Although not previously recorded in fauna survey in the vicinity of the project area it could occasionally be present.

It is Terrestrial Ecosystems' assessment that the proposed clearing of vegetation in the project area is unlikely to have a significant impact on this species as it will readily move when disturbed, and they are likely to be in a similar abundance in adjacent areas.

Hooded Plover (*Charadrius rubricollis*) – Priority 4 species with DPaW

This species frequents the margins and shallows of salt lakes, and also along coastal beaches, where it forages for invertebrates. It is found along the southern coast and salt lakes north to Port Gregory, Three Springs, Mt Gibson, Lake Brown, Lake Barlee, Lake Cowan and Eyre (Johnstone and Storr 1998). It is an uncommon to common resident on the southern sea beaches from Cape Naturaliste east to Eyre. It probably breeds in the samphire habitat along the boundary of some of the salt lakes in the bioregion.

It is Terrestrial Ecosystems' assessment that it is unlikely to be seen in the project area due to a lack of suitable habitat.

Rufous Fieldwren (*Calamanthus camestris montananellus*) – Priority 4 with DPaW

The Rufous Fieldwren's geographic distribution extends from Exmouth south to Dongara along the coast and then in the eastern part of the wheatbelt and along the southern coast to Eyre (Johnstone and Storr 2004). Its known geographical distribution includes the Sandy Ridge Project. It has a preference for heaths and other low shrubland on sand plains and lateritic ridges, shrub steppes (Maireana, Atriplex and Halosarcia samphires) on limestone plains and around salt lakes (Johnstone and Storr 2004). It was not reported in any of the other surveys in the vicinity of the project area, so it is unlikely to be present in the project area.

Western Brush Wallaby (*Macropus irma*) - Priority 4 species with DPaW

Western Brush Wallabies distribution once extended to near the project area, but there are no recent records around the project area. It has a preference for open forests or woodlands, often near a water source and scrubby thickets. It was found in mallee and heathland in the wheatbelt (Morris and Christensen 2008). There is a lack of recent records in the vicinity of the project area indicating it is no longer present, and therefore unlikely to be present in the project area. It is Terrestrial Ecosystems' view, the Western Brush Wallaby is unlikely to be seen in the project area and therefore not impacted by the proposed development.

Southern Brown Bandicoot or Quenda (*Isoodon obesulus fusciventer*) – Priority 5 species with DPaW

Quenda prefer dense scrub (up to one metre high), often in or near swampy or wetland vegetation. It will often feed in adjacent forest and woodland that is burnt and in areas of pasture and cropland lying close to dense cover (Paull 2008). Southern Brown Bandicoots have not been recorded in the vicinity of the project area for a long time, so, it is Terrestrial Ecosystems' view that Southern Brown Bandicoots are unlikely to be in the project area, and thus impacted by the proposed development.

4.6 Risk assessment

Fauna surveys to support Environmental Impact Assessments (EIA) are part of the environmental risk assessment undertaken to consider what potential impacts a development might have on the biodiversity of a particular area and region. Potential impacts on fauna from the proposed development are identified and briefly described above. Tables 7, 8 and 9 provide a summary of the risk assessment associated with this project.

The assessment contained in Table 9 is supported by more detail discussion in sections above and the management recommendations below.

Table 7. Fauna impact risk assessment descriptors

Any risk assessment is a product of the likelihood of an impact occurring and the consequences of that impact. Likelihood and consequences are categorised and described below. These criteria do not fit all circumstances (e.g. adequacy of fauna survey data), however, they are useful in providing the reader with an appreciation of the level of likelihood and consequences of an event. The assessed risk level (likelihood x consequences) is then calculated as the overall risk for the development. This is followed by an assessment of the acceptability of the risk associated with each of the events or impacts. Disturbances and vegetation clearing have an impact on the fauna at multiple scales – site, local, landscape and regional. Each of these is considered in the risk assessment. This assessment should be considered in the context of the summary in Table 9.

Likelihood		
Level	Description	Criteria
A	Rare	The environmental event may occur or one or more conservation significant species may be present in exceptional circumstances.
B	Unlikely	The environmental event could occur or one or more conservation significant species could be present at sometime.
C	Moderate	The environmental event should occur or one or more conservation significant species should be present at sometime.
D	Likely	The environmental event will probably occur or one or more conservation significant species will be present in most circumstances.
E	Almost certain	The environmental event is expected to occur or one or more conservation significant species is expected be present in most circumstances.
Consequences		
Level	Description	Criteria
1	Insignificant	Insignificant impact on fauna of conservation significance or regional biodiversity, and the loss of individuals will be insignificant in the context of the availability of similar fauna or fauna assemblages in the area.
2	Minor	Impact on fauna localised and no significant impact on species of conservation significance in the project area. Loss of species at the local scale.
3	Moderate	An appreciable loss of fauna in a regional context or a limited impact on species of conservation significance in the project area.
4	Major	Significant impact on conservation significant fauna or their habitat in the project area and/or regional biodiversity and/or a significant loss in the biodiversity at the landscape scale.
5	Catastrophic	Loss of species at the regional scale and/or a significant loss of species categorised as 'vulnerable' or 'endangered' under the *EPBC Act 1999* at a regional scale.

Acceptability of Risk	
Level of risk	Management of risk
Low	No action required.
Moderate	Avoid if possible, routine management with internal audit and review of monitoring results annually.
High	Externally approved management plan to reduce risks, monitor major risks annually with external audit and review of management plan outcomes annually. Will require a referral to the Commonwealth under the *EPBC Act 1999*.
Extreme	Unacceptable, project should be redesigned or not proceed.

Table 8. Levels of acceptable risk

		Likelihood				
		Rare or very low (A)	Unlikely or low (B)	Moderate (C)	Likely (D)	Almost certain (E)
Consequences	Insignificant (1)	Low	Low	Low	Low	Low
	Minor (2)	Low	Low	Low	Moderate	Moderate
	Moderate (3)	Low	Moderate	Moderate	High	High
	Major (4)	Moderate	Moderate	High	High	Extreme
	Catastrophic (5)	Moderate	High	High	Extreme	Extreme

Table 9. Risk assessment

		Before Management				With Management		
Factor	Potential Impact	Inherent Risk			Risk Controls / Management	Residual Risk		
		Likelihood	Consequence	Significance		Likelihood	Consequence	Significance
Inadequate fauna survey data.	Unknown loss of fauna, fauna of conservation significance, fauna assemblage(s) in project area.	C	2	Low				
Inadequate knowledge of potential impacts.	Unknown or poorly assessed impact(s) on fauna assemblage and conservation significant species.	B	2	Low				
Inadequate bioregional data for contextual purposes.	Incomplete analysis of data and appreciation of impacts on biodiversity values in a regional context.	B	2	Low				
Removal of habitat – site scale.	Almost complete loss of terrestrial fauna in cleared areas, severe impact on local fauna assemblage.	E	1	Low				
Significant reduction of habitats – local scale.	Loss of fauna and fauna habitat and impacts on local fauna assemblage (excluding conservation significant species).	B	1	Low				
Significant reduction of habitats – landscape scale.	Loss of fauna and fauna habitat and impacts on fauna in a landscape context (excluding conservation significant species).	A	1	Low				
Significant reduction of habitats – regional scale.	Loss of fauna and fauna habitat and impacts on fauna in a bioregional context (excluding conservation significant species).	A	1	Low				

		Before Management				With Management		
Factor	Potential Impact	Inherent Risk			Risk Controls / Management	Residual Risk		
		Likelihood	Consequence	Significance		Likelihood	Consequence	Significance
Loss of conservation significant species	Loss of a localised population or a few individuals – *Leipoa ocellata*.	A	3	Low				
	Loss of a localised population or a few individuals – *Platycercus icterotis xanthogenys*.	A	3	Low				
	Loss of a localised population or a few individuals – *Lophochroa leadbeateri.*	A	3	Low				
	Loss of a localised population or a few individuals – *Morelia spilota imbricata.*	A	2	Low				
	Loss of a localised population or a few individuals – *Pseudomys occidentalis.*	A	2	Low				
	Loss of a localised population or a few individuals – *Acanthophis antarcticus.*	B	2	Low				
	Loss of a localised population or a few individuals – *Aspidites ramsayi.*	C	2	Low				
	Loss of a localised population or a few individuals – *Oreoica gutturalis gutturalis.*	B	2	Low				
	Loss of a localised population or a few individuals – *Nyctophilus(timoriensis)* sp.	A	2	Low				
	Loss of a localised population or a few individuals – *Macropus irma.*	A	2	Low				

		Before Management				With Management		
Factor	Potential Impact	Inherent Risk			Risk Controls / Management	Residual Risk		
		Likelihood	Consequence	Significance		Likelihood	Consequence	Significance
	Loss of a localised population or a few individuals – *Isoodon obesulus fusciventer*	A	2	Low				
	Loss of a localised population or a few individuals – *Calamanthus camestris montananellus.*	A	2	Low				
	Loss of a localised population or a few individuals – *Falco peregrinus.*	A	2	Low				
	Loss of a localised population or a few individuals – *Dasyurus geoffroii.*	A	2	Low				
	Loss of a localised population or a few individuals – *Hylacola cauta whitlocki*	A	2	Low				
	Loss of a localised population or a few individuals – *Burhinus grallarius.*	A	2	Low				
Nomadic avian species	Loss of a localised population or a few individuals – *Ardeotis australis.*	A	2	Low				
Migratory avian species.	Loss of a localised population or a few individuals – *Merops ornatus.*	B	2	Low				
	Loss of a localised population or a few individuals – *Apus pacificus.*	A	2	Low				
Anthropogenic activity	Altered fire regimes adversely affecting fauna assemblages.	B	2	Low				
	Introduced fauna populations increasing.	C	2	Low				
	Road kills.	E	2	Low				

5 DISCUSSION

5.1 Adequacy of available vertebrate fauna data

The EPA *Terrestrial Biological Surveys as an Element of Biodiversity Protection:* Position Statement No. 3 (EPA 2002), *Guidance Statement for Assessment of Environmental Factors: Terrestrial Fauna Surveys for Environmental Impact Assessment in Western Australia No. 56* (EPA 2004) and the *Technical Guide – Terrestrial Vertebrate Fauna Surveys for Environmental Impact Assessment* (EPA / DEC 2010) are the three relevant regulatory documents to assess the adequacy of the available information and reporting for vertebrate fauna surveys in Western Australia.

Tellus proposes to develop a kaolin mine with complimentary storage and waste isolation facilities at its Sandy Ridge Project. There is an abundance of similar fauna habitat in very good to excellent condition in adjacent areas. Fauna survey data for Jackson-Kalgoorlie and the Boorabbin-Southern Cross sections of the Eastern Goldfields biological surveys (Dell and How 1985, McKenzie and Rolfe 1995a), plus fauna survey data from other surveys to support mining proposals (Ecologia Environmental Consultants 2001, 2003, Ninox Wildlife Consulting 2008, 2009b, a) and for research purposes (Dickman et al. 1991, Lyons and Chapman 1997) provide an adequate indication of the fauna assemblages likely to be encountered in the project area.

5.2 Biodiversity values of the project area

The EPA Position Statement No. 3 indicates an ecological assessment of a project must consider its biodiversity value at the genetic, species and ecosystem levels, and its ecological functional value at the ecosystem level (EPA 2002). There are insufficient data available to consider biodiversity at the genetic level.

Fauna habitat types represented in the project area are abundant and in very good condition in adjacent areas. Therefore, the fauna assemblage that is present in the project area will also be present and abundant in the adjacent areas. The available fauna survey data (Appendix A) provides a good indication of the vertebrate fauna that are potentially in the project area.

5.2.1 Condition of fauna habitat and extent of habitat degradation

There were two broad habitats available in the project area. These are an open eucalypt woodland with an open understorey of shrubs over ephemeral grasses or scattered spinifex on red sandy clay soils, and a moderately dense to dense sand plain shrubland varying in height from 0.5-1.8m on yellow sandy soils. Both habitats are in very good to excellent condition. Small sections have been degraded by exploration tracks and activity, and the presence of foxes and possibly cats will have impacted on the small vertebrate fauna.

5.2.2 Ecological linkages

The project area currently does not provide any important ecological linkages or fauna movement corridors, as it is part of a large and relatively undisturbed area. There are exploration tracks that dissect the project area, but all are relatively narrow and are unlikely to provide a barrier that would inhibit the movement of fauna within the general area.

5.2.3 Conservation significant species

The listed avian species of conservation significance potentially seen in the project area are the Major Mitchell's Cockatoo, Western Rosella, Peregrine Falcon, Australian Bustard, Crested Bellbird, Shy Heathwren, Bush Stone-curlew, Malleefowl, the migratory Rainbow Bee-eater and the Fork-tailed Swift. These birds would readily move from the area if disturbed by vegetation clearing. The only potential impact would be clearing a tree that contained eggs or chicks, and the likelihood of this happening is assessed as very low.

The Western Brush Wallaby, Southern Brown Bandicoot, Chuditch, Western Mouse and Carpet Python are unlikely to be in the project area and thus impacted by the proposed development. There is a possibility that the Woma Python is present in low numbers, but it will also be present in adjacent areas, so any impacts are likely to be non-significant in a regional context.

5.2.4 Great Western Woodland

The project area is within the Great Western Woodland (Department of Environment and Conservation 2010) which is an area of special interest to the Wilderness Society and the DPaW. Currently, there are no specific management strategies in place that focus on the vertebrate fauna, however, the proposed state government management strategies for pest and fire will have an indirect impact if and when they are implemented.

Conservation groups are keen for the Great Western Woodland to be preserved and will continually put pressure on DPaW and environmental regulators to limit development in this area.

5.3 Potential impacts on fauna

Clearing of vegetation will potentially affect vertebrate fauna in a number of ways, including:

- Death/injury of fauna during clearing, grading and impacts with vehicles;
- Loss of habitat;
- Fragmentation of habitat;
- Increase in feral fauna around the mining development; and
- Disturbance of fauna in nearby areas from light, noise and dust.

These impacts are discussed below.

5.3.1 Direct impacts

5.3.1.1 Animal deaths during the clearing process and displacement of fauna

Clearing vegetation and construction activities will result in the loss of most small fauna that retreat to burrows, such as reptiles and mammals. Nocturnal species are unlikely to be active when most of the land clearing and construction work is taking place which will inevitably result in these individuals being killed or injured in their burrows or as they attempt to escape. Larger terrestrial animals and avian species will most often move to adjacent areas. These species will be required to establish new activity areas and home ranges, and this could result in the temporary displacement of resident species. However, long-term impacts are likely to be low.

5.3.1.2 Reduction or loss of activity areas and closure of burrows

Clearing vegetation and associated construction activities are likely to destroy reptile and mammal burrows or foraging habitat that are currently in use, or could be used again. Clearing vegetation that forms part of the activity area of individuals has the potential to force these animals into adjacent areas. These areas may offer fewer resources placing individuals under survival pressure. It could also cause individuals to move into the territories of other individuals increasing competition for resources. Forced relocations could increase the possibility of predation.

5.3.2 Indirect impacts

In addition to the obvious impact of vegetation clearing there can be an equally significant or greater impact in the adjacent areas because of ‘edge effects’. Edge effects include disruption to ecological processes such as predation and dispersal, animal movements and can change assemblage structure. The consequence is that the impact area will always be much larger than the cleared area. Vehicle tracks also have the propensity to develop weed infestations which can impact on natural fauna habitats. Cleared corridors can also provide improved predator access to areas, enhance the invasion of pest species into areas and may act as inhibitors or disrupt fauna migration and movement patterns.

There are numerous potential threats associated with vegetation clearing and the construction of infrastructure that could have a significant impact on the vertebrate fauna in the project area. Some of these are discussed below.

5.3.2.1 Habitat fragmentation

In addition to vegetation clearing, infrastructure including tracks, has the potential to fragment habitat. Cleared linear tracks of land are 'unnatural' in much of the habitat. These linear structures that partition existing activity areas, isolate sections of established communities and may alter long and medium-term patterns of movement around established home ranges particularly for small mammals and reptiles. A reduction in the population as a result of this infrastructure would be difficult to detect given our current knowledge of the spatial ecology for most of the small mammals known to be in the area.

As most of the tracks within the project area will be relatively narrow, the potential impact associated with habitat fragmentation is likely to be low.

5.3.2.2 Introduced fauna

An increase in human activity is often associated with an increase in the abundance of introduced species such as the house mouse (*Mus musculus*), cat (*Felis catus*) and wild dogs (*Canis lupus*). This increase may be due to a decline in habitat health, increased road kills, poor disposal of waste and easier access to areas via tracks.

House mice, cats and wild dogs are known to be established in the area. In many situations they have become a 'naturalised' species in the Australian bush. Increases in dog or cat numbers can have a detrimental impact on native fauna because they predate on and compete with native species, severely disrupting the natural balance.

Infrastructure known to support feral species, such as rubbish disposal sites and bins, should be managed to minimise increases in these populations.

5.3.2.3 Road fauna deaths

An increase in road fauna deaths is likely to occur where new roads are constructed or upgraded, in particular, affecting kangaroos, nocturnal birds and ground dwelling large carnivorous predators. Species such as goannas and raptors are attracted to carrion on road verges. Therefore, there is an increased propensity for these species to be killed by vehicles.

5.3.2.4 Anthropogenic activity

Unnatural noises, vibrations, artificial light sources and vehicle and human movement in an area may be sufficient to force individuals or fauna species to move from an area, or alter their activity periods.

5.4 Native vegetation clearing principles

The *Environmental Protection Act* (*1986*) provides criteria to judge the potential impact of a development on clearing native vegetation on flora and fauna. These criteria have been listed below with a response to indicate how clearing of the vegetation at the Sandy Ridge Project might be judged against these principles as they relate to fauna and fauna assemblages.

Table 10. Assessment of impact on fauna and fauna assemblages using the Native Vegetation Clearing Principles

Principle	Response
It comprises a high level of biological diversity.	Clearing vegetation will not compromise a high level of biodiversity.
It comprises the whole or a part of, or is necessary for the maintenance of, a significant habitat for fauna indigenous to Western Australia.	The project area does not contain habitat that is necessary for fauna indigenous to Western Australia
It includes, or is necessary for the continued existence or, rare flora.	Not applicable.
It comprises the whole or a part of, or is necessary for the maintenance of, a threatened ecological community.	The area does not contain a threatened ecological community.
It is significant as a remnant of native vegetation in an area that has been extensively cleared.	The area is not a remnant nor will the proposed clearing create a remnant.
It is growing in, or in association with, an environment associated with a watercourses or wetland.	The proposed impact area does not contain a wetland.
The clearing of the vegetation is likely to cause appreciable land degradation.	Not applicable.
The clearing of the vegetation is likely to have an impact on the environmental values of any adjacent or nearby conservation area.	Clearing of vegetation is unlikely to impact on the environmental values of the bioregion.
The clearing of the vegetation is likely to cause deterioration in the quality of surface or underground water.	Not applicable.
The clearing of the vegetation is likely to cause, or exacerbate the incidence of flooding.	Not applicable.

6 MANAGEMENT STRATEGIES

6.1.1 Induction and awareness

All contractors and people involved in vegetation clearing, construction and operation of the facilities should be made aware of the possible presence and issues associated with terrestrial fauna in the area through the induction process.

Recommendation 1: Information on protecting fauna and reporting deaths and sightings of Malleefowl and other conservation significant species should be incorporated into the Sandy Ridge Project induction program.

6.1.2 Minimising habitat fragmentation

Loss of vegetation and habitat may contribute to the decline in the number of fauna on and in the vicinity of project area. Where possible, access routes should be aligned to existing tracks and other barriers or follow the boundaries of broad-scale vegetation associations in the area to minimise the impact on the terrestrial fauna, which are often dependent upon specific habitat types. Clearing should be minimised wherever possible and remnant vegetation fragmentation should be avoided wherever possible. Once areas are no longer required then they should be rehabilitated.

Recommendation 2: All areas disturbed during mining are rehabilitated as soon as practical after they are no longer required.

Recommendation 3: Where possible, access routes are aligned to existing roads, tracks and other barriers or follow the boundaries of broad-scale vegetation associations in the area.

6.1.3 Minimising secondary impacts to the habitat

Pets and feral animals have the potential to impact on conservation significant species. Pets should not be permitted on the project and feral animal numbers monitored and controlled. All rubbish likely to attract animals should be suitably contained and disposed of so as not to encourage the feeding of fauna around the project.

Recommendation 4: Pets are not permitted on the project.

Recommendation 5: All waste and rubbish be contained in bins and regularly removed from the project or placed in land fill.

Recommendation 6: Feeding of native fauna is prohibited.

6.1.4 Uncapped drill holes

Uncapped drill holes can pose a serious threat to small animals, including ground dwelling reptiles, frogs and small mammals. A log of all on-site drill holes should be maintained detailing when they were capped, how and by whom. All drill holes should be temporarily capped on completion of drilling and permanently capped or closed as soon as possible after exploration activities have ceased.

Recommendation 7: A log of all on-site drill holes be maintained detailing when they were capped, how and by whom.

6.1.5 Fauna management plan

Fauna management plans describe the procedures and protocols that must be implemented to avoid, mitigate and minimise impacts on fauna during the vegetation clearing, infrastructure development and operational stages of a project. Such plans, deal with the method of vegetation clearing, reducing fauna deaths on the roads, the impacts

of artificial light spill, vibration, dust, feral species management, monitoring and recording conservation species, monitoring impacts on fauna in adjacent areas, staff inductions, etc.

Recommendation 8: A fauna management plan is prepared and implemented for the life of the project.

7 SUMMARY AND CONCLUSIONS

Tellus is proposing to develop a kaolin mine with complimentary storage and waste isolation facilities at its Sandy Ridge Project. Fauna survey data from other projects in the bioregion (e.g. Boorabbin–Southern Cross and Kalgoorlie-Jackson bioregional surveys, mining development proposals at Carina and Chamaeleon, and research survey data from the Bungalbin sand plain, Mt Walton and the Helena and Aurora Range plus the records from NatureMap and the Western Australian Museum) provide an adequate indication of the fauna assemblages likely to be encountered in the project area. These data are adequate to assess potential impacts on the vertebrate fauna potentially found in the project area.

No conservation significant vertebrate fauna were assessed as being likely to be significantly impacted by the proposed development. There is a possibility that Major Mitchell's Cockatoo, Western Rosella, Woma Rainbow Bee-eater, Fork-tailed Swift, Peregrine Falcon, Crested Bellbird, Bush Stone-curlew, Australian Bustard and the Central Long-eared Bat are in the project area. However, the proposed impact area is relatively small, so the probability of significantly impacting on any of these species is very low. The project area was searched for Malleefowl tracks and mounds and none were found. Therefore there is a very low probability of impact on this species.

Vegetation clearing will result in the loss of numerous small vertebrates in the project area and indirect impacts such as a reduction or loss of activity areas and closure of burrows, habitat fragmentation, increased presence of feral predators, road deaths and unnatural noises, vibrations, artificial light sources and vehicle and human movement in an area may force animals into adjacent areas.

The implementation of the recommended management strategies will mitigate or minimise potential impacts on the vertebrate fauna in the project area.

As there is an abundance of similar fauna habitat in very good to excellent condition in adjacent areas, the project area does not provide an important ecological linkage or fauna movement corridor, there is limited potential for impacting on conservation significant fauna in a regional context and there are data available from multiple locations in the vicinity of the project area to provide an adequate indication of the fauna assemblages likely to be encountered in the project area (Plate 1), there is limited value in undertaking a Level 2 detailed or comprehensive survey. The fauna data collected during a Level 2 survey, if undertaken, is unlikely to provide any additional information which would alter the analysis of potential impacts on fauna and fauna assemblages during the environmental impact assessment process.

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Figures

Vertebrate Fauna Assessment – Sandy Ridge Project

TERRESTRIAL ECOSYSTEMS

TERRESTRIAL ECOSYSTEMS

Tellus Holdings Ltd
VERTEBRATE FAUNA RISK ASSESSMENT
SANDY RIDGE PROJECT

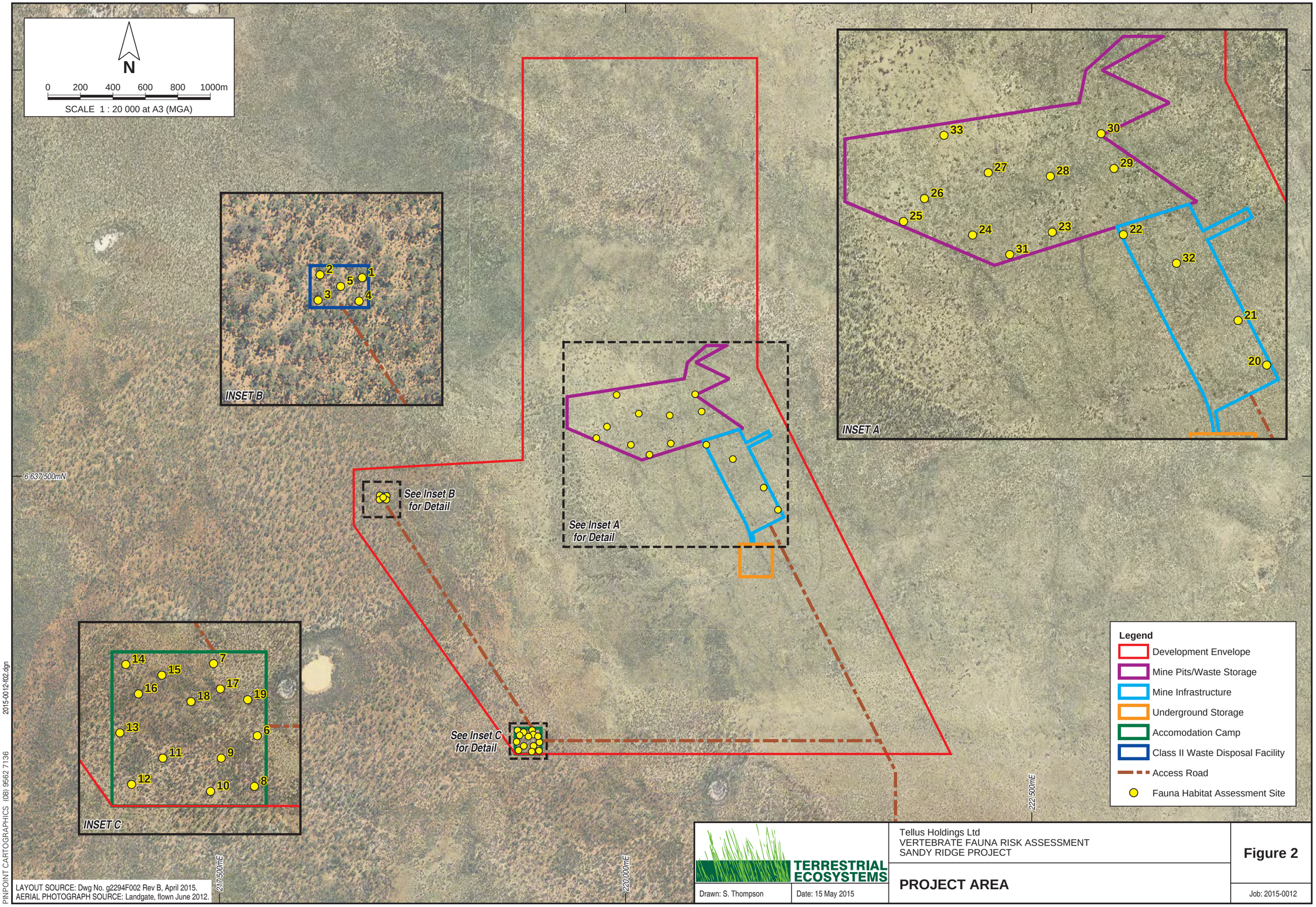
Figure 1

REGIONAL LOCATION

Drawn: S. Thompson | Date: 15 May 2015 | Job: 2015-0012

2015-0012-f01.dgn

PINPOINT CARTOGRAPHICS (08) 9562 7136



LAYOUT SOURCE: Dwg No. g2294F002 Rev B, April 2015.
AERIAL PHOTOGRAPH SOURCE: Landgate, flown June 2012.

TERRESTRIAL ECOSYSTEMS

Drawn: S. Thompson

Date: 15 May 2015

Tellus Holdings Ltd
VERTEBRATE FAUNA RISK ASSESSMENT
SANDY RIDGE PROJECT

PROJECT AREA

Figure 2

Job: 2015-0012

PINPOINT CARTOGRAPHICS (08) 9562 7136 2015-0012-f02.dgn

Appendix A
Vertebrate Fauna Recorded in Biological Surveys in the Region

Vertebrate Fauna Assessment – Sandy Ridge Project

TERRESTRIAL ECOSYSTEMS

Appendix A(1) Fauna survey data in the vicinity of the project area

		Survey Name	A																													
Family	Species	Common Name	Kooorawalyee Dam	Pools on granite	Site 7E	Site 7E01A	Site 7E02	Site 7E03	Site 7E03A	Site 7E04	Site 7E05	Site 7E06	Site 7E06A	Site 7W	Site 7W03	Site 7W04	Site 7W06	Site BN	Site BN1	Site BN2	Site BN4	Site BN6	South 6.5km 7E	West 1.9km 7W03	West 1.9km 7W04	West 1.9km 7W05	West 2.9km 7W03	West 2.9km 7W04	West 2.9km 7W05	West 2.9km 7W06	West 2.9km 7W07
Birds																																
Accipitridae	*Lophoictinia isura*	Square-tailed Kite												X																		
	Hamirostra melanosternon	Black-breasted Buzzard												X																		
	Accipiter cirrocephalus	Collared Sparrowhawk						1	1																							
	Aquila audax	Wedge-tailed Eagle																X														
	Hieraaetus morphnoides	Little Eagle								1																						
Anatidae	*Chenonetta jubata*	Australian Wood Duck																X														
	Anas gracilis	Grey Teal																X														
Aegothelidae	*Aegotheles cristatus*	Australian Owlet-nightjar								1								X														
Podargidae	*Podargus strigoides*	Tawny Frogmouth					1											X														
Casuariidae	*Dromaius novaehollandiae*	Emu					2								1																	
Charadriidae	*Vanellus tricolor*	Banded Lapwing																X														
Turnicidae	*Turnix varius*	Painted Button-quail																				1										
Columbidae	*Phaps chalcoptera*	Common Bronzewing					2			3												2										
	Ocyphaps lophotes	Crested Pigeon																X														
Alcedinidae	*Todiramphus pyrrhopygius*	Red-backed Kingfisher					1		2												4											
Meropidae	*Merops ornatus*	Rainbow Bee-eater					5	13	19	30																						
Cuculidae	*Chalcites basalis*	Horsfield's Bronze-Cuckoo			X													X														
	Cacomantis pallidus	Pallid Cuckoo					2											X														
	Cacomantis flabelliformis	Fan-tailed Cuckoo																														
Caprimulgidae	*Eurostopodus argus*	Spotted Nightjar					1									2																
Falconidae	*Falco cenchroides*	Nankeen Kestrel			X													X														
	Falco berigora	Brown Falcon			X													X														

TERRESTRIAL ECOSYSTEMS

		Survey Name	A																												
Family	Species	Common Name	Koorarawalyee Dam	Pools on granite	Site 7E	Site 7E01A	Site 7E02	Site 7E03	Site 7E03A	Site 7E04	Site 7E05	Site 7E06	Site 7E06A	Site 7W	Site 7W03	Site 7W04	Site 7W06	Site BN	Site BN1	Site BN2	Site BN4	Site BN6	South 6.5km 7E	West 1.9km 7W03	West 1.9km 7W04	West 1.9km 7W05	West 2.9km 7Wo3	West 2.9km 7Wo4	West 2.9km 7Wo5	West 2.9km 7Wo6	West 2.9km 7Wo7
	Falco peregrinus	Peregrine Falcon												X																	
Megapodiidae	*Leipoa ocellata*	Malleefowl												X		X															
Rallidae	*Fulica atra*	Eurasian Coot																X													
Acanthizidae	*Calamanthus cautus*	Shy Heathwren					1														3										
	Pyrrholaemus brunneus	Redthroat					6	1								1			4		2										
	Smicrornis brevirostris	Weebill				4	35	29		11	21				26	8					9	98									
	Acanthiza chrysorrhoa	Yellow-rumped Thornbill						10										X													
	Acanthiza apicalis	Inland Thornbill					6	4		5	4				22	18			9	20		7									
	Aphelocephala leucopsis	Southern Whiteface												X				X													
	Acanthiza uropygialis	Chestnut-rumped Thornbill					24	4							1						6	13									
Artamidae	*Artamus personatus*	Masked Woodswallow			X										52																
	Artamus cinereus	Black-faced Woodswallow								1								X													
	Artamus cyanopterus	Dusky Woodswallow					3			21	3										35										
	Cracticus torquatus	Grey Butcherbird					1												1		1										
	Cracticus nigrogularis	Pied Butcherbird						1	6	1								X													
	Cracticus tibicen	Australian Magpie			X													X													
	Strepera versicolor	Grey Currawong						1										X													
Campephagidae	*Coracina maxima*	Ground Cuckoo-Shrike																X													
	Coracina novaehollandiae	Black-faced Cuckoo-Shrike				3	5	1	2	1												1									
	Lalage sueurii	White-winged Triller			9	4																									
Climacteridae	*Climacteris rufa*	Rufous Treecreeper								29	39										20										
Corvidae	*Corvus coronoides*	Australian Raven																			2										
	Corvus bennetti	Little Crow																X													
Eupetidae	*Cinclosoma castanotum*	Chestnut Quail-thrush									1			X																	

TERRESTRIAL ECOSYSTEMS

		Survey Name	A																													
Family	Species	Common Name	Koorarawalyee Dam	Pools on granite	Site 7E	Site 7E01A	Site 7E02	Site 7E03	Site 7E03A	Site 7E04	Site 7E05	Site 7E06	Site 7E06A	Site 7W	Site 7W03	Site 7W04	Site 7W06	Site BN	Site BN1	Site BN2	Site BN4	Site BN6	South 6.5km 7E	West 1.9km 7W03	West 1.9km 7W04	West 1.9km 7W05	West 2.9km 7W03	West 2.9km 7W04	West 2.9km 7W05	West 2.9km 7W06	West 2.9km 7W07
Hirundinidae	*Petrochelidon nigricans*	Tree Martin					7														48										
Maluridae	*Malurus leucopterus*	White-winged Fairy-wren			X																										
	Malurus pulcherrimus	Blue-breasted Fairy-wren													14	2															
Meliphagidae	*Certhionyx variegatus*	Pied Honeyeater												X																	
	Lichenostomus virescens	Singing Honeyeater					2	2										X													
	Lichenostomus leucotis	White-eared Honeyeater					7	5							4	1						5									
	Lichenostomus flavicollis	Yellow-throated Honeyeater						12		1	1									1	4										
	Lichenostomus ornatus	Yellow-plumed Honeyeater					31			102	54										125	6									
	Lichenostomus plumulus	Grey-fronted Honeyeater																													
	Purnella albifrons	White-fronted Honeyeater					6	12		3	3				27	10						1									
	Manorina flavigula	Yellow-throated Miner																													
	Acanthagenys rufogularis	Spiny-cheeked Honeyeater					2	1	1										1	1	23	11									
	Anthochaera carunculata	Red Wattlebird						2		3	1											1									
	Epthianura tricolor	Crimson Chat												X																	
	Epthianura albifrons	White-fronted Chat			X									X				X													
	Glyciphila melanops	Tawny-crowned Honeyeater					2												5	2											
	Lichmera indistincta	Brown Honeyeater					8											2			1	1									
	Melithreptus brevirostris	Brown-headed Honeyeater					4								2			X													
Monarchidae	*Grallina cyanoleuca*	Magpie-Lark																X													
Motacilidae	*Anthus novaeseelandiae*	Australasian Pipit				7		1						X					3												
Nectariniidae	*Dicaeum hirundinaceum*	Mistletoebird													1						1										
Neosittidae	*Daphoenositta chrysoptera*	Varied Sittella			X																										
Pachycephalidae	*Pachycephala inornata*	Gilbert's Whistler					8				7										7										
	Pachycephala pectoralis	Golden Whistler														1															

TERRESTRIAL ECOSYSTEMS

		Survey Name	A																												
Family	Species	Common Name	Koorarawalyee Dam	Pools on granite	Site 7E	Site 7E01A	Site 7E02	Site 7E03	Site 7E03A	Site 7E04	Site 7E05	Site 7E06	Site 7E06A	Site 7W	Site 7W03	Site 7W04	Site 7W06	Site BN	Site BN1	Site BN2	Site BN4	Site BN6	South 6.5km 7E	West 1.9km 7W03	West 1.9km 7W04	West 1.9km 7W05	West 2.9km 7W03	West 2.9km 7W04	West 2.9km 7W05	West 2.9km 7W06	West 2.9km 7W07
	Pachycephala rufiventris	Rufous Whistler			X													X													
	Colluricincla harmonica	Grey Shrike-thrush					2	3	9	4					1	1			1		7										
	Oreoica gutturalis	Crested Bellbird					4	1	7	3					2	2					3	1									
Pardalotidae	*Pardalotus striatus*	Striated Pardalote					12	7		8	16										28	17									
Petroicidae	*Microeca leucophaea*	Jacky Winter					2	1			7										3	1									
	Petroica goodenovii	Red-capped Robin					7	7		1					3				4			1									
	Melanodryas cucullata	Hooded Robin					4											X													
	Drymodes brunneopygia	Southern Scrub-robin					2								4	6															
Pomatostomidae	*Pomatostomus superciliosus*	White-browed Babbler					12									18			5												
Rhipiduridae	*Rhipidura leucophrys*	Willie Wagtail						2	12	8											2										
Podicipedidae	*Tachybaptus novaehollandiae*	Australasian Grebe																X													
	Poliocephalus poliocephalus	Hoary-headed Grebe																X													
Cacatuidae	*Nymphicus hollandicus*	Cockatiel			X													X													
Psittacidae	*Glossopsitta porphyrocephala*	Purple-crowned Lorikeet				1		8	6									X													
	Polytelis anthopeplus	Regent Parrot						1	14						3						2										
	Platycercus icterotis xanthogenys	Western Rosella								1						1															
	Barnardius zonarius	Australian Ringneck					6	14	5	1											1	1									
	Psephotus varius	Mulga Parrot																			20										
	Neophema elegans	Elegant Parrot								1																					
Strigidae	*Ninox novaeseelandiae*	Southern Boobook			X									X				X													
Mammals																															
Canidae	*Canis lupus*	Dog						X																							
Felidae	*Felis catus*	House Cat			X	X																									
Molossidae	*Austronomus australis*	White-striped Freetail Bat	X	X	7					1					1	2	1	3			1		X	X			X				

TERRESTRIAL ECOSYSTEMS

		Survey Name	A																													
Family	Species	Common Name	Koorarawalyee Dam	Pools on granite	Site 7E	Site 7E01A	Site 7E02	Site 7E03	Site 7E03A	Site 7E04	Site 7E05	Site 7E06	Site 7E06A	Site 7W	Site 7W03	Site 7W04	Site 7W06	Site BN	Site BN1	Site BN2	Site BN4	Site BN6	South 6.5km 7E	West 1.9km 7W03	West 1.9km 7W04	West 1.9km 7W05	West 2.9km 7W03	West 2.9km 7W04	West 2.9km 7W05	West 2.9km 7W06	West 2.9km 7W07
	Mormopterus planiceps	Southern Freetail-bat							1	2																						
Vespertilionidae	*Chalinolobus gouldii*	Gould's Wattled Bat	X		13				1	3					4		1	5							X			X			
	Chalinolobus morio	Chocolate Wattled Bat			3				1	3													X						X		
	Nyctophilus geoffroyi	Lesser Longeared Bat			1										1															X	
	Nyctophilus major	Western Longeared Bat		X	X									X																	
	Scotorepens balstoni	Inland Broadnosed Bat							1																						
	Vespadelus regulus	Southern Forest Bat	X	X	11					5					1			3					X			X					X
Dasyuridae	*Antechinomys laniger*	Kultarr													2		1														
	Ningaui yvonneae	Mallee Ningaui				1		3	1	1							2			2											
	Sminthopsis crassicaudata	Fat-tailed Dunnart				8																1									
	Sminthopsis dolichura	Little Long-tailed Dunnart					1		2	1	4	1			1	2	2				1										
	Sminthopsis granulipes	White-tailed Dunnart													2		6														
	Sminthopsis hirtipes	Hairy-footed Dunnart										1	1																		
Burramyidae	*Cercartetus concinnus*	Southwestern Pygmy Possum				1					1																				
Macropodidae	*Macropus fuliginosus*	Western Grey Kangaroo			6	1			2		2				1																
Leporidae	*Oryctolagus cuniculus*	European Rabbit			X	X	X	X	X	X																					
Tachyglossidae	*Tachyglossus aculeatus*	Short-beaked Echidna			X					X																					
Muridae	*Mus musculus*	House Mouse				10				1		1				1		6	6	2	3										
	Notomys mitchellii	Mitchell's Hopping Mouse						1	1						1	1	2														
	Pseudomys albocinereus	Ash-grey Mouse								1									5	9											
	Pseudomys bolami	Bolam's Mouse				2	2	2					1																		
Amphibians																															
Limnodynastidae	*Neobatrachus kunapalari*	Kunapalari Frog													1					X	X	X									
	Neobatrachus pelobatoides	Humming Frog																			X										

TERRESTRIAL ECOSYSTEMS

		Survey Name	A																													
Family	Species	Common Name	Koorarawalyee Dam	Pools on granite	Site 7E	Site 7E01A	Site 7E02	Site 7E03	Site 7E03A	Site 7E04	Site 7E05	Site 7E06	Site 7E06A	Site 7W	Site 7W03	Site 7W04	Site 7W06	Site BN	Site BN1	Site BN2	Site BN4	Site BN6	South 6.5km 7E	West 1.9km 7W03	West 1.9km 7W04	West 1.9km 7W05	West 2.9km 7W03	West 2.9km 7W04	West 2.9km 7W05	West 2.9km 7W06	West 2.9km 7W07
Myobatrachidae	*Pseudophryne occidentalis*	Western Toadlet			X																	X									
Reptiles																															
Agamidae	*Ctenophorus adelaidensis*	Southern Heath Dragon																X													
	Ctenophorus cristatus	Bicycle Dragon			X		3	3	16	8				X							X	X									
	Ctenophorus isolepis											2							X	X											
	Ctenophorus maculatus	Spotted Military Dragon			X									X	1	13	3	X													
	Ctenophorus ornatus	Ornate Crevice Dragon																X													
	Ctenophorus reticulatus	Western Netted Dragon			X									X							X										
	Ctenophorus salinarum	Salt Pan Dragon			X	13						1		X	2	2	7		X	X											
	Ctenophorus scutulatus													X					X		X										
	Moloch horridus	Thorny Devil			X		1	2	1					X	2	1				X											
	Pogona minor	Bearded Dragon			X		1	1				1			2	3			X	X											
Carphodactylidae	*Nephrurus stellatus*														2																
Diplodactylidae	*Crenadactylus ocellatus*	Clawless Gecko			X																	X									
	Diplodactylus granariensis									1											X	X									
	Diplodactylus pulcher														1			X		X	X										
	Lucasium maini				X		2			2				X	2						X										
	Oedura reticulata				X					1	X											X									
	Strophurus assimilis	Goldfields Spiny-tailed Gecko			X							1							X												
Elapidae	*Echiopsis curta*	Bardick																X													
	Parasuta gouldii																			X											
	Pseudechis australis	Mulga Snake																	X												
	Pseudonaja affinis	Dugite			X														X												
	Pseudonaja modesta	Ringed Brown Snake			X																										

TERRESTRIAL ECOSYSTEMS

		Survey Name	A																													
Family	Species	Common Name	Koorarawalyee Dam	Pools on granite	Site 7E	Site 7E01A	Site 7E02	Site 7E03	Site 7E03A	Site 7E04	Site 7E05	Site 7E06	Site 7E06A	Site 7W	Site 7W03	Site 7W04	Site 7W06	Site BN	Site BN1	Site BN2	Site BN4	Site BN6	South 6.5km 7E	West 1.9km 7W03	West 1.9km 7W04	West 1.9km 7W05	West 2.9km 7W03	West 2.9km 7W04	West 2.9km 7W05	West 2.9km 7W06	West 2.9km 7W07
	Simoselaps bertholdi	Jan's Banded Snake					2														X										
	Simoselaps semifasciata													X																	
	Suta fasciata	Rosen's Snake			X																										
Gekkonidae	*Gehyra variegata*				X		X		2										X		X	X									
	Heteronotia binoei	Bynoe's Gecko			X									X					X		X										
Pygopodidae	*Delma australis*				X			1	X							X					X	X									
	Delma butleri				X														X	X											
	Lialis burtonis				X														X												
	Pygopus lepidopodus	Common Scaly Foot									1										X										
Scincidae	*Cryptoblepharus buchananii*				X					1	1											X									
	Ctenotus atlas				X			5											X	X											
	Ctenotus pantherinus	Leopard Skink			X									X					X	X											
	Ctenotus schomburgkii				X		1	2							6	1		X													
	Ctenotus uber																					X									
	Ctenotus xenopleura													X			1		X	X											
	Cyclodomorphus branchialis				X									X					X	X											
	Egernia formosa						X																								
	Egernia richardi				X									X		1	4	X													
	Hemiergis initialis						X			X	1																				
	Lerista picturata						1				2																				
	Lerista sp.				X		8				2			X							X										
	Liopholis inornata				X									X				X													
	Menetia greyii				X		X	1	1	X											X	X									
	Morethia adelaidensis																														

TERRESTRIAL ECOSYSTEMS

		Survey Name	A																												
Family	Species	Common Name	Koorarawalyee Dam	Pools on granite	Site 7E	Site 7E01A	Site 7E02	Site 7E03	Site 7E03A	Site 7E04	Site 7E05	Site 7E06	Site 7E06A	Site 7W	Site 7W03	Site 7W04	Site 7W06	Site BN	Site BN1	Site BN2	Site BN4	Site BN6	South 6.5km 7E	West 1.9km 7W03	West 1.9km 7W04	West 1.9km 7W05	West 2.9km 7Wo3	West 2.9km 7Wo4	West 2.9km 7Wo5	West 2.9km 7Wo6	West 2.9km 7Wo7
	Morethia butleri				X		X		1	1											X										
	Morethia obscura				X			1						X	X					X											
	Tiliqua occipitalis	Western Bluetongue													2	1															
	Tiliqua rugosa				X		1														X	X									
Typhlopidae	*Ramphotyphlops australis*							1																							
Varanidae	*Varanus gouldii*	Bungarra or Sand Monitor			X			1	1	1																					

A McKenzie NL and Rolfe JK (1995) Vertebrate fauna. In: Keighery GJ, McKenzie NL and Hall NJ. The Biological Surveys of the Eastern Goldfields of Western Australia. Part 11 Boorabbin-Southern Cross Study Area. *Records of the Western Australian Museum* Supplement No. 49. pp 31-65.

TERRESTRIAL ECOSYSTEMS

Appendix A(2) Fauna survey data in the vicinity of the project area

		Surveys	A	B								C								D					
Family	Species	Common Name	Bungalbin	CR1	CR2	CR3	CR4	CR5	CR6	Opportunistic	Polaris Dam	CR1	CR2	CR3	CR4	CR5	CR6	Opportunistic	Polaris Dam	CM1	CM2	CM3	CM4	CM5	CM6
Birds																									
Accipitridae	*Accipiter fasciatus*	Brown Goshawk													1										
	Aquila audax	Wedge-tailed Eagle			1																				
Casuariidae	*Dromaius novaehollandiae*	Emu		1									2										1		1
Columbidae	*Phaps chalcoptera*	Common Bronzewing								1		1					1	1							
	Ocyphaps lophotes	Crested Pigeon																							6
Alcedinidae	*Todiramphus pyrrhopygius*	Red-backed Kingfisher						1					1		2	1									
Meropidae	*Merops ornatus*	Rainbow Bee-eater										1	2												
Cuculidae	*Chalcites basalis*	Horsfield's Bronze-Cuckoo											1	1											
	Cacomantis pallidus	Pallid Cuckoo												3											
Falconidae	*Falco berigora*	Brown Falcon										2	2	1							3				
	Falco longipennis	Australian Hobby																				1			
Megapodiidae	*Leipoa ocellata*	Malleefowl																			2				
Otididae	*Ardeotis australis*	Australian Bustard																2							
Acanthizidae	*Pyrrholaemus brunneus*	Redthroat		1		1																			
	Smicrornis brevirostris	Weebill		1 0	4	1 0			2			3 0	4	1 2						1 6	1 0	1 2	8	1 6	6
	Acanthiza chrysorrhoa	Yellow-rumped Thornbill		7																1 0				5	
	Acanthiza apicalis	Inland Thornbill		4		6						8		3						5	2			2	
	Aphelocephala leucopsis	Southern Whiteface															3								
	Acanthiza uropygialis	Chestnut-rumped Thornbill				6						6		6						4	2		4		
Artamidae	*Artamus personatus*	Masked Woodswallow																8 0							
	Artamus cyanopterus	Dusky Woodswallow													2	2	4								
	Artamus minor	Little Woodswallow														2	1								
	Cracticus torquatus	Grey Butcherbird		2	1		1	1				2	1	1	1	2	2			1				1	1
	Cracticus nigrogularis	Pied Butcherbird		2				2	1				1									1			
	Cracticus tibicen	Australian Magpie			1				2				2		1										
	Strepera versicolor	Grey Currawong		2																					
Campephagidae	*Coracina maxima*	Ground Cuckoo-Shrike						1																	
	Coracina novaehollandiae	Black-faced Cuckoo-Shrike		1									2	2	1	1	1								
	Lalage sueurii	White-winged Triller												2			2								
Climacteridae	*Climacteris rufa*	Rufous Treecreeper			1		4	1 0	2				2		8	6	6								3
Corvidae	*Corvus coronoides*	Australian Raven				4	1					1													
	Corvus orru	Torresian Crow		4																					
Estrildidae	*Taeniopygia guttata*	Zebra Finch												6											
Eupetidae	*Cinclosoma castaneothorax*	Chestnut-breasted Quail-thrush										1													
Hirundinidae	*Petrochelidon nigricans*	Tree Martin													6	1									

TERRESTRIAL ECOSYSTEMS

		Surveys	A	B								C								D					
Family	Species	Common Name	Bungalbin	CR1	CR2	CR3	CR4	CR5	CR6	Opportunistic	Polaris Dam	CR1	CR2	CR3	CR4	CR5	CR6	Opportunistic	Polaris Dam	CM1	CM2	CM3	CM4	CM5	CM6
Maluridae	*Malurus splendens*	Splendid Fairy-wren				8								3											
	Malurus lamberti	Variegated Fairy-wren		6		4						3								4	1				
Meliphagidae	*Lichenostomus virescens*	Singing Honeyeater			1	3						2	1	6	1					1	2	2			
	Lichenostomus leucotis	White-eared Honeyeater		1								2								8	3	2			2
	Lichenostomus ornatus	Yellow-plumed Honeyeater		2	8	8	8	6	5	6		2	1 0	4	1 0	2 0		6			8	6	4	4	8
	Lichenostomus plumulus	Grey-fronted Honeyeater		2					1	2								2				2			
	Purnella albifrons	White-fronted Honeyeater										1 0	2	2											
	Manorina flavigula	Yellow-throated Miner		2			1	4						1		5	4					8	2		1 3
	Acanthagenys rufogularis	Spiny-cheeked Honeyeater				2						4	2	2	4	6	6								
	Anthochaera carunculata	Red Wattlebird		2	2		2		1	4		2	6	6	4	2	2	4		2	2	3	1	7	1 0
	Lichmera indistincta	Brown Honeyeater										4		8	2		2 8								
	Melithreptus brevirostris	Brown-headed Honeyeater		6		8			1 9	8		8		1 2	3		3	8		1 2	9	9			
Pachycephalidae	*Pachycephala inornata*	Gilbert's Whistler						1							2	2	2								
	Pachycephala rufiventris	Rufous Whistler		1		1		1				2	1	2						1	1	1			
	Colluricincla harmonica	Grey Shrike-thrush					4	1	2					2	2	2	3					1			1
	Oreoica gutturalis	Crested Bellbird				1		1						1	2	1	2			2	1				
Pardalotidae	*Pardalotus striatus*	Striated Pardalote		4	1 0		6	8	2			1 2	2	2	2	2					2	2	4	2	6
Petroicidae	*Microeca leucophaea*	Jacky Winter		1																		1			
	Petroica goodenovii	Red-capped Robin				1								2											
Pomatostomidae	*Pomatostomus superciliosus*	White-browed Babbler				4								8						8	9				
Rhipiduridae	*Rhipidura fuliginosa*	New Zealand Fantail				1						2	1												
Rhipiduridae	*Rhipidura leucophrys*	Willie Wagtail								1							1	1							
Cacatuidae	*Lophochroa leadbeateri*	Major Mitchell's Cockatoo												1											
	Eolophus roseicapillus	Galah											4												
Psittacidae	*Glossopsitta porphyrocephala*	Purple-crowned Lorikeet								6					2			6							
	Polytelis anthopeplus	Regent Parrot										1			7	2									
	Barnardius zonarius	Australian Ringneck		2	2	2	4	2	4			2			2		2			1			2	2	2
Mammals																									
Camelidae	*Camelus dromedarius*	Dromedary						1															X		X
Canidae	*Canis lupus*	Dingo								X															
	Vulpes vulpes	Red Fox								X															
Molossidae	*Austronomus australis*	White-striped Freetail Bat				X					X								X			X			
Vespertilionidae	*Chalinolobus gouldii*	Gould's Wattled Bat			X	X					X								X			X			
	Chalinolobus morio	Chocolate Wattled Bat				X					X								X			X			
	Mormopterus sp.				X	X					X								X			X			
	Nyctophilus sp.																		X						
	Scotorepens balstoni	Inland Broadnosed Bat																	X						

TERRESTRIAL ECOSYSTEMS

		Surveys	A	B								C								D					
Family	Species	Common Name	Bungalbin	CR1	CR2	CR3	CR4	CR5	CR6	Opportunistic	Polaris Dam	CR1	CR2	CR3	CR4	CR5	CR6	Opportunistic	Polaris Dam	CM1	CM2	CM3	CM4	CM5	CM6
	Vespadelus baverstocki	Inland Forest Bat																	X						
	Vespadelus regulus	Southern Forest Bat				X					X								X			X			
Dasyuridae	*Ningaui sp.*		X																						
	Ningaui yvonneae	Mallee Ningaui		1								2													
	Sminthopsis crassicaudata	Fat-tailed Dunnart																						4	
	Sminthopsis dolichura	Little Long-tailed Dunnart	X			2								1							1	1			
	Sminthopsis hirtipes	Hairy-footed Dunnart	X																						
Burramyidae	*Cercartetus concinnus*	Southwestern Pygmy Possum												1											
Macropodidae	*Macropus rufus*	Red Kangaroo																1							
Leporidae	*Oryctolagus cuniculus*	European Rabbit		X	X	X	X	X	X																
Muridae	*Leporillus apicalis*	Lesser Stick-nest Rat																	X						
	Mus musculus	House Mouse	X																						
	Notomys alexis	Spinifex Hopping Mouse	X																						
	Pseudomys albocinereus	Ash-grey Mouse	X																						
Reptiles																									
Agamidae	*Ctenophorus cristatus*	Bicycle Dragon	X									1	2		2	2	1								
	Ctenophorus fordi	Mallee Sand Dragon	X																						
	Ctenophorus isolepis	Crested Dragon	X																						
	Ctenophorus maculatus	Spotted Military Dragon	X																						
	Ctenophorus scutulatus		X																						
	Moloch horridus	Thorny Devil	X									1													
	Pogona minor	Bearded Dragon	X									1													
Carphodactylidae	*Nephrurus stellatus*		X																						
	Underwoodisaurus milii	Barking Gecko											1	1		1	1								
Diplodactylidae	*Diplodactylus granariensis*		X											1	1	1									
	Diplodactylus pulcher		X									1	1	7	1	1									
	Lucasium maini		X												5	4	4								
	Lucasium stenodactylus		X																						
	Oedura reticulata														1	1									
	Strophurus assimilis	Goldfields Spiny-tailed Gecko	X																						
	Strophurus elderi		X																						
Elapidae	*Acanthophis antarcticus*	Southern Death Adder	X																						
	Brachyurophis fasciolata		X																						
	Brachyurophis semifasciata		X									2				1									
	Neelaps bimaculatus	Black-naped Snake	X		1										5										
	Parasuta monachus		X									1			1	2	1								
	Simoselaps bertholdi	Jan's Banded Snake	X																						

TERRESTRIAL ECOSYSTEMS

		Surveys	A	B								C								D					
Family	Species	Common Name	Bungalbin	CR1	CR2	CR3	CR4	CR5	CR6	Opportunistic	Polaris Dam	CR1	CR2	CR3	CR4	CR5	CR6	Opportunistic	Polaris Dam	CM1	CM2	CM3	CM4	CM5	CM6
Gekkonidae	*Gehyra variegata*											1		1	1	1	1								
	Rhynchoedura ornata	Beaked Gecko	X																						
Pygopodidae	*Aprasia repens*		X																						
	Delma australis		X																						
	Delma butleri		X																						
	Delma nasuta		X																						
	Lialis burtonis		X																						
	Pygopus lepidopodus	Common Scaly Foot	X																						
	Pygopus nigriceps		X																						
Scincidae	*Cryptoblepharus buchananii*		X																						
	Ctenotus atlas		X																						
	Ctenotus brooksi		X																						
	Ctenotus mimetes		X																						
	Ctenotus pantherinus	Leopard Skink	X																						
	Ctenotus schomburgkii		X																						
	Ctenotus xenopleura		X																						
	Cyclodomorphus branchialis		X																						
	Cyclodomorphus melanops	Slender Blue-tongue												1		1									
	Egernia formosa												3	1	2										
	Eremiascincus richardsonii	Broad-banded Sand Swimmer	X																						
	Lerista macropisthopus		X																						
	Lerista muelleri		X																						
	Lerista rhodonoides				1												1								
	Liopholis inornata		X																						
	Menetia greyii		X									1		1		1									
	Morethia butleri						1						1			1	1								
	Morethia obscura		X																						
	Tiliqua occipitalis	Western Bluetongue	X																						
Typhlopidae	*Ramphotyphlops australis*											2	1	2	3										
	Ramphotyphlops bicolor														2										
Varanidae	*Varanus gouldii*	Bungarra or Sand Monitor	X																						

A Terrestrial Ecosystems unpublished data from Jason Fraser's PhD project

B Ninox Wildlife Consulting (2008) *Interim Report on the first field survey of the Carina Prospect, Yilgarn Iron Ore Project*. Unpublished report for Polaris Metals NL, Perth.

C Ninox Wildlife Consulting (2009) *A Fauna Survey of the Carina Prospect; Yilgarn Iron Ore Project*. Unpublished report for Polaris Metals NL; Perth.

D Ninox Wildlife Consulting (2008) *Interim report on the first field survey of the Chamaeleon Prospect, Yilgarn Iron Ore Project.* Unpublished report for Polaris Metals NL, Perth.

TERRESTRIAL ECOSYSTEMS

Appendix A(3) Fauna survey data in the vicinity of the project area

		Survey Name	A																										B								
Family	Species	Common Name	Opportunistic	Site 1	Site 1A	Site 1B	Site 1E	Site 2	Site 2A	Site 2B	Site 2E	Site 3	Site 3A	Site 3B	Site 3E	Site 4	Site 4A	Site 4B	Site 5	Site 5A	Site 5B	Site 6	Site 6A	Site 6B	Site 7	Site 7A	Site 7B	Site 18	Site 18a	Site 21	Site 35	Site 37	Site 39	Site 40a	Site 44	Site 8a
Birds																																					
Accipitridae	*Accipiter fasciatus*	Brown Goshawk	X																																		
	Aquila audax	Wedge-tailed Eagle	X					1																					X					X			
	Hieraaetus morphnoides	Little Eagle																													X				1		
Aegothelidae	*Aegotheles cristatus*	Australian Owlet-nightjar	X	1																									1						1	X	
Podargidae	*Podargus strigoides*	Tawny Frogmouth	X																																1		
Turnicidae	*Turnix velox*	Little Button-quail																											1								
Columbidae	*Phaps chalcoptera*	Common Bronzewing	X																																		
Meropidae	*Merops ornatus*	Rainbow Bee-eater																											2								
Cuculidae	*Chalcites basalis*	Horsfield's Bronze-Cuckoo	X																3																		
	Chalcites osculans	Black-eared Cuckoo									1																										
Caprimulgidae	*Eurostopodus argus*	Spotted Nightjar		1																									4								
Falconidae	*Falco cenchroides*	Nankeen Kestrel																													1		X	1		X	
	Falco berigora	Brown Falcon																											2						1		
	Falco longipennis	Australian Hobby						2																													
	Falco peregrinus	Peregrine Falcon	X	1																									1								
Megapodiidae	*Leipoa ocellata*	Malleefowl	X																															2		1	
Acanthizidae	*Calamanthus cautus*	Shy Heathwren																							8							3					
	Calamanthus fuliginosus	Striated Fieldwren																													7		17				
	Pyrrholaemus brunneus	Redthroat						1																				2	10		2	6		20		2	
	Smicrornis brevirostris	Weebill	X					X			4	3							X						1			91	29			27		2	133	142	
	Gerygone fusca	Western Gerygone																																		3	
	Acanthiza chrysorrhoa	Yellow-rumped Thornbill	X																									X			1				7	2	
	Acanthiza apicalis	Inland Thornbill		2							4														5			X	31		20	56	3	45		16	
	Acanthiza uropygialis	Chestnut-rumped Thornbill																										13	4		11	24		2	15	99	
Artamidae	*Artamus cinereus*	Black-faced Woodswallow																													10	1	6				
	Artamus cyanopterus	Dusky Woodswallow																																	1		
	Artamus minor	Little Woodswallow	X				5																						16			X					
	Cracticus torquatus	Grey Butcherbird		2											1													3	X						X	9	
	Cracticus nigrogularis	Pied Butcherbird	X								1								2									17	3						35	7	
	Cracticus tibicen	Australian Magpie																										6							X		
	Strepera versicolor	Grey Currawong	X				2				3																								X	4	
Campephagidae	*Coracina novaehollandiae*	Black-faced Cuckoo-Shrike		1																								5	2		X	X			32	X	
Climacteridae	*Climacteris rufa*	Rufous Treecreeper																	2									2							42		
Corvidae	*Corvus coronoides*	Australian Raven																											1								
	Corvus bennetti	Little Crow	X																															11		X	

TERRESTRIAL ECOSYSTEMS

		Survey Name	A																										B								
Family	Species	Common Name	Opportunistic	Site 1	Site 1A	Site 1B	Site 1E	Site 2	Site 2A	Site 2B	Site 2E	Site 3	Site 3A	Site 3B	Site 3E	Site 4	Site 4A	Site 4B	Site 5	Site 5A	Site 5B	Site 6	Site 6A	Site 6B	Site 7	Site 7A	Site 7B	Site 18	Site 18a	Site 21	Site 35	Site 37	Site 39	Site 40a	Site 44	Site 8a
	Corvus orru	Torresian Crow																														1	X		X	
Estrildidae	*Taeniopygia guttata*	Zebra Finch	X																																	
	Cinclosoma castanotum	Chestnut Quail-thrush	X																										5			2			1	
Hirundinidae	*Petrochelidon nigricans*	Tree Martin																																2	2	
Maluridae	*Malurus splendens*	Splendid Fairy-wren																														X		7		
	Malurus pulcherrimus	Blue-breasted Fairy-wren																														5				
Meliphagidae	*Lichenostomus virescens*	Singing Honeyeater	X					1			1																	3	X		6	3	3	13	4	6
	Lichenostomus leucotis	White-eared Honeyeater	X					1			2								2						3				25		3	1			7	16
	Lichenostomus flavicollis	Yellow-throated Honeyeater																											2						57	27
	Lichenostomus ornatus	Yellow-plumed Honeyeater										2							2									2							278	
	Purnella albifrons	White-fronted Honeyeater	X					2			1					1			1									2			X	7	3	5	18	17
	Manorina flavigula	Yellow-throated Miner									1																									
	Acanthagenys rufogularis	Spiny-cheeked Honeyeater	X	1				1								4			2									1	X		X	15	2	X	10	7
	Anthochaera carunculata	Red Wattlebird	X	5															X									4	2						34	18
	Epthianura tricolor	Crimson Chat																											X							
	Lichmera indistincta	Brown Honeyeater	X	1				1							X	1			2										X						20	
	Melithreptus brevirostris	Brown-headed Honeyeater																										4	10						2	2
Nectariniidae	*Dicaeum hirundinaceum*	Mistletoebird	X																												X			1	1	
Neosittidae	*Daphoenositta chrysoptera*	Varied Sittella																							7			2								
Pachycephalidae	*Pachycephala inornata*	Gilbert's Whistler																																1		
	Pachycephala pectoralis	Golden Whistler																														4				
	Pachycephala rufiventris	Rufous Whistler	X					2																	1			1	1			2		6	6	1
	Colluricincla harmonica	Grey Shrike-thrush	X	7				5			1																		9		1	11		5	X	5
	Oreoica gutturalis	Crested Bellbird	X								1	1				2			2									X	10		6	2	6	4	13	2
Pardalotidae	*Pardalotus striatus*	Striated Pardalote	X					1			2	2							2									50	X			4			138	65
Petroicidae	*Microeca leucophaea*	Jacky Winter	X																									9	1						41	
	Petroica goodenovii	Red-capped Robin	X																			1						15	15		5	14	2	4	4	28
	Melanodryas cucullata	Hooded Robin	X																														2			
	Eopsaltria griseogularis	Western Yellow Robin																							1							3				1
Pomatostomidae	*Pomatostomus superciliosus*	White-browed Babbler																											6					5		1
Rhipiduridae	*Rhipidura albiscapa*	Grey Fantail																														1		3		
	Rhipidura leucophrys	Willie Wagtail	X									1																	1		X				2	2
Cacatuidae	*Calyptorhynchus banksii*	Red-tailed Black-Cockatoo																																	6	
Psittacidae	*Glossopsitta porphyrocephala*	Purple-crowned Lorikeet	X																																17	
	Polytelis anthopeplus	Regent Parrot																	2															X		
	Barnardius zonarius	Australian Ringneck	X												1													11	3			1	2		41	24
	Melopsittacus undulatus	Budgerigar										X							X																	

TERRESTRIAL ECOSYSTEMS

		Survey Name	A																										B								
Family	Species	Common Name	Opportunistic	Site 1	Site 1A	Site 1B	Site 1E	Site 2	Site 2A	Site 2B	Site 2E	Site 3	Site 3A	Site 3B	Site 3E	Site 4	Site 4A	Site 4B	Site 5	Site 5A	Site 5B	Site 6	Site 6A	Site 6B	Site 7	Site 7A	Site 7B	Site 18	Site 18a	Site 21	Site 35	Site 37	Site 39	Site 40a	Site 44	Site 8a
Strigidae	*Ninox novaeseelandiae*	Southern Boobook	X	1																																2	
Mammals																																					
Canidae	*Canis lupus*	Dingo	X																																		
	Ningaui ridei	Wongai Ningaui																													3		4				
	Ningaui yvonneae	Mallee Ningaui																		1											1		1				
	Sminthopsis dolichura	Little Long-tailed Dunnart			1	2											1	1					1	1				2			2	2	2		3	3
	Sminthopsis hirtipes	Hairy-footed Dunnart																													1		1				
Burramyidae	*Cercartetus concinnus*	Southwestern Pygmy Possum			1									1				3														1			1	2
Macropodidae	*Macropus fuliginosus*	Western Grey Kangaroo																										X			X						
	Macropus robustus	Wallaroo or Euro	X				1				3				3														X								
Leporidae	*Oryctolagus cuniculus*	European Rabbit	X					1																	1								X			X
Tachyglossidae	*Tachyglossus aculeatus*	Short-beaked Echidna	X								X																										
Muridae	*Mus musculus*	House Mouse																										3					2		6	2
	Notomys alexis	Spinifex Hopping Mouse																														1	1			
	Notomys mitchellii	Mitchell's Hopping Mouse																														1				
	Pseudomys albocinereus	Ash-grey Mouse																													5		21		1	
	Pseudomys hermannsburgensis	Sandy Inland Mouse											1								1			1							2	2			1	
Amphibians																																					
Limnodynastidae	*Neobatrachus sutor*	Shoemaker Frog																										1								1
Reptiles																																					
Agamidae	*Ctenophorus cristatus*	Bicycle Dragon	X																							1		1							2	1
	Ctenophorus fordi	Mallee Sand Dragon																													1					
	Ctenophorus isolepis																														8		13			
	Ctenophorus reticulatus	Western Netted Dragon				1																								1	1					
	Ctenophorus scutulatus																																		1	1
	Moloch horridus	Thorny Devil																														1				
	Pogona minor	Bearded Dragon		1																								1	1		3	1	3			
	Tympanocryptis cephalus	Pebble Dragon	X		1		1																					2								
Carphodactylidae	*Nephrurus stellatus*																														2		2			
	Underwoodisaurus milii	Barking Gecko			1																					1				4					4	
Diplodactylidae	*Crenadactylus ocellatus*	Clawless Gecko																																	3	1
	Diplodactylus granariensis									1			1	3							2					1	1	2		3					3	1
	Diplodactylus pulcher					5			1	8			2	2						2	6							4			2				2	1
	Lucasium maini												5	1							1							1	2						9	
	Lucasium stenodactylus																														2		1			
	Oedura reticulata																											1							2	6
	Strophurus assimilis	Goldfields Spiny-tailed Gecko																								1										

TERRESTRIAL ECOSYSTEMS

		Survey Name	A																										B								
Family	Species	Common Name	Opportunistic	Site 1	Site 1A	Site 1B	Site 1E	Site 2	Site 2A	Site 2B	Site 2E	Site 3	Site 3A	Site 3B	Site 3E	Site 4	Site 4A	Site 4B	Site 5	Site 5A	Site 5B	Site 6	Site 6A	Site 6B	Site 7	Site 7A	Site 7B	Site 18	Site 18a	Site 21	Site 35	Site 37	Site 39	Site 40a	Site 44	Site 8a
	Strophurus elderi																																1				
	Strophurus intermedius																											1							9	10
Elapidae	*Demansia psammophis*		X																																		
	Parasuta monachus					1															1																
	Simoselaps semifasciata																																				2
Gekkonidae	*Gehyra variegata*																			1	2		3			1		3	1	4		1			11	2
	Heteronotia binoei	Bynoe's Gecko	X		2													1						1		1			3	12						
	Rhynchoedura ornata	Beaked Gecko																														2				1
Pygopodidae	*Delma australis*																																		8	3
	Delma nasuta																																1			
	Pygopus lepidopodus	Common Scaly Foot																								1										
Scincidae	*Cryptoblepharus buchananii*								3	1																			2						3	
	Cryptoblepharus ruber					2			2	1			4	6			2	1		1			3	1		5	2									
	Ctenotus atlas																														4		3			
	Ctenotus schomburgkii																														2	7				2
	Ctenotus uber																											2	1							
	Ctenotus xenopleura																														11	1	17			
	Cyclodomorphus branchialis		X		1																			1					4	3						
	Egernia formosa												1																							
	Eremiascincus richardsonii	Broad-banded Sand Swimmer											1	2																						
	Hemiergis initialis																											2	13	5					2	
	Lerista macropisthopus																													1	1				1	
	Lerista sp.																											3	2						4	2
	Liopholis inornata																																			1
	Menetia greyii				1				4																						2	1			3	3
	Morethia butleri								2									1			1														6	2
	Tiliqua occipitalis	Western Bluetongue																														1				
Typhlopidae	*Ramphotyphlops australis*				1													1			1							1							1	
	Ramphotyphlops bituberculatus												2							1																
	Ramphotyphlops hamatus													1																					1	
Varanidae	*Varanus giganteus*	Perentie	X																										1	1						
	Varanus gouldii	Bungarra or Sand Monitor																														1				
	Varanus tristis	Racehorse Monitor				2							1											1												

A Lyons MN and Chapman A (1997) *A Biological Survey of the Helena and Aurora Range; Eastern Goldfields Western Australia*. Unpublished report for Environment Australia, Canberra.

B Dell J and How RA (1985) Vertebrate fauna. In Dell; J; How; RA; Newbey K.R. and Hnatiuk RJ. The Biological Survey of the Eastern Goldfields of Western Australia Part 3; Jackson - Kalgoorlie. *Records of the Western Australian Museum*, Supplement No 23, pp. 39-66.

TERRESTRIAL ECOSYSTEMS

Appendix A(4) Fauna survey data in the vicinity of the project area

		Survey name	A									B																			C	D	E
Family	Species	Common Name	Opportunistic	Site 16	Site 22	Site 23	Site 24	Site 25	Site 6	Site 7	Site 8	Opportunistic	Site 16	Site 17	Site 18	Site 19	Site 20	Site 21	Site 22	Site 23	Site 24	Site 25	Site 26	Site 27	Site 28	Site 29	Site 30	Site 31	Site 32	Site 33	Mt Walton	Kurrawang	
Birds																																	
Accipitridae	*Lophoictinia isura*	Square-tailed Kite										1				1																	
	Accipiter fasciatus	Brown Goshawk						1														1										X	
	Aquila audax	Wedge-tailed Eagle								6					2							1										X	
	Hieraaetus morphnoides	Little Eagle				1														1												X	
Aegothelidae	*Aegotheles cristatus*	Australian Owlet-nightjar					1														1												
Podargidae	*Podargus strigoides*	Tawny Frogmouth	2														1																
Casuariidae	*Dromaius novaehollandiae*	Emu	1	1	1			1		X			1			X	X		1	X		1						X					
Columbidae	*Phaps chalcoptera*	Common Bronzewing				3														3													
	Ocyphaps lophotes	Crested Pigeon																														X	
Alcedinidae	*Todiramphus pyrrhopygius*	Red-backed Kingfisher																		5			1										
Meropidae	*Merops ornatus*	Rainbow Bee-eater					5							2							5												
Cuculidae	*Chalcites osculans*	Black-eared Cuckoo								4																							
	Cacomantis pallidus	Pallid Cuckoo								1																						X	
	Cacomantis flabelliformis	Fan-tailed Cuckoo									3																						
Caprimulgidae	*Eurostopodus argus*	Spotted Nightjar	1											1	1																		
Falconidae	*Falco cenchroides*	Nankeen Kestrel														3										1							
	Falco berigora	Brown Falcon																					1										
	Falco longipennis	Australian Hobby				1								1						1													
	Falco peregrinus	Peregrine Falcon	2																														
Megapodiidae	*Leipoa ocellata*	Malleefowl					1					1									1												
Otididae	*Ardeotis australis*	Australian Bustard										1																					
Acanthizidae	*Calamanthus cautus*	Shy Heathwren					1														2												
	Pyrrholaemus brunneus	Redthroat			3						5								3					2		6	1	1	2				
	Smicrornis brevirostris	Weebill		1 5	4		1 0	2 0	1 7		3		1 5			1		1 9	4		1 0	2 0	5 0	9	1 6	2 3	1 6	1 8	4 1	7		X	
	Gerygone fusca	Western Gerygone	1																														
	Acanthiza robustirostris	Slaty-backed Thornbill					5														1												
	Acanthiza chrysorrhoa	Yellow-rumped Thornbill	1	5	2		3	1					5						2		3	1	3									X	
	Acanthiza apicalis	Inland Thornbill		6	8		1			7	2 1		6					4	8		1		1 0	1 3		1 2	2 8	3 7				X	
	Aphelocephala leucopsis	Southern Whiteface			4														4														
	Acanthiza uropygialis	Chestnut-rumped Thornbill		1 2	2 3		5				7		1 2		1			2 6	2 3		5		5 0	3 6		1 3	1 8	2 3				X	
Artamidae	*Artamus cinereus*	Black-faced Woodswallow				1								1 2						1													
	Artamus cyanopterus	Dusky Woodswallow																							1							X	
	Artamus minor	Little Woodswallow													8			2												3			
	Cracticus torquatus	Grey Butcherbird	1	2				1		2	1		2	2								1			2	2	1					X	
	Cracticus nigrogularis	Pied Butcherbird				3		2	1 3		1					9				3		2		1								X	

TERRESTRIAL ECOSYSTEMS

		Survey name	A									B																				C	D	E
Family	Species	Common Name	Opportunistic	Site 16	Site 22	Site 23	Site 24	Site 25	Site 6	Site 7	Site 8	Opportunistic	Site 16	Site 17	Site 18	Site 19	Site 20	Site 21	Site 22	Site 23	Site 24	Site 25	Site 26	Site 27	Site 28	Site 29	Site 30	Site 31	Site 32	Site 33	Mt Walton	Kurrawang	
	Cracticus tibicen	Australian Magpie							5				1	2											3							X	
	Strepera versicolor	Grey Currawong		6			1	1					6			1		6			1	1		1			3	6					
Campephagidae	*Coracina maxima*	Ground Cuckoo-Shrike																							1 0								
	Coracina novaehollandiae	Black-faced Cuckoo-Shrike	1	5	2	2	3	6	1	1			5	8	8	7			2	2	3	6		2	6	4			3	2		X	
	Lalage sueurii	White-winged Triller																														X	
Climacteridae	*Climacteris rufa*	Rufous Treecreeper				4			2							8				4					1 2								
Corvidae	*Corvus coronoides*	Australian Raven		4		1			4	1			4			5				1												X	
	Corvus bennetti	Little Crow		2				3					2				5					3											
Estrildidae	*Taeniopygia guttata*	Zebra Finch	1																														
Eupetidae	*Cinclosoma castanotum*	Chestnut Quail-thrush		1									1							5			1		1			4					
Hirundinidae	*Cheramoeca leucosterna*	White-backed Swallow				1 2								2						1 2													
	Hirundo neoxena	Welcome Swallow	1																							2							
	Petrochelidon nigricans	Tree Martin							5					1 0										4	4								
Maluridae	*Malurus splendens*	Splendid Fairy-wren	3		2					1 3		1							2				7										
	Malurus leucopterus	White-winged Fairy-wren										1																					
	Malurus pulcherrimus	Blue-breasted Fairy-wren																										8				X	
Meliphagidae	*Lichenostomus virescens*	Singing Honeyeater	1	1	3 0			1	1	4	4		1	2	2 8			1 6	3 0			1	3	3	2	1	9	7	5 8	4 2		X	
	Lichenostomus leucotis	White-eared Honeyeater				1	5				2									1	5							1	2			X	
	Lichenostomus cratitius	Purple-gaped Honeyeater																														X	
	Lichenostomus ornatus	Yellow-plumed Honeyeater		1		3 7			2 4				1			5 3	4			3 7					6 0	3						X	
	Purnella albifrons	White-fronted Honeyeater			5			1		6	2								5			1										X	
	Manorina flavigula	Yellow-throated Miner		1			1 0	1 9			1		1		2	1 2	1				1 0	1 9				4						X	
	Acanthagenys rufogularis	Spiny-cheeked Honeyeater	1	1	3 0			1	1	4	4			3		9			3 7	4	7	1 3	2		5	1						X	
	Anthochaera carunculata	Red Wattlebird	1			2		2	4 5		1 1					2 8	3			2		2	3		1	8				2		X	
	Epthianura tricolor	Crimson Chat												1 0																			
	Lichmera indistincta	Brown Honeyeater	1		1 1				6		2				8					1 1									2	3		X	
	Melithreptus brevirostris	Brown-headed Honeyeater																1 1					2				1 0		7	5		X	
Monarchidae	*Grallina cyanoleuca*	Magpie-Lark																														X	
Motacilidae	*Anthus novaeseelandiae*	Australasian Pipit								3				2																			
Nectariniidae	*Dicaeum hirundinaceum*	Mistletoebird		1 2									1 2		2			4						3	3	1 1	1		6	8			
Neosittidae	*Daphoenositta chrysoptera*	Varied Sittella	1	8	8	5							8						8														
Pachycephalidae	*Pachycephala rufiventris*	Rufous Whistler	1	1		4	1						1							4	1			1		3	1	2					
	Colluricincla harmonica	Grey Shrike-thrush	1		5	7		3		1	3				4			2	5	7		3		2	4		1		5	6		X	
	Oreoica gutturalis	Crested Bellbird		5	5	2	1	4			1		5	3	1	4		1 0	5	2	1	4	2	2	7	4	2	1	1	1			
Pardalotidae	*Pardalotus striatus*	Striated Pardalote	1	4	9		2	2	3 4				4	2	5		2	2	9		2	2	6	9	6	1 5		1	9	6		X	
Petroicidae	*Microeca leucophaea*	Jacky Winter	4	2	1			3					2						1			3	1	1		1							
	Petroica goodenovii	Red-capped Robin	1	2	3		4	1		8	4		2						3		4	1	6			1	1	2				X	

TERRESTRIAL ECOSYSTEMS

		Survey name	A									B																				C	D	E
Family	Species	Common Name	Opportunistic	Site 16	Site 22	Site 23	Site 24	Site 25	Site 6	Site 7	Site 8	Opportunistic	Site 16	Site 17	Site 18	Site 19	Site 20	Site 21	Site 22	Site 23	Site 24	Site 25	Site 26	Site 27	Site 28	Site 29	Site 30	Site 31	Site 32	Site 33	Mt Walton	Kurrawang	
	Melanodryas cucullata	Hooded Robin		1									1		1														1			X	
	Eopsaltria griseogularis	Western Yellow Robin																									2	3		3			
	Drymodes brunneopygia	Southern Scrub-robin																										2					
Pomatostomidae	*Pomatostomus superciliosus*	White-browed Babbler	5		9														9				1 1									X	
Rhipiduridae	*Rhipidura albiscapa*	Grey Fantail										1																					
	Rhipidura leucophrys	Willie Wagtail						5		1				3	5			2				5								2			
Cacatuidae	*Calyptorhynchus banksii*	Red-tailed Black-Cockatoo										1																					
	Lophochroa leadbeateri	Major Mitchell's Cockatoo			2 2	2 3						1							1 2	2 3													
	Eolophus roseicapillus	Galah									2																						
Psittacidae	*Glossopsitta porphyrocephala*	Purple-crowned Lorikeet	1	4 8	4	2 7			138	4 7	230		4 8	1	1 4	8 5	4	4	4	2 7			5	6	2	3 5			3 7	8		X	
	Polytelis anthopeplus	Regent Parrot	2							1	1	1																					
	Barnardius zonarius	Australian Ringneck	4	5	8	5		4	2				5			1 5		3	8	5		4	2	3	8	1 1						X	
Strigidae	*Ninox novaeseelandiae*	Southern Boobook		1									1			1																	
Tytonidae	*Tyto alba*	Barn Owl					1					1									1												
Mammals																																	
Bovidae	*Capra hircus*	Goat																	1											2			
Canidae	*Canis lupus*	Dog					1					1									1									1			
Felidae	*Felis catus*	House Cat										2																			1		
Molossidae	*Austronomus australis*	White-striped Freetail Bat								X		1																					1 2
	Mormopterus planiceps	Southern Freetail-bat																															7
Vespertilionidae	*Chalinolobus gouldii*	Gould's Wattled Bat									X																						3 7
	Chalinolobus morio	Chocolate Wattled Bat																															2
	Nyctophilus geoffroyi	Lesser Longeared Bat										1																					2
	Scotorepens balstoni	Inland Broadnosed Bat																															1
	Vespadelus regulus	Southern Forest Bat										1																					1 9
Dasyuridae	*Antechinomys laniger*	Kultarr																															2
	Ningaui ridei	Wongai Ningaui																															1 1
	Ningaui yvonneae	Mallee Ningaui																							1		2						2 0
	Pseudantechinus woolleyae	Woolley's False Antechinus													1															1			1
	Sminthopsis crassicaudata	Fat-tailed Dunnart																															8
	Sminthopsis dolichura	Little Long-tailed Dunnart									1					3		2					1		2			2			1 7		4 2
	Sminthopsis gilberti	Gilbert's Dunnart																															2
	Sminthopsis granulipes	White-tailed Dunnart																															2
	Sminthopsis hirtipes	Hairy-footed Dunnart																													1		7
Burramyidae	*Cercartetus concinnus*	Southwestern Pygmy Possum		1				1	2				1									1				1			2			
Macropodidae	*Macropus fuliginosus*	Western Grey Kangaroo						2				1						1	1										1	1	3		5
	Macropus robustus	Wallaroo or Euro										1																					1

TERRESTRIAL ECOSYSTEMS

		Survey name	A									B																				C	D	E
Family	Species	Common Name	Opportunistic	Site 16	Site 22	Site 23	Site 24	Site 25	Site 6	Site 7	Site 8	Opportunistic	Site 16	Site 17	Site 18	Site 19	Site 20	Site 21	Site 22	Site 23	Site 24	Site 25	Site 26	Site 27	Site 28	Site 29	Site 30	Site 31	Site 32	Site 33	Mt Walton	Kurrawang	
	Macropus rufus	Red Kangaroo										1																					
Leporidae	*Oryctolagus cuniculus*	European Rabbit	2	1									1		1												1	1	1	2			
Tachyglossidae	*Tachyglossus aculeatus*	Short-beaked Echidna								X	X																				1		
Muridae	*Mus musculus*	House Mouse		1	4	1	2	7	7	1 0			1	1	1	2	1	1 0	4	1	2	7	1	6	1 4	3	3	2	5	5	2		2 4
	Notomys alexis	Spinifex Hopping Mouse																															4
	Notomys mitchellii	Mitchell's Hopping Mouse																															1 2
	Pseudomys albocinereus	Ash-grey Mouse			1																										9		4 2
	Pseudomys bolami	Bolam's Mouse																															6
	Pseudomys hermannsburgensis	Sandy Inland Mouse				2														1					1								1 0
Amphibians																																	
Limnodynastidae	*Neobatrachus albipes*	White-footed Trilling Frog																															3
	Neobatrachus kunapalari	Kunapalari Frog	1 0							2	1																						3 0
	Neobatrachus pelobatoides	Humming Frog																															5
	Neobatrachus sutor	Shoemaker Frog																															2
Myobatrachidae	*Pseudophryne guentheri*	Crawling Toadlet																															3
	Pseudophryne occidentalis	Western Toadlet	1 5																														1 6
Reptiles																																	
Agamidae	*Ctenophorus adelaidensis*	Southern Heath Dragon																															1
	Ctenophorus cristatus	Bicycle Dragon				1							1							1			3	1							1		2 8
	Ctenophorus fordi	Mallee Sand Dragon																													9		2 3
	Ctenophorus isolepis																																6 5
	Ctenophorus maculatus	Military Dragon																															1 0
	Ctenophorus ornatus	Ornate Crevice Dragon																															4 0
	Ctenophorus reticulatus	Western Netted Dragon		1	1			1											1			1	1					1			2		4 3
	Ctenophorus salinarum	Salt Pan Dragon																															3 8
	Ctenophorus scutulatus																														3		2 2
	Moloch horridus	Thorny Devil												1																	1		1 6
	Pogona minor	Bearded Dragon					1							1							1							1			2		3 1
	Tympanocryptis cephalus	Pebble Dragon																									1						
Boidae	*Aspidites ramsayi*	Woma																															2
	Morelia spilota imbricata	Carpet Python																															2
Carphodactylidae	*Nephrurus stellatus*																														2 6		2 4
	Underwoodisaurus milii	Barking Gecko														2	1	1															2 2
Diplodactylidae	*Crenadactylus ocellatus*	Clawless Gecko													1	5	1																2 6
	Diplodactylus granariensis											1							1						1		1	1	1		1		3 3
	Diplodactylus pulcher			1	4	3	1					1	1										4		2	1	1		1	3			2 9
	Lucasium maini					1	2										1			1	2	1									1		5 8

TERRESTRIAL ECOSYSTEMS

		Survey name	A									B																			C	D	E
Family	Species	Common Name	Opportunistic	Site 16	Site 22	Site 23	Site 24	Site 25	Site 6	Site 7	Site 8	Opportunistic	Site 16	Site 17	Site 18	Site 19	Site 20	Site 21	Site 22	Site 23	Site 24	Site 25	Site 26	Site 27	Site 28	Site 29	Site 30	Site 31	Site 32	Site 33	Mt Walton	Kurrawang	
	Lucasium stenodactylus																																2 2
	Oedura reticulata			1		2						1	1			5	1			2													2 9
	Strophurus assimilis	Goldfields Spiny-tailed Gecko																									2				1		4 4
	Strophurus elderi																																3
	Strophurus wellingtonae																																1
Elapidae	*Brachyurophis fasciolata*																																1
	Brachyurophis semifasciata																																8
	Demansia psammophis																																1
	Echiopsis curta	Bardick																															1
	Furina ornata	Moon Snake																									1						1
	Parasuta gouldii																																2
	Parasuta monachus										1																						1
	Pseudechis australis	Mulga Snake			1			1											1			1											1 1
	Pseudonaja affinis	Dugite			1														1														3
	Pseudonaja mengdeni	Gwardar																													1		5
	Pseudonaja modesta	Ringed Brown Snake																															9
	Simoselaps bertholdi	Jan's Banded Snake																					1			1							7
	Suta fasciata	Rosen's Snake	1																														5
Gekkonidae	*Gehyra purpurascens*																																1
	Gehyra variegata											1	1	1		3			4	3	1	1	6		1	1	5	3		1			104
	Heteronotia binoei	Bynoe's Gecko					2		2		3	1		1	3			1		1	2			6						1			4 0
	Rhynchoedura ornata	Beaked Gecko		1								1	1												1	1							9
Pygopodidae	*Delma australis*												1										1										2 5
	Delma butleri			1			2														2												1 8
	Lialis burtonis																																6
	Pygopus lepidopodus	Common Scaly Foot																								1							4
	Pygopus nigriceps																																3
Scincidae	*Cryptoblepharus buchananii*						1									3					1						1		1				2 3
	Ctenotus atlas						2	1													2	1											3 7
	Ctenotus brooksi																																1 0
	Ctenotus leonhardii																																1
	Ctenotus mimetes											1																					3
	Ctenotus pantherinus	Leopard Skink																															8
	Ctenotus schomburgkii													1																	1 3		3 0
	Ctenotus uber			1				2	2			1	1									2	1	1	3	1	6	3	2	1			
	Ctenotus uber uber																																3 2
	Ctenotus xenopleura																																6 6

TERRESTRIAL ECOSYSTEMS

		Survey name	A									B																			C	D	E
Family	Species	Common Name	Opportunistic	Site 16	Site 22	Site 23	Site 24	Site 25	Site 6	Site 7	Site 8	Opportunistic	Site 16	Site 17	Site 18	Site 19	Site 20	Site 21	Site 22	Site 23	Site 24	Site 25	Site 26	Site 27	Site 28	Site 29	Site 30	Site 31	Site 32	Site 33	Mt Walton	Kurrawang	
	Cyclodomorphus melanops	Slender Blue-tongue		1				1					1		3			1				1								1			2 9
	Egernia depressa	Pygmy Spiny-tailed Skink																								1	1						
	Egernia formosa															4																	7
	Egernia richardi																																4
	Eremiascincus richardsonii	Broad-banded Sand Swimmer			1	2		2											1	2		2	1										4
	Hemiergis initialis														1									1						1			4 0
	Lerista gerrardii								1								1																3
	Lerista macropisthopus																														1		1 2
	Lerista muelleri																																4 5
	Lerista picturata																																7
	Lerista sp.				1	2		1							1				1	2		1		3		2	1			2			
	Liopholis inornata				2									1					2												3		2 2
	Menetia greyii																	1							3				1	4	3		3 6
	Morethia adelaidensis																																3
	Morethia butleri							1														1		1		1	1						3 1
	Morethia obscura																														1		2 2
	Tiliqua occipitalis	Western Bluetongue																													2		3
	Tiliqua rugosa					1													1	1													4
Typhlopidae	*Ramphotyphlops australis*			1									1																		1		4
	Ramphotyphlops bicolor																																2
	Ramphotyphlops bituberculatus																							1				1					5
	Ramphotyphlops hamatus																																1
Varanidae	*Varanus giganteus*	Perentie										1														1							
Varanidae	*Varanus gouldii*	Bungarra or Sand Monitor			1	3	1					1		1					1	3	1										2		7
Varanidae	*Varanus tristis*	Racehorse Monitor														1													1		1		3

A Ecologia Environmental Consultants (2001) *Koolyanobbing Expansion Project - Fauna Assessment Survey*. Unpublished report for Portman Iron Ore Limited.

B Ecologia Environmental Consultants (2003) *Koolyanobbing Expansion Project - Transport Corridor Fauna Assessment Survey*. Unpublished report for Portman Iron Ore Limited, Perth.

C Dickman, C.R., Henry-Hall, N.J., Lloyd, H. and Romanow, K.A. (1991) A survey of the terrestrial vertebrate fauna of Mount Walton, western goldfields, Western Australia. *Western Australian Naturalist*, 18, 200-206.

D Bell, D. T., Bell, R. C. and Loneragan, W. A. (2007) Winter bird assemblages across an arid gradient in south-west Western Australia. *Journal of the Royal Society of Western Australia* 90, 219-227.

E Western Australian Museum records

TERRESTRIAL ECOSYSTEMS

Appendix B
Definitions of Significant Fauna under the WA *Wildlife Conservation Act 1950*

Vertebrate Fauna Assessment – Sandy Ridge Project

TERRESTRIAL ECOSYSTEMS

APPENDIX B
DEFINITIONS OF SIGNIFICANT FAUNA UNDER THE WESTERN AUSTRALIAN *WILDLIFE CONSERVATION ACT 1950*

In Western Australia, all native fauna species are protected under the Western Australian *Wildlife Conservation Act 1950-1979*. Fauna species that are considered rare, threatened with extinction or have a high conservation value are specially protected under the Act. In addition, some species of fauna are covered under the 1991 ANZECC convention, while certain birds are listed under the Japan and Australian Migratory Bird Agreement (JAMBA) and the China and Australian Migratory Bird Agreement (CAMBA).
Classification of rare and endangered fauna under the *Wildlife Conservation (Specially Protected Fauna) Notice* recognises four schedules of taxa. These are:

Schedule 1 – fauna which are rare or likely to become extinct and are declared to be fauna in need of special protection;
Schedule 2 – fauna which are presumed to be extinct and are declared to be fauna in need of special protection;
Schedule 3 – birds which are subject to an agreement between the governments of Australia and Japan relating to the protection of migratory birds and birds in danger of extinction which are declared to be fauna in need of special protection; and
Schedule 4 – fauna that are in need of special protection, for reasons other than mentioned in Schedules 1, 2 or 3.

In addition to the above classifications, DPaW also classifies fauna under five different Priority codes:

Priority one – ***Taxa with few, poorly known populations on threatened lands*.** Taxa which are known from few specimens or sight records from one or a few localities on lands not managed for conservation. The taxon needs urgent survey and evaluation of conservation status before consideration can be given to declaration as threatened fauna.
Priority two – *Taxa with few, poorly known populations on conservation lands, or taxa with several, poorly known populations not on conservation lands.* Taxa which are known from few specimens or sight records from one or a few localities on lands not under immediate threat from habitat destruction or degradation. The taxon needs urgent survey and evaluation of conservation status before consideration can be given to declaration as threatened fauna.
Priority three – *Taxa with several, poorly known populations, some on conservation lands*. Taxa which are known from few specimens or sight records from several localities, some of which are on lands not under immediate threat of habitat destruction or degradation. The taxon needs urgent survey and evaluation of conservation status before consideration can be given to declaration as threatened fauna.
Priority four – *Taxa in need of monitoring*. Taxa which are considered to have been adequately surveyed or for which sufficient knowledge is available and which are not considered currently threatened or in need of special protection, but could if present circumstances change. These taxa are usually represented on conservation lands. Taxa which are declining significantly but are not yet threatened.
Priority five – *Taxa in need of monitoring.* Taxa which are not considered threatened but are subject to a specific conservation program, the cessation of which would result in the species becoming threatened within five years

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Appendix C
Results of the *EPBC Act* Protected Matters Search

Vertebrate Fauna Assessment – Sandy Ridge Project

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TERRESTRIAL ECOSYSTEMS

Australian Government

Department of the Environment

EPBC Act Protected Matters Report

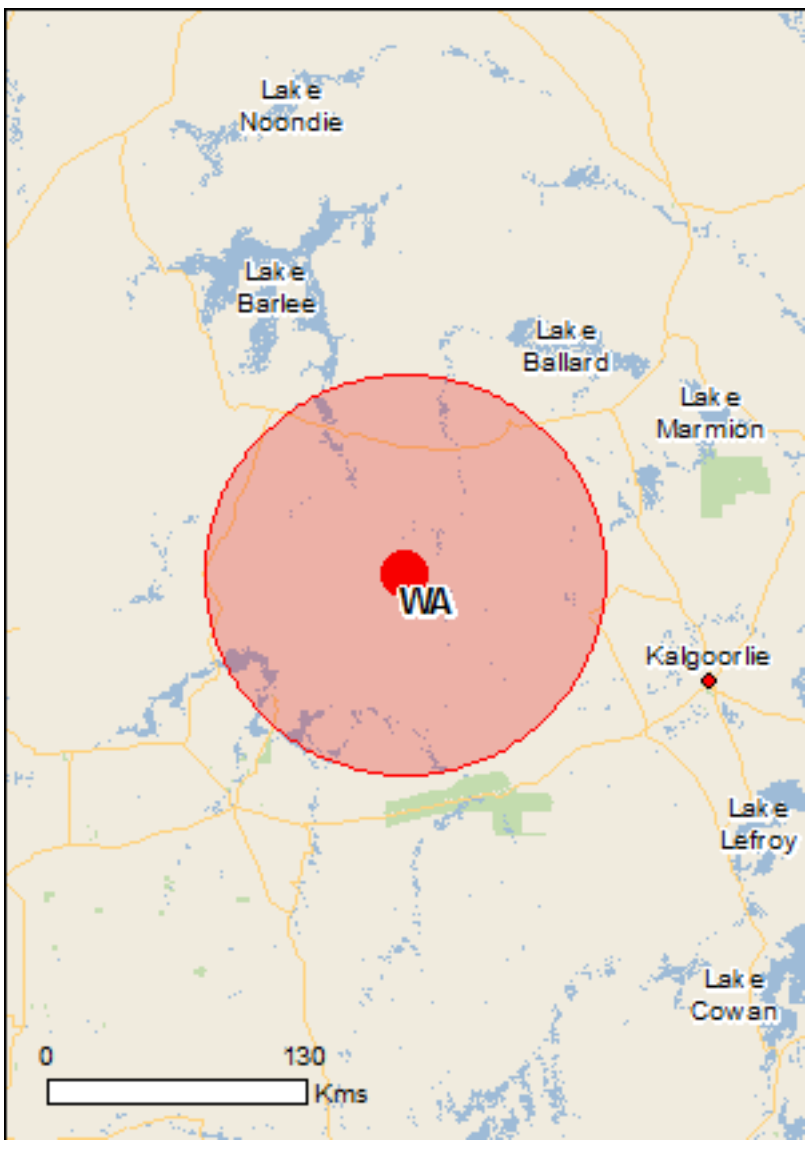
This report provides general guidance on matters of national environmental significance and other matters protected by the EPBC Act in the area you have selected.

Information on the coverage of this report and qualifications on data supporting this report are contained in the caveat at the end of the report.

Information is available about Environment Assessments and the EPBC Act including significance guidelines, forms and application process details.

Report created: 11/05/15 22:08:13

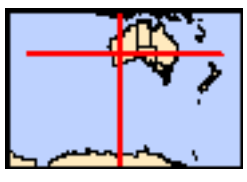
- Summary
- Details
  - Matters of NES
  - Other Matters Protected by the EPBC Act
  - Extra Information
- Caveat
- Acknowledgements



This map may contain data which are ©Commonwealth of Australia (Geoscience Australia), ©PSMA 2010

Coordinates

Buffer: 100.0Km



Summary

Matters of National Environmental Significance

This part of the report summarises the matters of national environmental significance that may occur in, or may relate to, the area you nominated. Further information is available in the detail part of the report, which can be accessed by scrolling or following the links below. If you are proposing to undertake an activity that may have a significant impact on one or more matters of national environmental significance then you should consider the Administrative Guidelines on Significance.

World Heritage Properties:	None
National Heritage Places:	1
Wetlands of International Importance:	None
Great Barrier Reef Marine Park:	None
Commonwealth Marine Area:	None
Listed Threatened Ecological Communities:	None
Listed Threatened Species:	14
Listed Migratory Species:	4

Other Matters Protected by the EPBC Act

This part of the report summarises other matters protected under the Act that may relate to the area you nominated. Approval may be required for a proposed activity that significantly affects the environment on Commonwealth land, when the action is outside the Commonwealth land, or the environment anywhere when the action is taken on Commonwealth land. Approval may also be required for the Commonwealth or Commonwealth agencies proposing to take an action that is likely to have a significant impact on the environment anywhere.

The EPBC Act protects the environment on Commonwealth land, the environment from the actions taken on Commonwealth land, and the environment from actions taken by Commonwealth agencies. As heritage values of a place are part of the 'environment', these aspects of the EPBC Act protect the Commonwealth Heritage values of a Commonwealth Heritage place. Information on the new heritage laws can be found at http://www.environment.gov.au/heritage/index.html

A permit may be required for activities in or on a Commonwealth area that may affect a member of a listed threatened species or ecological community, a member of a listed migratory species, whales and other cetaceans, or a member of a listed marine species.

Commonwealth Land:	1
Commonwealth Heritage Places:	None
Listed Marine Species:	5
Whales and Other Cetaceans:	None
Critical Habitats:	None
Commonwealth Reserves Terrestrial:	None
Commonwealth Reserves Marine:	None

Extra Information

This part of the report provides information that may also be relevant to the area you have nominated.

State and Territory Reserves:	11
Regional Forest Agreements:	None
Invasive Species:	14
Nationally Important Wetlands:	2
Key Ecological Features (Marine)	None

Details

Matters of National Environmental Significance

National Heritage Properties		[Resource Information]
Name	State	Status
Historic		
Goldfields Water Supply Scheme, Western Australia	WA	Listed place

Listed Threatened Species		[Resource Information]
Name	Status	Type of Presence
Birds		
Leipoa ocellata Malleefowl [934]	Vulnerable	Species or species habitat known to occur within area
Mammals		
Dasyurus geoffroii Chuditch, Western Quoll [330]	Vulnerable	Species or species habitat known to occur within area
Plants		
Acacia lobulata Chiddarcooping Wattle [55567]	Endangered	Species or species habitat may occur within area
Eremophila virens Campion Eremophila, Green-flowered Emu bush [21433]	Endangered	Species or species habitat may occur within area
Eremophila viscida Varnish Bush [2394]	Endangered	Species or species habitat may occur within area
Frankenia parvula Short-leaved Frankenia [20872]	Endangered	Species or species habitat known to occur within area
Gastrolobium graniticum Granite Poison [14872]	Endangered	Species or species habitat likely to occur within area
Leucopogon spectabilis Ironstone Beard-heath [83012]	Critically Endangered	Species or species habitat known to occur within area
Myriophyllum lapidicola Chiddarcooping myriophyllum [55940]	Endangered	Species or species habitat known to occur within area
Ricinocarpos brevis [82879]	Endangered	Species or species habitat known to occur within area
Roycea pycnophylloides Saltmat [21161]	Endangered	Species or species habitat may occur within area

Name	Status	Type of Presence
Tetratheca aphylla Bungalbin Tetratheca [2915]	Vulnerable	Species or species habitat likely to occur within area
Tetratheca harperi Jackson Tetratheca [6251]	Vulnerable	Species or species habitat likely to occur within area
Tetratheca paynterae Paynter's Tetratheca [66451]	Endangered	Species or species habitat known to occur within area

Listed Migratory Species

[Resource Information]

* Species is listed under a different scientific name on the EPBC Act - Threatened Species list.

Name	Threatened	Type of Presence
Migratory Marine Birds		
Apus pacificus Fork-tailed Swift [678]		Species or species habitat likely to occur within area
Migratory Terrestrial Species		
Merops ornatus Rainbow Bee-eater [670]		Species or species habitat may occur within area
Migratory Wetlands Species		
Ardea alba Great Egret, White Egret [59541]		Species or species habitat likely to occur within area
Ardea ibis Cattle Egret [59542]		Species or species habitat may occur within area

Other Matters Protected by the EPBC Act

Commonwealth Land

[Resource Information]

The Commonwealth area listed below may indicate the presence of Commonwealth land in this vicinity. Due to the unreliability of the data source, all proposals should be checked as to whether it impacts on a Commonwealth area, before making a definitive decision. Contact the State or Territory government land department for further information.

Name
Commonwealth Land -

Listed Marine Species

[Resource Information]

* Species is listed under a different scientific name on the EPBC Act - Threatened Species list.

Name	Threatened	Type of Presence
Birds		
Apus pacificus Fork-tailed Swift [678]		Species or species habitat likely to occur within area
Ardea alba Great Egret, White Egret [59541]		Species or species habitat likely to occur within area
Ardea ibis Cattle Egret [59542]		Species or species habitat may occur within area
Merops ornatus Rainbow Bee-eater [670]		Species or species habitat may occur within area
Thinornis rubricollis Hooded Plover [59510]		Species or species habitat known to occur

Name	Threatened	Type of Presence within area

Extra Information

State and Territory Reserves [Resource Information]

Name	State
Boorabbin	WA
Clear And Muddy Lakes	WA
Credo	WA
Goldfields Woodlands	WA
Goldfields Woodlands	WA
Mount Manning - Helena And Aurora Ranges	WA
Mount Manning Range	WA
Rowles Lagoon	WA
Unnamed WA36918	WA
Wallaroo Rock	WA
Yellowdine	WA

Invasive Species [Resource Information]

Weeds reported here are the 20 species of national significance (WoNS), along with other introduced plants that are considered by the States and Territories to pose a particularly significant threat to biodiversity. The following feral animals are reported: Goat, Red Fox, Cat, Rabbit, Pig, Water Buffalo and Cane Toad. Maps from Landscape Health Project, National Land and Water Resouces Audit, 2001.

Name	Status	Type of Presence
Birds		
Columba livia Rock Pigeon, Rock Dove, Domestic Pigeon [803]		Species or species habitat likely to occur within area
Streptopelia chinensis Spotted Turtle-Dove [780]		Species or species habitat likely to occur within area
Streptopelia senegalensis Laughing Turtle-dove, Laughing Dove [781]		Species or species habitat likely to occur within area
Mammals		
Camelus dromedarius Dromedary, Camel [7]		Species or species habitat likely to occur within area
Canis lupus familiaris Domestic Dog [82654]		Species or species habitat likely to occur within area
Capra hircus Goat [2]		Species or species habitat likely to occur within area
Equus asinus Donkey, Ass [4]		Species or species habitat likely to occur

Name	Status	Type of Presence
		within area
Equus caballus Horse [5]		Species or species habitat likely to occur within area
Felis catus Cat, House Cat, Domestic Cat [19]		Species or species habitat likely to occur within area
Mus musculus House Mouse [120]		Species or species habitat likely to occur within area
Oryctolagus cuniculus Rabbit, European Rabbit [128]		Species or species habitat likely to occur within area
Vulpes vulpes Red Fox, Fox [18]		Species or species habitat likely to occur within area
Plants		
Carrichtera annua Ward's Weed [9511]		Species or species habitat likely to occur within area
Cenchrus ciliaris Buffel-grass, Black Buffel-grass [20213]		Species or species habitat may occur within area

Nationally Important Wetlands

[Resource Information]

Name	State
Lake Barlee	WA
Rowles Lagoon System	WA

Caveat

The information presented in this report has been provided by a range of data sources as acknowledged at the end of the report.

This report is designed to assist in identifying the locations of places which may be relevant in determining obligations under the Environment Protection and Biodiversity Conservation Act 1999. It holds mapped locations of World and National Heritage properties, Wetlands of International and National Importance, Commonwealth and State/Territory reserves, listed threatened, migratory and marine species and listed threatened ecological communities. Mapping of Commonwealth land is not complete at this stage. Maps have been collated from a range of sources at various resolutions.

Not all species listed under the EPBC Act have been mapped (see below) and therefore a report is a general guide only. Where available data supports mapping, the type of presence that can be determined from the data is indicated in general terms. People using this information in making a referral may need to consider the qualifications below and may need to seek and consider other information sources.

For threatened ecological communities where the distribution is well known, maps are derived from recovery plans, State vegetation maps, remote sensing imagery and other sources. Where threatened ecological community distributions are less well known, existing vegetation maps and point location data are used to produce indicative distribution maps.

For species where the distributions are well known, maps are digitised from sources such as recovery plans and detailed habitat studies. Where appropriate, core breeding, foraging and roosting areas are indicated under 'type of presence'. For species whose distributions are less well known, point locations are collated from government wildlife authorities, museums, and non-government organisations; bioclimatic distribution models are generated and these validated by experts. In some cases, the distribution maps are based solely on expert knowledge.

Only selected species covered by the following provisions of the EPBC Act have been mapped:

- migratory and
- marine

The following species and ecological communities have not been mapped and do not appear in reports produced from this database:

- threatened species listed as extinct or considered as vagrants
- some species and ecological communities that have only recently been listed
- some terrestrial species that overfly the Commonwealth marine area
- migratory species that are very widespread, vagrant, or only occur in small numbers

The following groups have been mapped, but may not cover the complete distribution of the species:

- non-threatened seabirds which have only been mapped for recorded breeding sites
- seals which have only been mapped for breeding sites near the Australian continent

Such breeding sites may be important for the protection of the Commonwealth Marine environment.

Coordinates

-30.33549 120.10354

Acknowledgements

This database has been compiled from a range of data sources. The department acknowledges the following custodians who have contributed valuable data and advice:

-Department of Environment, Climate Change and Water, New South Wales
-Department of Sustainability and Environment, Victoria
-Department of Primary Industries, Parks, Water and Environment, Tasmania
-Department of Environment and Natural Resources, South Australia
-Parks and Wildlife Service NT, NT Dept of Natural Resources, Environment and the Arts
-Environmental and Resource Management, Queensland
-Department of Environment and Conservation, Western Australia
-Department of the Environment, Climate Change, Energy and Water
-Birds Australia
-Australian Bird and Bat Banding Scheme
-Australian National Wildlife Collection
-Natural history museums of Australia
-Museum Victoria
-Australian Museum
-SA Museum
-Queensland Museum
-Online Zoological Collections of Australian Museums
-Queensland Herbarium
-National Herbarium of NSW
-Royal Botanic Gardens and National Herbarium of Victoria
-Tasmanian Herbarium
-State Herbarium of South Australia
-Northern Territory Herbarium
-Western Australian Herbarium
-Australian National Herbarium, Atherton and Canberra
-University of New England
-Ocean Biogeographic Information System
-Australian Government, Department of Defence
-State Forests of NSW
-Geoscience Australia
-CSIRO
-Other groups and individuals

The Department is extremely grateful to the many organisations and individuals who provided expert advice and information on numerous draft distributions.

Please feel free to provide feedback via the Contact Us page.

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Appendix D
Fauna habitat assessment results
Vertebrate Fauna Assessment – Sandy Ridge Project

TERRESTRIAL ECOSYSTEMS

Date: 22/04/2015 Habitat Assessment #: 1 Observer: ST and AH

Zone: 51 Easting: 218530mE Northing: 6637379mN

Fire History: > 5 years Landform: Flat Habitat Quality: High Quality

Habitat Structure: Open Eucalypt woodland with an open understorey of shrubs over emphemeral grasses

Soil Colour: Orange Surface Stone: None

TERRESTRIAL ECOSYSTEMS

Date: 22/04/2015 Habitat Assessment #: 2 Observer: ST and AH

Zone: 51 Easting: 218487mE Northing: 6637382mN

Fire History: > 5 years Landform: Flat Habitat Quality: High Quality

Habitat Structure: Open Eucalypt woodland with an open understorey of shrubs over emphemeral grasses

Soil Colour: Orange Surface Stone: None

TERRESTRIAL ECOSYSTEMS

Date: 22/04/2015 Habitat Assessment #: 3 Observer: ST and AH

Zone: 51 Easting: 218485mE Northing: 6637356mN

Fire History: > 5 years Landform: Flat Habitat Quality: High Quality

Habitat Structure: Open Eucalypt woodland with an open understorey of shrubs over emphemeral grasses

Soil Colour: Orange Surface Stone: None

TERRESTRIAL ECOSYSTEMS

Date: 22/04/2015 Habitat Assessment #: 4 Observer: ST and AH

Zone: 51 Easting: 218527mE Northing: 6637355mN

Fire History: > 5 years Landform: Flat Habitat Quality: High Quality

Habitat Structure: Open Eucalypt woodland with an open understorey of shrubs over emphemeral grasses

Soil Colour: Orange Surface Stone: None

Date: 22/04/2015 Habitat Assessment #: 5 Observer: ST and AH

Zone: 51 Easting: 218508mE Northing: 6637370mN

Fire History: > 5 years Landform: Flat Habitat Quality: High Quality

Habitat Structure: Open Eucalypt woodland with an open understorey of shrubs over emphemeral grasses

Soil Colour: Orange Surface Stone: None

TERRESTRIAL ECOSYSTEMS

Date: 22/04/2015 Habitat Assessment #: 6 Observer: ST and AH

Zone: 51 Easting: 219470mE Northing: 6635863mN

Fire History: > 5 years Landform: Flat Habitat Quality: High Quality

Habitat Structure: Open Eucalypt woodland with an open understorey of shrubs over emphemeral grasses

Soil Colour: Orange Surface Stone: None

TERRESTRIAL ECOSYSTEMS

Date: 22/04/2015 Habitat Assessment #: 7 Observer: ST and AH

Zone: 51 Easting: 219425mE Northing: 6635937mN

Fire History: > 5 years Landform: Flat Habitat Quality: High Quality

Habitat Structure: Open Eucalypt woodland with an open understorey of shrubs over scattered spinifex

Soil Colour: Orange Surface Stone: None

TERRESTRIAL ECOSYSTEMS

Date: 22/04/2015 Habitat Assessment #: 8 Observer: ST and AH

Zone: 51 Easting: 219467mE Northing: 6635811mN

Fire History: > 5 years Landform: Flat Habitat Quality: High Quality

Habitat Structure: Open Eucalypt woodland with an open understorey of shrubs over emphemeral grasses

Soil Colour: Orange Surface Stone: None

TERRESTRIAL ECOSYSTEMS

Date: 22/04/2015 Habitat Assessment #: 9 Observer: ST and AH

Zone: 51 Easting: 219433mE Northing: 6635840mN

Fire History: > 5 years Landform: Flat Habitat Quality: High Quality

Habitat Structure: Open Eucalypt woodland with an open understorey of shrubs over emphemeral grasses

Soil Colour: Orange Surface Stone: None

TERRESTRIAL ECOSYSTEMS

Date: 22/04/2015 Habitat Assessment #: 10 Observer: ST and AH

Zone: 51 Easting: 219422mE Northing: 6635806mN

Fire History: > 5 years Landform: Flat Habitat Quality: High Quality

Habitat Structure: Open Eucalypt woodland with an open understorey of shrubs over emphemeral grasses

Soil Colour: Orange Surface Stone: None

TERRESTRIAL ECOSYSTEMS

Date: 22/04/2015 Habitat Assessment #: 11 Observer: ST and AH

Zone: 51 Easting: 219373mE Northing: 6635840mN

Fire History: > 5 years Landform: Flat Habitat Quality: High Quality

Habitat Structure: Open Eucalypt woodland with an open understorey of shrubs over emphemeral grasses

Soil Colour: Orange Surface Stone: None

TERRESTRIAL ECOSYSTEMS

Date: 22/04/2015 Habitat Assessment #: 12 Observer: ST and AH

Zone: 51 Easting: 219341mE Northing: 6635813mN

Fire History: > 5 years Landform: Flat Habitat Quality: High Quality

Habitat Structure: Open Eucalypt woodland with an open understorey of shrubs over emphemeral grasses

Soil Colour: Orange Surface Stone: None

TERRESTRIAL ECOSYSTEMS

Date: 22/04/2015 Habitat Assessment #: 13 Observer: ST and AH

Zone: 51 Easting: 219329mE Northing: 6635866mN

Fire History: > 5 years Landform: Flat Habitat Quality: High Quality

Habitat Structure: Open Eucalypt woodland with an open understorey of shrubs over emphemeral grasses

Soil Colour: Orange Surface Stone: None

TERRESTRIAL ECOSYSTEMS

Date: 22/04/2015 Habitat Assessment #: 14 Observer: ST and AH

Zone: 51 Easting: 219335mE Northing: 6635936mN

Fire History: > 5 years Landform: Flat Habitat Quality: High Quality

Habitat Structure: Open Eucalypt woodland with an open understorey of shrubs over scattered spinifex

Soil Colour: Orange Surface Stone: None

TERRESTRIAL ECOSYSTEMS

Date: 22/04/2015 Habitat Assessment #: 15 Observer: ST and AH

Zone: 51 Easting: 219372mE Northing: 6635925mN

Fire History: > 5 years Landform: Flat Habitat Quality: High Quality

Habitat Structure: Open Eucalypt woodland with an open understorey of shrubs over scattered spinifex

Soil Colour: Orange Surface Stone: None

TERRESTRIAL ECOSYSTEMS

Date: 22/04/2015 Habitat Assessment #: 16 Observer: ST and AH

Zone: 51 Easting: 219348mE Northing: 6635906mN

Fire History: > 5 years Landform: Flat Habitat Quality: High Quality

Habitat Structure: Open Eucalypt woodland with an open understorey of shrubs over scattered spinifex

Soil Colour: Orange Surface Stone: None

TERRESTRIAL ECOSYSTEMS

Date: 22/04/2015 Habitat Assessment #: 17 Observer: ST and AH

Zone: 51 Easting: 219432mE Northing: 6635911mN

Fire History: > 5 years Landform: Flat Habitat Quality: High Quality

Habitat Structure: Open Eucalypt woodland with an open understorey of shrubs over scattered spinifex

Soil Colour: Orange Surface Stone: None

TERRESTRIAL ECOSYSTEMS

Date: 22/04/2015 Habitat Assessment #: 18 Observer: ST and AH

Zone: 51 Easting: 219402mE Northing: 6635898mN

Fire History: > 5 years Landform: Flat Habitat Quality: High Quality

Habitat Structure: Open Eucalypt woodland with an open understorey of shrubs over scattered spinifex

Soil Colour: Orange Surface Stone: None

TERRESTRIAL ECOSYSTEMS

Date: 22/04/2015 Habitat Assessment #: 19 Observer: ST and AH

Zone: 51 Easting: 219460mE Northing: 6635900mN

Fire History: > 5 years Landform: Flat Habitat Quality: High Quality

Habitat Structure: Open Eucalypt woodland with an open understorey of shrubs over scattered spinifex

Soil Colour: Orange Surface Stone: None

TERRESTRIAL ECOSYSTEMS

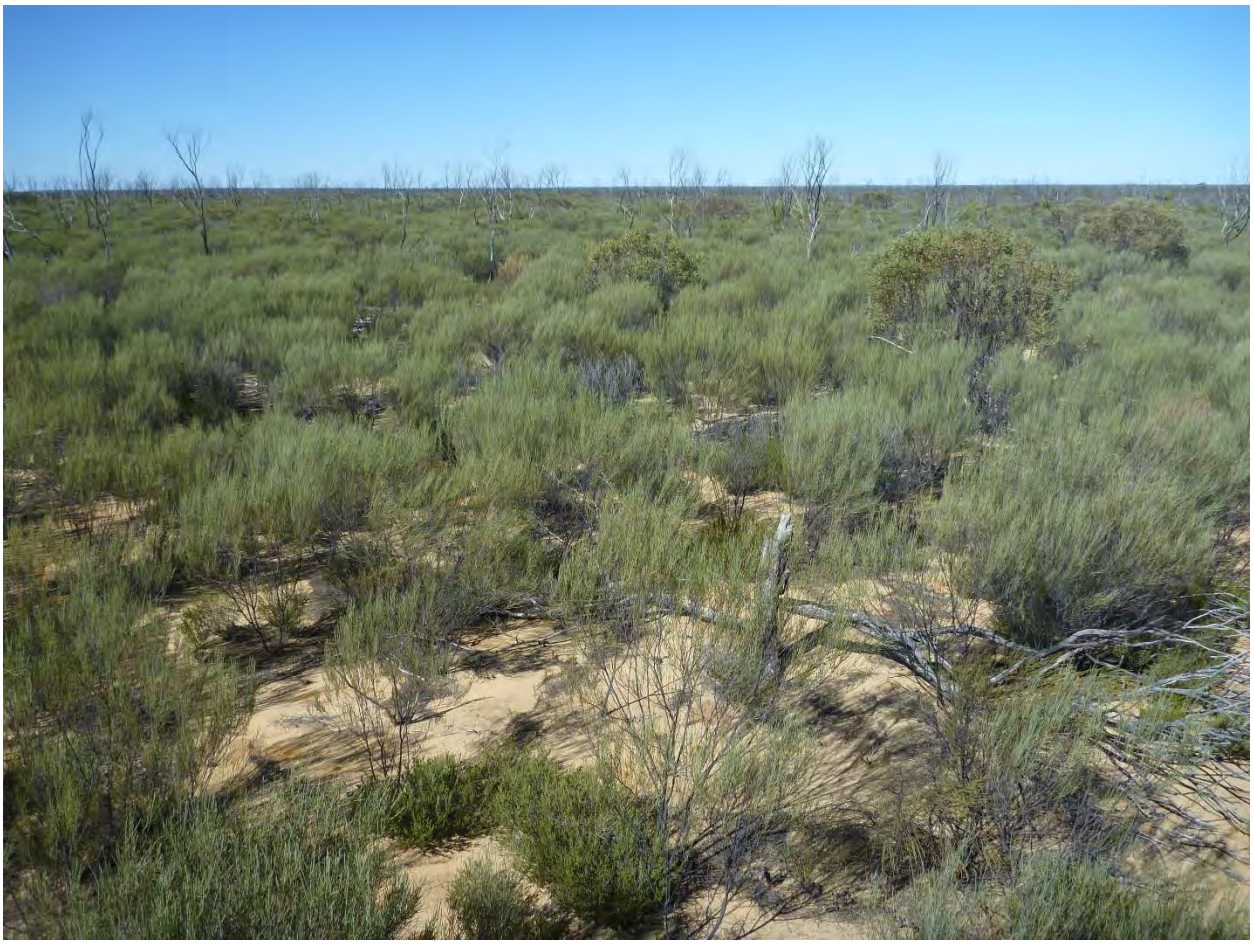
Date: 22/04/2015 Habitat Assessment #: 20 Observer: ST and AH

Zone: 51 Easting: 220938mE Northing: 6637293mN

Fire History: > 5 years Landform: Flat Habitat Quality: High Quality

Habitat Structure: Moderately dense to dense sanplain shrubland varying in height from 0.5-1.8m

Soil Colour: Yellow Surface Stone: None



TERRESTRIAL ECOSYSTEMS

Date: 22/04/2015 Habitat Assessment #: 21 Observer: ST and AH

Zone: 51 Easting: 220850mE Northing: 6637430mN

Fire History: > 5 years Landform: Flat Habitat Quality: High Quality

Habitat Structure: Moderately dense to dense sanplain shrubland varying in height from 0.5-1.8m

Soil Colour: Yellow Surface Stone: None

TERRESTRIAL ECOSYSTEMS

Date: 22/04/2015 Habitat Assessment #: 22 Observer: ST and AH

Zone: 51 Easting: 220497mE Northing: 6637694mN

Fire History: > 5 years Landform: Flat Habitat Quality: High Quality

Habitat Structure: Moderately dense to dense sanplain shrubland varying in height from 0.5-1.8m

Soil Colour: Yellow Surface Stone: None

TERRESTRIAL ECOSYSTEMS

Date: 22/04/2015 Habitat Assessment #: 23 Observer: ST and AH

Zone: 51 Easting: 220278mE Northing: 6637702mN

Fire History: > 5 years Landform: Flat Habitat Quality: High Quality

Habitat Structure: Moderately dense to dense sanplain shrubland varying in height from 0.5-1.8m

Soil Colour: Yellow Surface Stone: None

TERRESTRIAL ECOSYSTEMS

Date: 22/04/2015 Habitat Assessment #: 24 Observer: ST and AH

Zone: 51 Easting: 220033mE Northing: 6637693mN

Fire History: > 5 years Landform: Flat Habitat Quality: High Quality

Habitat Structure: Moderately dense to dense sanplain shrubland varying in height from 0.5-1.8m

Soil Colour: Yellow Surface Stone: None

TERRESTRIAL ECOSYSTEMS

Date: 22/04/2015 Habitat Assessment #: 25 Observer: ST and AH

Zone: 51 Easting: 219820mE Northing: 6637735mN

Fire History: > 5 years Landform: Flat Habitat Quality: High Quality

Habitat Structure: Moderately dense to dense sanplain shrubland varying in height from 0.5-1.8m

Soil Colour: Yellow Surface Stone: None

TERRESTRIAL ECOSYSTEMS

Date: 22/04/2015 Habitat Assessment #: 26 Observer: ST and AH

Zone: 51 Easting: 219885mE Northing: 6637805mN

Fire History: > 5 years Landform: Flat Habitat Quality: High Quality

Habitat Structure: Moderately dense to dense sanplain shrubland varying in height from 0.5-1.8m

Soil Colour: Yellow Surface Stone: None

TERRESTRIAL ECOSYSTEMS

Date: 22/04/2015 Habitat Assessment #: 27 Observer: ST and AH

Zone: 51 Easting: 220081mE Northing: 6637885mN

Fire History: > 5 years Landform: Flat Habitat Quality: High Quality

Habitat Structure: Moderately dense to dense sanplain shrubland varying in height from 0.5-1.8m

Soil Colour: Yellow Surface Stone: None

TERRESTRIAL ECOSYSTEMS

Date: 22/04/2015 Habitat Assessment #: 28 Observer: ST and AH

Zone: 51 Easting: 220272mE Northing: 6637874mN

Fire History: > 5 years Landform: Flat Habitat Quality: High Quality

Habitat Structure: Moderately dense to dense sanplain shrubland varying in height from 0.5-1.8m

Soil Colour: Yellow Surface Stone: None

TERRESTRIAL ECOSYSTEMS

Date: 22/04/2015 Habitat Assessment #: 29 Observer: ST and AH

Zone: 51 Easting: 220468mE Northing: 6637898mN

Fire History: > 5 years Landform: Flat Habitat Quality: High Quality

Habitat Structure: Moderately dense to dense sanplain shrubland varying in height from 0.5-1.8m

Soil Colour: Yellow Surface Stone: None

TERRESTRIAL ECOSYSTEMS

Date: 22/04/2015 Habitat Assessment #: 30 Observer: ST and AH

Zone: 51 Easting: 220428mE Northing: 6638005mN

Fire History: > 5 years Landform: Flat Habitat Quality: High Quality

Habitat Structure: Moderately dense to dense sanplain shrubland varying in height from 0.5-1.8m

Soil Colour: Yellow Surface Stone: None

TERRESTRIAL ECOSYSTEMS

Date: 22/04/2015 Habitat Assessment #: 31 Observer: ST and AH

Zone: 51 Easting: 220147mE Northing: 6637633mN

Fire History: > 5 years Landform: Flat Habitat Quality: High Quality

Habitat Structure: Moderately dense to dense sanplain shrubland varying in height from 0.5-1.8m

Soil Colour: Yellow Surface Stone: None

TERRESTRIAL ECOSYSTEMS

Date: 22/04/2015 Habitat Assessment #: 32 Observer: ST and AH

Zone: 51 Easting: 220660mE Northing: 6637606mN

Fire History: > 5 years Landform: Flat Habitat Quality: High Quality

Habitat Structure: Moderately dense to dense sanplain shrubland varying in height from 0.5-1.8m

Soil Colour: Yellow Surface Stone: None

TERRESTRIAL ECOSYSTEMS

Date: 22/04/2015 Habitat Assessment #: 33 Observer: ST and AH

Zone: 51 Easting: 219945mE Northing: 6638000mN

Fire History: > 5 years Landform: Flat Habitat Quality: Very Good

Habitat Structure: Moderately dense to dense sanplain shrubland varying in height from 0.5-1.8m

Soil Colour: Yellow Surface Stone: None

TERRESTRIAL ECOSYSTEMS

Terrestrial Fauna Surveys

TELLUS

TELLUS HOLDINGS LIMITED:
SANDY RIDGE PROJECT

Malleefowl Assessment, January 2016

Prepared for: Tellus Holdings Limited.
Level 18, Central Park,
152-158 St George. Terrace,
Perth, WA, 6000

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3rd February 2016

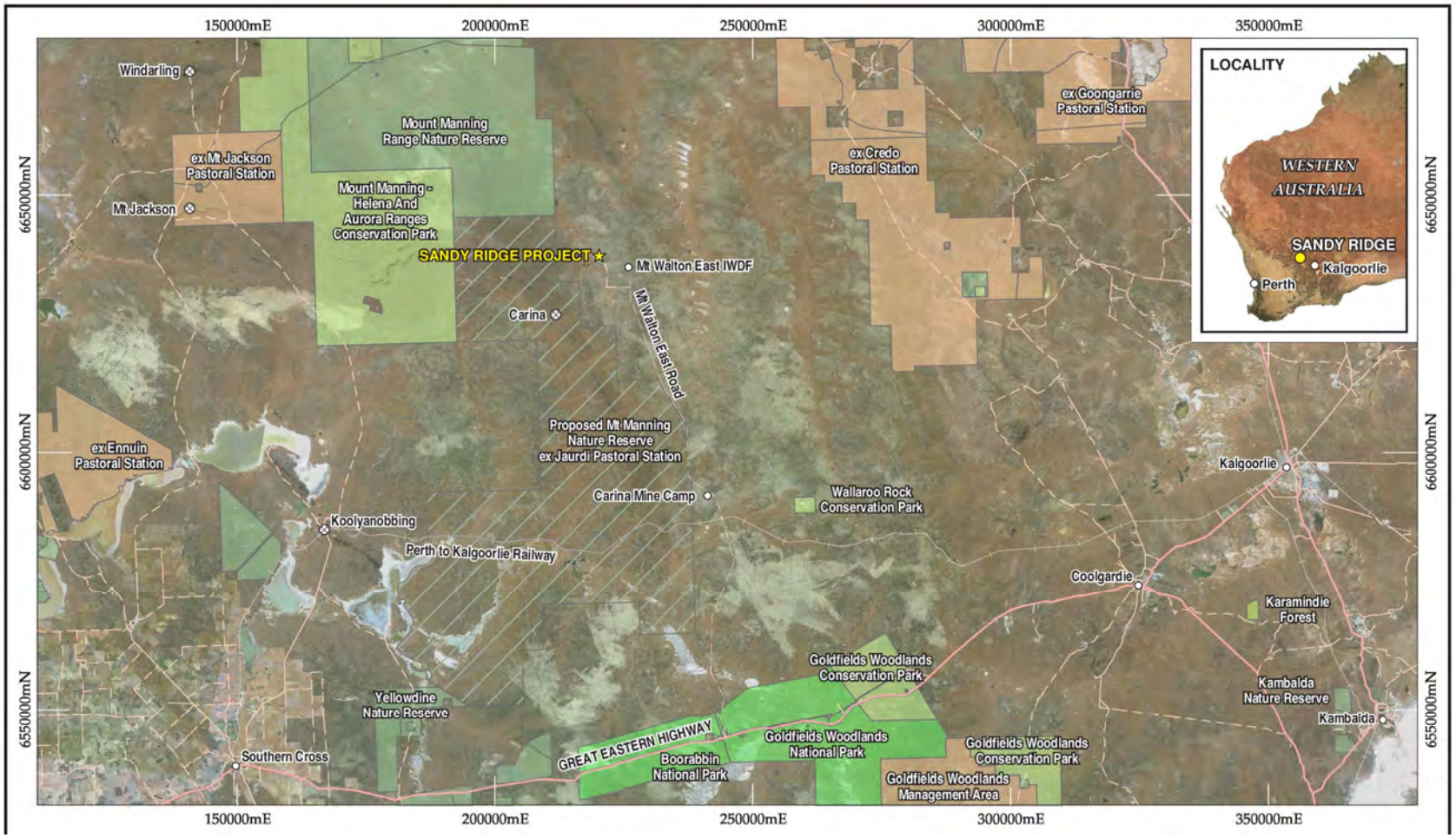
INTRODUCTION

Tellus Holdings Limited (Tellus) is proposing to develop the Sandy Ridge Project, a kaolin clay mining and waste storage project, located approximately 140 km north-west of Kalgoorlie and 120km north-east of Southern Cross, in Western Australia (see Figure 1). The Sandy Ridge Project has a clearing footprint of 276.05ha including pits/cells, mine infrastructure, accommodation camp, Class II landfill, underground storage area, access roads and a water pipeline corridor. Tellus has currently one granted exploration license covering 59 km^2 over the Sandy Ridge kaolin bed (E16/440) and a mining lease is pending.

The Malleefowl, *Leipoa ocellata,* is a fauna species of high conservation significance, listed as Schedule 3 under the WA *Wildlife Conservation Act (1950)* and as Vulnerable under the Federal *Environment Protection and Biodiversity Conservation Act (1999)*. It is known to occur in areas surrounding the Sandy Ridge Project (Bamford Consulting Ecologists (BCE) records, DPaW, 2016) with recent records within 10km of Sandy Ridge (DPaW, 2016) and numerous records from the Mount Manning-Helena and Aurora Ranges Conservation Park (30km, west of Sandy Ridge) and from the Carina minesite (20km south of Sandy Ridge, BCE database). As a result of the species' potential occurrence within the Sandy Ridge Project, the Department of Parks and Wildlife (DPaW) has requested that a targeted Malleefowl survey be carried out across the proposed disturbance areas to determine the site's importance for this species.

To support the Public Environmental Review for this project, BCE was commissioned by Tellus to carry out this targeted Malleefowl survey of the Sandy Ridge Project development envelope focusing on areas of proposed disturbance. Malleefowl surveys consist of systematic searching for their distinctive breeding mounds, as the birds themselves are cryptic and occur at low densities. In contrast, the mounds are large and provide information on breeding activity and the status of the species in an area. As such, BCE conducted a survey of Malleefowl mounds across the Sandy Ridge Project disturbance areas.

Figure 1. Location of the project.



BACKGROUND

Regional description

The Sandy Ridge Project development envelope is located within the Coolgardie Bioregion and the Southern Cross Subregion (Coolgardie 2, IBRA, 2008). The Southern Cross Subregion is described as having subdued relief, comprising gently undulating uplands dissected by broad valleys with bands of low greenstone hills of the Yilgarn Craton. Vegetation includes diverse Eucalyptus woodlands (*Eucalyptus salmonophloia, E. salubris, E transcontinentalis, E. longicornis, Eucalyptus loxophleba*) rich in endemic eucalypts around these salt lakes, on the low greenstone hills, valley alluvials and broad plains of calcareous earths. Upper levels in the landscape are the eroded remnants of a lateritic duricrust yielding yellow sandplains, gravelly sandplains and laterite breakaways. Mallees (*Eucalyptus leptopoda, E. platycorys* and *E. scyphocalyx*) and scrub-heaths (*Allocasuarina corniculata, Callitris preissii, Melaleuca uncinata* and *Acacia beauverdiana*) occur on these uplands, as well as on sand lunettes associated with playas along the broad valley floors, and sand sheets around the granite outcrops. The scrubs are rich in endemic acacias and Myrtaceae (Cowan, Graham and McKenzie, 2001).

Regional vegetation mapping (Beard, 1979) shows two units across the Sandy Ridge Project development envelope:

1. E6, 8, 34Mi (141): Eucalyptus loxophleba / *E. salmonophloia / E. salubris* Woodland;
2. anSc (437): mixed acacia thicket on sandplain.

The south west end of the pipeline route also contains associations 'Eucalyptus open woodland/Triodia open hummock grassland (538)' and a small amount of 'Acacia sparse shrubland/Cryptandra mixed sparse heath (435).

Description of Survey Area

The Sandy Ridge development envelope (see Figure 2) encompasses the project and contains the proposed pit / cell areas (202.3 ha), roads (22.2 ha), water pipeline (27.6 ha), underground storage area (4.0 ha), infrastructure area (17.2 ha), accommodation camp (2.5 ha) and Class II landfill (0.25 ha). Surveying for the Malleefowl concentrated within these proposed areas of disturbance.

A review of previous surveys conducted in the Sandy Ridge area included both flora (PGV Environmental 2016) and fauna (Terrestrial Ecosystems 2015, BCE 2012). PGV Environmental conducted a flora and vegetation survey of the Sandy Ridge area during October 2015.

A range of different vegetation types were described and mapped on the Sandy Ridge lease (E16/440). The survey area was described as dominated by the:

- *Acacia resinimarginea* Open Heath with variations;
- *Acacia resinimarginea / Eucalyptus pileata / Triodia scariosa* Open Heath and Open Grassland;

- Mallee shrublands; and
- Eucalyptus woodlands (*E. corrugata, E. salmonophloia, E. salubris*).

However vegetation was observed as a mosaic of types, with many of the vegetation types intergrading and considered variations of the main types noted. Additionally, PGV Environmental (2016) noted the impact of a fire (thought to be approximately 5 years previous) affecting the structure of large parts of the dominant *Acacia resinimarginea* communites. *Callitris preissii* shrubs which were clearly evident as a dead shrub up to 2-3m high were killed by the fire and the regenerating seedlings are growing very slowly at less than 0.3m tall. Overall, fifteen major vegetation types were noted:

1. *Acacia resinimarginea* Open Heath;
2. *Callitris preissii/Acacia resinimarginea* Tall Shrubland;
3. *Acacia resinimarginea/Allocasuarina acutivalvis* Open Heath;
4. *Acacia resinimarginea/Melaleuca uncinata* Open Low Heath;
5. *Leptospermum roei* Open Heath;
6. *Acacia resinimarginea* Open Heath with scattered *Eucalyptus pileata* over *Triodia scariosa* Open Grassland;
7. *Eucalyptus pileata* Open Shrub Mallee over *Melaleuca uncinata* Open Shrubland over *Triodia scariosa* Open Grassland.
8. *Eucalyptus gracilis* Shrub Mallee over *Acacia nigripilosa /Acacia burkittii* Low Shrubland;
9. *Eucalyptus gracilis* Open Shrub Mallee over *Acacia acuminata/Eremophila oppositifolia* Open Shrubland;
10. *Acacia burkittii* Tall Shrubland;
11. *Eucalyptus rigidula* Very Open Shrub Mallee over *Melaleuca uncinata/Acacia acuminata* Open Low Heath
12. *Eucalyptus corrugata* Low Woodland over *Acacia tetragonophylla* Tall Open Shrubland;
13. *Eucalyptus salmonophloia* Woodland over *Acacia tetragonophylla* Tall Open Shrubland
14. *Eucalyptus salmonophloi*a Woodland over *Eremophila oppositifolia* Open Heath;
15. *Eucalyptus salubris var. salubris* Open Shrub Mallee over *Melaleuca uncinata* Open Shrubland.

<u>Malleefowl</u>

The Malleefowl is listed as Vulnerable under the Environmental Protection and Biodiversity Conservation (EPBC) and Wildlife Conservation Acts (WC Act). In Western Australia, Malleefowl occur mainly in scrubs and thickets of Mallee (*Eucalyptus* spp.), Boree (*Melaleuca pauperiflora*), Bowgada (*Acacia linophylla*), and also other dense litter-forming shrublands including Mulga (*Acacia aneura*) shrublands (Johnstone and Storr, 1998). The species distribution was once larger and less fragmented, but the widespread clearing of suitable habitat, coupled with the degradation of habitat by fire and livestock and fox predation, has reduced Malleefowl numbers considerably (Johnstone and Storr, 1998).

The Malleefowl Mound

Malleefowl have developed a highly sophisticated method of temperature control for egg incubation. They construct distinctive nests that comprise a large mound covering a central core of leaf litter. The mound is constructed out of sand, loam, pebbles or small rocks, depending on the substrate available. Mounds have a large central depression which is filled with leaf litter and covered with soil. Eggs are laid within the mound, buried and left to incubate by the heat generated from decomposing leaf litter (Malleefowl Preservation Group 2013). An adult pair maintains the mound temperature of 32 – 34 °C by adjusting soil cover to either retain or expel heat from the egg chamber (Malleefowl Preservation Group 2013).

Malleefowl are monogamous with pair bonds maintained for life (Priddel and Wheeler 2003). The mound is constructed and maintained by an adult pair over 9 - 11 months of the year. Nest preparation occurs in autumn and the male will tend the nest through summer until temperatures begin to fall (Malleefowl Preservation Group, 2013).

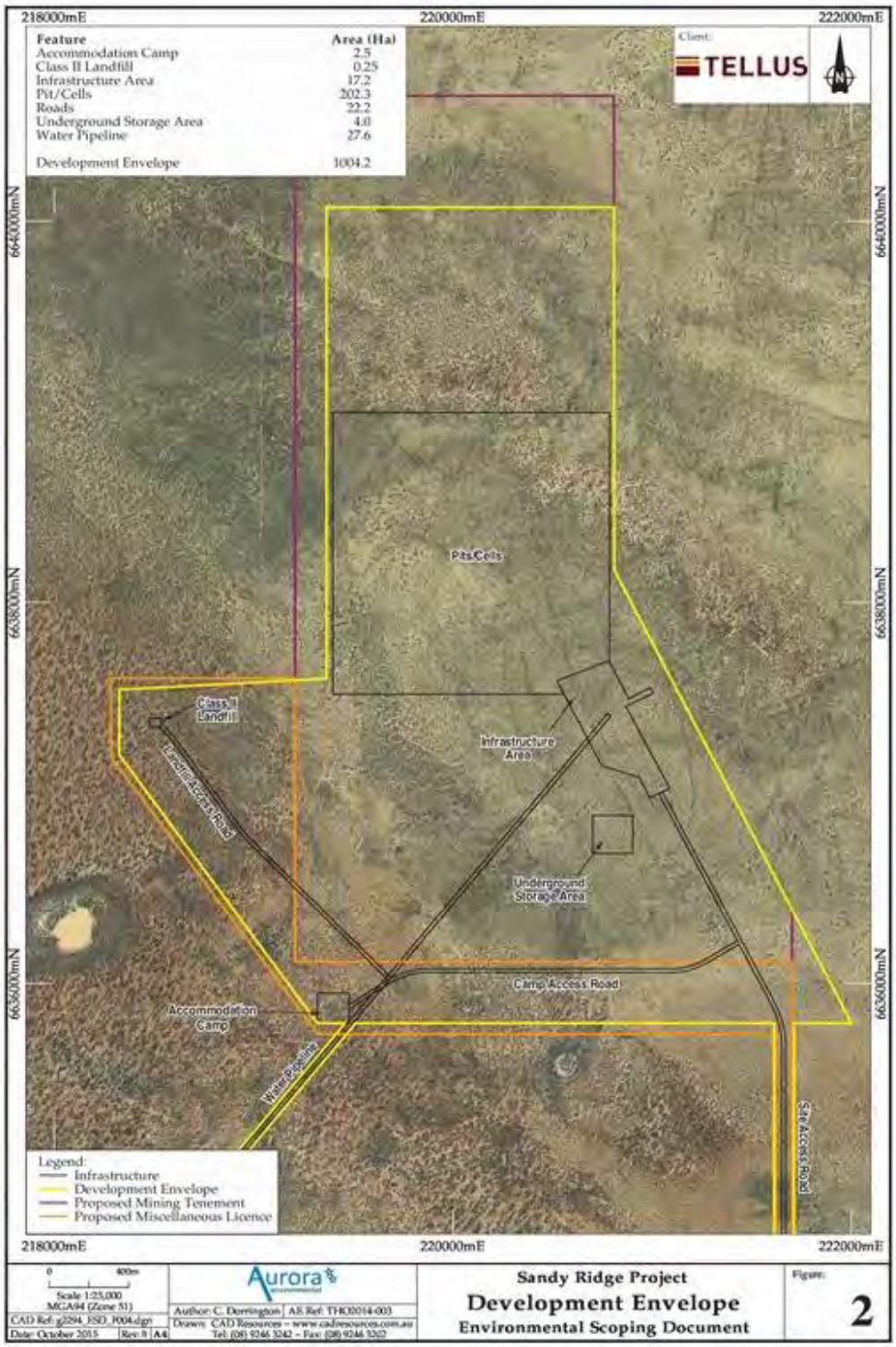
Malleefowl mounds range in size and diameter, depending on age and activity, however mounds commonly span more than five metres and up to one metre high. A pair of Malleefowl will often use the same nest over subsequent seasons however nest fidelity is highly variable. Some Malleefowl pairs have been recorded using the same mound for up to nine years while others relocate seasonally between a cluster of two, three or four mounds (Priddel and Wheeler, 2003). Where Malleefowl mounds are used over many generations, mounds can attain a size of over 20 metres (Malleefowl Preservation Group, 2013).

Mound construction and breeding rely heavily on rainfall. Malleefowl have been recorded abandoning mound construction or failing to use a mound during seasons of low rainfall (Priddel and Wheeler, 2003). Priddel and Wheeler (2003) studied the nesting activity of Malleefowl within an isolated remnant of mallee in central New South Wales. The maximum longevity recorded for breeding adults was 12 years with an average of 7.5 years. Over a twenty year period the population declined, with large population decreases coincident with years of low rainfall and unsuccessful breeding.

Breeding Malleefowl tend to be sedentary, as they nest and roost in the same area year after year. Breeding males do not stray far from the active nest however birds may range over several kilometres outside the breeding season (DPaW, 2016). Malleefowl also require large amounts of leaf litter for egg incubation and so are generally restricted to areas of dense vegetation that have not been burnt for many years. In the Kalgoorlie region, Malleefowl are often associated with dense vegetation on rocky hills, slopes and gravelly rises (BCE records).

Established pairs generally breed annually with eggs laid from September to January. The average clutch size is 16 (but may range from five to 30) and the incubation period lasts for between 62 and 64 days. Malleefowl chicks receive no parental care and as a result chick mortality is high due to predation and exposure (Priddel and Wheeler, 2003).

Figure 2. Overview of the development envelope.



METHODS

Dates and Personnel

Field investigations were carried out from 23rd -27th January 2016. The field survey was conducted under DPaW Regulation 17 (Licence to take Fauna for Scientific Purposes) licence number SF010659 by the following personnel:

- Dr Mike Bamford (B.Sc. Hons. Ph.D);
- Mr Robert Browne-Cooper (B. Sc.);
- Mr Jeff Turpin (B.Sc.);
- Mrs Sarah Smith (B.Sc.);
- Mr Peter Smith (Dip. Ag.).

Field assistance was also provided by Nathan Dimer and Wayne O'Sullivan (Millennium Kids). This document was prepared by Dr Mike Bamford and Jeff Turpin.

Survey Approach

The survey methodology followed the national guidelines for surveying of Malleefowl (Benshemesh *et. al.,* 2000, DEWHA, 2010, Bancroft and Bamford, 2007) and was conducted using a line survey approach within the proposed disturbance areas. This involved a human chain survey with observers walking in a line at about 10-15m intervals, looking for Malleefowl mounds, with the line passing backwards and forwards through the survey area so that the entire site was inspected. Surveying boundaries were defined using hand-held GPS units. In this way, all the impact areas (except for the southern end of the water pipeline alignment) of the Sandy Ridge Project were surveyed for Malleefowl mounds, with the survey extending slightly beyond the boundary of the footprint (Figure 2 and Figure 3). The water pipeline alignment was surveyed to as far south as 214888E, 6630096N (2.4km south-west of Mt Dimer Road). Mt Dimer Road was searched from the access road turnoff to the intersection with Mt Walton Road. As the alignment and the existing road were effectively the same area, this section was searched from slowly moving vehicles with regular stops being made to investigate the roadside for possible mounds that might be affected by road widening and roadworks.

When Malleefowl mounds were detected, the location, vegetation type, physical characteristics (mound width, height, depth, shape / profile and substrate) and mound status (level of activity) was recorded. Note profile is based upon national guidelines (Benshemesh *et. al.,* 2000), while the status categories have been developed by BCE to allow for interpretation of the activity at a mound. Profile and status are defined in Appendix 1.

Other observations

In addition to the survey of Malleefowl mounds, observations on other fauna were maintained opportunistically. This included noting birds, reptiles and mammals seen or indicated by signs such as scats and tracks.

Figure 3. Survey effort conducted at Sandy Ridge – note each survey transect was 60 – 100m wide with personnel on transects margins defining their boundaries.

RESULTS

Site Description

The Sandy Ridge development envelope has low relief and is based on an elevated, undulating sandplain, punctuated by small, lateritic, gravelly rises. On the sandplains, vegetation consists of low mallee over spinifex with areas of Acacia and Allocasuarina shrubland. Lateritic gravelly rises support dense Acacia shrublands and some areas of eucalypt open woodland occur over open shrubs. *Melaleuca* spp. occur on sandy loam, particularly in low lying areas. Small areas of sandy rises support *Callitris* and mallee over spinifex and there is a low-lying area subject to seasonal inundation along the proposed access road between 221648E, 6633000N and 221660E, 6632824N.

The vegetation of the site has been highly affected by recent fire events, particularly on the sandplain. Large areas show evidence of recent fires (within the last approximately 5-10 years), reflected in the reduced height of the *Acacia* shrublands (less than 2m) in areas where burnt shrubs indicate the former height of vegetation was over four metres. As such, much of the vegetation of the site (especially recently burnt areas), is in the early stages of regeneration as the vegetation matures through a succession of stages and heights. Some small areas of long-unburnt vegetation remain, supporting tall *Acacia* and *Allocasuarina* shrublands.

Malleefowl

Sixty-three Malleefowl mounds were found; five of these were large and distinctive although not recently used, while the remaining 58 were little more than circular raised areas of gravel; potentially unused for decades or even centuries and mostly eroded away (see Figures 1-3). Only four mounds had the distinctive raised profile with a central depression shape (profile 1) typical of intact Malleefowl mounds, and even these had large shrubs growing in them, suggesting that it had not been used for many decades (Table 1; see Appendix 2 for location details and descriptions of all mounds).

Table 1. Significant Malleefowl mounds recorded from the project area. Mound dimensions are recorded in metres – width (W), height (H), depth (D). Profile (P) and status are described in Appendix 1).

	Easting	Northing	Habitat / Vegetation	Landform	W	H	D	Status (age)	P
1	220065	6636392	Acacia shrubland on gravelly loam	Lateritic gravelly rise	9	0.4	0.2	E (o)	1
2	219444	6638691	Acacia shrubland on gravelly loam	Lateritic gravelly rise	5	0.5	0.2	E (o)	1
3	219862	6638783	Acacia shrubland on gravelly loam	Lateritic gravelly rise	7	0.5	0.3	E (o)	1
4	214993	6630192	Acacia shrubland on gravelly loam	Lateritic gravelly rise	9	0.4	0.2	E (o)	1
5	219851	6638833	Acacia shrubland on gravelly loam	Lateritic gravelly rise	8	0.2		E (vo)	6

The mounds were not evenly distributed across the disturbance areas but were located mostly in the north of the pit/cells area, with one mound near an access track and one mound located along the water pipeline route. Mounds were found where the soils were a gravelly loam, with the mounds themselves being composed largely of lateritic gravel (Appendix 2). In these areas, the vegetation was a shrubland of *Acacia* and *Allocasuarina*. Much of the development envelope has either sandy soils (typically

supporting mallee over spinifex), red loam soils (supporting eucalypt woodland) or pale brown loam-clay soils (supporting a mixed shrubland), and these soil and vegetation types did not support mound construction. In the case of sandy soils, if mounds had been constructed in the past, they would have eroded away very quickly. However, the birds may prefer the gravelly-loam soils for mound construction and this has been observed elsewhere (M. Bamford pers. obs.).

Data on mounds found during transect surveys are presented in Appendix 2 and locations of mounds are given on Figure 4.

Other fauna observations

Fauna recorded within the survey area are listed in Appendix 3, with an annotated species list of fauna observations provided in Appendix 4 (total of 82 vertebrate species comprising 2 frogs, 24 reptiles, 49 birds, four native mammals and three introduced mammals). The project area is of interest because of the unusual richness of reptile species; a tally of 24 species without any systematic sampling suggests that the reptile assemblage is very rich, perhaps in the order of over 50 species. This richness probably reflects the characteristics of the area, with variable soils over short distances, and the sites location which is transitional between the south-west and inland provinces. In contrast, the bird assemblage recorded over several days was poor; likely a result of seasonal conditions and also may be a consequence of fires that burnt across the bulk of the area within approximately the last 10 years.

Figure 4. Significant Malleefowl mounds recorded from Sandy Ridge – pit/cells area.

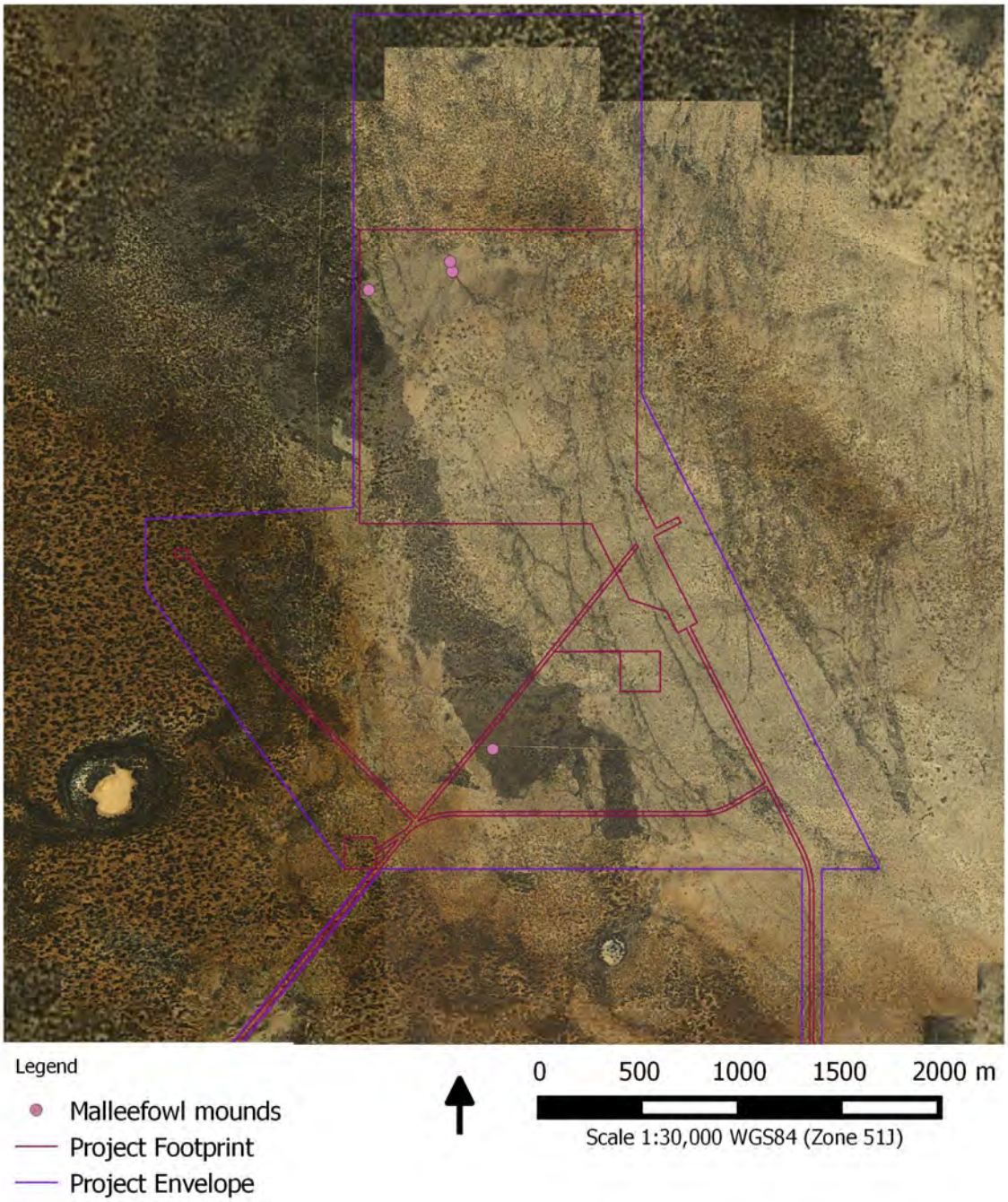
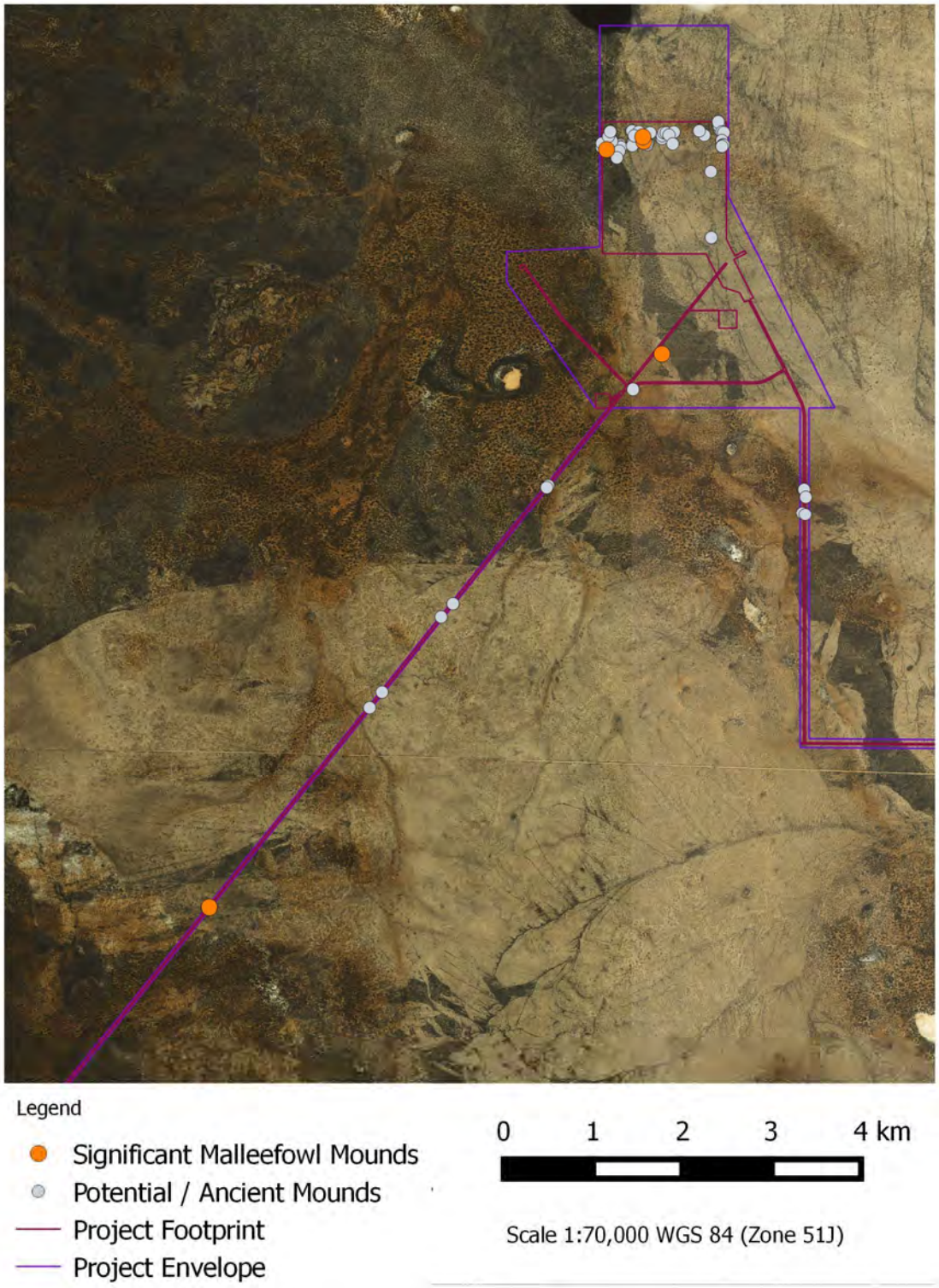


Figure 5. Malleefowl mounds recorded from Sandy Ridge disturbance areas.



DISCUSSION

Malleefowl have previously occurred in the disturbance areas but now appear to be absent as a breeding species, at least from the areas surveyed. This may be a consequence of the extensive recent fires (within approximately the last 10 years) which would have reduced the supply of leaf-litter that is essential for the birds to operate their mounds. While the breeding distribution of the species was limited to areas of gravelly-loam soils, the birds probably foraged widely through all vegetation types. Malleefowl will presumably return to the area when the vegetation is sufficiently mature to support breeding, and a few birds may occasionally pass through the site as there are recent records of the species nearby, such as in the vicinity of the Carina North Mine (BCE database).

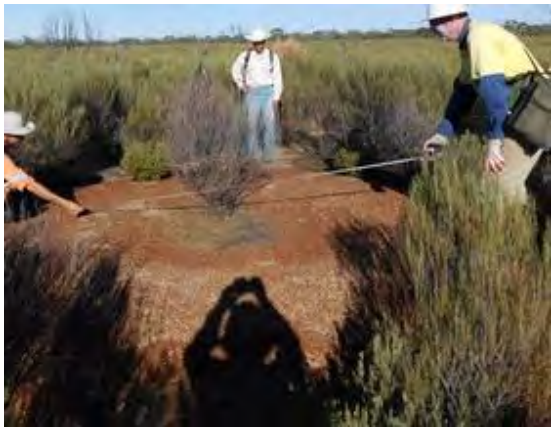
In terms of impact, the risk of the project to Malleefowl is very low with no direct impact upon current breeding sites. Birds are likely to occur in the development envelope only as occasional visitors. Therefore, risk such as from roadkill is low. While Malleefowl can be expected to return to the development envelope and surrounding areas as a breeding species at a low density when the vegetation has matured, it favours gravelly soils for mound construction and these lie mostly outside the development envelope.

The survey did not include the southern end of the water pipeline route (the southern, terminal 4.3 km) as the area could be accessed only on foot and there were concerns with walking long distances away from vehicles in hot weather. This last section of the water pipeline route (4.3 km) could be checked for Malleefowl mounds at the time when the alignment for the pipeline is being surveyed, and any mounds could be avoided as the route has some flexibility. Much of this final section appears to support eucalypt woodland on red loam soils and thus the likelihood of Malleefowl mounds being present is low.

Figure 6. Malleefowl Mounds observed at Sandy Ridge.

Malleefowl Mound 1; raised profile (1) with well defined central depression.

A very old mound; little more than a raised patch of gravel (Malleefowl Mound 18).

Malleefowl Mound 21: Profile 1, some colonisation of small shrubs.	 Mound MF02. Profile 1 with a distinct crater, but a dead bush growing in the centre.

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APPENDICES

Appendix 1. Definitions of mound profile and status

Mound Profile

The profile of a Malleefowl Mound changes with breeding activity and age (erosion and vegetation growth). Malleefowl mounds should be defined using the following system, obtained from the National Manual for the Malleefowl Monitoring System (Benshemesh 2000):

- Profile 1: Typical crater with raised rims. This is the typical shape of an inactive nest (however the nest may also be active and open);
- Profile 2: Nest fully dugout. The characteristic of this profile is that the crater slopes down steeply and at the base the sides drop vertically to form a box- like structure with side usually 20 to 30 cm deep. Often, litter will have been raked into windrows, and may have started to enter the nest;
- Profile 3: Nest with litter. This is the next stage after profile 2. Litter will have been raked into the nest by Malleefowl, and thick layers of litter are evident on the surface. There may or may not be sand mixed with the litter at this stage.
- Profile 4: Nest mounded up (no crater). This is the typical profile of an active but unopened Malleefowl nest. The active mound is closed and dome shaped.
- Profile 5: Nest a crater with peak in centre. This is a typical profile of an active nest which is in the process of being closed by Malleefowl.
- Profile 6: Nest low and flat without peak or crater. This mound has not been used for some time and weathering and erosion have ‘flattened” the original mound.

Examples of each mound profile are displayed below:

Profile 1 Mound

Profile 2 Mound

Profile 3 Mound

Profile 4 Mound

Profile 5 Mound

Profile 6 Mound

(Pictures from the National Manual for the Malleefowl Monitoring System and J. Turpin)

Mound Status

In addition to mound profiles, mound status can be recorded. The mound profiles describe the appearance of the mound and while this is related to activity status, there can be some ambiguity, particularly in the harsh, rocky or gravelly environments. For example, Profiles 1 to 5 may all be mounds that are active in some sense, but only some mounds of Profile 4 are active in the sense of containing eggs that are being incubated. For example, it is possible to have a Profile 4 mound that has been abandoned and does not contain eggs. Statuses A to D all apply to mounds that have been technically active in the current breeding season, but only mounds of status A are active in that they are being used for breeding.

Status A.
Active (Profile 4): Mound almost certainly contains eggs. Mound is covered over, dome-shaped and surface is freshly disturbed (that day), often with small excavations around the lower perimeter where the male has scratched material onto the centre of the mound. There will be no ant-line tracks and very few tracks of small animals present, as the surface of the mound is being worked constantly.

Status B.
Inactive (Profile 4): Mound is covered over and dome-shaped, but surface is not disturbed, having assorted animal tracks and ant-lion traps on it. This is a mound that has been fully-prepared for incubation in that year, but has been abandoned. Note that it may also have been prepared in an earlier year but this will have been recorded.

Status C.
Inactive (Profile 3 or 5): Mound has been excavated and filled with leaf-litter, but has been abandoned.

Status D.
Inactive (Profile 1 or 2): Mound has been excavated but no further progress has been made.

Status E.
Inactive (profile 1 or 6): No recent activity. Profile 1 and 6 grade into each other, but mounds can be roughly aged (i.e. time since last used) by their appearance. For example:

Recently used: Eggshell and plant material in centre still present. It is not known how long it takes for such material to degenerate in the Sandy Ridge region, but such a mound could be >5 years old. If very young, the plant material in the centre is like compost, may contain beetle larvae and termites, and may be excavated by foraging goannas and echidnas.

Not recently used: No eggshell or plant material in centre, but central depression still well-formed, crater still distinct, with central depression often lower than the surrounding soil surface. Such mounds may be decades old. One that has been

observed annually for five years has not changed in appearance at all. Weathering of such mounds and colonisation by plants may be very slow except after rare heavy rainfall events.

Old: Clearly weathered by still distinctly Profile 1. Often with small plants in centre. Probably several decades old or older.

Very Old: Profile 6 or still with a hint of Profile 1. The age of such mounds may be in the order of 50 to 500 years. Shrubs and even trees may be present.

Appendix 2. Observations on Malleefowl mounds; January 2016. Mound dimensions in metres.

Code	Date	Easting	Northing	Profile	Status	Width	Height	Crater width	Crater depth	Material	VSA	Notes
Malleefowl Mounds												
MF1	23/01/2016	220065	6636392	1	E (o)	9	0.4	2	0.2	gravel	Acacia shrubland on gravelly loam	Last used 20-50 years. Has bush growing in crater
MF2	24/01/2016	219444	6638691	1	E (o)	5	0.5	2	0.2	gravel	Acacia shrubland on gravelly loam	Last used 20-50 years. Has bush growing in crater
MF21	24/01/2016	219862	6638783	1	E (o)	7	0.5	3	0.3	gravel	Acacia shrubland on gravelly loam	Last used 20-50 years. Has bush growing in crater
MF41	27/01/2016	214993	6630192	1	E (o)	9.5	0.4	2	0.2	Gravel, loam	Acacia and allocasuarina shrubland on gravelly loam	Shrubs in crater
MF23	24/01/2016	219851	6638833	6	E (vo)	8	0.15			gravel	Acacia shrubland on gravelly loam	Unused for 100+ years. Appears as a bare patch of gravel
Potential Ancient Mounds												
MF3	24/01/2016	219392	6638715	6	E (vo)	3	0.1			gravel	Acacia shrubland on gravelly loam	Unused for 100+ years. Appears as a bare patch of gravel
MF4	24/01/2016	219410	6638754	6	E (vo)	1.5	0.1			gravel	Acacia shrubland on gravelly loam	Unused for 100+ years. Appears as a bare patch of gravel
MF5	24/01/2016	219392	6638762	6	E (vo)	1.5	0.1			gravel	Acacia shrubland on gravelly loam	Unused for 100+ years. Appears as a bare patch of gravel
MF6	24/01/2016	219444	6638691	6	E (vo)	1.5	0.1			gravel	Acacia shrubland on gravelly loam	Unused for 100+ years. Appears as a bare patch of gravel
MF7	24/01/2016	219593	6638748	6	E (vo)	1.5	0.1			gravel	Acacia shrubland on gravelly loam	Unused for 100+ years. Appears as a bare patch of gravel
MF8	24/01/2016	219579	6638737	6	E (vo)	1.5	0.1			gravel	Acacia shrubland on gravelly loam	Unused for 100+ years. Appears as a bare patch of gravel
MF9	24/01/2016	219500	6638686	6	E (vo)	2	0			gravel	Acacia shrubland on gravelly loam	Unused for 100+ years. Appears as a bare patch of gravel
MF10	24/01/2016	219580	6638715	6	E (vo)	2.5	0.2			gravel	Acacia shrubland on gravelly loam	Unused for 100+ years. Appears as a bare patch of gravel
MF11	24/01/2016	219606	6638718	6	E (vo)	2	0.1			gravel	Acacia shrubland on gravelly loam	Unused for 100+ years. Appears as a bare patch of gravel
MF12	24/01/2016	219489	6638731	7	E (vo)	3	1.1			gravel	Acacia shrubland on gravelly loam	Unused for 100+ years. Appears as a bare patch of gravel

Code	Date	Easting	Northing	Profile	Status	Width	Height	Crater width	Crater depth	Material	VSA	Notes
MF13	24/01/2016	219586	6638674	6 E (vo)		2	0.1			gravel	Acacia shrubland on gravelly loam	Unused for 100+ years. Appears as a bare patch of gravel
MF14	24/01/2016	219560	6638599	6 E (vo)		3	0.1			gravel	Acacia shrubland on gravelly loam	Unused for 100+ years. Appears as a bare patch of gravel
MF15	24/01/2016	219730	6638899	6 E (vo)		2	0			gravel	Acacia shrubland on gravelly loam	Unused for 100+ years. Appears as a bare patch of gravel
MF16	24/01/2016	219775	6638847	6 E (vo)		1.5	0.1			gravel	Acacia shrubland on gravelly loam	Unused for 100+ years. Appears as a bare patch of gravel
MF17	24/01/2016	219809	6638776	6 E (vo)		2.5	0.3			gravel	Acacia shrubland on gravelly loam	Unused for 100+ years. Appears as a bare patch of gravel
MF18	24/01/2016	219740	6638765	6 E (vo)		2	0			gravel	Acacia shrubland on gravelly loam	Unused for 100+ years. Appears as a bare patch of gravel
MF19	24/01/2016	219733	6638735	6 E (vo)		1.5	0			gravel	Acacia shrubland on gravelly loam	Unused for 100+ years. Appears as a bare patch of gravel
MF20	24/01/2016	219901	6638748	6 E (vo)		2	0.1			gravel	Acacia shrubland on gravelly loam	Unused for 100+ years. Appears as a bare patch of gravel
MF22	24/01/2016	219900	6638768	6 E (vo)		1.5	0			gravel	Acacia shrubland on gravelly loam	Unused for 100+ years. Appears as a bare patch of gravel
MF24	24/01/2016	219806	6638890	6 E (vo)		1.5	0.1			gravel	Acacia shrubland on gravelly loam	Unused for 100+ years. Appears as a bare patch of gravel
MF25	24/01/2016	219933	6638879	6 E (vo)		2	0.05			gravel	Acacia shrubland on gravelly loam	Unused for 100+ years. Appears as a bare patch of gravel
MF16	24/01/2016	219754	6638846	6 E (vo)		2	0			gravel	Acacia shrubland on gravelly loam	Unused for 100+ years. Appears as a bare patch of gravel
mf	24/01/2016	219504	6638785	6 E (vo)		2	0			gravel	Acacia shrubland on gravelly loam	Unused for 100+ years. Appears as a bare patch of gravel
mf	24/01/2016	219465	6638838	6 E (vo)		2	0			gravel	Acacia shrubland on gravelly loam	Unused for 100+ years. Appears as a bare patch of gravel
mf	24/01/2016	219486	6638892	6 E (vo)		1.5	0			gravel	Acacia shrubland on gravelly loam	Unused for 100+ years. Appears as a bare patch of gravel
MF26	25/01/2016	220066	6638816	6 E (vo)		2.5	0			gravel	Acacia shrubland on gravelly loam	Unused for 100+ years. Appears as a bare patch of gravel
MF27	25/01/2016	220068	6638847	6 E (vo)		1.5	0.1			gravel	Acacia shrubland on gravelly loam	Unused for 100+ years. Appears as a bare patch of gravel

Code	Date	Easting	Northing	Profile	Status	Width	Height	Crater width	Crater depth	Material	VSA	Notes
MF28	25/01/2016	220085	6638880	6 E (vo)		3	0			gravel	Acacia shrubland on gravelly loam	Unused for 100+ years. Appears as a bare patch of gravel
MF29	25/01/2016	220112	6638879	6 E (vo)		2	0.05			gravel	Acacia shrubland on gravelly loam	Unused for 100+ years. Appears as a bare patch of gravel
MF30	25/01/2016	220200	6638887	6 E (vo)		2	0.15			gravel	Acacia shrubland on gravelly loam	Unused for 100+ years. Appears as a bare patch of gravel
MF31	25/01/2016	220144	6638854	6 E (vo)		2	0			gravel	Acacia shrubland on gravelly loam	Unused for 100+ years. Appears as a bare patch of gravel
MF32	25/01/2016	220185	6638755	6 E (vo)		2	0.05			gravel	Acacia shrubland on gravelly loam	Unused for 100+ years. Appears as a bare patch of gravel
MF37	25/01/2016	220539	6638852							gravel		
MF38	25/01/2016	220483	6638901							gravel		
MF39	25/01/2016	220613	6638444							gravel		Boodie warren
MF40	25/01/2016	220618	6637706	6 E (vo)		6	0.1			Gravel. loam	Mallee over shrubs	Unused for 100+ years. A low risse
MF42	27/01/2016	214969	6630187	6 E (vo)		2	0.2			gravel and loam	Acacia and allocasuarina shrubland on gravelly loam	
Mf50	27/01/2016	220718	6638908	6 E (vo)		3	0.1			gravel	Acacia shrubland on gravelly loam	3 metres diameter, slight mound, gravel, very old
Mf51	27/01/2016	220704	6638957	6 E (vo)		3	0.15			gravel	Acacia shrubland on gravelly loam	3 metres diameter, slight mound 150mm high, gravel, very old
Mf52	27/01/2016	220696	6638997	6 E (vo)		2.5	0.15			gravel	Acacia shrubland on gravelly loam	2.5 metres diameter, 150mm high, very old
Mf53	27/01/2016	220738	6638890	6 E (vo)		4	0.15			gravel	Acacia shrubland on gravelly loam	4 metres across, slight mound, gravel, very old
Mf54	27/01/2016	220758	6638882	6 E (vo)		2	0.1			gravel	Acacia shrubland on gravelly loam	2 metres across, 50mm high, slight mound, gravel, very old.
Mf55	27/01/2016	220736	6638792	6 E (vo)		4	0.1			gravel	Acacia shrubland on gravelly loam	4 metres across, 100mm high, gravel, very old
Mf56	27/01/2016	220742	6638739	6 E (vo)		3	0.1			gravel	Acacia shrubland on gravelly loam	3 metres diameter, low mound, gravel, very old
Mf57	27/01/2016	220750	6638743	6 E (vo)		2	0.1			gravel	Acacia shrubland on gravelly loam	2 metre diameter, gravel patch, very old.

Code	Date	Easting	Northing	Profile	Status	Width	Height	Crater width	Crater depth	Material	VSA	Notes
Mf58	27/01/2016	220755	6638742	6 E (vo)		1.5	0.1			gravel	Acacia shrubland on gravelly loam	1.5 metre diameter gravel patch, very old
Mf59	27/01/2016	220737	6638727	6 E (vo)		2	0.1			gravel	Acacia shrubland on gravelly loam	2 metre diameter, gravel patch, very old.
Mf60	27/01/2016	219741	6635997	6 E (vo)		6	0.2			sand	Acacia shrubland on gravelly loam	6 metre diameter, 300mm high, all sand, old
Mf61	27/01/2016	218791	6634919	6 E (vo)		2	0.2			gravel	Acacia shrubland on gravelly loam	2 metre diameter gravel mound 200mm high, overgrowwwn, ancient
Mf62	27/01/2016	218774	6634897	6 E (vo)		2	0.1			gravel	Acacia shrubland on gravelly loam	2 metre diameter, 100mm high, gravel/loam, ancient
Mf63	27/01/2016	221657	6634875	6 E (vo)		2	0.15			gravel	Acacia shrubland on gravelly loam	2 metre diameter, 50mm high, gravel, very old
Mf64	27/01/2016	221676	6634789	6 E (vo)		2.5	0.1			gravel	Acacia shrubland on gravelly loam	2.5metres diameter, 100mm high, gravel/loam, 2 mounds together like a figure of 8, very old
Mf65	27/01/2016	221638	6634608	6 E (vo)		3	0.1			gravel	Acacia shrubland on gravelly loam	3 metres diameter gravel patch, very old
Mf66	27/01/2016	221670	6634592	6 E (vo)		2.5	0.2			gravel	Acacia shrubland on gravelly loam	2.5 metres diameter, 200mm high, gravel, very old
Mf67	27/01/2016	216790	6632430	6 E (vo)		1	0.2			gravel	Acacia shrubland on gravelly loam	1 metre diameter made of large gravel stones and sand, very slight mound, very old.
Mf68	27/01/2016	216929	6632605	6 E (vo)		3	0.2			gravel	Acacia shrubland on gravelly loam	3 metres diameter, 200mm high, gravel and sand, very old, 2 mounds together like a figure of 8
Mf69	27/01/2016	217591	6633441	6 E (vo)		2	0.1			gravel	Acacia shrubland on gravelly loam	2 metres diameter, 100mm high, gravel/sand, very old
Mf70	27/01/2016	217724	6633589	6 E (vo)		2	0.2			gravel	Acacia shrubland on gravelly loam	2 metres diameter, 200mm high, very fine gravel, very old.

Appendix 3. Fauna recorded or expected to occur in the survey area (Table 1 to Table 4).

These lists are derived from the results of database and literature searches and from previous field surveys conducted in the region. These are:

- Species listed under fauna databases – NatureMap (records within 40km on Sandy Ridge, DPaW, 2016), Birdata (BirdLife Australia, 2016), Atlas of Living Australia (ALA, 2016) or EPBC Protected Matters Search (DotE, 2016), or from the literature;
- Local Records (BCE database);
- Species recorded at Sandy Ridge by BCE during the 2016 field survey.
- Note conservation significant fauna are listed under CS.

CS= conservation significance; CS1 = listed under legislation; CS2 = listed a Priority by DPaW; CS3 = locally significant.

Table 1. Frog species expected to occur in the survey area.

FROGS		CS	Databases	Sandy Ridge
Myobatrachidae (ground-frogs)				
Kunapalri Frog	*Neobatrachus kunapalari*		X	X
Humming Frog	*Neobatrachus pelobatoides*			
Shoemaker Frog	*Neobatrachus sutor*		X	X
Goldfields Bull Frog	*Neobatrachus wilsmorei*			
Western Toadlet	*Pseudophryne occidentalis*		X	
Total Number of Species Expected: 5			3	**2**

Table 2. Reptile species recorded or expected to occur in the survey area.

REPTILES		CS	Databases	Sandy Ridge
AGAMIDAE				
Crested Dragon	*Ctenophorus cristatus*		X	X
Mallee Military Dragon	*Ctenophorus fordi*		X	X
Western Netted Dragon	*Ctenophorus reticulatus*		X	
Military Dragon	*Ctenophorus isolepis*		X	X
Claypan Dragon	*Ctenophorus salinarum*			
Lozenge-marked Dragon	*Ctenophorus scutulatus*		X	X
Thorny Devil	*Moloch horridus*		X	X
Bearded Dragon	*Pogona minor*		X	X
Pebble Dragon	*Tympanocryptis cephalus*		X	
DIPLODACTYLIDAE				
Clawless Gecko	*Crenadactylus ocellatus*		X	
Western Stone Gecko	*Diplodactylus granariensis*		X	X
Beautiful Gecko	*Diplodactylus pulcher*		X	X
Main's Ground Gecko	*Lucasium maini*		X	X
Southern Sandplain Gecko	*Lucasium bungabinna*		X	
Reticulated Velvet Gecko	*Oedura reticulata*		X	X
Beaked Gecko	*Rhynchoedura ornata*		X	X
Thorn -tailed Gecko	*Strophurus assimilis*		X	
Jewelled Gecko	*Strophurus elderi*		X	
Ring-tailed Gecko	*Strophurus strophurus*			
CARPHODACTYLIDAE				
Southern Knob-tail	*Nephrurus stellatus*		X	
Barking Gecko	*Nephrurus milii*		X	
GEKKONIDAE				
Marbled Gecko	*Christinus marmoratus*			
Purplish Dtella	*Gehyra purpurascens*			X
Tree Dtella	*Gehyra variegata*		X	X
Bynoe's Gecko	*Heteronotia binoei*		X	
PYGOPODIDAE				
Marble-faced Delma	*Delma australis*		X	
Unbanded Dema	*Delma butleri*		X	
Fraser's Delma	*Delma fraseri*			
Burton's Legless-Lizard	*Lialis burtonis*		X	

REPTILES		CS	Databases	Sandy Ridge
Common Scaly-foot	*Pygopus lepidopodus*		X	
Western Scaly-foot	*Pygopus nigriceps*		X	
SCINCIDAE				
A skink	*Cryptoblepharus australis*		X	X
A skink	*Cryptoblepharus buchananii*		X	
A skink	*Ctenotus ariadnae*		X	
Southern Mallee Skink	*Ctenotus atlas*		X	X
A skink	*Ctenotus brooksi*		X	
Leonhardi's Ctenotus	*Ctenotus leonhardii*		X	
Barred Wedge-snouted Ctenotus	*Ctenotus schomburgkii*		X	X
Leopard Ctenotus	*Ctenotus pantherinus*		X	
Wide-striped Ctenotus	*Ctenotus xenopleura*		X	X
Spotted Ctenotus	*Ctenotus uber*		X	
Spinifex Slender Blue-tongue	*Cyclodomorphus melanops*		X	
Pygmy Spiny-tailed Skink	*Egernia depressa*			
Goldfields Crevice Skink	*Egernia formosa*			
Desert Skink	*Egernia inornata*		X	X
Woodland Crevice Skink	*Egernia richardi*			
Night Skink	*Egernia striata*			
Broad-banded Sandswimmer	*Eremiascincus richardsonii*			
Southern Five-toed Mulch Skink	*Hemiergis initialis*		X	
Four-toed Mulch Skink	*Hemiergis peronii*			
A skink	*Lerista gerrardi*		X	
King's Lerista	*Lerista kingi*		X	
Goldfields Robust Lerista	*Lerista picturata*		X	
Common Mulch Lerista	*Lerista timda*		X	
Bull-headed Skink	*Liopholis multiscutata*			
Common Dwarf Skink	*Menetia greyii*		X	X
Saltbush Flecked Skink	*Morethia adelaidensis*			
Woodland Dark Fleck Skink	*Morethia butleri*		X	
Woodland Flecked Skink	*Morethia obscura*		X	
Western Blue-tongue	*Tiliqua occipitalis*		X	X
Bobtail	*Tiliqua rugosa*			
VARANIDAE				
Perentie	*Varanus giganteus*		X	
Bungarra	*Varanus gouldii*		X	X

REPTILES		CS	Databases	Sandy Ridge
Racehorse Monitor	*Varanus tristis tristis*		X	X
TYPHLOPIDAE				
Southern Blind Snake	*Anilios australis*			X
Dark-spinned Blind Snake	*Anilios bicolor*			
Prong-snouted Blind Snake	*Anilios bituberculatus*			
Hook-Snouted Blind Snake	*Anilios hamatus*			
Common Beaked Blind Snake	*Anilios waitii*			
BOIDAE				
Stimson's Python	*Antaresia stimsoni*			
Woma	*Aspidites ramsayi*	CS2		
Carpet Python	*Morelia spilota imbricata*	CS3	X	
ELAPIDAE				
Desert Death Adder	*Acanthophis pyrrhus*			
Narrow-banded Shovel-nosed Snake	*Brachyurophis fasciolata*		X	
Southern Shovel-nosed Snake	*Brachyurophis semifasciata*		X	X
Yellow-faced Whipsnake	*Demansia psammophis*		X	
Bardick	*Echiopsis curta*			
Moon Snake	*Furina ornata*		X	
Black-naped Snake	*Neelaps bimaculatus*			
Gould's Snake	*Parasuta gouldii*			
Monk Snake	*Parasuta monachus*		X	
Black-backed Hooded Snake	*Parasuta nigriceps*			
Mulga Snake	*Pseudechis australis*		X	
Dugite	*Pseudonaja affinis*			
Ringed Brown Snake	*Pseudonaja modesta*		X	
Western Brown Snake	*Pseudonaja mengdeni*		X	
Jan's Banded Snake	*Simoselaps bertholdi*		X	
Rosen's Snake	*Suta fasciata*			
Total Number of Species		1	**60**	**24**

Table 3. Bird species recorded or expected to occur in the survey area.

Birds		CS	Databases	Sandy Ridge
CASUARIIDAE				
Dromaius novaehollandiae	Emu		X	X
PHASIANIDAE				
Coturnix pectoralis	Stubble Quail			
MEGAPODIIDAE				
Leipoa ocellata	Malleefowl	CS1	X	X
ANATIDAE				
Cygnus atratus	Black Swan		X	
Tadorna tadornoides	Australian Shelduck		X	
Chenonetta jubata	Australian Wood Duck		X	
Anas superciliosa	Pacific Black Duck		X	
Anas rhynchotis	Australasian Shoveler		X	
Malacorhynchus membranaceus	Pink-eared Duck		X	
Anas gracilis	Grey Teal		X	
Anas castanea	Chestnut Teal			
Aythya australis	Hardhead			
Stictonetta naevosa	Freckled Duck		X	
Biziura lobata	Musk Duck		X	
PODICIPEDIDAE				
Tachybaptus novaehollandiae	Australasian Grebe		X	
Poliocephalus poliocephalus	Hoary-headed Grebe		X	
COLUMBIDAE				
Phaps chalcoptera	Common Bronzewing		X	X
Ocyphaps lophotes	Crested Pigeon		X	
Geopelia cuneata	Diamond Dove			
PODARGIDAE				
Podargus strigoides	Tawny Frogmouth		X	X
EUROSTOPODIDAE				
Eurostopodus argus	Spotted Nightjar			
AEGOTHELIDAE				
Aegotheles cristatus	Australian Owlet-nightjar		X	X
APODIDAE				

Birds		CS	Databases	Sandy Ridge
Apus pacificus	Fork-tailed Swift	CS1	X	
ANHINGIDAE				
Microcarbo melanoleucos	Little Pied Cormorant		X	
Phalacrocorax sulcirostris	Little Black Cormorant			
ARDEIDAE				
Egretta novaehollandiae	White-faced Heron		X	
Ardea pacifica	White-necked Heron		X	
Ardea modesta	Eastern Great Egret	CS1		
PLATALEIDAE				
Threskiornis spinicollis	Straw-necked Ibis		X	
Platalea flavipes	Yellow-billed Spoonbill		X	
ACCIPITRIDAE				
Elanus axillaris	Black-shouldered Kite		X	
Lophoictinia isura	Square-tailed Kite	CS3	X	
Hamirostra melanosternon	Black-breasted Buzzard			
Haliastur sphenurus	Whistling Kite		X	
Milvus migrans	Black Kite			
Accipiter fasciatus	Brown Goshawk		X	
Accipiter cirrocephalus	Collared Sparrowhawk		X	X
Circus assimilis	Spotted Harrier		X	
Aquila audax	Wedge-tailed Eagle		X	
Hieraaetus morphnoides	Little Eagle		X	
FALCONIDAE				
Falco cenchroides	Nankeen Kestrel		X	X
Falco berigora	Brown Falcon		X	X
Falco longipennis	Australian Hobby		X	
Falco peregrinus	Peregrine Falcon	CS1	X	
RALLIDAE				
Fulica atra	Eurasian Coot		X	
Rallus philippensis	Buff-banded Rail			
Porzana pusilla	Baillon's Crake			
Porzana tabuensis	Spotless Crake			
Porzana fluminea	Australian Crake			

Birds		CS	Databases	Sandy Ridge
Tribonyx ventralis	Black-tailed Native-hen		X	
RECURVIROSTRIDAE				
Recurvirostra novaehollandiae	Red-necked Avocet		X	
Himantopus himantopus	Black-winged Stilt		X	
Cladorhynchus leucocephalus	Banded Stilt			
OTIDIDAE				
Ardeotis australis	Australian Bustard	CS2	X	
BURHINIDAE				
Burhinus grallarius	Bush Stone-curlew	CS3		
CHARADRIIDAE				
Charadrius ruficapillus	Red-capped Plover		X	
Elseyornis melanops	Black-fronted Dotterel		X	
Erythrogonys cinctus	Red-kneed Dotterel			
Thinornis rubricollis	Hooded Plover	CS2	X	
Charadrius australis	Inland Dotterel			
Vanellus tricolor	Banded Lapwing		X	
SCOLOPACIDAE				
Tringa nebularia	Common Greenshank	CS1		
Actitis hypoleucos	Common Sandpiper	CS1	X	
Tringa glareola	Wood Sandpiper	CS1		
Calidris acuminata	Sharp-tailed Sandpiper	CS1		
Calidris ferruginea	Curlew Sandpiper	CS1		
Calidris ruficollis	Red-necked Stint	CS1		
TURNICIDAE				
Turnix velox	Little Button-quail			X
CACATUIDAE				
Eolophus roseicapillus	Galah		X	
Cacatua sanguinea	Little Corella			
Nymphicus hollandicus	Cockatiel		X	
Lophochroa leadbeateri	Major Mitchell's Cockatoo	CS3	X	
PSITTACIDAE				
Glossopsitta porphyrocephala	Purple-crowned Lorikeet	CS3	X	X
Platycercus icterotis	Western Rosella	CS1		

Birds		CS	Databases	Sandy Ridge
Polytelis anthopeplus	Regent Parrot	CS3	X	
Barnardius zonarius	Australian Ringneck		X	X
Psephotus varius	Mulga Parrot		X	
Melopsittacus undulatus	Budgerigar		X	
Neophema splendida	Scarlet-chested Parrot	CS3	X	
CUCULIDAE				
Chalcites basalis	Horsfield's Bronze-Cuckoo		X	X
Chalcites osculans	Black-eared Cuckoo		X	
Cacomantis pallidus	Pallid Cuckoo		X	
Cacomantis flabelliformis	Fan-tailed Cuckoo		X	
STRIGIDAE				
Ninox novaeseelandiae	Southern Boobook		X	
TYTONIDAE				
Tyto alba	Eastern Barn Owl		X	
HALCYONIDAE				
Todiramphus pyrrhopygius	Red-backed Kingfisher		X	
Todiramphus sanctus	Sacred Kingfisher		X	
MEROPIDAE				
Merops ornatus	Rainbow Bee-eater	CS1	X	X
CLIMACTERIDAE				
Climacteris affinis	White-browed Treecreeper	CS3		
Climacteris rufa	Rufous Treecreeper	CS3	X	X
MALURIDAE				
Malurus splendens	Splendid Fairy-wren		X	X
Malurus leucopterus	White-winged Fairy-wren		X	
Malurus lamberti	Variegated Fairy-wren			X
Malurus pulcherrimus	Blue-breasted Fairy-wren		X	X
ACANTHIZIDAE				
Sericornis frontalis	White-browed Scrubwren			
Hylacola cauta whitlocki	Shy Heathwren	CS2		
Calamanthus campestri	Rufous Fieldwren			X
Pyrrholaemus brunneus	Redthroat		X	X
Smicrornis brevirostris	Weebill		X	X

Birds		CS	Databases	Sandy Ridge
Gerygone fusca	Western Gerygone		X	
Acanthiza chrysorrhoa	Yellow-rumped Thornbill		X	X
Acanthiza uropygialis	Chestnut-rumped Thornbill		X	X
Acanthiza robustirostris	Slaty-backed Thornbill			
Acanthiza apicalis	Inland Thornbill		X	X
Aphelocephala leucopsis	Southern Whiteface		X	
PARDALOTIDAE				
Pardalotus punctatus	Spotted Pardalote			
Pardalotus striatus	Striated Pardalote		X	
MELIPHAGIDAE				
Certhionyx variegatus	Pied Honeyeater		X	
Lichenostomus virescens	Singing Honeyeater		X	X
Lichenostomus leucotis	White-eared Honeyeater		X	X
Lichenostomus cratitius	Purple-gaped Honeyeater	CS3		
Lichenostomus ornatus	Yellow-plumed Honeyeater	CS3	X	X
Lichenostomus plumulus	Grey-fronted Honeyeater		X	X
Purnella albifrons	White-fronted Honeyeater		X	X
Manorina flavigula	Yellow-throated Miner		X	X
Acanthagenys rufogularis	Spiny-cheeked Honeyeater		X	X
Anthochaera carunculata	Red Wattlebird		X	X
Epthianura albifrons	White-fronted Cat		X	
Epthianura tricolor	Crimson Chat		X	
Epthianura aurifrons	Orange Chat			
Sugomel niger	Black Honeyeater		X	
Lichmera indistincta	Brown Honeyeater		X	
Melithreptus brevirostris	Brown-headed Honeyeater		X	
POMATOSTOMIDAE				
Pomatostomus superciliosus	White-browed Babbler		X	X
PSOPHODIDAE				
Cinclosoma castanotus	Copper-backed Quail-thrush	CS3	X	X
NEOSITTIDAE				
Daphoenositta chrysoptera	Varied Sittella		X	

Birds		CS	Databases	Sandy Ridge
CAMPEPHAGIDAE				
Coracina maxima	Ground Cuckoo-shrike		X	
Coracina novaehollandiae	Black-faced Cuckoo-shrike		X	X
Lalage sueurii	White-winged Triller		X	
PACHYCEPHALIDAE				
Pachycephala inornata	Gilbert's Whistler	CS3	X	
Pachycephala rufiventris	Rufous Whistler		X	X
Pachycephala pectoralis	Golden Whistler		X	
Colluricincla harmonica	Grey Shrike-thrush		X	X
Oreoica gutturalis	Crested Bellbird	CS3	X	X
ARTAMIDAE				
Artamus personatus	Masked Woodswallow		X	
Artamus cinereus	Black-faced Woodswallow		X	X
Artamus cyanopterus	Dusky Woodswallow		X	X
Artamus minor	Little Woodswallow		X	
Cracticus torquatus	Grey Butcherbird		X	X
Cracticus nigrogularis	Pied Butcherbird		X	X
Cracticus tibicen	Australian Magpie		X	X
Strepera versicolor	Grey Currawong		X	X
RHIPIDURIDAE				
Rhipidura albiscapa	Grey Fantail		X	
Rhipidura leucophrys	Willie Wagtail		X	X
CORVIDAE				
Corvus bennetti	Little Crow		X	X
Corvus orru	Torresian Crow		X	X
Corvus coronoides	Australian Raven		X	
MONARCHIDAE				
Grallina cyanoleuca	Magpie-lark		X	
PETROICIDAE				
Petroica goodenovii	Red-capped Robin		X	
Melanodryas cucullata	Hooded Robin		X	
Microeca fascinans	Jacky Winter		X	X
Eopsaltria griseogularis	Western Yellow Robin	CS3	X	

Birds		CS	Databases	Sandy Ridge
Drymodes brunneopygia	Southern Scrub-robin	CS3	X	
ZOSTEROPIDAE				
Zosterops lateralis	Silvereye			
MEGALURIDAE				
Cincloramphus mathewsi	Rufous Songlark		X	
Cincloramphus cruralis	Brown Songlark		X	
HIRUNDINIDAE				
Cheramoeca leucosterna	White-backed Swallow		X	
Hirundo neoxena	Welcome Swallow		X	
Petrochelidon ariel	Fairy Martin		X	X?
Petrochelidon nigricans	Tree Martin		X	
NECTARINIIDAE				
Dicaeum hirundinaceum	Mistletoebird		X	X
ESTRILDIDAE				
Taeniopygia guttata	Zebra Finch		X	
MOTACILLIDAE				
Anthus novaeseelandiae	Australasian Pipit		X	
Total Number of Species Expected: 166			128	49

Table 4. Mammal species recorded or expected to occur in the survey area.

MAMMALS		CS	Databases	Sandy Ridge
Tachyglossidae				
Tachyglossus aculeatus	Echidna			X
Dasyuridae				
Ningaui ridei	Ride's Ningaui		X	
Ningaui yvonneae	Mallee Ningaui		X	
Antechinomys laniger	Kultarr	CS3		
Pseudantechinus woolleyae	Woolley's Pseudantechinus		X	
Sminthopsis crassicaudata	Fat-tailed Dunnart			
Sminthopsis dolichura	Little Long-tailed Dunnart		X	
Sminthopsis gilberti	Gilbert's Dunnart			
Burramyidae				
Cercartetus concinnus	Western Pygmy Possum		X	
Macropodidae				
Macropus fuliginosus	Western Grey Kangaroo			X
Macropus robustus	Euro		X	
Macropus rufus	Red Kangaroo			
Molossidae				
Mormopterus sp. 3	Inland Freetail Bat		X	
Mormopterus sp. 4	Southern Freetail Bat			
Tadarida australis	White-striped Freetail Bat		X	X
Vespertilionidae				
Chalinolobus gouldii	Gould's Wattled Bat		X	X
Chalinolobus morio	Chocolate Wattled Bat		X	
Nyctophilus geoffroyi	Lesser Long-eared Bat		X	
Nyctophilus major tor	Inland Greater Long-eared Bat	CS2	X	
Scotorepens balstoni	Inland Broad-nosed Bat		X	
Vespadelus regulus	Southern Forest Bat		X	
Vespadelus baverstocki	Inland forest bat		X	
Muridae				
Notomys alexis	Spinifex Hopping Mouse		X	
Notomys mitchelli	Mitchell's Hopping Mouse		X	
Pseudomys albocinereus	Ash-Grey Mouse		X	

MAMMALS		CS	Databases	Sandy Ridge
Pseudomys bolami	Bolam's Mouse			
Pseudomys hermannsburgensis	Sandy Inland Mouse		X	
INTRODUCED MAMMALS				
Canis lupus	Dingo			X
Vulpes vulpes	European Red Fox			
Felis catus	Feral Cat			
Oryctolagus cuniculus	Rabbit		X	X
Mus musculus	House Mouse		X	
Capra hircus	Goat			
Equus caballus	Horse			
Camelus dromedarius	Dromedary Camel			X
Bos taurus	Cattle		X	
Ovis aries	Sheep			
Total Number of Native Species Expected: 26				**4**
Total Number of Introduced Species Expected: 10				**3**

Appendix 4. Annotated Species list – fauna recorded from Sandy Ridge.

1. *Neobatrachus sutor* About 10 found sitting around margins of nearby claypan that flooded on 25/01. They were just sitting in shallow scrapes filled with water in broad daylight! In evening they were found our foraging up to 500m from the claypan, and they were calling from around the wetland.
2. *Neobatrachus kunapalari*. Two very large (60mm+) specimens found at night.
3. *Diplodactylus granariensis*. Found around camp by headtorching.
4. *Diplodactylus pulcher*. Found around camp by headtorching.
5. *Gehyra purpurascens*. Found around camp headtorching.
6. *Gehyra variegata*. Found around camp headtorching.
7. *Hesperoedura reticulata*. Found around camp by headtorching.
8. *Lucasium maini*. Found around camp by headtorching.
9. *Rhynchoedura ornata*. Found around camp by headtorching.
10. *Ctenotus atlas*. One seen in area of mallee over spinifex.
11. *Ctenotus xenopleura*. One caught in area of mallee over spinifex on red sandy-loam.
12. *Ctenotus schomburgkii*. Hatchling seen in pit area and few seen elsewhere.
13. *Liopholis inornata*. Burrows in sandy areas. Immature seen at entrance to a burrow in late afternoon (24/01).
14. *Tiliqua occipitalis*. Skull found in pit area and along access road.
15. *Cryptoblepharus australis*. One on tree near camp.
16. *Menetia greyii*. Several hatchlings seen.
17. *Ctenophorus cristatus*. Several seen along road from highway and in woodland areas of site.
18. *Ctenophorus fordi*. Sympatric with *C.isolepis*.
19. *Ctenophorus scutullatus*. Few in pit area and around camp in areas of shrubland.
20. *Ctenophorus isolepis citrinus*. Adults and hatchlings in sandy areas of pit area.
21. *Moloch horridus*. Several seen in pit area.
22. *Pogona minor*. One basked in top of tall shrub 2.5m above ground.
23. *Varanus gouldii*. Several recently-hatched animals along road from highway. Tracks and diggings in project area.
24. *Varanus tristis*. Tracks around site going from tree to tree.
25. *Anilios australis*. One active at night near camp (26/01).
26. *Brachyurophis semifasciata*. Found around camp by headtorching.

1. Emu. Fresh tracks in accommodation area.
2. Malleefowl. Old mounds.
3. Common Bronzewing. Several seen in pit area.
4. Purple-crowned Lorikeet. Dead juvenile in camp.
5. Australian Ringneck. Few around camp on one occasion, and heard along south access road.
6. Little Button-quail. Occasional individual flushed during surveys.
7. Collared Sparrowhawk. Adult male flew through camp (24/01).
8. Brown Falcon. Pair over pit area (24/01) and seen around camp most days.
9. Owlet-nightjar. One calling near camp (night of 23/01).
10. Tawny Frogmouth. One flushed during the day on walk to claypan and one calling near camp night of 26/01.
11. Rainbow Bee-eater. Two near camp (23/01).

12. Rufous Treecreeper. Heard just north-west of camp (23/01).
13. Blue-breasted Fairy-wren. Group in shrubland on pit area and along southern access road.
14. Variegated Fairy-wren. Parties along southern access road and southern pipeline route.
15. Splendid Fairy-wren. Party near camp and along southern pipeline route.
16. Inland Thornbill. Few in pit area.
17. Chestnut-rumped Thornbill. Widespread in project area.
18. Weebill. Amongst eucalypts throughout project area.
19. Redthroat. Few in project area.
20. Rufous Fieldwren. Few calling in heath area.
21. Red Wattlebird. Seen occasionally near camp.
22. Spiny-cheeked Honeyeater. Small parties throughout.
23. Yellow-throated Miner. Party in project area.
24. White-eared Honeyeater. Few in pit area.
25. Yellow-plumed Honeyeater. Few near camp.
26. Grey-fronted Honeyeater. Occasionally in Marri and sand pine areas.
27. Singing Honeyeater. Few heard in shrubland areas.
28. White-fronted Honeyeater. Heard in pit area.
29. White-browed Babbler. Several parties in pit area.
30. Willie Wagtail. One near camp (23/01, 26/01).
31. Crested Bellbird. Calling around camp.
32. Jacky Winter. Few in woodland areas.
33. Rufous Whistler. Seen occasionally but not calling. Only female-coloured birds.
34. Grey Shrike-thrush. Seen and heard in pit area (24/01).
35. Copper-backed Quail-thrush. Party near camp (26/01).
36. Black-faced Cuckoo-shrike. Seen near camp (23/01) and group of six flying across pit area (26/01).
37. Dusky Woodswallow. Few small groups over pit area most days.
38. Black-faced Woodswallow. Few near Mt Dimer Rd (26/01).
39. Grey Currawong. Heard near camp.
40. Torresian Crow. Several calling around camp at sunrise (24/01).
41. Australian Magpie. Small group near camp.
42. Grey Butcherbird. Calling around camp at dawn.
43. Pied Butcherbird. Heard once in pit area.
44. Martin sp. One seen in distance over pit area (24/01).

1. Echidna. Fresh tracks at several locations and dead specimen in pit area.
2. *Tadarida australis*. Few calling at night.
3. *Chalinolobus gouldii*. One flushed from tree hollow in accommodation area.
4. Camel. Fresh tracks of 2 adults and 2 smaller animals along track near Mt Dimer Rd.
5. Kangaroo. Fresh tracks in puddles but species uncertain.
6. Rabbit. Diggings and scats along southern pipeline route.
7. Dingo. Old tracks around claypan.

At least three species of trapdoor spiders present.
Gaius villosus. Several found and some exceptionally large, with burrow diameter >40mm.
Aganippe sp. Burrow with fan of leaves and thick lid with heavy architecture of twigs, some upright. One found in middle of MF2.
Aganippe? Sp. Burrow with fan of leaves; lid flat and slightly flexible.

Checklists for Biodiversity

TELLUS

GOVERNMENT OF WESTERN AUSTRALIA

Environmental Protection Authority

Checklist for documents submitted for EIA of proposals that have the potential to significantly impact on Sea and Land factors[1]

This checklist should be used by proponents and their environmental consultants both during the proponent's initial project planning and environmental scoping process, and specifically in the final checking of documents they intend to submit to the Environmental Protection Authority (EPA) for environmental impact assessment (EIA). This checklist will be reviewed and revised periodically to refer to contemporary EPA guidance documents as they are released.

The purpose of this checklist is to provide the basis for proponents and their consultants to conduct initial in-house screening of the quality of their EIA documents (QAQC). The intent is to more clearly define a minimum standard that is expected to be met for some of the more common and fundamental elements of EIA documentation submitted to the EPA under Land and Sea themes.

Meeting this minimum standard should, in turn, facilitate timely and efficient consideration of documents by the EPA. It is complementary to, but does not replace, the approved Scoping document.

The checklist has been set out in four parts. Part 1 addresses general elements of document quality. Parts 2 and 3 deal with key EIA requirements specific to marine and terrestrial fauna, habitat and environmental quality impacts. Part 4 sets out the requirements for proponent certification of the checklist.

To confirm that each element has been addressed, proponents are asked to place a tick in the boxes provided. Where an element of the checklist is not relevant to the proposal, checking the box with "N/A" will be adequate.

A copy of this checklist certified by an appropriate proponent representative as complete and accurate must be lodged with EIA documentation submitted to the EPA. Completed checklists will be reviewed by the EPA when documents are lodged. **Incomplete or inaccurate checklists will be returned for proponents to address outstanding matters before the EPA will commence its review of EIA documents.**

It should be noted that the EPA's acceptance of a complete and accurate checklist simply indicates that basic requirements in terms of document quality and general comprehensiveness have been met. **The EPA's acceptance of the checklist does not imply adequacy of technical work or appropriateness of 'policy' application / interpretation.** These matters are reviewed in more detail later in the EIA process.

[1] See EAG 8 Environmental Assessment Guideline for Environmental Principles, Factors and Objectives (EPA 2015) for description of Sea and Land factors and objectives.

THE CHECKLIST

PART 1 – GENERAL QUALITY OF DOCUMENTS

Ensure that the following standard elements are present in all documentation (including appendices):

- A clear and concise title that outlines basic information about the proposal and purpose of the document. ☑
- Date and document revision number. ☑
- Information identifying the document's author and publishing entity. ☑
- All issues identified in a scoping guideline or scoping document have been addressed and covered in the report (note: there should also be a stand-alone document that explicitly considers each element of the scoping document and how/where it is addressed). ☑
- Complete and correct tables of contents, maps, tables and figures. ☑
- Suitably-sized scale maps placing the proposal into both a regional and local context. ☑
- Figures, plates, maps, technical drawings or similar including scale bar, legend, informative caption, labels identifying important or relevant locations/features referred to in the document text. ☑
- Proposed footprint and development envelope are shown on scale maps and associated spatial data is provided in an appropriate format and coordinate system/projection (GDA94/MGA Zone or GDA94). For EPA notes on spatial data please refer to Appendix 1 of Environmental Assessment Guideline No. 1 Defining the Key Characteristics of a Proposal. ☑
- All survey site locations and derived data products (e.g. benthic habitat maps, vegetation maps) have been provided in appropriate electronic spatial data format. ☑
- All survey data from biological surveys have been provided in electronic database form (Access/Excel) with coordinate system/projection specified (GDA94/MGA Zone or GDA94). ☑
- A list of references that have been cross-checked to ensure that all references in the Reference list are cited in the text (and vice versa). ☑
- All information based on 'expert' opinion/judgement are explicitly attributed, by name and qualification, to a person/s or organisation. ☑
- Where relevant, appendices are attached to the main EIA document that describe the details of technical work undertaken to underpin the content of the main document, and explicitly attributed by name to the author/s and (if applicable) their organisation. ☑
- Description(s) of the proposal are internally consistent throughout all documentation and allow potential environmental impacts to be placed in local and regional contexts, including cumulative impacts of existing and approved developments. ☑

Please identify relevant sections of the report in the box below.

chapter 5

- Descriptions of the local and regional environmental features most likely to be directly or indirectly affected by the proposal. ☑

Please identify relevant sections of the report in the box below.

chapter 9

PART 2 – MARINE ENVIRONMENTAL ISSUES

For proposals where benthic communities and habitats is a relevant factor, and where it is likely to impact on tropical arid zone mangroves in the Pilbara, the EIA document describes how potential impacts have been addressed in the context of Guidance Statement No.1: Guidance Statement for Protection of Tropical Arid Zone Mangroves Along the Pilbara Coastline (April 2001). ❑

If applicable, please identify relevant sections of the report in the box below.

Not applicable

For proposals likely to impact on benthic primary producer habitat, including tropical arid zone mangroves in the Pilbara, the EIA document describes how potential impacts have been addressed in the context of Environmental Assessment Guideline No.3 Protection of Benthic Primary Producer *Habitats in Western Australia's Marine* Environment (December 2009), including: ❑

- details of the measures taken to address the Overarching Environmental Protection Principles; ❑
- scale benthic habitat maps showing the current extent and distribution of benthic habitats and the areas of habitat predicted to be lost if the proposal proceeds; ❑
- descriptions of technical work (e.g. benthic habitat surveys) carried out to underpin the benthic habitat map (e.g. a technical appendix); and ❑
- clearly set out calculations of cumulative loss. ❑

If applicable, please identify relevant sections of the report in the box below.

Not applicable

For proposals likely to impact on benthic primary producer habitat in Port Hedland, the Local Assessment Unit for application of EAG 3 is consistent with Environmental Protection Bulletin No. 14: Guidance for the assessment of benthic primary producer habitat loss in and around Port Hedland. ❑

For proposals that involve marine dredging activities, potential impacts have been addressed in the context of the Environmental Assessment Guideline No.7 for Marine Dredging Proposals (September 2011) to ensure that the predicted extent, severity and duration of impacts to benthic habitats are presented in a clear and consistent manner. The most likely best case and most likely worse case scenarios should be presented and discussed

If applicable, please identify relevant sections of the report in the box below. ❑

Not applicable

For proposals that involve any type of waste discharge or disposal in State coastal waters, potential impacts have been addressed in the context of: ❑

- *Environmental Assessment Guideline No.15 for Protecting the Quality of Western Australia's* Marine Environment (EAG 15); as well as ❑
- Environmental Quality Criteria Reference Document for Cockburn Sound (EPA, 2015), *Perth's Coastal Waters: Environmental Values and Objectives* (EPA, 2000), or Pilbara Coastal Water Quality Project Consultation Outcomes document (DoE, 2006) for the relevant regions; and ❑
- relevant guidance provided in the Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZECC/ARMCANZ, 2000).

If applicable, please identify relevant sections of the report in the box below.

Not applicable

For proposals with potential to impact on an existing or proposed marine conservation reserve, potential impacts have been addressed in the context of the guidance provided in the relevant indicative or final Management Plan for the reserve on the advice of DPaW or another designated management agency. ☐

If applicable, please identify relevant sections of the report in the box below.

Not applicable

For proposals with light emissions likely to impact marine turtles, the potential impacts have been addressed in the context of Environmental Assessment Guideline No. 5 Environmental Assessment Guideline for Protecting Marine Turtles from Light Impacts (November 2010) to ensure appropriate avoidance and management approaches are in place. ☐

If applicable, please identify relevant sections of the report in the box below.

Not applicable

If numerical modelling has been carried out to inform the prediction of environmental impacts, each report associated with this modelling, including the key assumptions, is provided as a technical appendix. ☐

If applicable, please identify the relevant appendices in the box below.

Not applicable

PART 3 – TERRESTRIAL BIODIVERSITY ISSUES

For proposals likely to impact on native flora and vegetation, the EIA document describes how potential direct and indirect impacts have been addressed in the context of EPA Guidance Statement No. 51 - Terrestrial Flora and Vegetation Surveys for Environmental Impact Assessment in Western Australia (June 2004) and Technical Guide – Flora and Vegetation Surveys for Environmental Impact Assessment EPA and DPaW (2015) including:

- determining the level of flora and vegetation survey, including a survey area encompassing direct and indirect impacts, utilising suitable survey methodology and listing survey limitations; ☑
- maps illustrating the survey area in both a local and regional context, location of quadrats, vegetation unit mapping, location of significant species or vegetation, vegetation condition and predicted extent of impact on the vegetation; ☑
- a comprehensive list of flora species (using the nomenclature of the WA Herbarium) which are known or reasonably expected to occur in the area and a quantitative assessment of direct and indirect impacts to threatened, priority or other significant flora and/or threatened, priority or other significant vegetation (as defined in Technical Guide); ☑
- an evaluation of the impact of the proposal on flora and vegetation, including analysis of the local, regional and cumulative impacts of the project; and ☑
- quadrat data provided as excel spreadsheet in raw form, in addition to hardcopy reports. ☑

If applicable, please identify relevant sections of the report in the box below.

chapter 9

For proposals likely to impact on vertebrate fauna or fauna habitat, the EIA document describes how potential impacts have been addressed in the context of EPA Guidance Statement No. 56, Terrestrial Fauna Surveys for Environmental Impact Assessment (June 2004) and Technical Guide – Terrestrial Vertebrate Fauna Surveys for Environmental Impact Assessment EPA and DEC (2010), including:

- determining the level of fauna survey consistent with that expected ; ☑
- describing the survey methodologies, including timing, duration and survey effort used to sample each of the fauna groups sampled, any survey limitations and the nomenclature used (WA Museum/Birdlife Australia); ☑
- maps illustrating the survey area in both a regional and local context; fauna habitats within and outside the development envelope; description of predicted extent of impact on the habitat; location of survey sites and conservation significant fauna in relation to the proposal; and ☑
- a comprehensive list and assessment of vertebrate fauna known or reasonably expected to occur in the area, including Specially Protected, Priority and other significant fauna (as defined in Guidance Statement No. 56), and an evaluation of the impact of the proposal on the species and key habitat/s. ☑

If applicable, please identify relevant sections of the report in the box below.

Chapter 9

For proposals with the potential to impact on short range endemic (SRE) invertebrate fauna or SRE habitat, the EIA document describes how potential impacts have been addressed in the context of EPA Guidance Statement No. 20, Sampling of Short Range Invertebrate Fauna for Environmental Impact Assessment in Western Australia (May 2009), including:

- assessment for restricted habitat types that have potential to support SRE fauna, including advice from the WA Museum, DPaW and OEPA; ☐
- maps illustrating the survey area in both a regional and local context, and identifying potential SRE habitats within and outside the development envelope and extent of predicted impact on the habitat; ☐
- a description of the survey methodologies, including timing and survey effort used to sample each of the fauna groups and any survey limitations; ☐
- the results and interpretation of any molecular analysis used; and ☐
- a survey report with assessment of SRE fauna found or reasonably expected to occur in the area, their conservation status, their known occurrence/habitats locally and their wider status if known, and an evaluation of the risk of the proposal to long-term survival of the species and community. ☐

If applicable, please identify relevant sections of the report in the box below.

Not applicable

For proposals with the potential to impact on subterranean (stygofauna and troglofauna) fauna, the EIA document describes how potential impacts have been addressed in the context of EPA Environmental Assessment Guideline 12 Consideration of subterranean fauna in EIA in WA and Guidance Statement No. 54a, Sampling Methods and Survey Considerations for Subterranean Fauna in Western Australia (Draft, August 2007), including:

- an assessment of the likely presence of habitat that could support subterranean fauna, including advice from the WA Museum and OEPA; ☐
- maps identifying survey sites and illustrating the known or predicted extent of habitats in relation to the proposal; a description of the geology/habitat supporting subterranean fauna within and outside the development envelope; extent of predicted impacts on the subterranean fauna and habitat; ☐

- a description of the survey methodologies (see Guidance Statement No. 54a), including reference to site selection, sampling techniques, survey effort, specimen collection and molecular analysis used undertaken as part of the survey, and any survey limitations; and ❑
- a list of subterranean fauna recorded and their distribution or reasonably expected to occur in the area, including their conservation status, their known occurrence/habitats locally and their wider status if known, and an evaluation of the risk of the proposal to long-term survival of the species and community. ❑

If applicable, please identify relevant sections of the report in the box below.

not applicable

PART 4 – PROPONENT'S CERTIFICATION OF COMPLETENESS AND ACCURACY OF RESPONSES

Name

RICHARD PHILLIPS

Position

ENVIRONMENT & APPROVALS MANAGER

Signature

Date

12 / 08 / 2016

Hydrology Assessment

TELLUS

SANDY RIDGE FACILITY

SURFACE WATER ASSESSMENT AND MANAGEMENT PLAN

REPORT FOR TELLUS HOLDINGS

JANUARY 2016

Rockwater
HYDROGEOLOGICAL AND ENVIRONMENTAL CONSULTANTS

Report No. 454-0/15/01a

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1 Road Catchments and Crossings
2 Catchment Areas and Locations of Depressions
3 Mining Area and Stream Cross-Sections
4 Planned Mining Area and Proposed Levee

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A Hydrological Results
B Hydraulic Results

REVISION	AUTHOR	REVIEW	ISSUED
Rev 0	J Goh	P Wharton	3 July 2015
Rev1	P Wharton		27 January 2016

1 INTRODUCTION

Tellus Holdings commissioned Rockwater Pty Ltd to carry out an investigation of the surface water hydrology and to prepare a preliminary concept surface water management plan for the proposed Sandy Ridge Kaolinite Project at Mt Walton, located about 140 km north-west of Kalgoorlie. This report presents the results of the investigation and includes sufficient detail for Mining Approval requirements.

1.1 SCOPE AND DELIVERABLES

The scope and deliverables of this report include the following:

- Demarcation of the catchment areas and waterways likely to impact on the 0 to 25-year mining area, plant site and access road.
- Hydrological analysis of relevant catchment areas in order to estimate peak run-off for rainfall events between 1-in-2 and 1-in-100 years average recurrence intervals (ARI), and the extreme Probable Maximum Precipitation (PMP) event.
- Examination of historical rainfall records for nearby stations in order to assess the maximum total rainfall and ARIs, if possible.
- Preparation of Intensity Frequency Duration (IFD) Rainfall curves using the polynomials as recommended by the Australian Rainfall & Run-off Publication (1987).
- Examination of recorded total losses due to evaporation and infiltration in the Mt Walton area in order to estimate realistic flow depths and widths.
- Carry out relevant surface water hydraulic analysis in order to assess the extent, depths and velocities of natural flow paths likely to impact the mine site, plant site and access road.
- If warranted, design and recommend of preliminary concept flood protection levees for the mine site, plant site and waterway crossings along the access road.

1.2 INFORMATION PROVIDED BY TELLUS HOLDINGS

The following information was provided by Tellus Holdings:

- Plans showing the proposed boundaries of two stages of mining (0 to 25, and 25+ years); the proposed plant site (two alternative locations); and the mine access road. This investigation only focuses on the 0 to 25 year mining area and the plant site located south of that area (Figure 3).
- A 5.0 m-interval topographic contour plan on a satellite image of the mining area, including outlines of the mining lease, the plant site and the access road. These

contours were only used to identify the general topography but were not used for the concept design levels.

- A 1.0 m- interval topographic contour plan that also shows the planned mining area, the plant site, and the northern part of the access road.

2 SURFACE CATCHMENT HYDROLOGY

The Sandy Ridge Project is located about 140 km north-west of Kalgoorlie on the eastern side of Manning Nature Reserve. The area is generally flat with a slightly undulating surface ranging in elevation from approximately 460 m AHD to 500 m AHD, sloping down to the west.

There are no obvious channels or creeks within this area. There are no major flow paths in the planned mining area, and so surface water management is only required for short-term flows during and following infrequent high-rainfall events. These flows will be from small local catchments which drain residual runoff after infiltration losses, to low-lying depressions. Generally surface water will only be retained for short periods in the depressions due to continual infiltration. Water could pond for longer periods if the depressions have a clay base. In addition, there will be evaporation of water in claypans, mainly from three days after of a major rainfall event once clouds have lifted.

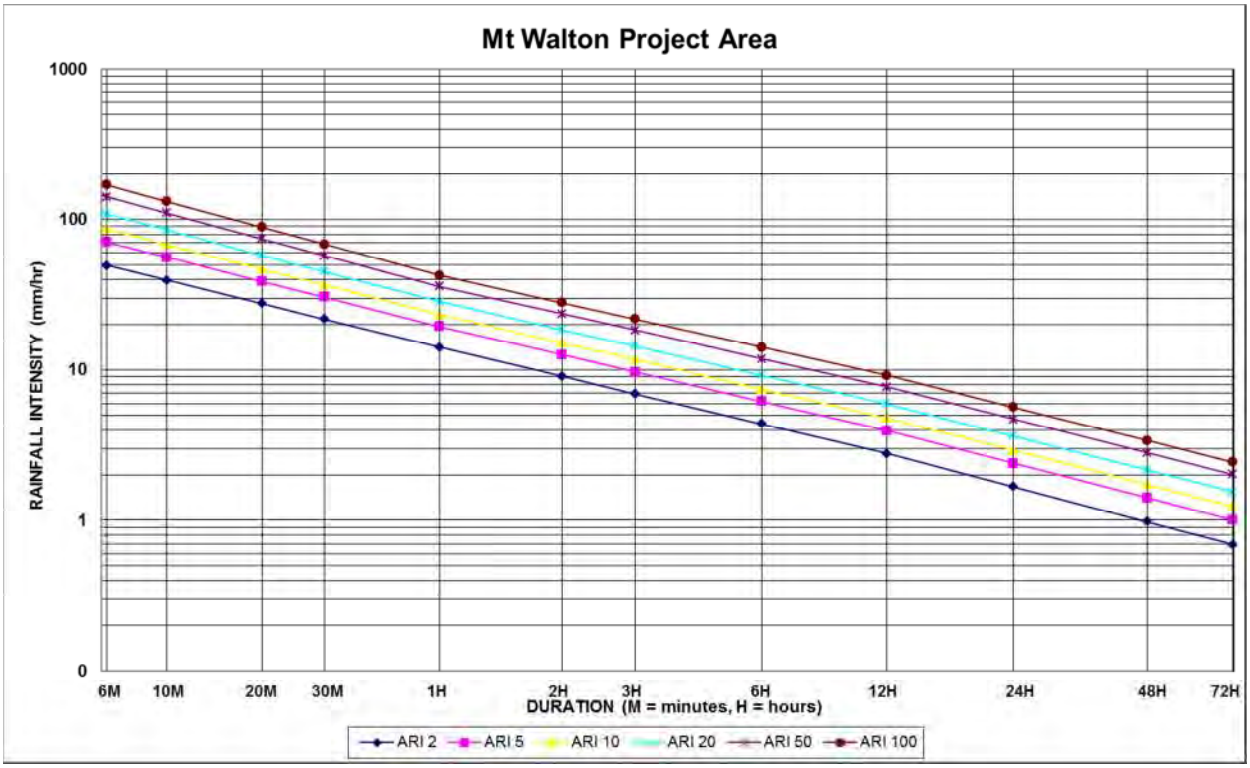
The peak discharge estimation techniques such as the Statistical Rational Method recommended by Australia Rainfall and Runoff (ARR, 1987) for the arid interior of Western Australia (WA) tend to greatly over-estimate peak flows. This is because the equation was derived from gauged stations that have very different catchment characteristics to those at the Sandy Ridge project where there are sandy soils. Similarly, the alternative run-off routing method cannot be adopted because there are no gauging data for small catchments in the arid region of WA to derive catchment parameters.

Runoff observed following high rainfall events should be recorded and used later in the detailed design stage to reassess flood protection requirements.

2.1 RAINFALL ANALYSIS

The IFD curves for the Sandy Ridge Project area were prepared using the set of polynomials recommended by ARR (1987). The IFD tables and curves are included in Appendix A.

Text-Figure 1 below shows the IFD curves for the Sandy Ridge (Mt Walton) project area.



Text-Figure 1: IFD Curves for the Sandy Ridge Project Area

The Probable Maximum Precipitation for the area has also been computed using the CRC_FORGE method and the results tabulated in Table 1 below.

Table 1: Total Rainfall including Probable Maximum Precipitation (PMP)

	ARI/Total Rainfall (mm)									
Duration (Hours)	**2**	**5**	**10**	**20**	**50**	**100**	**200**	**500**	**1000**	**2000**
24	40	57	70	87	113	136	155	180	201	222
48	47	68	83	104	135	163	186	216	241	266
72	50	72	89	111	146	176	200	232	258	285

The rainfall analysis included in this report comprises both the computation of the Intensity Frequency Duration information and the total rainfalls for a range of ARIs up to the PMP of 1-in-2000 years. The IFD information is required to estimate the peak flows for catchments at the mining and plant areas, and along the access road.

The computed total rainfall from the IFD curves is supplemented with the historical rainfall record from meteorological stations at Menzies, north-east of the project area on Goldfields Highway, and Ora Banda, approximately halfway between Kalgoorlie and Sandy Ridge. The largest three-day (72 hour) total rainfalls for these two stations are presented in Table 2.

Table 2: Total maximum 72-hour Rainfalls at Menzies and Ora Banda Stations

Date	Menzies	Date	Menzies	Date	Ora Banda	Date	Ora Banda
Record Period	**1907 to 2015**		**1907 to 2015**		**1916 to 2015**		**1916 to 2015**
25/02/1995	81.0	21/02/1948	4.1	25/02/1995	41.6	21/02/1948	0.0
26/02/1995	31.4	22/02/1948	121.9	26/02/1995	5.8	22/02/1948	177.3
27/02/1995	168.4	23/02/1948	85.6	27/02/1995	142.4	23/02/1948	76.7
Total (mm)	**280.8**	**Total (mm)**	**211.6**	**Total (mm)**	**189.8**	**Total (mm)**	**254.0**

The two largest recorded total rainfalls over 72 hours occurred in 1948 and 1995 at both Menzies and Ora Banda. They would suggest that the computed IFD under-estimates the rainfall intensities. However, close inspection of the rainfall data for these stations shows that these two events are extreme – as much as twice as large as the next closest event. Therefore statistically these events would be closer to the PMP.

The total rainfall for a range of ARI and the maximum recorded rainfalls need to be compared with infiltration losses. Infiltration rates for sandy soils can be up to 720 mm/day and are typically about 500 mm/day for sandy, loamy soil. The Sandy Ridge project area has predominantly sandy soil; possibly with some small claypans where infiltration rates could be between 24 and 120 mm/day. With sandy loam soil the highest recorded rainfalls should infiltrate within 12 hours, or if not, soon after.

Therefore, very little (if any) catchment flow is likely to impact the mining area, plant site and access road. However, over-estimates of flow using the Rational Method have been adopted for hydraulic analysis, until observation data are available for a more-accurate analysis at the detailed design stage.

2.2 CATCHMENT AREAS

The catchment areas in the vicinity of the mining area, plant and access road were demarcated from aerial photography and the 1.0 m and 5.0 m-interval contour plans provided by Tellus Holdings. This information was used in the peak flow estimation analysis as shown in Appendix A and described below.

2.3 TIME OF CONCENTRATION

The time of concentration is required to estimate the critical storm duration for peak flow in each catchment. This was estimated using Equation 1, which is the most conservative method of those recommended by AR&R (1987):

$$t_c = 0.76 \cdot A^{0.38}$$ **Equation 1**

Where:

t_c is the time of concentration (hours)

A is the catchment area (km^2)

2.4 RATIONAL METHOD

The first technique used in peak-flow estimation was the Statistical Rational Method (Equation 2).

$$Q_y = 0.278 \cdot C_y \cdot I_{tcy} \cdot A$$

Equation 2

Where:

Q_y is the peak flow for return period *y* years (m^3/s)

0.278 is a dimensionless metric conversion factor

C_y is the runoff coefficient for *y* years (dimensionless)

I_{tcy} is rainfall intensity (mm/hr)

A is catchment area (km^2)

2.5 HYDROLOGICAL RESULTS FOR CATCHMENT AREAS

Fourteen local catchments have been identified in the general project area. These include catchments A to K and P1 to P3, only a few of which could impact the planned mining area and infrastructure (Figure 2). The flow paths of these catchments are shown with the approximate locations of depressions where any residual flow not lost through infiltration could pond until infiltrating or evaporating. Five depressions near the mining area and infrastructure have been named D1 to D5 as shown in Figure 3.

In addition to these local catchments, there are four larger catchments all flowing east to west that could cross the proposed access road, named as RA, RB, RC and RD (Figure 1). The locations where the residual water from these flows could cross the road and warrant a floodway and nominal culvert have been marked and named in Figures 1 and 3.

The characteristics, and estimated peak discharge of these catchments for typical ARIs up to the 100 year event and up to the probably maximum flood (PMF, 1-in-2000 year) are summarised in Tables 3 and 4, respectively.

Table 3: Characteristics of Catchments

Catchment	A (km^2)	L (km)
A	0.32	0.88
B	0.15	0.73
C	0.31	0.91
D	0.39	0.90
E	0.24	0.65
F	0.26	1.18
G	0.11	0.96
H	0.11	0.44
I	0.23	0.63
J	0.07	0.41
K	0.48	1.03
P1	0.41	0.75
P2	0.07	0.18
P3	0.50	1.06
RA	1.48	1.58
RB	2.80	2.37
RC	13.85	6.70
RD	15.22	5.65

Notes: A = area of catchment
L = length of catchment

Table 4: Peak Discharge of Local Catchments Including Probable Maximum Flood (PMF)

	ARI (Years)									
Discharge (m^3/s)	2	5	10	20	50	100	200	500	1000	2000
A	0.24	0.70	1.20	1.89	3.07	4.30	4.88	6.45	9.45	15.28
B	0.24	0.70	1.21	1.90	3.08	4.32	4.90	6.47	9.49	15.35
C	0.23	0.67	1.16	1.82	2.95	4.14	4.70	6.21	9.10	14.71
D	0.28	0.80	1.38	2.18	3.52	4.94	5.61	7.41	10.86	17.55
E	0.22	0.64	1.10	1.73	2.80	3.93	4.46	5.89	8.64	13.97
F	0.18	0.53	0.91	1.43	2.32	3.25	3.69	4.87	7.15	11.55
G	0.10	0.29	0.51	0.80	1.31	1.84	2.09	2.76	4.05	6.55
H	0.14	0.41	0.71	1.12	1.82	2.56	2.90	3.83	5.62	9.09
I	0.22	0.62	1.07	1.69	2.75	3.86	4.38	5.78	8.48	13.71
J	0.10	0.29	0.51	0.81	1.32	1.86	2.11	2.78	4.08	6.60
K	0.31	0.89	1.53	2.41	3.89	5.45	6.19	8.17	11.98	19.37
P1	0.31	0.90	1.55	2.44	3.95	5.53	6.28	8.30	12.17	19.67
P2	0.14	0.42	0.72	1.14	1.86	2.62	2.98	3.94	5.77	9.33
P3	0.32	0.91	1.56	2.45	3.96	5.55	6.30	8.32	12.20	19.73
RA	0.61	1.74	2.98	4.66	7.49	10.45	11.87	15.68	22.98	37.16
RB	0.84	2.37	4.06	6.35	10.21	14.23	16.16	21.35	31.29	50.60
RC	1.81	5.17	8.87	13.93	22.47	31.43	35.69	47.14	69.11	111.73
RD	2.08	5.96	10.24	16.07	25.94	36.28	41.21	54.43	79.79	129.01

The computed no-infiltration 1-in-100 year ARI peak flows in the vicinity of the mine site range from approximately 2 m^3/s to 5.5 m^3/s and for the PMF 2000-year event from 7 m^3/s to 20 m^3/s. The estimated peak flows over the access road range from about 10 m^3/s to 35 m^3/s for the 100 year ARI event and 40 m^3/s to 130 m^3/s for the PMF.

With infiltration the peak flows, which typically occur about 20 minutes after the start of a rainfall event, will be much the same; but flow depths and widths at the end of a rainfall event will be substantially reduced, and flow durations will be short.

3 SURFACE CATCHMENT RUNOFF HYDRAULICS

3.1 MANNING'S AND CONTINUITY EQUATIONS

The Manning's and continuity equations were used to identify the theoretical extents, depths and velocities of flows at relevant locations on the flow paths (Appendix B). This hydraulic information is required for preliminary concept design for flood mitigation where required. Again, no infiltration is assumed.

Manning's equation (Equation 4) was used to estimate flow velocity V (m/s):

$$V = \frac{1}{n} \cdot \left(\frac{A}{P} \right)^{2/3} \cdot (S)^{1/2}$$

Equation 4

Where:

n is a dimensionless roughness coefficient
A is the wetted waterway area (m^2)
P is the wetted perimeter (m)
S is the hydraulic gradient (m/m)

The continuity equation (Equation 5) was used to estimate the flow Q (m^3/s):

$$Q = A \cdot V$$

Equation 5

Where:

A is the waterway area in (m^2)
V is the velocity (m/s)

3.2 HYDRAULIC ANALYSIS OF MINING AREA AND PLANT SITE

Water management requirements associated with the planned mining area, the plant site, and the access road are discussed below.

Hydraulic analyses were carried out for five cross sections, selected to represent key locations that are possibly at risk of flooding. The cross sections, the catchments that contribute flow and the 1-in-100 year ARI peak flows are presented in Table 5.

Table 5: Contributing Catchments and Peak Flows

Cross Section	Contributing Catchments	100 Year ARI Flow (m^3/s)
XS1	E	3.93
XS2	0.5*F	1.63
XS3	F	3.25
XS4	G	1.84
XS5	H	2.56

The hydraulic results for these cross sections, including the 100-year ARI flood levels, maximum depths, velocities and flood widths (extent) are given in Appendix B and summarised in Table 6.

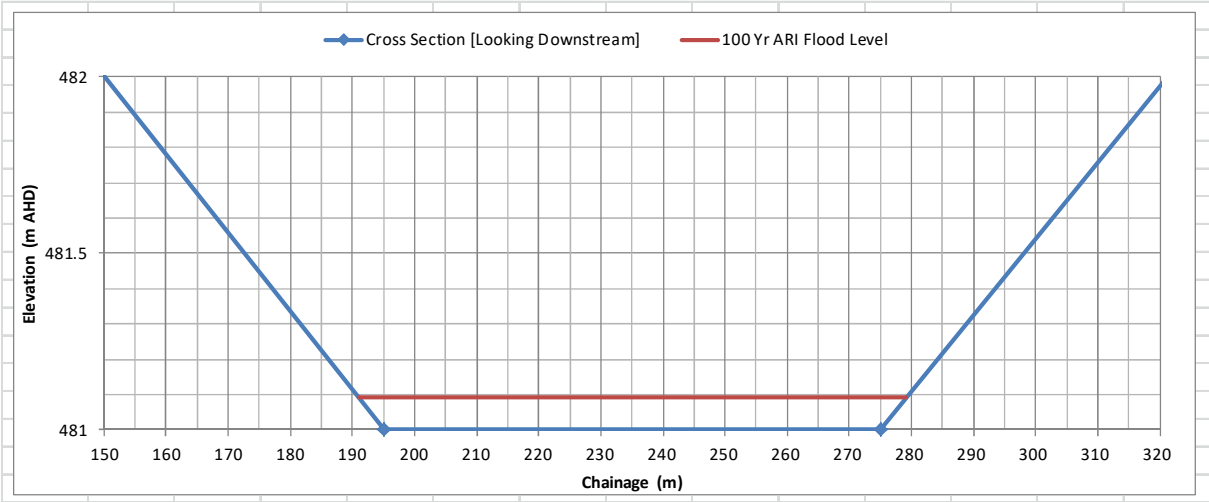
Table 6: Summary of 100 Year ARI Flood Levels, Depths, Velocity and Extents

Cross-Section	100 Year ARI Flow (m^3/s)	Flood Level Elevation (m AHD)	Maximum Depth (mm)	Maximum Velocity (m/s)	Extent of Flood Level (m)
XS1	3.93	481.09	90	0.55	88
XS2	1.63	476.23	230	0.56	27
XS3	3.25	470.61	110	0.46	76
XS4	1.84	476.24	240	0.58	27
XS5	2.56	474.20	200	0.79	33

The conceptual water management options are discussed in the following sub-sections.

3.2.1 Mining Area

Flow from Catchment E could directly impact the mining area. The 100-year ARI peak flow of 3.93 m^3/s at XS1 (Text-Fig. 2) would be slow-moving, 88 m wide and 90 mm deep.



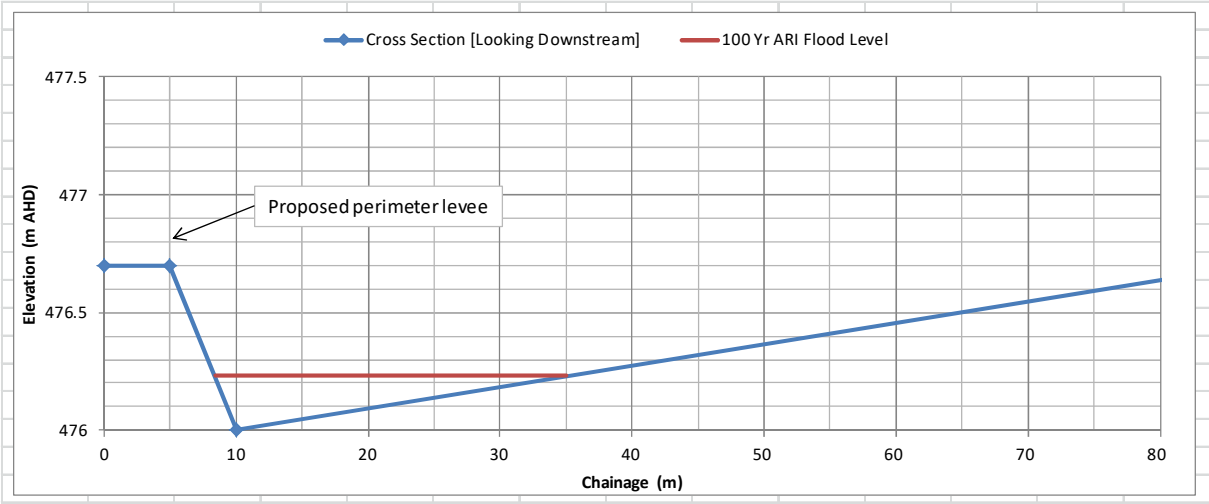
Text-Figure 2: Cross-section XS1

The results for XS1 suggest that even with freeboard allowance of 500 mm and the overly-conservative peak flow, the minimum flood mitigation levee requirement at the eastern boundary of the mining area is lower than the typical nominal 1.0 m safety bund around a pit. Therefore, it is recommended that the safety bund be strategically located and constructed to act as both a safety bund and a flood mitigation levee.

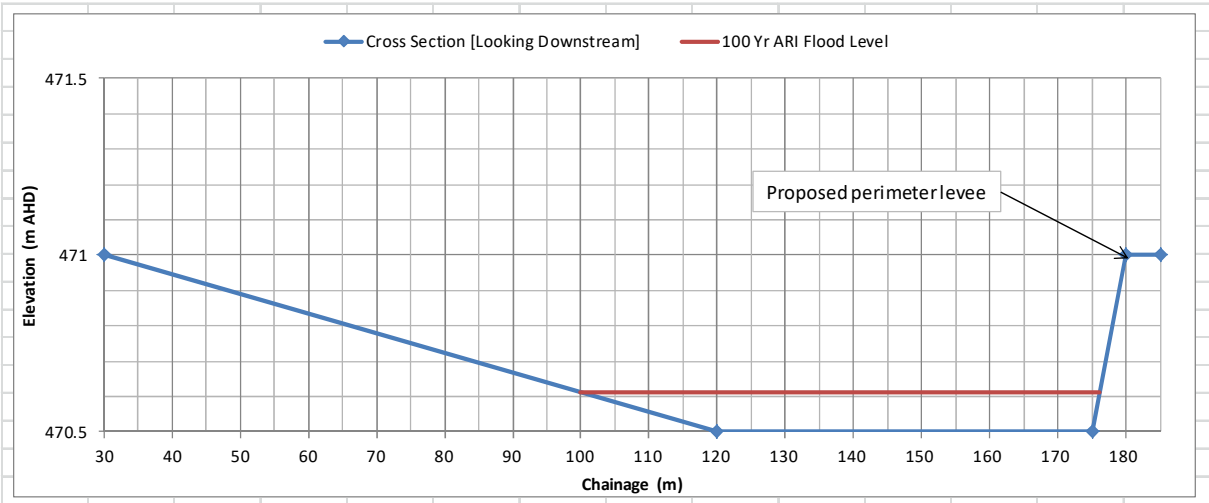
The cross sections at locations XS2 and XS3 were also analysed to determine the impact of flow from Catchment F which would pass between the mining area and the northern perimeter of the plant site.

At XS2, about half of the flow from Catchment F could potentially impact the mining area and plant site. The results at XS2 show that the total 1.63 m^3/s discharge would flow at a depth of up to 230 mm over a 27 m width. Due to the natural topography this will flow against the perimeter of the Plant Site as shown in Text-Fig. 3. This flow will continue against the northern perimeter of Plant Site until it gets to a level of 473 m AHD where it will spread over approximately 375 m width and most likely pond and infiltrate. Any residual water will flow towards lower ground either to the west or south-west.

At XS3 the results indicate that the 100-year ARI peak flow from Catchment F (3.25 m^3/s) would flow against the southern side of the proposed mining area at a width of 76 m and a maximum depth of 110 mm (Text-Fig. 4). If flood mitigation was required, a levee of approximately 0.60 m height would be needed. However, again the indicated flow is probably conservatively high and overstates the magnitude of risk. In reality, most of the flow would spread out and remain upstream of XS3 in a low area between 473 m AHD and 472 m AHD where it would infiltrate or migrate to the south-west towards depression D1.

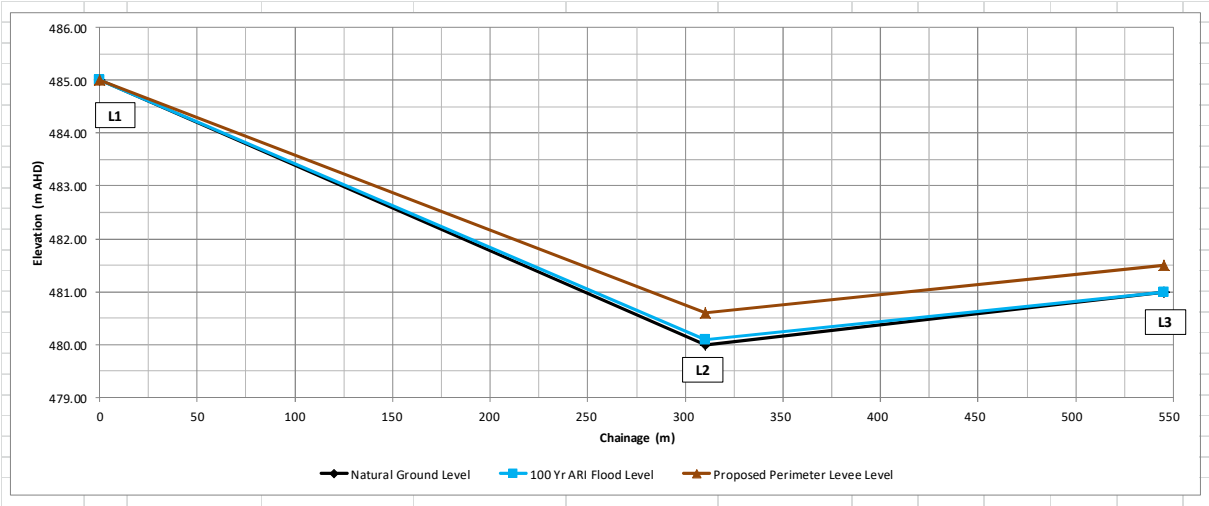


Text-Figure 3: Cross-section XS2



Text-Figure 4: Cross-section XS3

The general alignment and configuration of the flood protection levees recommended in this section takes into account the most efficient diversion path/s for the project. Based on this criterion, it is recommended that a 545 m-long levee system, as shown in Figure 4, be constructed from L1-L2-L3. The levee would be approximately 0.60 m high at the deepest location L2, tying to a height of 0.50 m at L3 and to the natural ridge at L1 (Text-Fig. 5, and summarised in Table 7). The purpose of this levee is to stop surface water from entering the mining area and diverting any overflow water to the south of the plant site as discussed in Section 3.2.2. The fact that L3 is higher than L2 is advantageous, as any small flows from Catchment F will pond and infiltrate in a short time.



Text-Figure 5: Long Section of Proposed Levee L1-L3

Table 7: Summary of Long Section L1-L3 Details

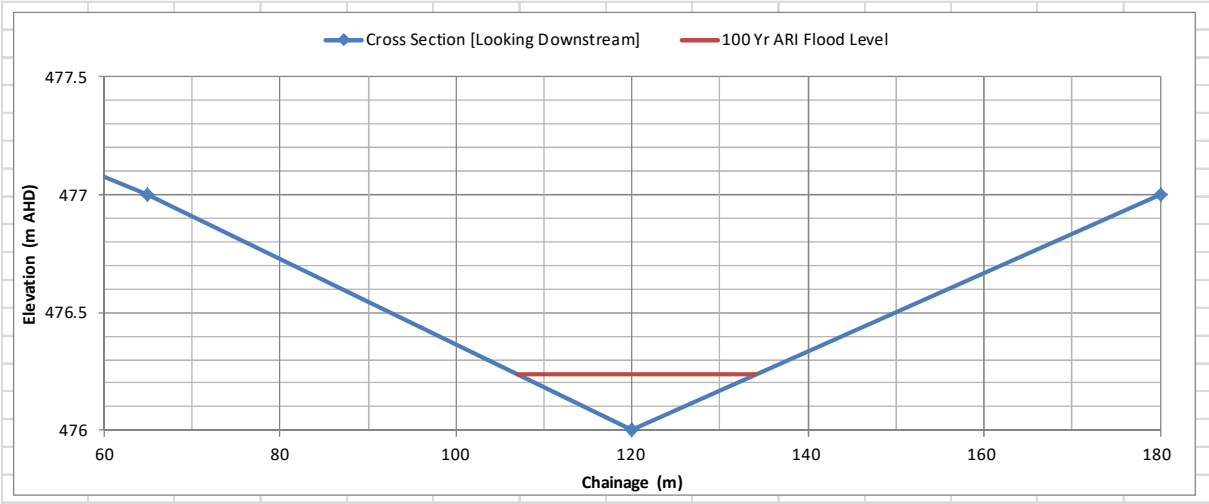
Location	Chainage (m)	Minimum Natural Ground Level @ Levee Location (m AHD)	100 Year ARI Flood Level (m AHD)	Proposed Perimeter Levee Level (m AHD)	Minimum Levee Height (m)
L1	0	485.00	485.00	485.00	0.00
L2	310	480.00	480.09	480.60	0.60
L3	545	481.00	481.00	481.50	0.50

3.2.2 Plant Site

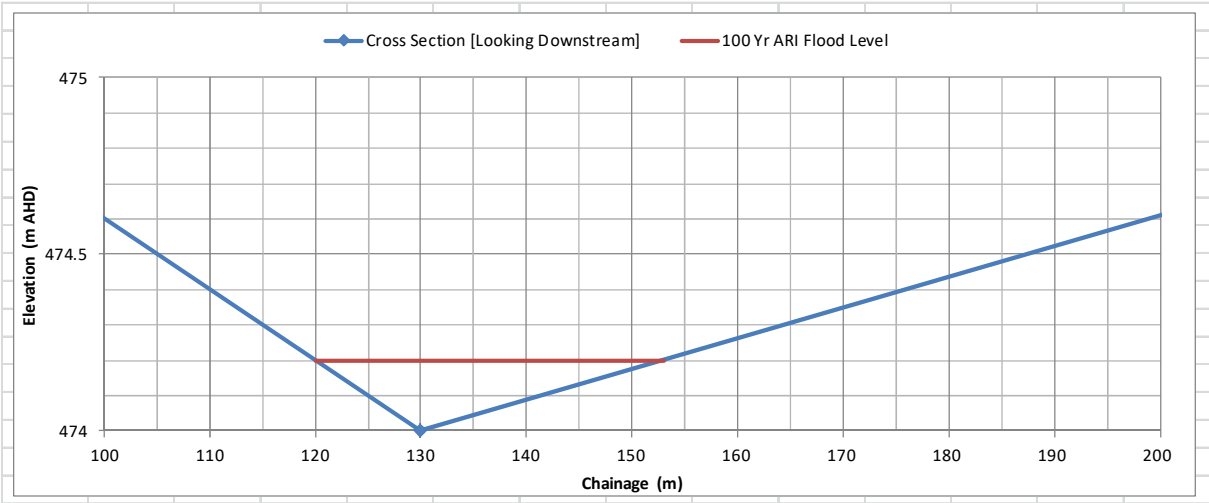
The results from cross section XS2 presented in Text-Fig. 3 can also be used to determine the required protection for the north-eastern perimeter of the plant site. They indicate that the required levee height is 0.60 m.

Cross sections XS4 and XS5 were also used to assess the depth and extent of flow towards the eastern perimeter of the plant site. The results for XS4 show that peak flow from Catchment G of 1.84 m^3/s would be up to 240 mm deep and 27 m wide. The results are summarised in Table 6 and are shown in Text-Fig. 6.

Similarly the results for XS5 in Table 6 and shown in Text-Fig. 7 indicate that the peak flow of 2.56 m^3/s from Catchment H would have a depth of up to 200 mm and a width of 33 m.



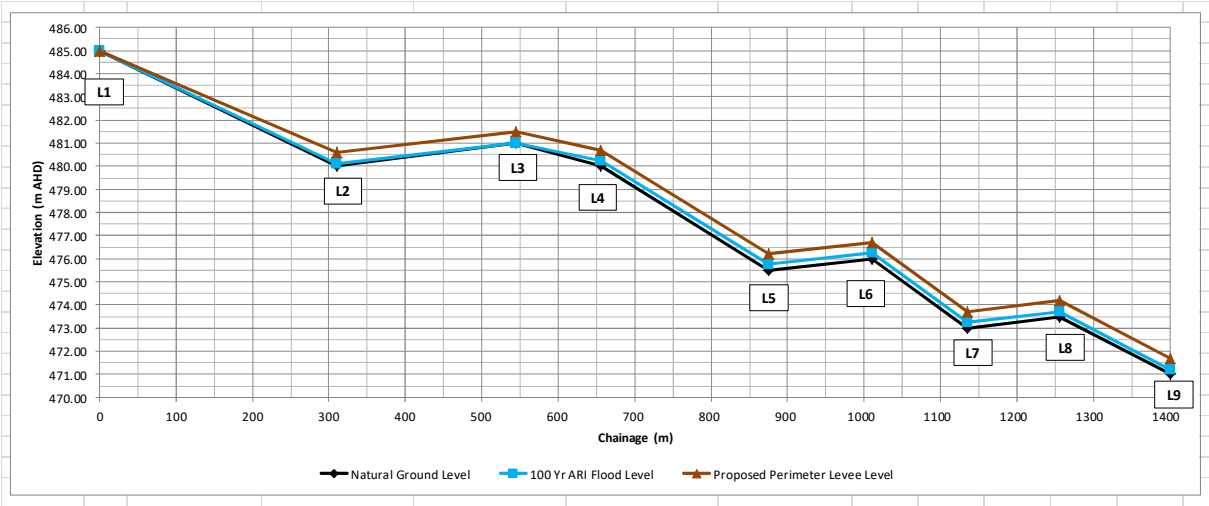
Text-Figure 6: Cross-section XS4



Text-Figure 7: Cross-section XS5

It is recommended that the L1-L3 levee be extended from L3 to L9 (Figure 4) to cover the mining area and plant site. The levee would channel the calculated total peak flow of 11.58 m^3/s contributed by catchments E, F, G and H to location L9 from where it would flow to the depression D5 (Figure 4). This will also obviate the need for flood-protection levees along the northern perimeter of the plant southern perimeter of the mining area.

Some grading would be needed of higher ground at locations L3, L6 and L8 in order for the flow to drain to the south. However, maintaining the high points could be beneficial – the peak flow would be too small to over-top the proposed levee, and the resulting ponding would increase infiltration and eliminate the ponded water within a short time. A long section of the entire L1-L9 levee is shown in Text-Fig. 8, and the details are given in Table 8.



Text-Figure 8: Long Section of Proposed Levee L1-L9

Table 8: Summary of Long Section L1-L9 Details

Location	Chainage (m)	Minimum Natural Ground Level @ Levee Location (m AHD)	100 Year ARI Flood Level (m AHD)	Proposed Perimeter Levee Level (m AHD)	Minimum Levee Height (m)
L1	0	485.00	485.00	485.00	0.00
L2	310	480.00	480.09	480.60	0.60
L3	545	481.00	481.00	481.50	0.50
L4	655	480.00	480.23	480.70	0.70
L5	875	475.50	475.75	476.20	0.70
L6	1010	476.00	476.25	476.70	0.70
L7	1135	473.00	473.24	473.70	0.70
L8	1255	473.50	473.70	474.20	0.70
L9	1400	471.00	471.20	471.70	0.70

3.2.3 Access Road

The hydraulics of the waterway crossings along the 6 km access road to the mine site are described below. Six waterway crossings were identified that could channel residual flows from catchments of various sizes. The catchments are shown in Figures 1 & 3. The time of concentration and the 1-in-2 year and 1-in-100 year ARI peak flows that could impact on these crossings are summarised in Table 9.

At this stage there are no detailed long sections available of the road that can be used to prepare accurate cross sections at the crossings. For this concept design, it is assumed that the flows over the crossings are in the form of wide sheet flows with shallow and sometimes undefined low-flow channels. This assumption is consistent with the available 5.0 m contour plans, and at road-crossing locations R1 and R2 which were identified on the 1.0 m contour plan.

Table 9: Catchments and Flows Contributing to Access Road Crossings

Cross-Section	Contributing Catchments	tc (Hours)	2 Year ARI Flow (m^3/s)	100 Year ARI Flow (m^3/s)
R1	0.25*E	0.20	0.06	0.98
R2	0.6*G	0.25	0.06	1.10
R3	RA	0.88	0.61	10.45
R4	RB	1.12	0.84	14.23
R5	RC	2.06	1.81	31.43
R6	RD	2.14	2.08	36.28

Note: tc = time of concentration

A floodway and culvert system is the most cost effective option for the crossings on the access road. Those at R5 and R6 appear to be the two that require the greatest scrutiny as they will need to cater for the largest flows, and R5 is situated in a topographic depression (as is R3). Even though the flow is expected to peak in around two hours at these two crossings, flows following a major rainfall event could persist for a day or two. While the depth of flow would still enable them to be passable for heavy vehicles, the risk of damage to the road surface at the crossings needs to be taken into consideration. At the detailed design stage adequate drainage and nominal culvert design should be considered together with the pavement design in order to prevent bogging and pavement damage. The same consideration should also be applied to the other smaller crossings.

Due to these crossings being flat and with insignificant low-flow channels, they should be constructed as low-level floodways to cater for the 1-in-2 year ARI rainfall event, with nominal drainage culverts positioned as near to the natural ground level as possible. When larger floods eventuate, the smaller crossings would be impassable for less than one hour. The largest two crossings would close the road for less than two hours in a 1-in-100 year ARI flood event.

Approximate floodway lengths for the 1-in-2 year and 1-in-100 year ARI peak flow events are given in Table 10. Appropriate sheeting should be applied at each floodway location. Preliminary design and costings should include nominal drainage culverts and inlet and outlet channels to ensure efficient drainage. It is envisaged that no detailed end treatment of culverts will be required.

If possible the access road should be re-aligned to the east to avoid the depression at crossing R5. This could increase the road length by 500 m, but eliminate the risk of water ponding at R5 and reduce the floodway length to about 100 m.

Table 10: Summary of Floodway and Culvert Systems on Access Road

Cross-Section	tc (Hours)	2 Year ARI Flow (m^3/s)	Floodway Length (m)	100 Year ARI Flow (m^3/s)	Floodway Length (m)	Depth of Flow over Road (mm)	Culverts for Drainage	Velocity (m/s)
R1	0.20	0.06	Not required	0.98	5	200	Nominal	1.14
R2	0.25	0.06	Not required	1.10	5	200	Nominal	1.14
R3	0.88	0.61	Not required	10.45	45	200	Nominal	1.14
R4	1.12	0.84	5	14.23	60	200	Nominal	1.14
R5	2.06	1.81	10	31.43	140	200	Nominal	1.14
R6	2.14	2.08	10	36.28	160	200	Nominal	1.14

Notes: tc = time of concentration..
Each crossing requires nominal culverts.

4 SUMMARY OF RECOMMENDATIONS, AND COMMENTS

This section summarises the hydrological and hydraulic analyses presented in this report and makes comments on the recommended surface water management options.

4.1 HYDROLOGY OF CATCHMENTS

The planned mining area is unaffected by any major flow paths, and surface water management is only required for short-term flows during rare high rainfall events. These flows are generally from small local catchments which drain residual runoff after infiltration losses to low-lying depressions. Generally water will only be retained for very short periods in the depressions due to continuing infiltration loss. Water could pond for longer periods if the depressions are clay pans. Evaporation will contribute to the loss of ponded water.

Based on the maximum recorded rainfalls in the area and typical infiltration rates for sandy and sandy loam soils, it is concluded that flow depths, widths and durations will be much smaller than they would be without infiltration losses. However, the Rational Method, which does not allow for infiltration losses, was used in the hydraulic analysis for conceptual design of flood management works. Site observations of actual flows following rainfall events should be collected as they will play an important role in refining the water management requirements in the detailed design stage.

4.2 PROTECTION OF MINING AREA AND PLANT SITE

It is recommended that a 1400 m levee L1 to L9 (Figure 4) be constructed to divert a theoretical peak flow of 11.58 m^3/s from catchments E, F, G and H to location L9 where it will then flow towards depression D5 (Figure 4). The natural topography along this levee will require minimal grading, and protect both the mining area and the plant site.

A conceptual long section of the levee is shown in Text-Fig. 8, and the approximate levee heights are given in Table 8.

4.3 RECOMMENDATIONS FOR THE ACCESS ROAD

There are six locations (R1 to R6) along the access road where there are likely to be surface water crossings. The hydrology of catchments contributing flow to these crossings is summarised in Table 9. Indicative floodway lengths required for serviceability for the 1-in-2 year and 1-in-100 year ARI rainfall events are summarised in Table 10.

It is recommended that all six waterway crossings be constructed as floodways without any raised embankment in order to minimise scouring during events that overtop the road. It is also recommended that appropriate drainage systems either in the form of nominal culverts or a pervious layer of graded rocks be included in the detailed design and construction of these floodways, in order to minimise the risk of bogging and damage by heavy vehicles. The floodways should be appropriately sheeted.

It is also recommended that the access road be re-aligned to the east if practicable to avoid the depression that currently includes crossing R5. This could increase the road length by up to 500 m, but would reduce the risk of road damage due to ponded water, and the floodway length at R5 could be reduced to about 100 m.

Dated: 27 January 2016 Rockwater Pty Ltd

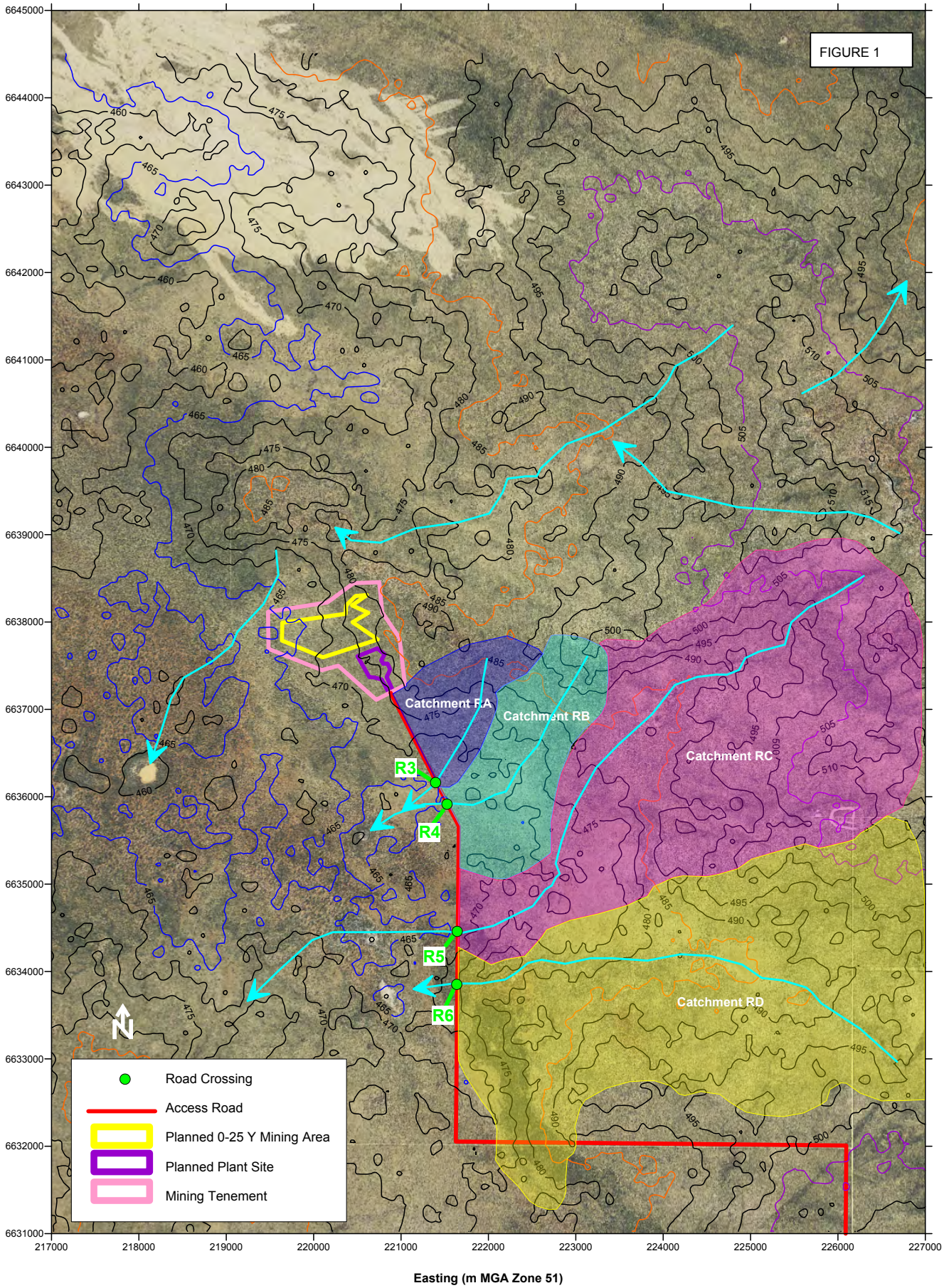
Jerome Goh
Hydrologist/Engineer

P H Wharton
Principal

REFERENCE

Australian Rainfall and Runoff, 1987, A Guide to Flood Estimation, Volume 1. The Institution of Engineers, Australia, Canberra.

FIGURES



I:/454-0/Surfer/15-002/Fig.1 Catchment Areas and Road Crossings.srf

Client: Tellus Holdings

Project: Sandy Ridge Project

Date: June 2015

Dwg. No: 454-0/15/1-1

ROAD CATCHMENTS AND CROSSINGS

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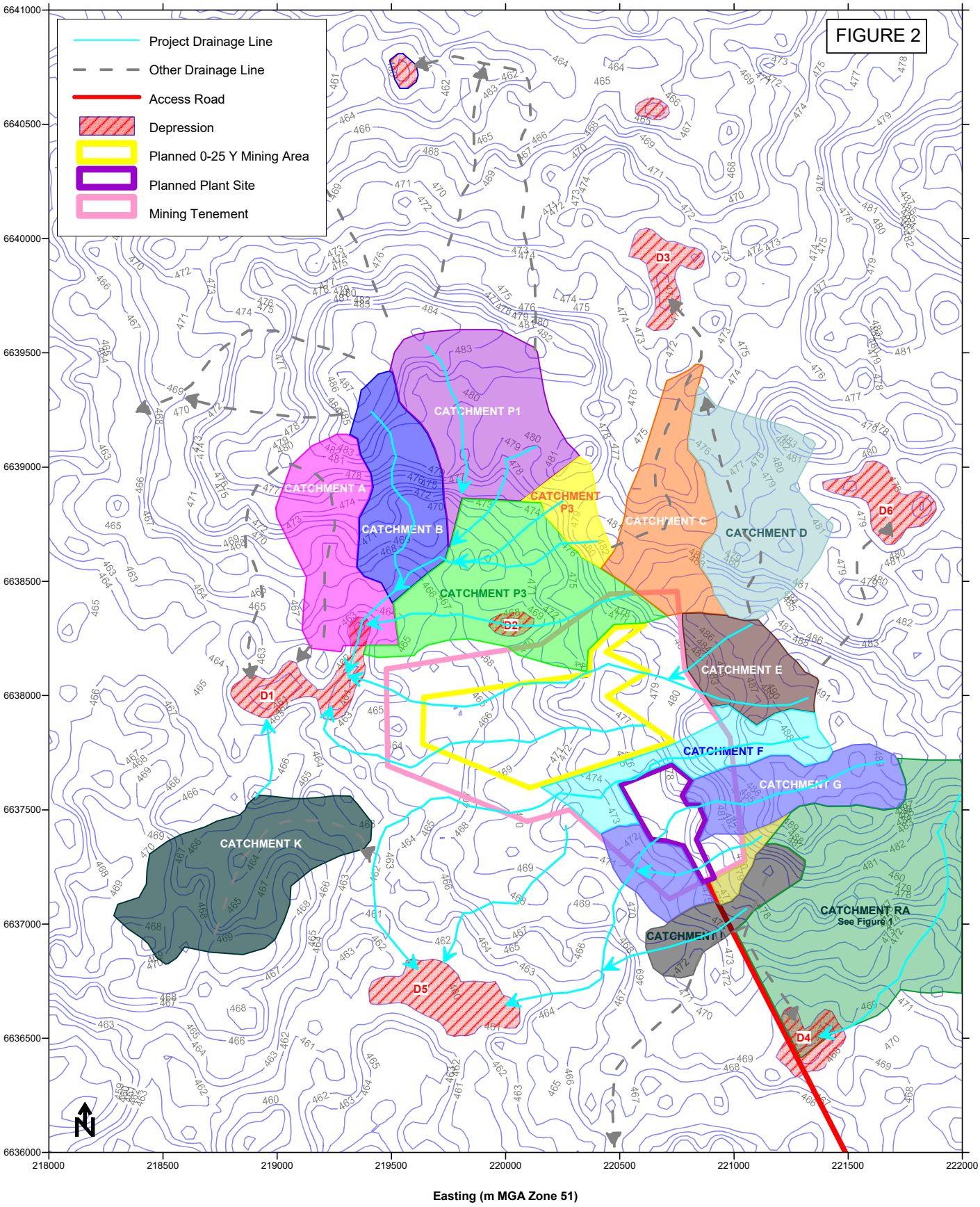

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Client: Tellus Holdings

Project: Sandy Ridge Project

Date: June 2015

Dwg. No: 454-0/15/1-2

CATCHMENT AREAS AND LOCATIONS OF DEPRESSIONS

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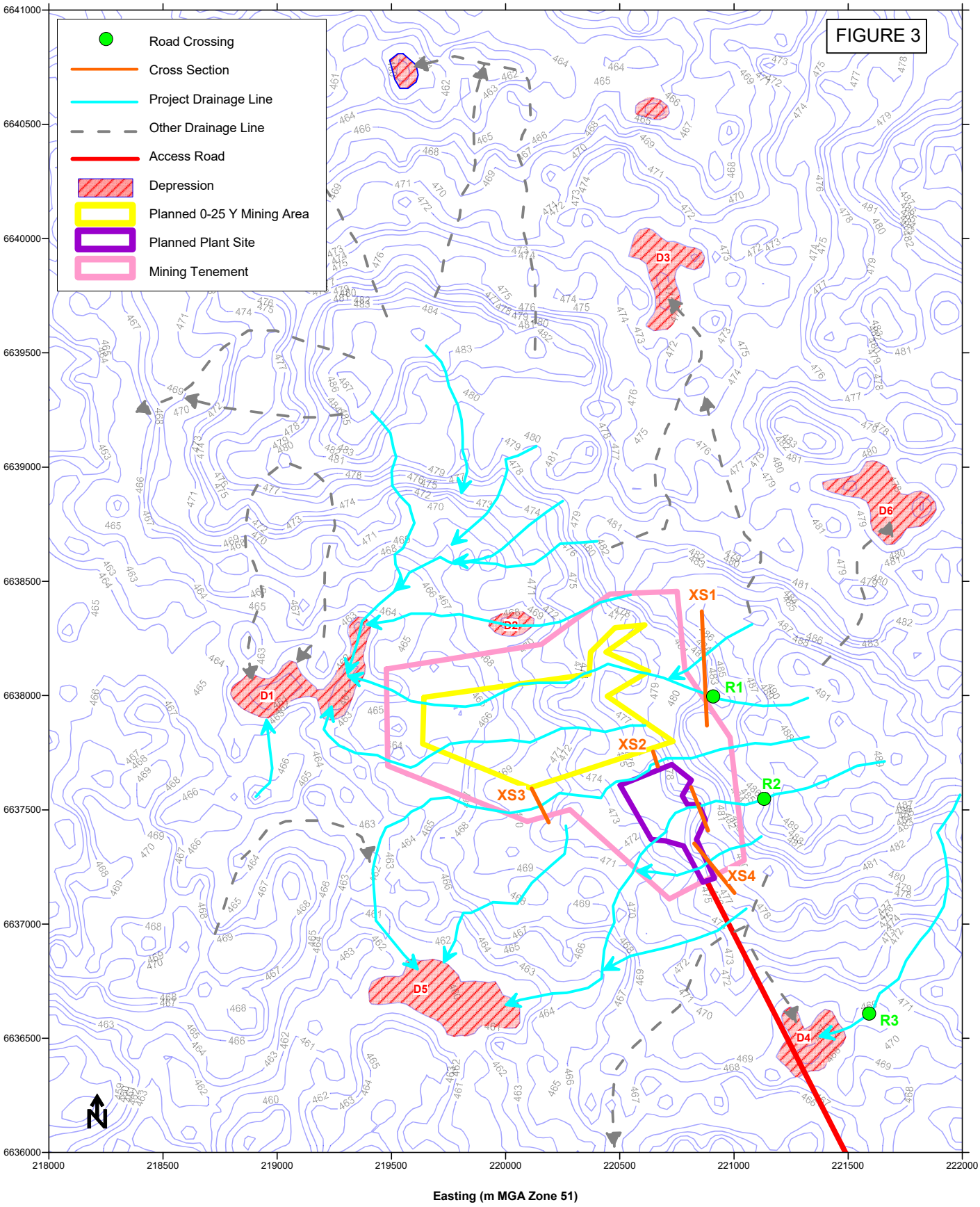


I:/454-0/Surfer/15-002/Fig.3 Final Mine Cross-Sections and Road Crosssings.srf

Client: Tellus Holdings

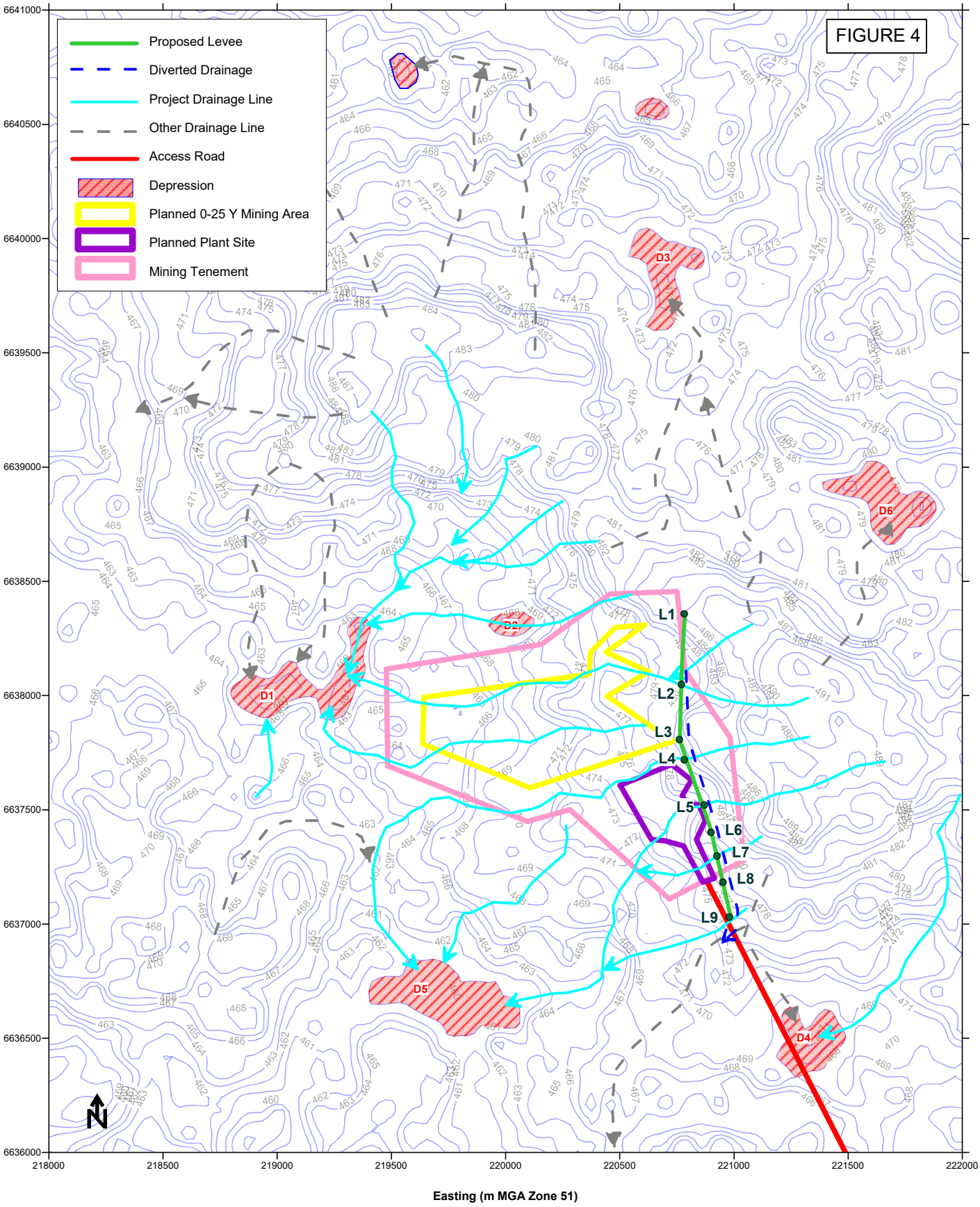
Project: Sandy Ridge Project

Date: June 2015

Dwg. No: 454-0/15/1-3

MINING AREA AND STREAM CROSS-SECTIONS

Rockwater PROPRIETARY LIMITED



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Client: Tellus Holdings

Project: Sandy Ridge Project

Date: June 2015

Dwg. No: 454-0/15/1-4

PLANNED MINING AREA AND PROPOSED LEVEE

Rockwater PROPRIETARY LIMITED

APPENDIX A: Hydrological Results

AUSTRALIAN RAINFALL AND RUNOFF VOLUME 1 & 2 (1987)
RATIONAL AND INDEX METHODS - WESTERN AUSTRALIA

REGION: **ARID INTERIOR**

LOCATION: Sandy Ridge Project Area

CATCHMENT: Catchment A

i. Wandoo Woodland (75-100% cleared) - Loamy Soils

Catchment	A (km^2)	L (km)	
Characteristics	0.32	0.88	

RATIONAL METHOD:

Care needs to be taken when catchment characteristics fall outside the following:

A =	59	km^2
L =	11.5	km
S_e =	5.71	m/km
P =	255	mm

$Q_Y = 0.278 C_Y . I_{tc,Y} . A$ ..... **(1.1)**

$t_c = 0.76A^{0.38}$ ..... **(1.29)**

t_c = 0.493 hours

$C_{10} = 3.46x10^{-1}L^{-0.42}$ ..... **(1.30)**

C_{10} = 0.365

Frequency Factors (C_Y/C_{10})

	ARI (years)					
	2	5	10	20	50	*100*
C_Y/C_{10}	0.34	0.70	1.00	1.28	1.62	*1.91*

100 year ARI extroplated using the power trendline

Therefore:

	ARI (years)					
	2	5	10	20	50	100
C_Y	0.124	0.256	0.365	0.467	0.591	0.698

AUSTRALIAN RAINFALL AND RUNOFF VOLUME 1 & 2 (1987)
RATIONAL AND INDEX METHODS - WESTERN AUSTRALIA

REGION: **ARID INTERIOR**

LOCATION: Sandy Ridge Project Area

CATCHMENT: Catchment A

RATIONAL METHOD:
CONTINUES

DETERMINE AVERAGE RAINFALL INTENSITY FOR DESIGN DURATION

t_c = 0.493 hours

P_D = -0.295 ..... **A(3.8)**
P_L = -0.837
P_U = 0.000
N = 0.647

Intensity upper and lower bound parameters

	ARI (Years)					
	2	5	10	20	50	100
I_L	49.380	70.803	86.660	108.003	140.387	168.685
I_U	14.123	19.454	23.265	28.411	36.045	42.581

Use Equation A(3.9)

Duration	ARI (Years) [mm/hr]					
(hours)	2	5	10	20	50	100
0.493	21.973	30.699	37.014	45.527	58.256	69.234

Calculate peak discharge using equation (1.1)

Discharge	ARI (Years)					
(m^3/s)	2	5	10	20	50	100
Q	0.24	0.70	1.20	1.89	3.07	4.30

AUSTRALIAN RAINFALL AND RUNOFF VOLUME 1 & 2 (1987)
RATIONAL AND INDEX METHODS - WESTERN AUSTRALIA

REGION: **ARID INTERIOR**

LOCATION: Sandy Ridge Project Area

CATCHMENT: Catchment B

i. Wandoo Woodland (75-100% cleared) - Loamy Soils

Catchment	A (km^2)	L (km)	
Characteristics	0.29	0.73	

RATIONAL METHOD:

Care needs to be taken when catchment characteristics fall outside the following:

A =	59	km^2
L =	11.5	km
S_e =	5.71	m/km
P =	255	mm

$Q_Y = 0.278 C_Y . I_{tc,Y} . A$ ..... **(1.1)**

$t_c = 0.76A^{0.38}$ ..... **(1.29)**

t_c = 0.475 hours

$C_{10} = 3.46x10^{-1}L^{-0.42}$ ..... **(1.30)**

C_{10} = 0.395

Frequency Factors (C_Y/C_{10})

	ARI (years)					
	2	5	10	20	50	*100*
C_Y/C_{10}	0.34	0.70	1.00	1.28	1.62	*1.91*

100 year ARI extroplated using the power trendline

Therefore:

	ARI (years)					
	2	5	10	20	50	100
C_Y	0.134	0.276	0.395	0.505	0.640	0.755

AUSTRALIAN RAINFALL AND RUNOFF VOLUME 1 & 2 (1987)
RATIONAL AND INDEX METHODS - WESTERN AUSTRALIA

REGION: **ARID INTERIOR**

LOCATION: Sandy Ridge Project Area

CATCHMENT: Catchment B

RATIONAL METHOD:
CONTINUES

DETERMINE AVERAGE RAINFALL INTENSITY FOR DESIGN DURATION

t_c = 0.475 hours

P_D = -0.310 ..... **A(3.8)**
P_L = -0.837
P_U = 0.000
N = 0.629

Intensity upper and lower bound parameters

	ARI (Years)					
	2	5	10	20	50	100
I_L	49.380	70.803	86.660	108.003	140.387	168.685
I_U	14.123	19.454	23.265	28.411	36.045	42.581

Use Equation A(3.9)

Duration	ARI (Years) [mm/hr]					
(hours)	2	5	10	20	50	100
0.475	22.467	31.411	37.889	46.619	59.680	70.947

Calculate peak discharge using equation (1.1)

Discharge	ARI (Years)					
(m^3/s)	2	5	10	20	50	100
Q	0.24	0.70	1.21	1.90	3.08	4.32

AUSTRALIAN RAINFALL AND RUNOFF VOLUME 1 & 2 (1987)
RATIONAL AND INDEX METHODS - WESTERN AUSTRALIA

REGION: **ARID INTERIOR**

LOCATION: Sandy Ridge Project Area

CATCHMENT: Catchment C

i. Wandoo Woodland (75-100% cleared) - Loamy Soils

Catchment	A (km^2)	L (km)	
Characteristics	0.31	0.91	

RATIONAL METHOD:

Care needs to be taken when catchment characteristics fall outside the following:

A =	59	km^2
L =	11.5	km
S_e =	5.71	m/km
P =	255	mm

$Q_Y = 0.278 C_Y . I_{tc,Y} . A$ ..... **(1.1)**

$t_c = 0.76A^{0.38}$ ..... **(1.29)**

t_c = 0.487 hours

$C_{10} = 3.46x10^{-1}L^{-0.42}$ ..... **(1.30)**

C_{10} = 0.360

Frequency Factors (C_Y/C_{10})

	ARI (years)					
	2	5	10	20	50	*100*
C_Y/C_{10}	0.34	0.70	1.00	1.28	1.62	*1.91*

100 year ARI extroplated using the power trendline

Therefore:

	ARI (years)					
	2	5	10	20	50	100
C_Y	0.122	0.252	0.360	0.461	0.583	0.688

AUSTRALIAN RAINFALL AND RUNOFF VOLUME 1 & 2 (1987)
RATIONAL AND INDEX METHODS - WESTERN AUSTRALIA

REGION: **ARID INTERIOR**

LOCATION: Sandy Ridge Project Area

CATCHMENT: Catchment C

RATIONAL METHOD:
CONTINUES

DETERMINE AVERAGE RAINFALL INTENSITY FOR DESIGN DURATION

t_c = 0.487 hours

P_D = -0.300 ..... **A(3.8)**
P_L = -0.837
P_U = 0.000
N = 0.641

Intensity upper and lower bound parameters

	ARI (Years)					
	2	5	10	20	50	100
I_L	49.380	70.803	86.660	108.003	140.387	168.685
I_U	14.123	19.454	23.265	28.411	36.045	42.581

Use Equation A(3.9)

Duration	ARI (Years) [mm/hr]					
(hours)	2	5	10	20	50	100
0.487	22.131	30.927	37.295	45.877	58.713	69.783

Calculate peak discharge using equation (1.1)

Discharge	ARI (Years)					
(m^3/s)	2	5	10	20	50	100
Q	0.23	0.67	1.16	1.82	2.95	4.14

AUSTRALIAN RAINFALL AND RUNOFF VOLUME 1 & 2 (1987)
RATIONAL AND INDEX METHODS - WESTERN AUSTRALIA

REGION: **ARID INTERIOR**

LOCATION: Sandy Ridge Project Area

CATCHMENT: Catchment D

i. Wandoo Woodland (75-100% cleared) - Loamy Soils

Catchment	A (km^2)	L (km)	
Characteristics	0.39	0.9	

RATIONAL METHOD:

Care needs to be taken when catchment characteristics fall outside the following:

A =	59	km^2
L =	11.5	km
S_e =	5.71	m/km
P =	255	mm

$Q_Y = 0.278 C_Y . I_{tc,Y} . A$ ..... **(1.1)**

$t_c = 0.76A^{0.38}$ ..... **(1.29)**

t_c = 0.531 hours

$C_{10} = 3.46x10^{-1}L^{-0.42}$ ..... **(1.30)**

C_{10} = 0.362

Frequency Factors (C_Y/C_{10})

	ARI (years)					
	2	5	10	20	50	*100*
C_Y/C_{10}	0.34	0.70	1.00	1.28	1.62	*1.91*

100 year ARI extroplated using the power trendline

Therefore:

	ARI (years)					
	2	5	10	20	50	100
C_Y	0.123	0.253	0.362	0.463	0.586	0.691

AUSTRALIAN RAINFALL AND RUNOFF VOLUME 1 & 2 (1987)
RATIONAL AND INDEX METHODS - WESTERN AUSTRALIA

REGION: **ARID INTERIOR**

LOCATION: Sandy Ridge Project Area

CATCHMENT: Catchment D

RATIONAL METHOD:
CONTINUES

DETERMINE AVERAGE RAINFALL INTENSITY FOR DESIGN DURATION

t_c = 0.531 hours

P_D = -0.265 ..... **A(3.8)**
P_L = -0.837
P_U = 0.000
N = 0.683

Intensity upper and lower bound parameters

	ARI (Years)					
	2	5	10	20	50	100
I_L	49.380	70.803	86.660	108.003	140.387	168.685
I_U	14.123	19.454	23.265	28.411	36.045	42.581

Use Equation A(3.9)

Duration	ARI (Years) [mm/hr]					
(hours)	2	5	10	20	50	100
0.531	21.005	29.304	35.304	43.391	55.475	65.888

Calculate peak discharge using equation (1.1)

Discharge	ARI (Years)					
(m^3/s)	2	5	10	20	50	100
Q	0.28	0.80	1.38	2.18	3.52	4.94

AUSTRALIAN RAINFALL AND RUNOFF VOLUME 1 & 2 (1987)
RATIONAL AND INDEX METHODS - WESTERN AUSTRALIA

REGION: **ARID INTERIOR**

LOCATION: Sandy Ridge Project Area

CATCHMENT: Catchment E

i. Wandoo Woodland (75-100% cleared) - Loamy Soils

Catchment	A (km^2)	L (km)	
Characteristics	0.24	0.65	

RATIONAL METHOD:

Care needs to be taken when catchment characteristics fall outside the following:

A =	59	km^2
L =	11.5	km
S_e =	5.71	m/km
P =	255	mm

$Q_Y = 0.278 C_Y . I_{tc,Y} . A$ ..... **(1.1)**

$t_c = 0.76A^{0.38}$ ..... **(1.29)**

t_c = 0.442 hours

$C_{10} = 3.46x10^{-1}L^{-0.42}$ ..... **(1.30)**

C_{10} = 0.415

Frequency Factors (C_Y/C_{10})

	ARI (years)					
	2	5	10	20	50	*100*
C_Y/C_{10}	0.34	0.70	1.00	1.28	1.62	*1.91*

100 year ARI extroplated using the power trendline

Therefore:

	ARI (years)					
	2	5	10	20	50	100
C_Y	0.141	0.290	0.415	0.531	0.672	0.792

AUSTRALIAN RAINFALL AND RUNOFF VOLUME 1 & 2 (1987)
RATIONAL AND INDEX METHODS - WESTERN AUSTRALIA

REGION: **ARID INTERIOR**

LOCATION: Sandy Ridge Project Area

CATCHMENT: Catchment E

RATIONAL METHOD:
CONTINUES

DETERMINE AVERAGE RAINFALL INTENSITY FOR DESIGN DURATION

t_c = 0.442 hours

P_D = -0.339 ..... **A(3.8)**
P_L = -0.837
P_U = 0.000
N = 0.595

Intensity upper and lower bound parameters

	ARI (Years)					
	2	5	10	20	50	100
I_L	49.380	70.803	86.660	108.003	140.387	168.685
I_U	14.123	19.454	23.265	28.411	36.045	42.581

Use Equation A(3.9)

Duration	ARI (Years) [mm/hr]					
(hours)	2	5	10	20	50	100
0.442	23.438	32.814	39.612	48.773	62.489	74.329

Calculate peak discharge using equation (1.1)

Discharge	ARI (Years)					
(m^3/s)	2	5	10	20	50	100
Q	0.22	0.64	1.10	1.73	2.80	3.93

AUSTRALIAN RAINFALL AND RUNOFF VOLUME 1 & 2 (1987)
RATIONAL AND INDEX METHODS - WESTERN AUSTRALIA

REGION: **ARID INTERIOR**

LOCATION: Sandy Ridge Project Area

CATCHMENT: Catchment F

i. Wandoo Woodland (75-100% cleared) - Loamy Soils

Catchment	A (km^2)	L (km)	
Characteristics	0.26	1.18	

RATIONAL METHOD:

Care needs to be taken when catchment characteristics fall outside the following:

A =	59	km^2
L =	11.5	km
S_e =	5.71	m/km
P =	255	mm

$Q_Y = 0.278 C_Y . I_{tc,Y} . A$ ..... **(1.1)**

$t_c = 0.76A^{0.38}$ ..... **(1.29)**

t_c = 0.456 hours

$C_{10} = 3.46 \times 10^{-1} L^{-0.42}$ ..... **(1.30)**

C_{10} = 0.323

Frequency Factors (C_Y/C_{10})

	ARI (years)					
	2	5	10	20	50	*100*
C_Y/C_{10}	0.34	0.70	1.00	1.28	1.62	*1.91*

100 year ARI extroplated using the power trendline

Therefore:

	ARI (years)					
	2	5	10	20	50	100
C_Y	0.110	0.226	0.323	0.413	0.523	0.617

RATIONAL METHOD:

AUSTRALIAN RAINFALL AND RUNOFF VOLUME 1 & 2 (1987)
RATIONAL AND INDEX METHODS - WESTERN AUSTRALIA

REGION: **ARID INTERIOR**

LOCATION: Sandy Ridge Project Area

CATCHMENT: Catchment F
CONTINUES

DETERMINE AVERAGE RAINFALL INTENSITY FOR DESIGN DURATION

t_c = 0.456 hours

P_D = -0.327 ..... **A(3.8)**
P_L = -0.837
P_U = 0.000
N = 0.610

Intensity upper and lower bound parameters

	ARI (Years)					
	2	5	10	20	50	100
I_L	49.380	70.803	86.660	108.003	140.387	168.685
I_U	14.123	19.454	23.265	28.411	36.045	42.581

Use Equation A(3.9)

Duration	ARI (Years) [mm/hr]					
(hours)	2	5	10	20	50	100
0.456	23.024	32.215	38.876	47.853	61.289	72.884

Calculate peak discharge using equation (1.1)

Discharge	ARI (Years)					
(m^3/s)	2	5	10	20	50	100
Q	0.18	0.53	0.91	1.43	2.32	3.25

AUSTRALIAN RAINFALL AND RUNOFF VOLUME 1 & 2 (1987)
RATIONAL AND INDEX METHODS - WESTERN AUSTRALIA

REGION: **ARID INTERIOR**

LOCATION: Sandy Ridge Project Area

CATCHMENT: Catchment G

i. Wandoo Woodland (75-100% cleared) - Loamy Soils

Catchment	A (km^2)	L (km)	
Characteristics	0.11	0.96	

RATIONAL METHOD:

Care needs to be taken when catchment characteristics fall outside the following:

A =	59	km^2
L =	11.5	km
S_e =	5.71	m/km
P =	255	mm

$Q_Y = 0.278 C_Y . I_{tc,Y} . A$ ..... **(1.1)**

$t_c = 0.76A^{0.38}$ ..... **(1.29)**

t_c = 0.329 hours

$C_{10} = 3.46x10^{-1}L^{-0.42}$ ..... **(1.30)**

C_{10} = 0.352

Frequency Factors (C_Y/C_{10})

	ARI (years)					
	2	5	10	20	50	*100*
C_Y/C_{10}	0.34	0.70	1.00	1.28	1.62	*1.91*

100 year ARI extroplated using the power trendline

Therefore:

	ARI (years)					
	2	5	10	20	50	100
C_Y	0.120	0.246	0.352	0.451	0.570	0.673

AUSTRALIAN RAINFALL AND RUNOFF VOLUME 1 & 2 (1987)
RATIONAL AND INDEX METHODS - WESTERN AUSTRALIA

REGION: **ARID INTERIOR**

LOCATION: Sandy Ridge Project Area

CATCHMENT: Catchment G

RATIONAL METHOD:
CONTINUES

DETERMINE AVERAGE RAINFALL INTENSITY FOR DESIGN DURATION

t_c = 0.329 hours

P_D = -0.452 ..... **A(3.8)**
P_L = -0.837
P_U = 0.000
N = 0.460

Intensity upper and lower bound parameters

	ARI (Years)					
	2	5	10	20	50	100
I_L	49.380	70.803	86.660	108.003	140.387	168.685
I_U	14.123	19.454	23.265	28.411	36.045	42.581

Use Equation A(3.9)

Duration	ARI (Years) [mm/hr]					
(hours)	2	5	10	20	50	100
0.329	27.755	39.068	47.310	58.412	75.083	89.515

Calculate peak discharge using equation (1.1)

Discharge	ARI (Years)					
(m^3/s)	2	5	10	20	50	100
Q	0.10	0.29	0.51	0.80	1.31	1.84

AUSTRALIAN RAINFALL AND RUNOFF VOLUME 1 & 2 (1987)
RATIONAL AND INDEX METHODS - WESTERN AUSTRALIA

REGION: **ARID INTERIOR**

LOCATION: Sandy Ridge Project Area

CATCHMENT: Catchment H

i. Wandoo Woodland (75-100% cleared) - Loamy Soils

Catchment	A (km^2)	L (km)	
Characteristics	0.11	0.44	

RATIONAL METHOD:

Care needs to be taken when catchment characteristics fall outside the following:

A =	59	km^2
L =	11.5	km
S_e =	5.71	m/km
P =	255	mm

$Q_Y = 0.278 C_Y . I_{tc,Y} . A$ ..... **(1.1)**

$t_c = 0.76A^{0.38}$ ..... **(1.29)**

t_c = 0.329 hours

$C_{10} = 3.46x10^{-1}L^{-0.42}$ ..... **(1.30)**

C_{10} = 0.488

Frequency Factors (C_Y/C_{10})

	ARI (years)					
	2	5	10	20	50	*100*
C_Y/C_{10}	0.34	0.70	1.00	1.28	1.62	*1.91*

100 year ARI extroplated using the power trendline

Therefore:

	ARI (years)					
	2	5	10	20	50	100
C_Y	0.166	0.342	0.488	0.625	0.791	0.933

AUSTRALIAN RAINFALL AND RUNOFF VOLUME 1 & 2 (1987)
RATIONAL AND INDEX METHODS - WESTERN AUSTRALIA

REGION: **ARID INTERIOR**

LOCATION: Sandy Ridge Project Area

CATCHMENT: Catchment H

RATIONAL METHOD:
CONTINUES

DETERMINE AVERAGE RAINFALL INTENSITY FOR DESIGN DURATION

t_c = 0.329 hours

P_D = -0.452 ..... **A(3.8)**
P_L = -0.837
P_U = 0.000
N = 0.460

Intensity upper and lower bound parameters

	ARI (Years)					
	2	5	10	20	50	100
I_L	49.380	70.803	86.660	108.003	140.387	168.685
I_U	14.123	19.454	23.265	28.411	36.045	42.581

Use Equation A(3.9)

Duration	ARI (Years) [mm/hr]					
(hours)	2	5	10	20	50	100
0.329	27.755	39.068	47.310	58.412	75.083	89.515

Calculate peak discharge using equation (1.1)

Discharge	ARI (Years)					
(m^3/s)	2	5	10	20	50	100
Q	0.14	0.41	0.71	1.12	1.82	2.56

AUSTRALIAN RAINFALL AND RUNOFF VOLUME 1 & 2 (1987)
RATIONAL AND INDEX METHODS - WESTERN AUSTRALIA

REGION: **ARID INTERIOR**

LOCATION: Sandy Ridge Project Area

CATCHMENT: Catchment I

i. Wandoo Woodland (75-100% cleared) - Loamy Soils

Catchment	A (km^2)	L (km)	
Characteristics	0.23	0.63	

RATIONAL METHOD:

Care needs to be taken when catchment characteristics fall outside the following:

A =	59	km^2
L =	11.5	km
S_e =	5.71	m/km
P =	255	mm

$Q_Y = 0.278 C_Y . I_{tc,Y} . A$ ..... **(1.1)**

$t_c = 0.76A^{0.38}$ ..... **(1.29)**

t_c = 0.435 hours

$C_{10} = 3.46x10^{-1}L^{-0.42}$ ..... **(1.30)**

C_{10} = 0.420

Frequency Factors (C_Y/C_{10})

	ARI (years)					
	2	5	10	20	50	*100*
C_Y/C_{10}	0.34	0.70	1.00	1.28	1.62	*1.91*

100 year ARI extroplated using the power trendline

Therefore:

	ARI (years)					
	2	5	10	20	50	100
C_Y	0.143	0.294	0.420	0.538	0.681	0.803

AUSTRALIAN RAINFALL AND RUNOFF VOLUME 1 & 2 (1987)
RATIONAL AND INDEX METHODS - WESTERN AUSTRALIA

REGION: **ARID INTERIOR**

LOCATION: Sandy Ridge Project Area

CATCHMENT: Catchment I

RATIONAL METHOD:
CONTINUES

DETERMINE AVERAGE RAINFALL INTENSITY FOR DESIGN DURATION

t_c = 0.435 hours

P_D = -0.345 ..... **A(3.8)**
P_L = -0.837
P_U = 0.000
N = 0.588

Intensity upper and lower bound parameters

	ARI (Years)					
	2	5	10	20	50	100
I_L	49.380	70.803	86.660	108.003	140.387	168.685
I_U	14.123	19.454	23.265	28.411	36.045	42.581

Use Equation A(3.9)

Duration	ARI (Years) [mm/hr]					
(hours)	2	5	10	20	50	100
0.435	23.661	33.136	40.008	49.267	63.134	75.106

Calculate peak discharge using equation (1.1)

Discharge	ARI (Years)					
(m^3/s)	2	5	10	20	50	100
Q	0.22	0.62	1.07	1.69	2.75	3.86

AUSTRALIAN RAINFALL AND RUNOFF VOLUME 1 & 2 (1987)
RATIONAL AND INDEX METHODS - WESTERN AUSTRALIA

REGION: **ARID INTERIOR**

LOCATION: Sandy RidgeProject Area

CATCHMENT: Catchment J

i. Wandoo Woodland (75-100% cleared) - Loamy Soils

Catchment	A (km^2)	L (km)	
Characteristics	0.07	0.41	

RATIONAL METHOD:

Care needs to be taken when catchment characteristics fall outside the following:

A =	59	km^2
L =	11.5	km
S_e =	5.71	m/km
P =	255	mm

$Q_Y = 0.278 C_Y . I_{tc,Y} . A$ ..... **(1.1)**

$t_c = 0.76A^{0.38}$ ..... **(1.29)**

t_c = 0.277 hours

$C_{10} = 3.46x10^{-1}L^{-0.42}$ ..... **(1.30)**

C_{10} = 0.503

Frequency Factors (C_Y/C_{10})

	ARI (years)					
	2	5	10	20	50	*100*
C_Y/C_{10}	0.34	0.70	1.00	1.28	1.62	*1.91*

100 year ARI extroplated using the power trendline

Therefore:

	ARI (years)					
	2	5	10	20	50	100
C_Y	0.171	0.352	0.503	0.644	0.815	0.962

AUSTRALIAN RAINFALL AND RUNOFF VOLUME 1 & 2 (1987)
RATIONAL AND INDEX METHODS - WESTERN AUSTRALIA

REGION: **ARID INTERIOR**

LOCATION: Sandy Ridge Project Area

CATCHMENT: Catchment J

RATIONAL METHOD:
CONTINUES

DETERMINE AVERAGE RAINFALL INTENSITY FOR DESIGN DURATION

t_c = 0.277 hours

P_D = -0.514 ..... **A(3.8)**
P_L = -0.837
P_U = 0.000
N = 0.385

Intensity upper and lower bound parameters

	ARI (Years)					
	2	5	10	20	50	100
I_L	49.380	70.803	86.660	108.003	140.387	168.685
I_U	14.123	19.454	23.265	28.411	36.045	42.581

Use Equation A(3.9)

Duration	ARI (Years) [mm/hr]					
(hours)	2	5	10	20	50	100
0.277	30.478	43.030	52.199	64.546	83.119	99.221

Calculate peak discharge using equation (1.1)

Discharge	ARI (Years)					
(m^3/s)	2	5	10	20	50	100
Q	0.10	0.29	0.51	0.81	1.32	1.86

AUSTRALIAN RAINFALL AND RUNOFF VOLUME 1 & 2 (1987)
RATIONAL AND INDEX METHODS - WESTERN AUSTRALIA

REGION: **ARID INTERIOR**

LOCATION: Sandy Ridge Project Area

CATCHMENT: Catchment K

i. Wandoo Woodland (75-100% cleared) - Loamy Soils

Catchment	A (km^2)	L (km)	
Characteristics	0.48	1.03	

RATIONAL METHOD:

Care needs to be taken when catchment characteristics fall outside the following:

A =	59	km^2
L =	11.5	km
S_e =	5.71	m/km
P =	255	mm

$Q_Y = 0.278 C_Y . I_{tc,Y} . A$ ..... **(1.1)**

$t_c = 0.76A^{0.38}$ ..... **(1.29)**

t_c = 0.575 hours

$C_{10} = 3.46x10^{-1}L^{-0.42}$ ..... **(1.30)**

C_{10} = 0.342

Frequency Factors (C_Y/C_{10})

	ARI (years)					
	2	5	10	20	50	*100*
C_Y/C_{10}	0.34	0.70	1.00	1.28	1.62	*1.91*

100 year ARI extroplated using the power trendline

Therefore:

	ARI (years)					
	2	5	10	20	50	100
C_Y	0.116	0.239	0.342	0.437	0.554	0.653

AUSTRALIAN RAINFALL AND RUNOFF VOLUME 1 & 2 (1987)
RATIONAL AND INDEX METHODS - WESTERN AUSTRALIA

REGION: **ARID INTERIOR**

LOCATION: Sandy Ridge Project Area

CATCHMENT: Catchment K

RATIONAL METHOD:
CONTINUES

DETERMINE AVERAGE RAINFALL INTENSITY FOR DESIGN DURATION

t_c = 0.575 hours

P_D = -0.233 ..... **A(3.8)**
P_L = -0.837
P_U = 0.000
N = 0.721

Intensity upper and lower bound parameters

	ARI (Years)					
	2	5	10	20	50	100
I_L	49.380	70.803	86.660	108.003	140.387	168.685
I_U	14.123	19.454	23.265	28.411	36.045	42.581

Use Equation A(3.9)

Duration	ARI (Years) [mm/hr]					
(hours)	2	5	10	20	50	100
0.575	20.024	27.893	33.573	41.232	52.666	62.512

Calculate peak discharge using equation (1.1)

Discharge	ARI (Years)					
(m^3/s)	2	5	10	20	50	100
Q	0.31	0.89	1.53	2.41	3.89	5.45

AUSTRALIAN RAINFALL AND RUNOFF VOLUME 1 & 2 (1987)
RATIONAL AND INDEX METHODS - WESTERN AUSTRALIA

REGION: **ARID INTERIOR**

LOCATION: Sandy Ridge Project Area

CATCHMENT: Catchment P1

i. Wandoo Woodland (75-100% cleared) - Loamy Soils

Catchment	A (km^2)	L (km)	
Characteristics	0.41	0.75	

RATIONAL METHOD:

Care needs to be taken when catchment characteristics fall outside the following:

A =	59	km^2
L =	11.5	km
S_e =	5.71	m/km
P =	255	mm

$Q_Y = 0.278 C_Y . I_{tc,Y} . A$ ..... **(1.1)**

$t_c = 0.76A^{0.38}$ ..... **(1.29)**

t_c = 0.542 hours

$C_{10} = 3.46x10^{-1}L^{-0.42}$ ..... **(1.30)**

C_{10} = 0.390

Frequency Factors (C_Y/C_{10})

	ARI (years)					
	2	5	10	20	50	*100*
C_Y/C_{10}	0.34	0.70	1.00	1.28	1.62	*1.91*

100 year ARI extroplated using the power trendline

Therefore:

	ARI (years)					
	2	5	10	20	50	100
C_Y	0.133	0.273	0.390	0.500	0.633	0.746

AUSTRALIAN RAINFALL AND RUNOFF VOLUME 1 & 2 (1987)
RATIONAL AND INDEX METHODS - WESTERN AUSTRALIA

REGION: **ARID INTERIOR**

LOCATION: Sandy Ridge Project Area

CATCHMENT: Catchment P1

RATIONAL METHOD:
CONTINUES

DETERMINE AVERAGE RAINFALL INTENSITY FOR DESIGN DURATION

t_c = 0.542 hours

P_D = -0.258 ..... **A(3.8)**
P_L = -0.837
P_U = 0.000
N = 0.692

Intensity upper and lower bound parameters

	ARI (Years)					
	2	5	10	20	50	100
I_L	49.380	70.803	86.660	108.003	140.387	168.685
I_U	14.123	19.454	23.265	28.411	36.045	42.581

Use Equation A(3.9)

Duration	ARI (Years) [mm/hr]					
(hours)	2	5	10	20	50	100
0.542	20.766	28.959	34.881	42.863	54.788	65.062

Calculate peak discharge using equation (1.1)

Discharge	ARI (Years)					
(m^3/s)	2	5	10	20	50	100
Q	0.31	0.90	1.55	2.44	3.95	5.53

AUSTRALIAN RAINFALL AND RUNOFF VOLUME 1 & 2 (1987)
RATIONAL AND INDEX METHODS - WESTERN AUSTRALIA

REGION: **ARID INTERIOR**

LOCATION: Sandy Ridge Project Area

CATCHMENT: Catchment P2

i. Wandoo Woodland (75-100% cleared) - Loamy Soils

Catchment	A (km^2)	L (km)	
Characteristics	0.07	0.18	

RATIONAL METHOD:

Care needs to be taken when catchment characteristics fall outside the following:

A =	59	km^2
L =	11.5	km
S_e =	5.71	m/km
P =	255	mm

$Q_Y = 0.278 C_Y . I_{tc,Y} . A$ ..... **(1.1)**

$t_c = 0.76A^{0.38}$ ..... **(1.29)**

t_c = 0.277 hours

$C_{10} = 3.46x10^{-1}L^{-0.42}$ ..... **(1.30)**

C_{10} = 0.711

Frequency Factors (C_Y/C_{10})

	ARI (years)					
	2	5	10	20	50	*100*
C_Y/C_{10}	0.34	0.70	1.00	1.28	1.62	*1.91*

100 year ARI extroplated using the power trendline

Therefore:

	ARI (years)					
	2	5	10	20	50	100
C_Y	0.242	0.498	0.711	0.910	1.152	1.359

AUSTRALIAN RAINFALL AND RUNOFF VOLUME 1 & 2 (1987)
RATIONAL AND INDEX METHODS - WESTERN AUSTRALIA

REGION: **ARID INTERIOR**

LOCATION: Sandy Ridge Project Area

CATCHMENT: Catchment P2

RATIONAL METHOD:
CONTINUES

DETERMINE AVERAGE RAINFALL INTENSITY FOR DESIGN DURATION

t_c = 0.277 hours

P_D = -0.514 ..... **A(3.8)**
P_L = -0.837
P_U = 0.000
N = 0.385

Intensity upper and lower bound parameters

	ARI (Years)					
	2	5	10	20	50	100
I_L	49.380	70.803	86.660	108.003	140.387	168.685
I_U	14.123	19.454	23.265	28.411	36.045	42.581

Use Equation A(3.9)

Duration	ARI (Years) [mm/hr]					
(hours)	2	5	10	20	50	100
0.277	30.478	43.030	52.199	64.546	83.119	99.221

Calculate peak discharge using equation (1.1)

Discharge	ARI (Years)					
(m^3/s)	2	5	10	20	50	100
Q	0.14	0.42	0.72	1.14	1.86	2.62

AUSTRALIAN RAINFALL AND RUNOFF VOLUME 1 & 2 (1987)
RATIONAL AND INDEX METHODS - WESTERN AUSTRALIA

REGION: **ARID INTERIOR**

LOCATION: Sandy Ridge Project Area

CATCHMENT: Catchment P3

i. Wandoo Woodland (75-100% cleared) - Loamy Soils

Catchment	A (km^2)	L (km)	
Characteristics	0.5	1.06	

RATIONAL METHOD:

Care needs to be taken when catchment characteristics fall outside the following:

A =	59	km^2
L =	11.5	km
S_e =	5.71	m/km
P =	255	mm

$Q_Y = 0.278 C_Y . I_{tc,Y} . A$ ..... **(1.1)**

$t_c = 0.76A^{0.38}$ ..... **(1.29)**

t_c = 0.584 hours

$C_{10} = 3.46 \times 10^{-1} L^{-0.42}$ ..... **(1.30)**

C_{10} = 0.338

Frequency Factors (C_Y/C_{10})

	ARI (years)					
	2	5	10	20	50	*100*
C_Y/C_{10}	0.34	0.70	1.00	1.28	1.62	*1.91*

100 year ARI extroplated using the power trendline

Therefore:

	ARI (years)					
	2	5	10	20	50	100
C_Y	0.115	0.236	0.338	0.432	0.547	0.645

AUSTRALIAN RAINFALL AND RUNOFF VOLUME 1 & 2 (1987)
RATIONAL AND INDEX METHODS - WESTERN AUSTRALIA

REGION: **ARID INTERIOR**

LOCATION: Sandy Ridge Project Area

CATCHMENT: Catchment P3

RATIONAL METHOD:
CONTINUES

DETERMINE AVERAGE RAINFALL INTENSITY FOR DESIGN DURATION

t_c = 0.584 hours

P_D = -0.227 ..... **A(3.8)**
P_L = -0.837
P_U = 0.000
N = 0.729

Intensity upper and lower bound parameters

	ARI (Years)					
	2	5	10	20	50	100
I_L	49.380	70.803	86.660	108.003	140.387	168.685
I_U	14.123	19.454	23.265	28.411	36.045	42.581

Use Equation A(3.9)

Duration	ARI (Years) [mm/hr]					
(hours)	2	5	10	20	50	100
0.584	19.836	27.622	33.241	40.818	52.127	61.864

Calculate peak discharge using equation (1.1)

Discharge	ARI (Years)					
(m^3/s)	2	5	10	20	50	100
Q	0.32	0.91	1.56	2.45	3.96	5.55

AUSTRALIAN RAINFALL AND RUNOFF VOLUME 1 & 2 (1987)
RATIONAL AND INDEX METHODS - WESTERN AUSTRALIA

REGION: **ARID INTERIOR**

LOCATION: Sandy Ridge Project Area

CATCHMENT: Catchment RA

i. Wandoo Woodland (75-100% cleared) - Loamy Soils

Catchment	A (km^2)	L (km)	
Characteristics	1.48	1.58	

RATIONAL METHOD:

Care needs to be taken when catchment characteristics fall outside the following:

A =	59	km^2
L =	11.5	km
S_e =	5.71	m/km
P =	255	mm

$Q_Y = 0.278 C_Y . I_{tc,Y} . A$ ..... **(1.1)**

$t_c = 0.76A^{0.38}$ ..... **(1.29)**

t_c = 0.882 hours

$C_{10} = 3.46 \times 10^{-1} L^{-0.42}$ ..... **(1.30)**

C_{10} = 0.286

Frequency Factors (C_Y/C_{10})

	ARI (years)					
	2	5	10	20	50	*100*
C_Y/C_{10}	0.34	0.70	1.00	1.28	1.62	*1.91*

100 year ARI extroplated using the power trendline

Therefore:

	ARI (years)					
	2	5	10	20	50	100
C_Y	0.097	0.200	0.286	0.365	0.463	0.546

AUSTRALIAN RAINFALL AND RUNOFF VOLUME 1 & 2 (1987)
RATIONAL AND INDEX METHODS - WESTERN AUSTRALIA

REGION: **ARID INTERIOR**

LOCATION: Sandy Ridge Project Area

CATCHMENT: Catchment RA

RATIONAL METHOD:
CONTINUES

DETERMINE AVERAGE RAINFALL INTENSITY FOR DESIGN DURATION

t_c = 0.882 hours

P_D = -0.054 ..... **A(3.8)**
P_L = -0.837
P_U = 0.000
N = 0.935

Intensity upper and lower bound parameters

	ARI (Years)					
	2	5	10	20	50	100
I_L	49.380	70.803	86.660	108.003	140.387	168.685
I_U	14.123	19.454	23.265	28.411	36.045	42.581

Use Equation A(3.9)

Duration	ARI (Years) [mm/hr]					
(hours)	2	5	10	20	50	100
0.882	15.315	21.151	25.333	30.976	39.361	46.550

Calculate peak discharge using equation (1.1)

Discharge	ARI (Years)					
(m^3/s)	2	5	10	20	50	100
Q	0.61	1.74	2.98	4.66	7.49	10.45

AUSTRALIAN RAINFALL AND RUNOFF VOLUME 1 & 2 (1987)
RATIONAL AND INDEX METHODS - WESTERN AUSTRALIA

REGION: **ARID INTERIOR**

LOCATION: Sandy Ridge Project Area

CATCHMENT: Catchment RB

i. Wandoo Woodland (75-100% cleared) - Loamy Soils

Catchment	A (km^2)	L (km)	
Characteristics	2.8	2.37	

RATIONAL METHOD:

Care needs to be taken when catchment characteristics fall outside the following:

A =	59	km^2
L =	11.5	km
S_e =	5.71	m/km
P =	255	mm

$Q_Y = 0.278 C_Y . I_{tc,Y} . A$ ..... **(1.1)**

$t_c = 0.76A^{0.38}$ ..... **(1.29)**

t_c = 1.124 hours

$C_{10} = 3.46x10^{-1}L^{-0.42}$ ..... **(1.30)**

C_{10} = 0.241

Frequency Factors (C_Y/C_{10})

	ARI (years)					
	2	5	10	20	50	*100*
C_Y/C_{10}	0.34	0.70	1.00	1.28	1.62	*1.91*

100 year ARI extroplated using the power trendline

Therefore:

	ARI (years)					
	2	5	10	20	50	100
C_Y	0.082	0.169	0.241	0.308	0.390	0.460

AUSTRALIAN RAINFALL AND RUNOFF VOLUME 1 & 2 (1987)
RATIONAL AND INDEX METHODS - WESTERN AUSTRALIA

REGION: **ARID INTERIOR**

LOCATION: Sandy Ridge Project Area

CATCHMENT: Catchment RB

RATIONAL METHOD:
CONTINUES

DETERMINE AVERAGE RAINFALL INTENSITY FOR DESIGN DURATION

t_c = 1.124 hours

P_D = 0.051 ..... **A(3.8)**
P_L = 0.000
P_U = 1.126
N = 0.045

Intensity upper and lower bound parameters

	ARI (Years)					
	2	5	10	20	50	100
I_L	14.123	19.454	23.265	28.411	36.045	42.581
I_U	2.788	3.952	4.805	5.953	7.685	9.189

Use Equation A(3.9)

Duration	ARI (Years) [mm/hr]					
(hours)	2	5	10	20	50	100
1.124	13.123	18.099	21.661	26.469	33.608	39.724

Calculate peak discharge using equation (1.1)

Discharge	ARI (Years)					
(m^3/s)	2	5	10	20	50	100
Q	0.84	2.37	4.06	6.35	10.21	14.23

AUSTRALIAN RAINFALL AND RUNOFF VOLUME 1 & 2 (1987)
RATIONAL AND INDEX METHODS - WESTERN AUSTRALIA

REGION: **ARID INTERIOR**

LOCATION: Sandy Ridge Project Area

CATCHMENT: Catchment RC

i. Wandoo Woodland (75-100% cleared) - Loamy Soils

Catchment	A (km^2)	L (km)	
Characteristics	13.85	6.7	

RATIONAL METHOD:

Care needs to be taken when catchment characteristics fall outside the following:

A =	59	km^2
L =	11.5	km
S_e =	5.71	m/km
P =	255	mm

Q_Y = $0.278C_Y.I_{tc,Y}.A$ ..... **(1.1)**

t_c = $0.76A^{0.38}$ ..... **(1.29)**

t_c = 2.063 hours

C_{10} = $3.46x10^{-1}L^{-0.42}$ ..... **(1.30)**

C_{10} = 0.156

Frequency Factors (C_Y/C_{10})

	ARI (years)					
	2	5	10	20	50	*100*
C_Y/C_{10}	0.34	0.70	1.00	1.28	1.62	*1.91*

100 year ARI extroplated using the power trendline

Therefore:

	ARI (years)					
	2	5	10	20	50	100
C_Y	0.053	0.109	0.156	0.199	0.252	0.297

AUSTRALIAN RAINFALL AND RUNOFF VOLUME 1 & 2 (1987)
RATIONAL AND INDEX METHODS - WESTERN AUSTRALIA

REGION: **ARID INTERIOR**

LOCATION: Sandy Ridge Project Area

CATCHMENT: Catchment RC

RATIONAL METHOD:
CONTINUES

DETERMINE AVERAGE RAINFALL INTENSITY FOR DESIGN DURATION

t_c = 2.063 hours

P_D = 0.323 ..... **A(3.8)**
P_L = 0.000
P_U = 1.126
N = 0.287

Intensity upper and lower bound parameters

	ARI (Years)					
	2	5	10	20	50	100
I_L	14.123	19.454	23.265	28.411	36.045	42.581
I_U	2.788	3.952	4.805	5.953	7.685	9.189

Use Equation A(3.9)

Duration	ARI (Years) [mm/hr]					
(hours)	2	5	10	20	50	100
2.063	8.872	12.322	14.805	18.155	23.147	27.440

Calculate peak discharge using equation (1.1)

Discharge	ARI (Years)					
(m^3/s)	2	5	10	20	50	100
Q	1.81	5.17	8.87	13.93	22.47	31.43

AUSTRALIAN RAINFALL AND RUNOFF VOLUME 1 & 2 (1987)
RATIONAL AND INDEX METHODS - WESTERN AUSTRALIA

REGION: **ARID INTERIOR**

LOCATION: Sandy Ridge Project Area

CATCHMENT: Catchment RD

i. Wandoo Woodland (75-100% cleared) - Loamy Soils

Catchment	A (km^2)	L (km)	
Characteristics	15.22	5.65	

RATIONAL METHOD:

Care needs to be taken when catchment characteristics fall outside the following:

A =	59	km^2
L =	11.5	km
S_e =	5.71	m/km
P =	255	mm

$Q_Y = 0.278 C_Y . I_{tc,Y} . A$ ..... **(1.1)**

$t_c = 0.76A^{0.38}$ ..... **(1.29)**

t_c = 2.139 hours

$C_{10} = 3.46x10^{-1}L^{-0.42}$ ..... **(1.30)**

C_{10} = 0.167

Frequency Factors (C_Y/C_{10})

	ARI (years)					
	2	5	10	20	50	*100*
C_Y/C_{10}	0.34	0.70	1.00	1.28	1.62	*1.91*

100 year ARI extroplated using the power trendline

Therefore:

	ARI (years)					
	2	5	10	20	50	100
C_Y	0.057	0.117	0.167	0.214	0.271	0.320

AUSTRALIAN RAINFALL AND RUNOFF VOLUME 1 & 2 (1987)
RATIONAL AND INDEX METHODS - WESTERN AUSTRALIA

REGION: **ARID INTERIOR**

LOCATION: Sandy Ridge Project Area

CATCHMENT: Catchment RD

RATIONAL METHOD:
CONTINUES

DETERMINE AVERAGE RAINFALL INTENSITY FOR DESIGN DURATION

t_c = 2.139 hours

P_D = 0.339 ..... **A(3.8)**
P_L = 0.000
P_U = 1.126
N = 0.301

Intensity upper and lower bound parameters

	ARI (Years)					
	2	5	10	20	50	100
I_L	14.123	19.454	23.265	28.411	36.045	42.581
I_U	2.788	3.952	4.805	5.953	7.685	9.189

Use Equation A(3.9)

Duration	ARI (Years) [mm/hr]					
(hours)	2	5	10	20	50	100
2.139	8.667	12.041	14.472	17.750	22.636	26.838

Calculate peak discharge using equation (1.1)

Discharge	ARI (Years)					
(m^3/s)	2	5	10	20	50	100
Q	2.08	5.96	10.24	16.07	25.94	36.28

APPENDIX B: Hydraulic Results

CROSS SECTION 1

slope = 0.019231 m/m

Stage (mAHD)	Q (m3/s)	A (m2)	V (m/s)
481.00	0.0		
481.01	0.1	0.8	0.13
481.02	0.3	1.6	0.2
481.03	0.6	2.4	0.27
481.04	1.1	3.3	0.32
481.05	1.5	4.1	0.37
481.06	2.1	5.0	0.42
481.07	2.7	5.8	0.46
481.08	3.4	6.7	0.51
481.09	4.1	7.6	0.55
481.10	4.9	8.5	0.59
481.11	5.8	9.4	0.62
481.12	6.8	10.3	0.66
481.13	7.7	11.2	0.69
481.14	8.8	12.1	0.73
481.15	9.9	13.0	0.76
481.16	11.1	14.0	0.79
481.17	12.3	14.9	0.82
481.18	13.5	15.9	0.85
481.19	14.9	16.8	0.88
481.20	16.3	17.8	0.91
481.21	17.7	18.8	0.94
481.22	19.2	19.8	0.97
481.23	20.7	20.8	1
481.24	22.3	21.8	1.02
481.25	24.0	22.9	1.05
481.26	25.7	23.9	1.07
481.27	27.4	24.9	1.1
481.28	29.2	26.0	1.13
481.29	31.1	27.0	1.15
481.30	33.0	28.1	1.17
481.31	35.0	29.2	1.2
481.32	37.0	30.3	1.22
481.33	39.1	31.4	1.25
481.34	41.2	32.5	1.27
481.35	43.4	33.6	1.29
481.36	45.6	34.7	1.31
481.37	47.9	35.8	1.34
481.38	50.2	37.0	1.36
481.39	52.6	38.1	1.38
481.40	55.1	39.3	1.4
481.41	57.6	40.5	1.42
481.42	60.1	41.6	1.44
481.43	62.7	42.8	1.46
481.44	65.4	44.0	1.48
481.45	68.1	45.2	1.5
481.46	70.8	46.5	1.52
481.47	73.6	47.7	1.54
481.48	76.5	48.9	1.56
481.49	79.4	50.2	1.58
481.50	82.4	51.4	1.6
481.51	85.4	52.7	1.62
481.52	88.5	53.9	1.64

CROSS SECTION 2

slope = 0.021212 m/m

Stage (mAHD)	Q (m3/s)	A (m2)	V (m/s)
476.00	0.0		
476.01	0.0	0.0	0.07
476.02	0.0	0.0	0.11
476.03	0.0	0.1	0.14
476.04	0.0	0.1	0.17
476.05	0.0	0.1	0.2
476.06	0.0	0.2	0.23
476.07	0.1	0.3	0.25
476.08	0.1	0.4	0.28
476.09	0.1	0.5	0.3
476.10	0.2	0.6	0.32
476.11	0.2	0.7	0.34
476.12	0.3	0.8	0.36
476.13	0.4	1.0	0.38
476.14	0.5	1.1	0.4
476.15	0.5	1.3	0.42
476.16	0.6	1.5	0.44
476.17	0.8	1.7	0.46
476.18	0.9	1.9	0.48
476.19	1.0	2.1	0.49
476.20	1.2	2.3	0.51
476.21	1.3	2.5	0.53
476.22	1.5	2.8	0.54
476.23	1.7	3.0	0.56
476.24	1.9	3.3	0.58
476.25	2.1	3.6	0.59
476.26	2.4	3.9	0.61
476.27	2.6	4.2	0.62
476.28	2.9	4.5	0.64
476.29	3.2	4.8	0.65
476.30	3.5	5.2	0.67
476.31	3.8	5.5	0.68
476.32	4.1	5.9	0.7
476.33	4.5	6.3	0.71
476.34	4.8	6.6	0.73
476.35	5.2	7.0	0.74
476.36	5.6	7.5	0.75
476.37	6.0	7.9	0.77
476.38	6.5	8.3	0.78
476.39	7.0	8.7	0.8
476.40	7.4	9.2	0.81
476.41	8.0	9.7	0.82
476.42	8.5	10.1	0.84
476.43	9.0	10.6	0.85
476.44	9.6	11.1	0.86
476.45	10.2	11.6	0.88
476.46	10.8	12.2	0.89
476.47	11.4	12.7	0.9
476.48	12.1	13.2	0.91
476.49	12.8	13.8	0.93
476.50	13.5	14.4	0.94
476.51	14.2	15.0	0.95
476.52	15.0	15.5	0.96

CROSS SECTION 3

slope = 0.011299 m/m

Stage (mAHD)	Q (m3/s)	A (m2)	V (m/s)
470.50	0.0		
470.51	0.1	0.6	0.1
470.52	0.2	1.1	0.15
470.53	0.3	1.7	0.2
470.54	0.6	2.3	0.24
470.55	0.8	3.0	0.28
470.56	1.1	3.6	0.31
470.57	1.5	4.3	0.35
470.58	1.9	5.0	0.38
470.59	2.3	5.7	0.41
470.60	2.8	6.4	0.43
470.61	3.3	7.2	0.46
470.62	3.8	7.9	0.49
470.63	4.4	8.7	0.51
470.64	5.1	9.5	0.53
470.65	5.7	10.3	0.56
470.66	6.4	11.1	0.58
470.67	7.2	12.0	0.6
470.68	8.0	12.9	0.62
470.69	8.8	13.8	0.64
470.70	9.7	14.7	0.66
470.71	10.6	15.6	0.68
470.72	11.5	16.5	0.7
470.73	12.5	17.5	0.72
470.74	13.6	18.5	0.73
470.75	14.6	19.5	0.75
470.76	15.8	20.5	0.77
470.77	16.9	21.5	0.79
470.78	18.1	22.6	0.8
470.79	19.4	23.7	0.82
470.80	20.7	24.8	0.84
470.81	22.0	25.9	0.85
470.82	23.4	27.0	0.87
470.83	24.8	28.1	0.88
470.84	26.3	29.3	0.9
470.85	27.8	30.5	0.91
470.86	29.4	31.7	0.93
470.87	31.0	32.9	0.94
470.88	32.6	34.1	0.96
470.89	34.3	35.4	0.97
470.90	36.1	36.7	0.98
470.91	37.8	38.0	1
470.92	39.7	39.3	1.01
470.93	41.6	40.6	1.02
470.94	43.5	41.9	1.04
470.95	45.5	43.3	1.05
470.96	47.5	44.7	1.06
470.97	49.6	46.1	1.08
470.98	51.7	47.5	1.09
470.99	53.9	49.0	1.1
471.00	56.2	50.4	1.11
471.01	58.7	51.9	1.13
471.02	61.3	53.4	1.15

CROSS SECTION 4

slope = 0.014035 m/m

Stage (mAHD)	Q (m3/s)	A (m2)	V (m/s)
476.00	0.0		
476.01	0.0	0.0	0.07
476.02	0.0	0.0	0.11
476.03	0.0	0.1	0.14
476.04	0.0	0.1	0.17
476.05	0.0	0.1	0.2
476.06	0.0	0.2	0.23
476.07	0.1	0.3	0.25
476.08	0.1	0.4	0.28
476.09	0.1	0.5	0.3
476.10	0.2	0.6	0.32
476.11	0.2	0.7	0.34
476.12	0.3	0.8	0.36
476.13	0.4	1.0	0.38
476.14	0.5	1.1	0.4
476.15	0.5	1.3	0.42
476.16	0.6	1.5	0.44
476.17	0.8	1.7	0.46
476.18	0.9	1.9	0.48
476.19	1.0	2.1	0.49
476.20	1.2	2.3	0.51
476.21	1.3	2.5	0.53
476.22	1.5	2.8	0.54
476.23	1.7	3.0	0.56
476.24	1.9	3.3	0.58
476.25	2.1	3.6	0.59
476.26	2.4	3.9	0.61
476.27	2.6	4.2	0.62
476.28	2.9	4.5	0.64
476.29	3.2	4.8	0.65
476.30	3.5	5.2	0.67
476.31	3.8	5.5	0.68
476.32	4.1	5.9	0.7
476.33	4.5	6.3	0.71
476.34	4.8	6.6	0.73
476.35	5.2	7.0	0.74
476.36	5.6	7.5	0.75
476.37	6.0	7.9	0.77
476.38	6.5	8.3	0.78
476.39	7.0	8.7	0.8
476.40	7.4	9.2	0.81
476.41	8.0	9.7	0.82
476.42	8.5	10.1	0.84
476.43	9.0	10.6	0.85
476.44	9.6	11.1	0.86
476.45	10.2	11.6	0.88
476.46	10.8	12.2	0.89
476.47	11.4	12.7	0.9
476.48	12.1	13.2	0.91
476.49	12.8	13.8	0.93
476.50	13.5	14.4	0.94
476.51	14.2	15.0	0.95
476.52	15.0	15.5	0.96

CROSS SECTION 5

slope = 0.033333 m/m

Stage (mAHD)	Q (m3/s)	A (m2)	V (m/s)
474.00	0.0		
474.01	0.0	0.0	0.11
474.02	0.0	0.0	0.17
474.03	0.0	0.1	0.22
474.04	0.0	0.1	0.27
474.05	0.1	0.2	0.31
474.06	0.1	0.3	0.35
474.07	0.2	0.4	0.39
474.08	0.2	0.5	0.43
474.09	0.3	0.7	0.46
474.10	0.4	0.8	0.5
474.11	0.5	1.0	0.53
474.12	0.7	1.2	0.56
474.13	0.8	1.4	0.59
474.14	1.0	1.6	0.62
474.15	1.2	1.9	0.65
474.16	1.4	2.1	0.68
474.17	1.7	2.4	0.71
474.18	2.0	2.7	0.73
474.19	2.3	3.0	0.76
474.20	2.6	3.3	0.79
474.21	3.0	3.6	0.81
474.22	3.3	4.0	0.84
474.23	3.8	4.4	0.86
474.24	4.2	4.8	0.89
474.25	4.7	5.2	0.91
474.26	5.2	5.6	0.94
474.27	5.8	6.0	0.96
474.28	6.4	6.5	0.98
474.29	7.0	6.9	1.01
474.30	7.6	7.4	1.03
474.31	8.3	7.9	1.05
474.32	9.1	8.4	1.08
474.33	9.9	9.0	1.1
474.34	10.7	9.5	1.12
474.35	11.5	10.1	1.14
474.36	12.4	10.7	1.16
474.37	13.4	11.3	1.18
474.38	14.4	11.9	1.21
474.39	15.4	12.5	1.23
474.40	16.5	13.2	1.25
474.41	17.6	13.9	1.27
474.42	18.8	14.6	1.29
474.43	20.0	15.3	1.31
474.44	21.2	16.0	1.33
474.45	22.6	16.7	1.35
474.46	23.9	17.5	1.37
474.47	25.3	18.2	1.39
474.48	26.8	19.0	1.41
474.49	28.3	19.8	1.43
474.50	29.9	20.6	1.45
474.51	31.5	21.5	1.47
474.52	33.2	22.3	1.49

SANDY RIDGE FACILITY

SURFACE WATER ASSESSMENT AND MANAGEMENT PLAN: ADDENDUM

REPORT FOR TELLUS HOLDINGS

JANUARY 2016

Rockwater
HYDROGEOLOGICAL AND ENVIRONMENTAL CONSULTANTS

Report No. 454-0/15/01adr1

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2 Planned Mining Area and Proposed Levees

REVISION	AUTHOR	REVIEW	ISSUED
Rev 0	P Wharton	P de Broekert	19 November 2015
Rev1	P Wharton		27 January 2016

1 INTRODUCTION

Tellus Holdings commissioned Rockwater Pty Ltd to carry out an investigation of the surface water hydrology and to prepare a preliminary concept surface water management plan for the proposed Sandy Ridge Kaolinite Project at Mt Walton, located about 140 km north-west of Kalgoorlie. A report with the results of the investigation and the management plan was completed in July 2015 (Rockwater, 2015). Since then the proposed layout of the planned mining area has changed, necessitating a revision of the protective bunds proposed for around the mining area.

This addendum presents the additional and revised hydrological and hydraulic calculations, and recommendations for bunds to control surface water flows to prevent them from entering the mining area. It should be read in conjunction with the original (main) report.

2 SURFACE CATCHMENT HYDROLOGY

As discussed in the main report, the area is generally flat with a slightly undulating surface ranging in elevation from approximately 460 m AHD to 500 m AHD, sloping down to the west.

There are no obvious channels or creeks within this area, which is adjacent to, and on a catchment divide. Consequently, surface water management is only required for short-term flows during infrequent high-rainfall events. These flows will be from small local catchments which drain residual runoff after infiltration losses to low-lying depressions. Generally surface water will only be retained for short periods in the depressions due to continuing infiltration. With the larger mining area there will be some drainage towards it from the north, as well as the drainage from the east.

Catchment areas in the vicinity of the mining area were delineated from aerial photography and the 1.0 m and 5.0 m-interval contour plans provided by Tellus Holdings. This information was used in estimating the peak flows as described below.

2.1 HYDROLOGICAL RESULTS FOR CATCHMENT AREAS

Four local catchments have been identified that could result in surface water flows to the planned mining area: catchments B, P1, E and F (Fig. 1). The flow paths of these catchments are shown with the approximate locations of depressions where any residual flow not lost through infiltration could pond until infiltrating or evaporating (Fig. 2).

The characteristics, and estimated peak discharge of these catchments at the boundaries of the planned mining area, for a 1-in-100 year ARI rainfall are given in Table 1 (for catchments E & F, from Rockwater, 2015) and Table 2 (catchments B and P1). The latter catchment is divided into two sub-catchments, P1a and P1b for two separate drainage lines. The peak flows were estimated using the Rational Method as described in the main report and as recommended by AR&R (1987).

Table 1: Characteristics of Catchments E & F, and Estimated Peak 1-in-100 Year Flows

Catchment	Area (km^2)	Stream Length L (km)	Q100 (m^3/s)
E	0.24	0.65	3.9
F	0.26	1.18	3.3

Table 2: Characteristics of Catchments B & P1, and Estimated Peak 1-in-100 Year Flows

Catchment	Area (km^2)	Time of Conc. (hour)	Stream Length L (km)	C10	C100/C10 100Yr	Itcy	Q100 (m^3/s)
B	0.11	0.32	0.30	0.57	1.91	90	2.9
P1a	0.29	0.47	0.60	0.43	1.91	70	4.6
P1b	0.10	0.31	0.14	0.79	1.91	92	3.7

Owing to the very small area of the catchments, the computed 1-in-100 year ARI peak flows in the vicinity of the mine site are relatively small, and range from 2.9 m^3/s to 4.6 m^3/s. These flows all assume the absence of infiltration loss. With infiltration there is likely to be minimal flows in these catchments, if any, a short time after rainfall events, even a high rainfall event.

3 SURFACE CATCHMENT RUNOFF HYDRAULICS

3.1 MANNING'S AND CONTINUITY EQUATIONS

The Manning's and continuity equations were used to identify theoretical flow widths, depths and velocities in the flow paths at the margin of the planned mining area. This information is used in the conceptual design for flood mitigation. Again, no infiltration is assumed.

Manning's equation (Equation 4) was used to estimate flow velocity V (m/s):

$$V = \frac{1}{n} \cdot \left(\frac{A}{P} \right)^{2/3} \cdot (S)^{1/2}$$

Where:

n is a dimensionless roughness coefficient
A is the wetted waterway area (m^2)
P is the wetted perimeter (m)
S is the hydraulic gradient (m/m)

The continuity equation (Equation 5) was used to estimate the flow Q (m^3/s):

$$Q = A \cdot V$$

Where:
A is the waterway area in (m^2)
V is the velocity (m/s)

3.2 HYDRAULIC ANALYSIS FOR MINING AREA

Hydraulic analyses were carried out for five drainage lines that enter the planned mining area. The results for two, from catchments E and F, are described in the main report (cross sections XS1 and XS2) and are included with those for the three additional drainages from catchments B and P1 in Tables 3 and 4 below.

Table 3: Contributing Catchments and Peak Flows

Cross Section/Drainage	Contributing Catchments	100 Year ARI Flow (m^3/s)
XS1	E	3.9
XS2	0.5*F	1.6
B	B	2.9
P1a	0.74*P1	4.6
P1b	0.26*P1	3.7

The hydraulic results for these drainage lines, including the 100-year ARI flood levels, maximum depths, velocities and flood widths are summarised in Table 4.

Table 4: Summary of 100 Year ARI Flood Levels, Depths, Velocity and Widths

Cross-Section/Drainage	100 Year ARI Flow (m^3/s)	Flood Level Elevation (m AHD)	Maximum Depth (mm)	Maximum Velocity (m/s)	Width of Flood Level (m)
XS1	3.9	481.1	90	0.55	88
XS2	1.6	476.2	230	0.56	27
B	2.9	478.0	150	0.72	54
P1a	4.6	478.1	260	0.78	40
P1b	3.7	477.3	240	0.72	43

Infiltration losses will reduce the maximum depths of flow in the drainages (Table 5), that will occur at or near the end of each rainfall event.

Table 5: Maximum Flow Depths in Each Drainage

Calc. Peak Flow Depth (mm)		
Cross-section /Drainage	Without Infiltration	With Infiltration
B	150	120
P1a	260	220
P1b	240	215
XS1	90	30
XS2	230	170

3.3 WATER MANAGEMENT REQUIREMENTS

Bunding/levees will be required on the western part of the northern boundary and southern part of the eastern boundary of the planned mining area to prevent runoff from entering the area and to drain water away. As discussed in the main report these levees can form part of the normal safety bunds that are constructed around the mining area, and need to be up to 500 mm high (or more) to cope with runoff in high rainfall events with a margin for safety. Even without drainage, most or all of the water ponding behind the levees would infiltrate in a short time.

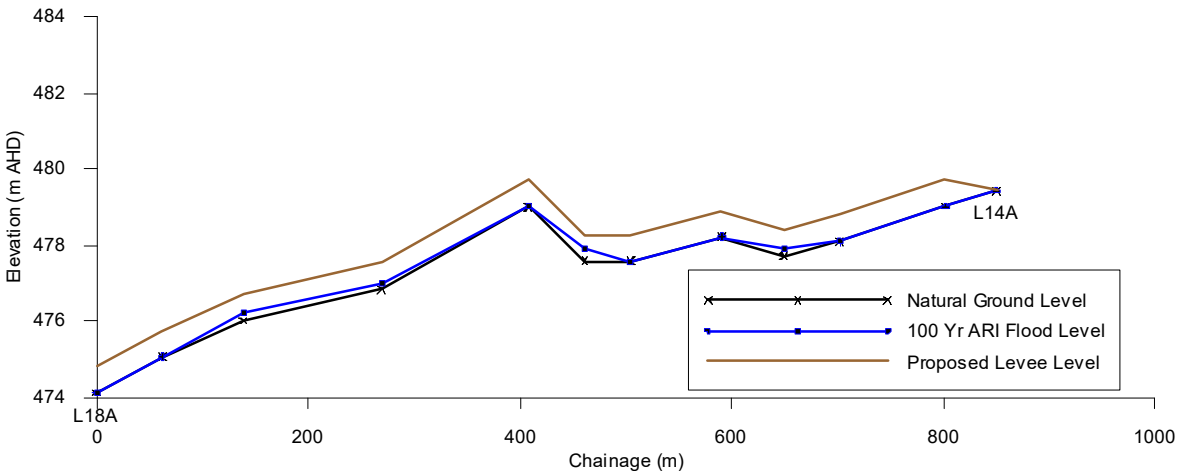
The requirements for each of the levees are discussed below.

3.2.1 Northern Levee

Flows in one drainage line from Catchment B and two drainage lines from catchment P1 (Fig. 1) could directly impact the mining area. The 100-year ARI peak flows of 2.9 to 4.6 m^3/s would have relatively low velocities, be 40 to 54 m wide, and up to 220 mm deep.

The results suggest that even with a freeboard allowance of 500 mm and the overly-conservative peak flows, the minimum flood mitigation levee requirement at the northern boundary of the mining area is lower than the typical nominal 1 m-high safety bund around a pit. Therefore, it is recommended that the safety bund be strategically located and constructed to act as both a safety bund and a flood mitigation levee along the alignment shown in Fig. 2. A long-section of the proposed levee is shown below.

Text-Figure 1: Long Section of Proposed Levee L14a–L18a



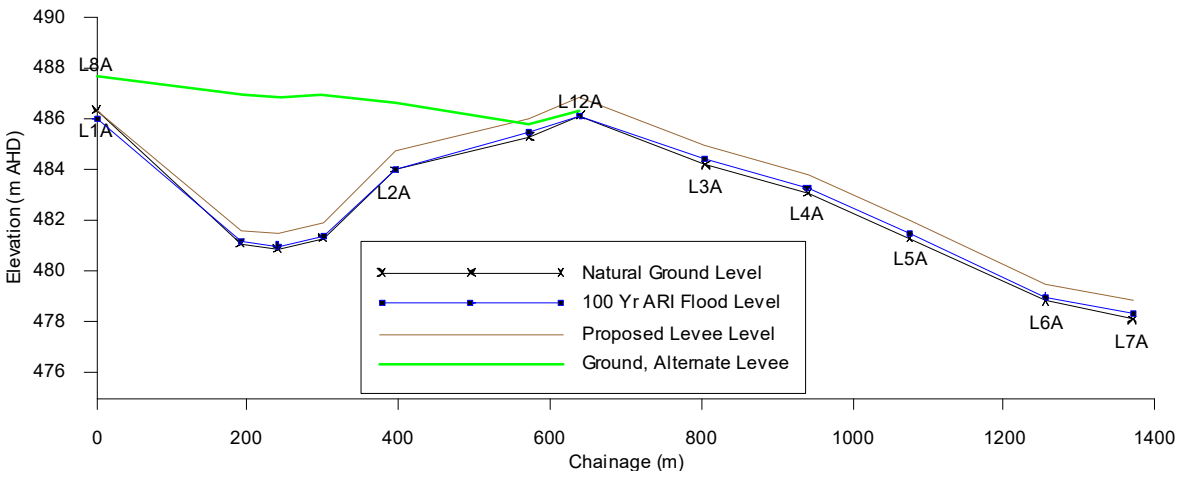
The natural topography along this levee will require minimal grading to promote the flow of runoff to the west from where it will flow south towards depression D1 (Fig. 2).

3.2.2 Eastern Levee

The eastern levee, L1a to L7a (Fig. 2) is generally as proposed in the main report, to direct water flowing towards the mining area and plant site to the south, towards depression D4 (Fig. 2). A nominal 1 m-high bund is recommended from L1a to L7a to intercept and divert the flows from catchments E, F, G, H and I. The flows will be similar to those to the northern boundary of the mining area.

Without substantial modification to the natural topography, the flows from catchment E would generally pond behind the levee prior to infiltrating the ground, in a low area between L1a and L2A shown below.

Text-Figure 2: Long Section of Proposed Levee L1a–L7a, and L8a–L12a



Provided the levee can be constructed outside of the mining tenement, it should be re-aligned to the alternate shown above and in Fig. 2, to minimise the grading required so that all runoff is diverted to the south.

4 CONCLUSIONS

The planned mining area is unaffected by any major flow paths, and surface water management is only required for short-term flows during rare high rainfall events. These flows are generally from very small local catchments which drain residual runoff after infiltration losses to low-lying depressions. Generally water will only be retained for very short periods in the depressions due to continuing infiltration loss. Water could pond for longer periods if the depressions are clay pans. Evaporation will contribute to the loss of ponded water.

Based on the maximum recorded rainfalls in the area and typical infiltration rates for sandy and sandy loam soils, it is concluded that the peak flows estimated using the only Rational Method for the arid interior region of WA are over-estimated. However, the Rational Method was used in the hydraulic analysis for conceptual design of flood management works. Site observations of actual flows following rainfall events should be collected as they will play an important role in refining the water management requirements in the detailed design stage.

It is recommended that two levees L14a to L18a and L8a to L7a (Figure 2) be constructed to divert peak flows around the mining and plant areas. The natural topography along these levees would require minimal grading.

Dated: **27 January 2016** **Rockwater Pty Ltd**

P H Wharton
Principal

REFERENCES

Australian Rainfall and Runoff, 1987, A Guide to Flood Estimation, Volume 1. The Institution of Engineers, Australia, Canberra.

Rockwater, 2015, Sandy Ridge Kaolinite Project, surface water assessment and management plan. Report for Tellus Holdings.

FIGURES

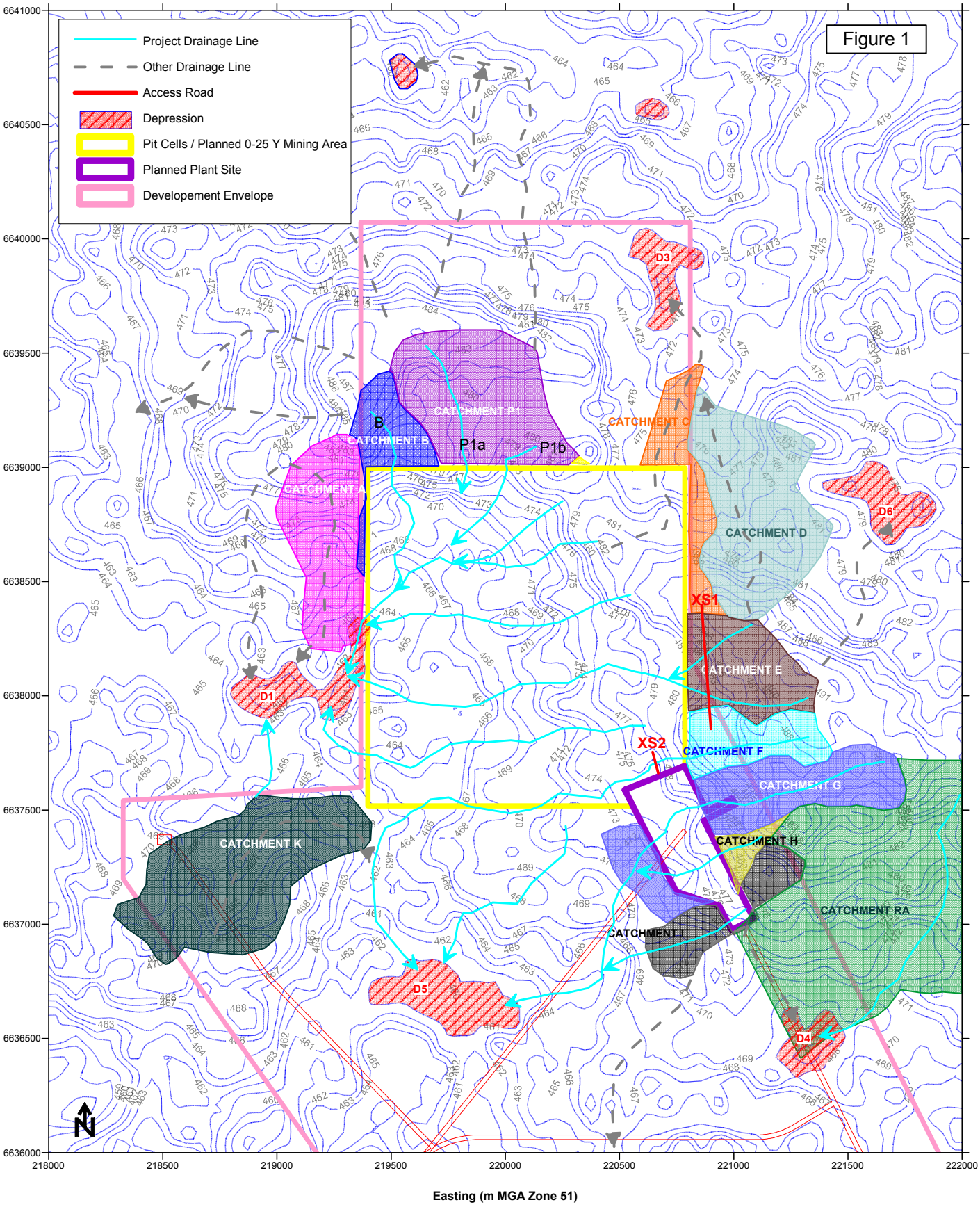


Fig.1 Catchment Areas and Locations of Depressions.srf

Client: Tellus Holdings

Project: Sandy Ridge Project

Date: November 2015

Dwg. No: 454-0/15/1a-1

CATCHMENT AREAS AND LOCATIONS OF DEPRESSIONS

Rockwater

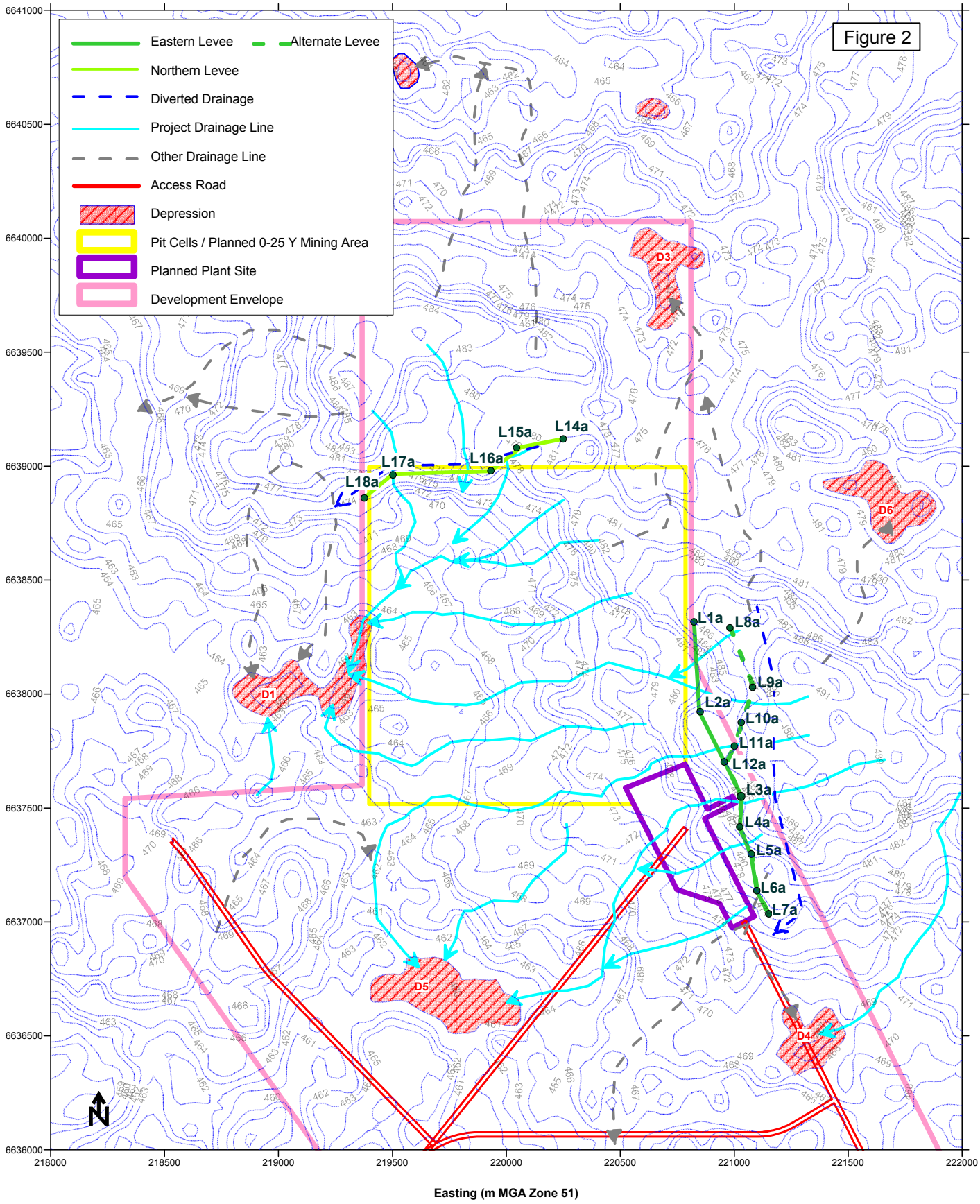


Fig.2 Final Mine Proposed Levee.srf

Client: Tellus Holdings

Project: Sandy Ridge Project

Date: November 2015

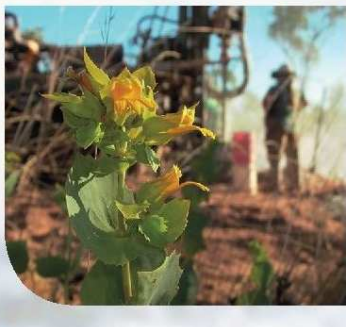
Dwg. No: 454-0/15/1a-2

PLANNED MINING AREA AND PROPOSED LEVEES

Rockwater

Hydrogeology Assessment

TELLUS



HYDROGEOLOGICAL STUDIES FOR THE SANDY RIDGE PROJECT

DRILLING, PERMEABILITY TESTING AND POTENTIAL WATER SOURCES REPORT

REPORT FOR TELLUS HOLDINGS

AUGUST 2015

Rockwater
HYDROGEOLOGICAL AND ENVIRONMENTAL CONSULTANTS

Report No. {454-0/15/01c}

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5 Wet and Dry Drillhole Locations

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II Permeability Test Plots and Calculations

REVISION	AUTHOR	REVIEW	ISSUED
Rev 0	R Wroe	P Wharton	28/7/15
Rev1	R Wroe	P Wharton	11/8/15
Rev2	C Kasperkiewicz	P Wharton	3/11/15

1 INTRODUCTION

Tellus Holdings Limited (Tellus) is proposing to develop a kaolin mine at its Sandy Ridge project at Mount Walton, approximately 140 km north-west of Kalgoorlie (Fig. 1). It plans to utilise mined-out pits for a complementary storage and waste disposal business.

Rockwater was engaged to make an assessment of the hydrogeology and hydrology of the project area. The hydrogeological assessment is to include the characteristics of any groundwater at the site, and a desk-top study of potential water sources for the project. A water supply of about 120 kL/d will be needed for processing the kaolinite, plus water for dust suppression and compaction (possibly about 495 kL/d in total).

This report includes:

1. The results of a desk-top study of the hydrogeology of the project area;
2. The results of drilling, monitoring bore construction and permeability testing conducted in March 2015;
3. The characteristics of groundwater at the site; and
4. A desk-top study of potential water sources for the project.

The surface water study results and the protection required for mine pits are covered in a separate report.

1.1 PREVIOUS INVESTIGATIONS

Hirschberg (1988) conducted a hydrogeological reconnaissance of Mt Walton Northeast Area A which included the area now used for the Mt Walton waste facility, and Sandy Ridge, and found the area to be generally suitable for the disposal of hazardous wastes, but recommended drilling to prove it up. Marcos (1988) made a preliminary appraisal of the same area from a geotechnical perspective, although that report has not been reviewed for this report.

Soil & Rock Engineering (1989) conducted a geotechnical investigation of the Mt Walton waste facility site. Four holes were drilled by coring techniques, and eight holes were drilled using air-hammer and air-core methods. No groundwater indications were obtained from the first four holes, as mud was used for circulation. The other holes intersected sand to depths of up to 1.5 m, overlying gravel to depths of up to 2.6 m, and then weathered to fresh granite. They were all dry. Permeability tests conducted on four of the air-core holes gave approximate permeabilities of the weathered granite ranging from 2.5×10^{-8} m/sec to 3.2×10^{-7} m/sec.

ATA (1995) conducted a drilling programme at Mt Walton, as well as an additional nine holes on a 1.8 km grid in a 25 km^2 area to the north-west that includes the Sandy Ridge project area. Sandy Ridge lies within the central to south-western part of the ATA grid. No groundwater was intersected in the ATA holes, although some dampness was recorded in the south-western-most hole (No. 61) of those in the western (Sandy Ridge) area (Fig. 2). The holes in the western area had depths to basement of 20.5 m to 44 m, and kaolinite thicknesses of 11 m to 38 m.

The Department of Water WIR database was checked for any bore data in the Sandy Ridge region. There are none (other than investigation holes at the Mt Walton site) – the nearest are water-supply bores constructed at sites selected by Rockwater for the Mt Dimer gold mine, 23 km or more to the west.

The Sandy Ridge site is in an area characterised by Kern (1994) as weathered granitoid rock with minor groundwater resources.

2 METHODOLOGY

2.1 DRILLING AND MONITORING BORE CONSTRUCTION

Investigation holes/monitoring bores were drilled and constructed at seven sites in the project area (Fig. 2) to depths in the range 21 to 49 m below ground level (bgl). They were completed by Wallis Drilling on the 14 and 15 April using a Mantus 300 drilling rig and reverse-circulation air-core and air-hammer drilling techniques at a diameter of 152 mm.

All sites were within the planned mining area, except for bore SRMB150 which is located close to the western boundary. Bores SRMB150 to 152) targeted an area where the fresh granite was known to be deep and so it was more likely that groundwater would be intersected.

The air-core drilling method resulted in very slow penetration rates or bit refusal through hard silcrete layers. These hard layers were typically intersected around 8 m below the surface. Also, the sampling cyclone was prone to blockage in drilling the silcrete. Where possible, air-core methods were used to drill the entire hole, otherwise air-hammer techniques were used through the silcrete before switching back to an air-core bit. For more details on drilling methods for each bore see Appendix I.

The holes were continued until bit refusal with air-core methods, in weathered or fresh granite, and were geologically logged.

All the holes were cased with 55 mm ID, 61 mm OD, Class 9 blank and slotted PVC casing (1 mm aperture) as monitoring bores. Surface casing consisted of 127 mm ID, 145 mm OD steel casing. The annuli of slotted sections of the bores were packed with 1.6 to 3.2 mm graded gravel with a 4 m bentonite seal installed above the gravel pack. Above the bentonite, the annuli were back-filled to the surface with drill cuttings, and a 150 mm ND galvanised bore cover with lockable lid was set in place (with concrete) to protect the bores at the surface. Bore construction details are summarised in Table 1 (Page 4) and details are included in Appendix I. The bore design is shown in Figure 3.

2.2 MONITORING BORE PERMEABILITY TESTS

Falling-head permeability tests were conducted on each of the seven monitoring bores. A slug of water (9 L or 18 L) was poured into the uPVC casing of each bore, and water-level recession was monitored using manual measurements and a pressure transducer/data logger.

In the four bores where no water was intersected (SRMB 146, 147, 148 and 149), kaolinite or highly weathered granite was being tested. Where water was intersected (SRMB150 to 152) the transition zone (weathered granite) was being tested.

The data for bores SRMB 146, 147, 148 and 149 were analysed using the method of Oosterbaan and Nijland (1994) for calculating permeability (hydraulic conductivity) of material above the water table; and the Bouwer and Rice (1976) method was used for bores SRMB150 to 152 where the water table was intersected.

3 RESULTS

3.1 GEOLOGY

All seven holes intersected a typical granite weathering profile with generally 2 to 3 m of surficial aeolian sand overlying up to 8 m of silcreted clay and/or laterite, then mottled and pallid zone clays/very deeply to completely weathered granite; with slightly weathered to fresh granite at depth in the deep holes and from 26 to 31 m depth in SRMB146. Geological logs are included with the bore completion data in Appendix I.

Minor vugs were noted in the silcrete, clay, kaolinite and weathered granite. An example is shown in the photograph in Page 5, below.

Geological sections prepared for Tellus by Terra Search, and the results of this drilling, show that the top of the moderately weathered to fresh granite is generally at lower elevations to the west and north of the project area (Fig. 4).

Table 1: Monitoring Bore Construction Details

Bore	Const. Date	Easting (mE)	Northing (mN)	RLGL (DTM) (mAHD)	Casing Depth (mbtoc)[3]	Casing Material	Casing I.D. (mm)	PVC (magl)[4]	Steel (magl)	Slotted Interval (mbgl)[5]	Water Level			Airlift Yield[1] (L/s)	Salinity[2] (mg/L TDS)
											6/05/15 (mbtoc)	30/07/15 (mbtoc)	19/10/15 (mbtoc)		
SRMB146	16/03/15	219888	6637794	466.8	30.5	PVC	55	0.66	0.88	24.5-30.5	wet at base	wet at base	30.5 (base)	dry	n/a
SRMB147	16/03/15	219890	6638007	465.7	20.6	PVC	55	0.88	0.88	14.6-20.6	wet at base	wet at base	mud at base	dry	n/a
SRMB148	16/03/15	219702	6637808	463.9	24.3	PVC	55	0.89	1.00	18.3-24.3	dry	wet at base	23.82	dry	n/a
SRMB149	16/03/15	220238	6637886	471.6	22.9	PVC	55	1.06	1.15	16.9-22.9	dry	wet at base	mud at base	dry	n/a
SRMB150	17/03/15	219372	6638392	463.9	49.0	PVC	55	0.92	1.07	40.0-49.0	36.10	35.92	35.99	0.03	6565
SRMB151	17/03/15	219681	6638402	465.3	44.7	PVC	55	0.58	0.58	38.7-44.7	36.65	36.52	mud at base?	moist at 36m, nil	n/a
SRMB152	17/03/15	219499	6637606	464.1	38.4	PVC	55	0.54	0.54	32.4-38.4	34.35	34.14	34.22	<0.01	6032

Airlift yield from open hole

Salinity as TDS calculated from field EC (electrical conductivity)

m btoc = metres below top of casing, steel

m agl = metres above ground level

m bgl = metres below ground level

Vugs in weathered granite from 18 m depth, SRMB148

3.2 HYDROGEOLOGY

Four of the bores (SRMB146 to 149) were dry when drilled, and two remained dry when sounded in May 2015 (Table 1). The other two bores (SRMB146 and 147) had a thin layer of water in their bases, as did all four bores in July and October 2015 – at levels well above that of the water table in the deep bores. The water is residual water that remains following the falling-head permeability tests and/or very minor seepage water.

Very small quantities of groundwater were airlifted from bores SRMB150 (~0.03 L/s) and SRMB152 (<0.01 L/s) when they were drilled, and those two bores and SRMB151 contained groundwater when they were sounded in May to October 2015. The static water levels on 6 May 2015 were 34.4 to 36.7 mbtoc (below the top of the casings), and at elevations of 428.9 to 430.3 m AHD. Water levels in the bores were 0.13 to 0.21 m higher on 30 July than on 6 May even though there had been no significant rainfalls between the two monitoring events, and it is likely that the higher levels on 30 July resulted from continuing slow water-level recovery following bore construction, or low barometric pressures prior to a major rainfall event on 31 July and 1 August: 69 mm fell at Koolyanobbing on those two days. Water levels on 19 October were recorded at

34.2 mbtoc (bore SRMB152) and 36 mbtoc (bore SRMB150), similar to levels recorded in July 2015.

The water from bores SRMB150 and 152 is saline, with salinities of 6,570 and 6,030 mg/L TDS (total dissolved solids), respectively.

All three bores that intersected groundwater had a water level at a depth lower than the planned excavation depth of 30 m. Bore SRMB150 had the shallowest water level (34.23 mbtoc) on 6 May 2015, this bore is located outside of the mining area. The low airlift yields and low permeabilities (Section 3.3) show that the zones containing the groundwater do not constitute an aquifer.

Assuming the groundwater levels have reached near equilibrium (static) levels, they indicate that the groundwater flows to the north-west under a low hydraulic gradient.

All of the kaolinite exploration holes drilled by Tellus were dry. Five of them intersected some damp kaolinite/weathered granite in the planned mining area (Fig. 5). One of those two holes (the southern-most) intersected a damp zone above the base of the kaolinite (Fig. 6).

In summary, only negligible groundwater has been intersected in the planned mining area, at a depth below the planned excavations, and only one hole in the south-western part of that area intersected damp kaolinite.

3.3 MONITORING BORE PERMEABILITY TESTS

The falling-head test data were analysed using the method of Bouwer and Rice (1976) for those bores that intersected the water table (SRMB150 to 152); and Oosterbaan and Nijland (1994) for the dry bores (SRMB146 to 149) to determine permeability (hydraulic conductivity). Plots and calculations are given in Appendix II and the results are summarised in Table 2.

The hydraulic conductivities ranged from 0.02 to 0.99 m/day. Those calculated using the Oosterbaan and Nijland (1994) method (SRMB146 to 149) should be considered as first estimates only, as the method assumes that material in the test interval is saturated prior to testing. In reality the material was not saturated, and so the hydraulic conductivities obtained are probably higher than the true values. The values from the tests on SRMB150 to 152 – analysed by the Bouwer and Rice method – ranged from 0.02 to 0.33 m/d. These low to moderately low values are in the range of values commonly assigned to clayey/silty sand.

Table 2: Results of Permeability Testing, Monitoring Bores

Bore	Test No.	KH (m/d)	KH (m/s)	Lithology of screened Interval
SRMB146	1	0.14	1.62E-06	Kaolinite, & deeply weathered granite
SRMB146	2	0.12	1.39E-06	
SRMB147	1	0.93	1.08E-05	Kaolinite (saprolite)
SRMB148	1	0.99	1.15E-05	Kaolinite (weathered granite)
SRMB149	1	0.39	4.51E-06	Weathered granite
SRMB149	2	0.22	2.55E-06	
SRMB150	1	0.03	3.47E-07	Weathered & fresh granite
SRMB150	2	0.02	2.31E-07	
SRMB151	1	0.33	3.82E-06	Mod. to slightly weathered granite
SRMB152	1	0.19	2.20E-06	Weathered granite
SRMB152	2	0.18	2.08E-06	

*KH = hydraulic conductivity (horizontal) = permeability.

4 WATER SUPPLY ASSESSMENT

A water supply of 180,000 kL per annum (~495 kL/d or about 6 L/s) will be required when mining and mineral processing is ramped-up to full production. Initially a much smaller volume would be required.

There are two untested areas with good potential for obtaining saline groundwater supplies, although neither is close to the project. One is 12 to 15 km to the south-west and south of Sandy Ridge on tenements held by Polaris Metals where several south-westerly trending drainage lines cross a chert ridge in the Yendilberin Hills (Fig. 7). These drainages appear to be following cross-cutting faults. The other is a probable palaeochannel aquifer, 16 km to the east of Sandy Ridge that is interpreted to follow a north-south chain of saline playas. It is covered by a Miscellaneous Licence held by Norilsk Nickel.

Groundwater in both areas is expected to be saline: about 20,000 mg/L TDS in the south-western area, and possibly around 100,000 mg/L TDS in the eastern area.

The most practical source of water for the project is probably the Carina iron ore mine owned by Polaris Metals Pty Ltd. The Carina mine is located 12 km south-west of Sandy Ridge in the Yendilberin Hills. The hills are a narrow, approximately north-west- to south-east-trending rocky ridge composed principally of banded chert and ferruginous banded chert with minor BIF and quartzite (Fig. 7).

At Carina the goethite-hematite orebody constitutes the main aquifer. The ore is known to be highly vuggy and locally cavernous with a correspondingly high permeability. The adjoining mafic rocks appear to be relatively unfractured and, excluding the contact zones between the BIF and country rock which are often highly permeable groundwater conduits, only minor aquifers exist outside of the major ore-body aquifer.

The water at Carina has salinity of about 33,000 mg/L TDS (similar to seawater). If used for dust suppression the application of water will need to be carefully controlled to prevent runoff or over-spray into vegetated areas.

Based on climatic records from Kalgoorlie, the long-term average potential evaporation of the area is about 2,650 mm, with evaporation greatly exceeding rainfall during every month of the year. Groundwater recharge is therefore limited, probably being restricted to more-intense, short-term rainfall events when rainfall exceeds evaporation.

Prior to the commencement of mining at Carina, groundwater levels ranged from 40 to 70 m below ground level, depending on ground elevation. Mine dewatering commenced in mid-2011, and pumping rates in 2014/15 have averaged about 2,000 kL/d, and are expected to increase to around 3,000 kL/d. The water is currently stored in a series of turkeys nest dams and is used for dust suppression, ore processing and camp use. An unknown quantity is evaporated or lost as seepage back into the ground.

The volume of water required by Tellus for the Sandy Ridge project (180,000 kL/a) represents only a small fraction of the quantity being pumped and should be readily available from the Carina mine, and would reduce the quantity of water lost by evaporation and seepage by a similar amount. The impact of the usage by Tellus would, therefore, be negligible.

The nearest groundwater licence (GWL) to the Carina mine groundwater licence (GWL 177188) is GWL166014 held by Rob Hoppmann Mining Pty Ltd, 10 km to the north-north-west, for 200 kL/a. It is highly unlikely that utilising the excess water from Carina mine will have any impact on GWL166014 which is across-strike in a different stratigraphic unit.

5 CONCLUSIONS

The Sandy Ridge project is in an area underlain by granitic rocks where there is a thick weathering profile. Little or no groundwater has been intersected within the project area, in either the mineral exploration drilling or the 2015 investigation programme conducted by Rockwater. One mineral exploration hole intersected damp kaolinite within the planned mining area.

Three holes located in areas of greater depth to fresh granite, in the west and south-western parts of the project area, intersected small quantities of moderately saline groundwater (6,000 to 7,000 mg/L TDS). Airlift water yields ranged from zero to about 0.03 L/s, and permeabilities of the water-bearing zones were low, showing they do not constitute an aquifer.

The kaolinite and weathered granite are indicated to be of low to moderately low permeability (0.02 to 0.99 m/d, or 2.3E-07 to 1.2E-05 m/s). Permeability values for the dry holes should be taken as first estimates and are probably higher than actual values, because of limitations of the test method.

The most practical source of water for the project is probably the Carina iron ore mine, located 12 km south-west of Sandy Ridge in the Yendilberin Hills, where there is abundant water available from the pit and/or dewatering bores (up to 3,000 kL/d). The water has a salinity of about 33,000 mg/L TDS. It is highly unlikely that accessing water from Carina mine will have any additional impact at Carina because the volume sought is small and will replace water that is currently lost by evaporation and seepage. Also, the mine is remote (at least 10 km) from other groundwater users (except Polaris Metals).

Dated: 3 November 2015 **Rockwater Pty Ltd**

P H Wharton
Principal

R Wroe
Project Hydrogeologist

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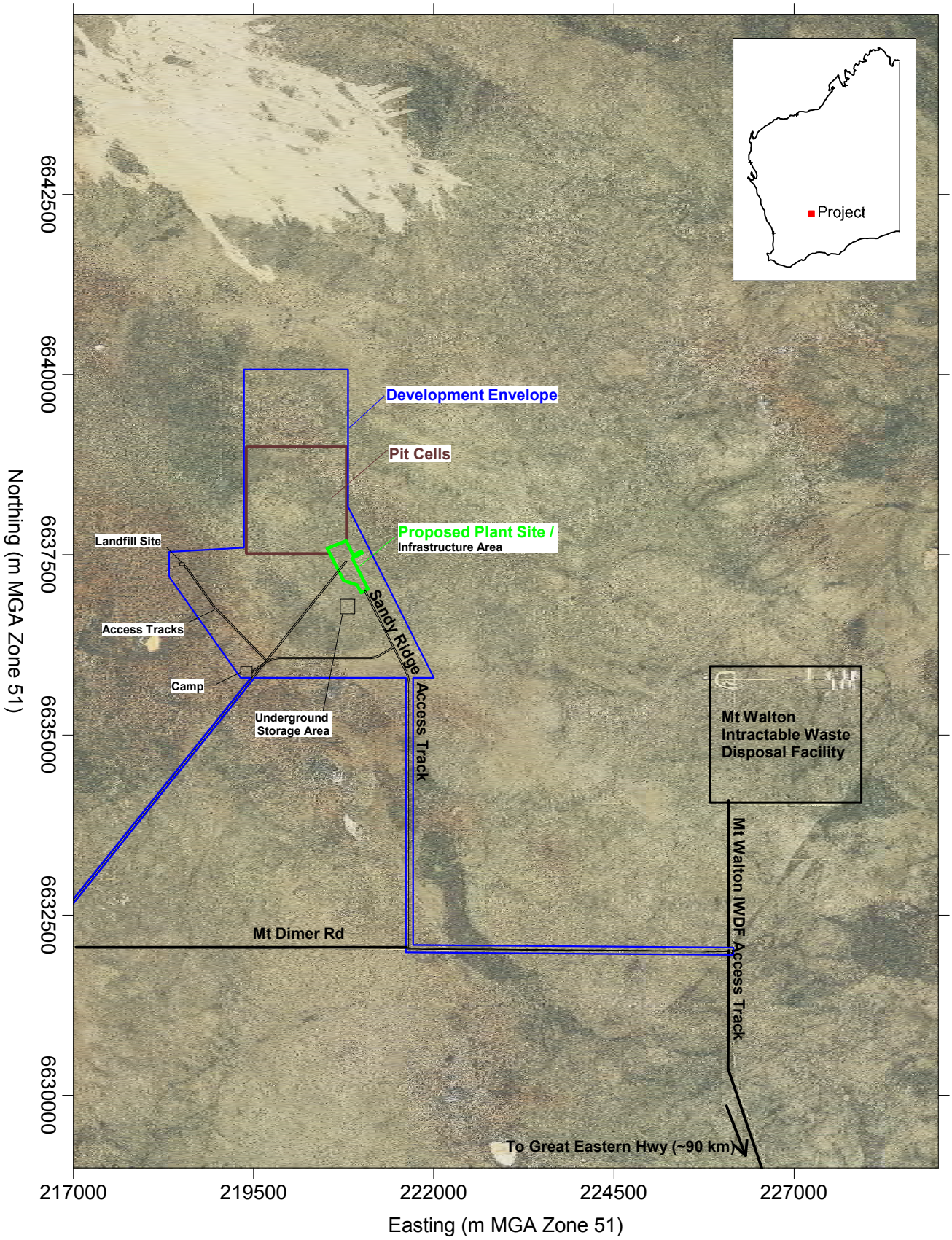
FIGURES

Figure 1



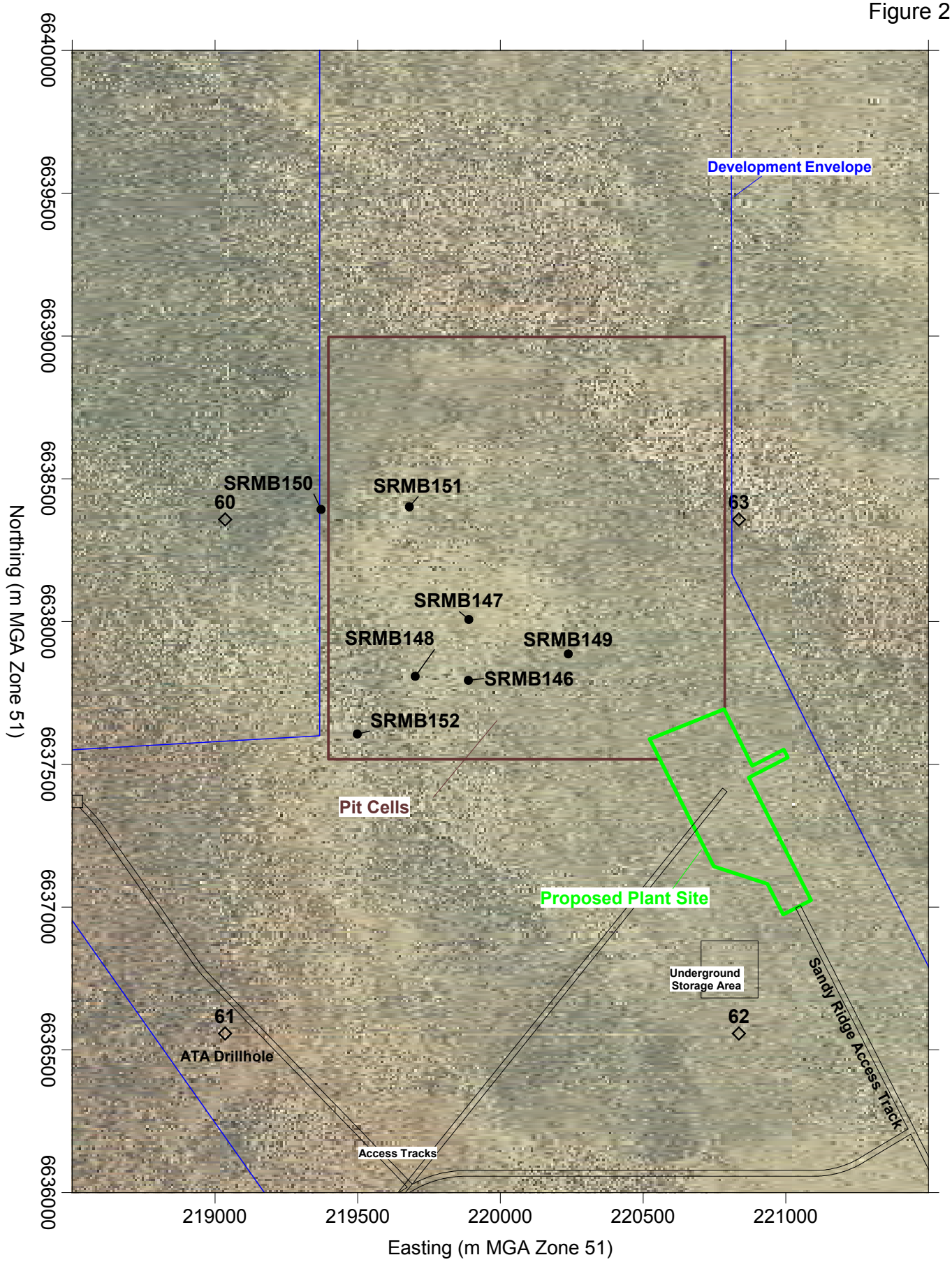
454-0/Surfer/15-001/Fig. 1.srf

CLIENT:	Tellus Holdings
PROJECT:	Sandy Ridge
DATE:	October 2015
Dwg. No:	454-0/15/01-1

PROJECT LOCATION

Rockwater PROPRIETARY LIMITED

Figure 2



454-0/Surfer/15-001/Fig. 2.srf

CLIENT: Tellus Holdings

PROJECT: Sandy Ridge

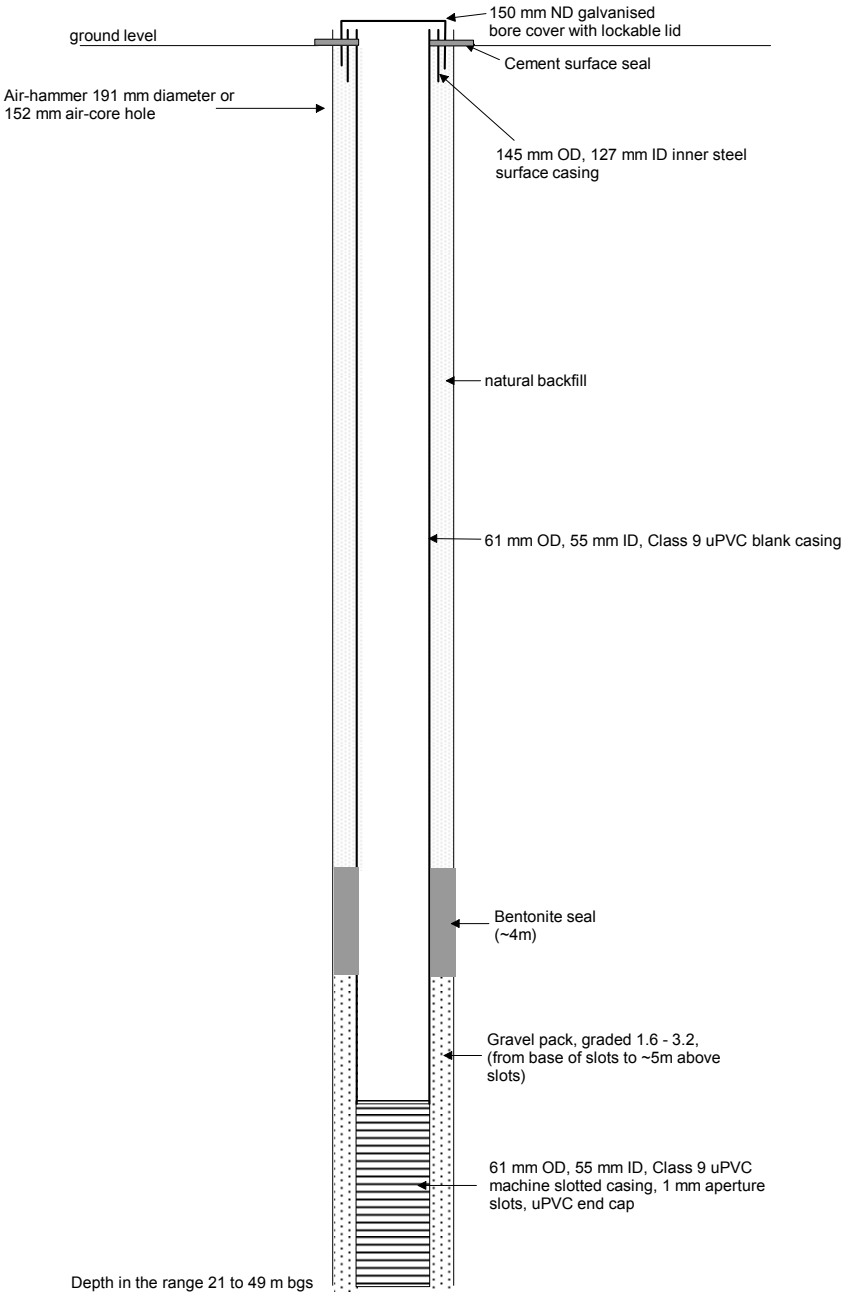
DATE: October 2015

Dwg. No: 454-0/15/01-2

BORE LOCATIONS

Rockwater PROPRIETARY LIMITED

Figure 3



NOT TO SCALE

454-0/Surfer/15-001/Fig. 3 Conceptual Log.grf

CLIENT: Tellus Holdings

PROJECT: Sandy Ridge

DATE: June 2015

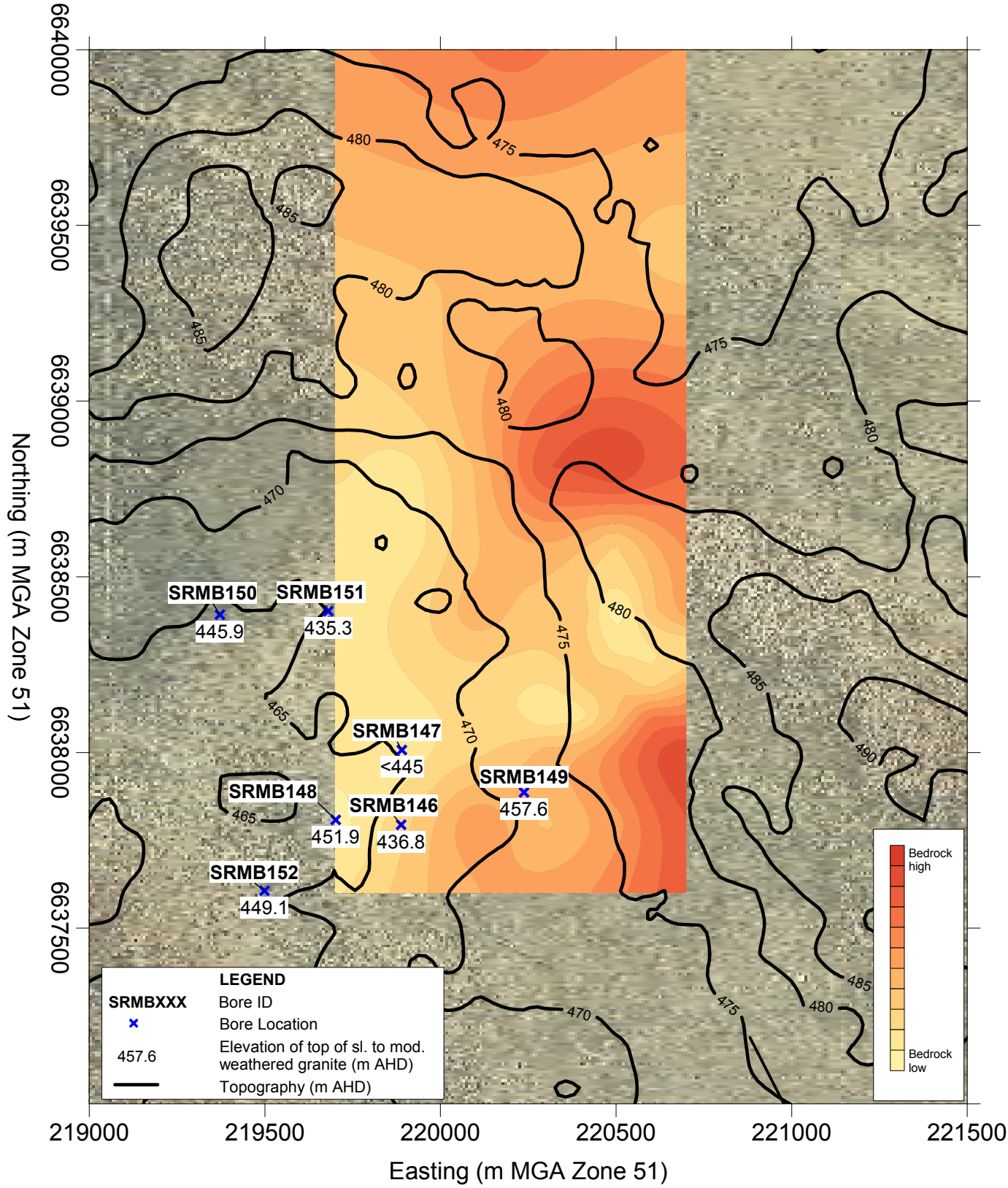
Dwg. No: 454.0/15/01-3

GENERAL CONSTRUCTION DIAGRAM

FOR MONITORING BORES

Rockwater

Figure 4



454-0/Surfer/15-001/Fig. 4.srf

CLIENT: Tellus Holdings

PROJECT: Sandy Ridge

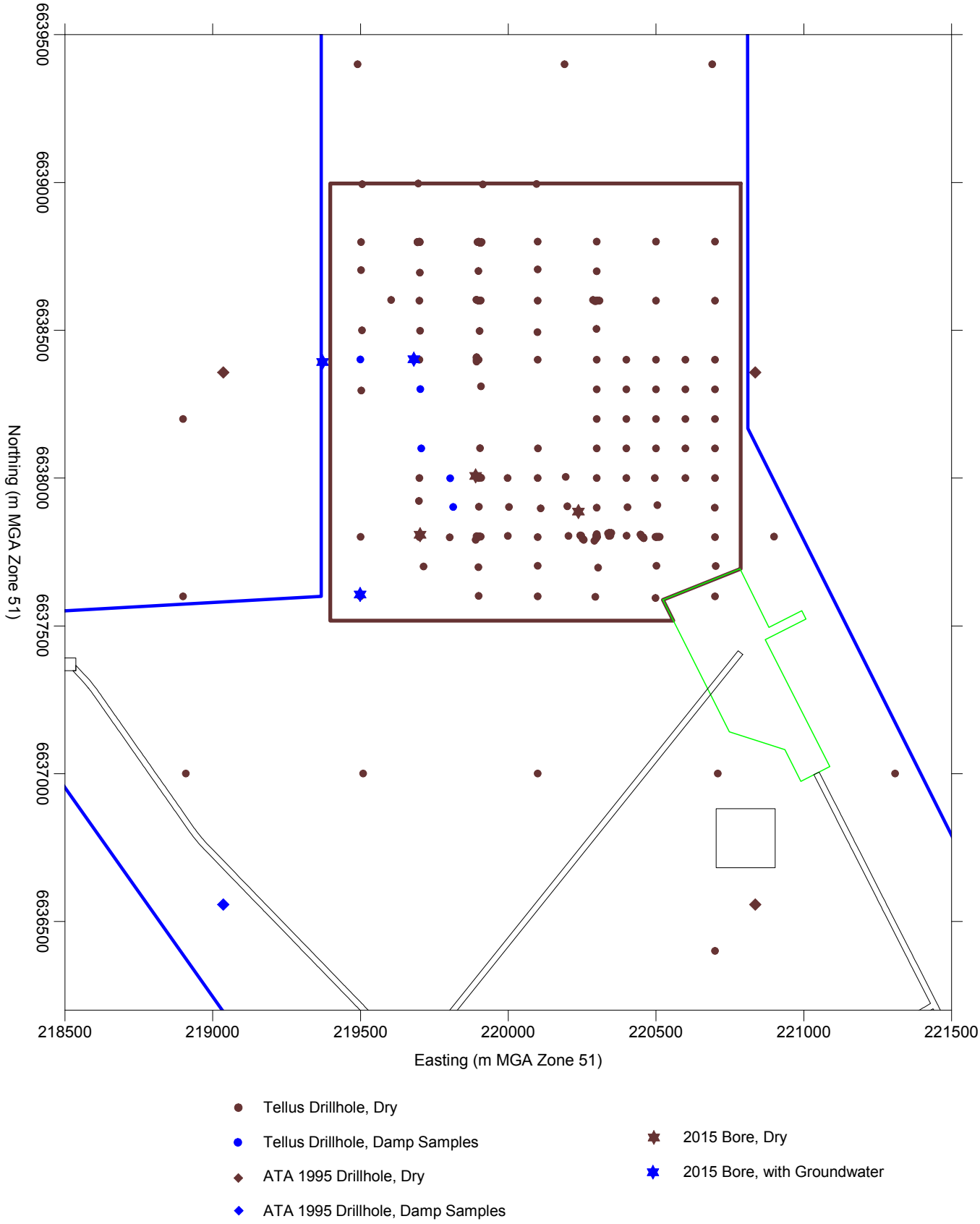
DATE: October 2015

Dwg. No: 454-0/15/01-4

GROUND-SURFACE TOPOGRAPHY, & ELEVATION OF TOP OF WEATHERED GRANITE

Rockwater PROPRIETARY LIMITED

Figure 5



454-0/Surfer/15-001/Fig. 5.srf

CLIENT: Tellus Holdings

PROJECT: Sandy Ridge

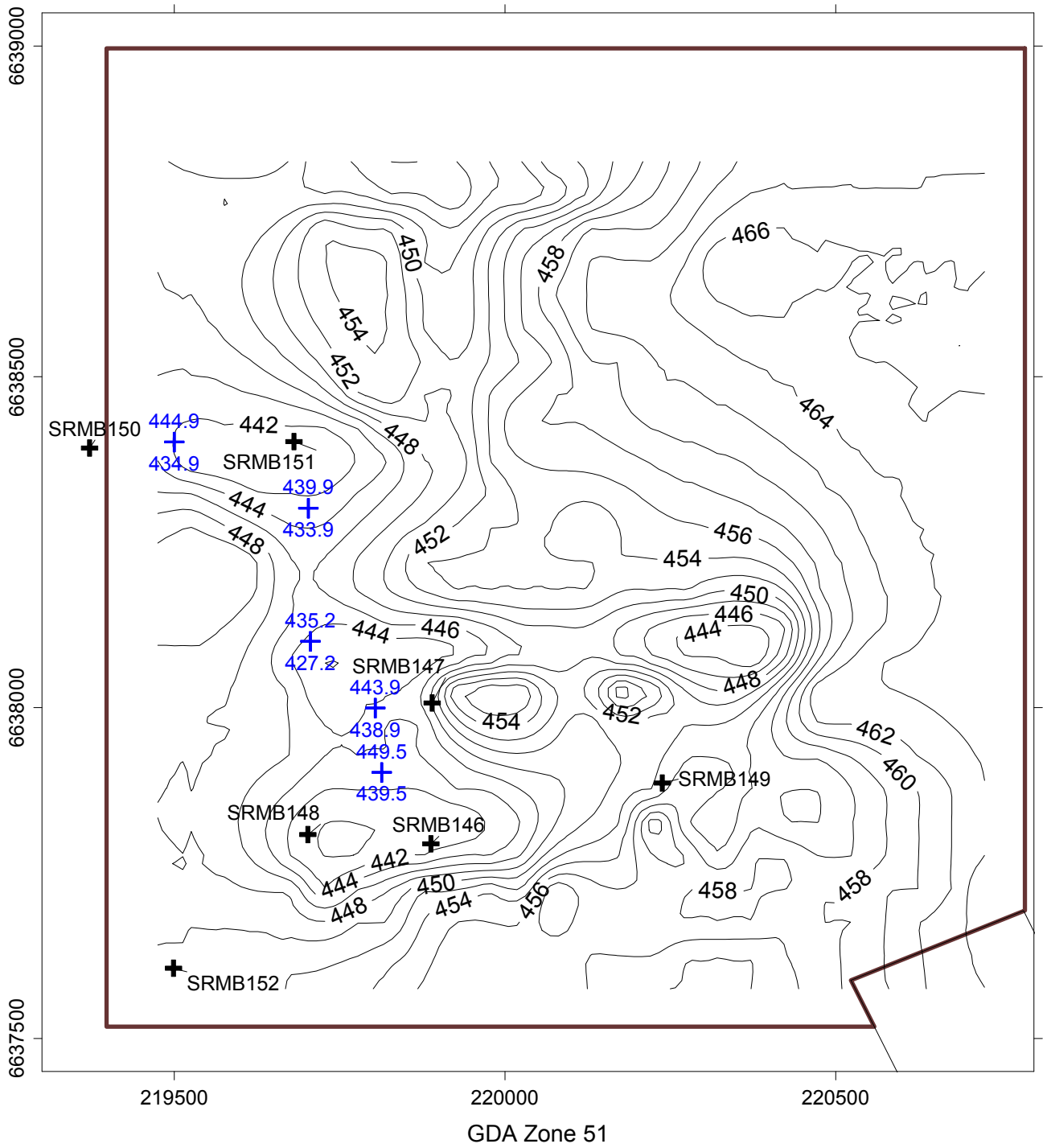
DATE: October 2015

Dwg. No: 454-0/15/01-5

WET AND DRY DRILLHOLE LOCATIONS

Rockwater PROPRIETARY LIMITED

Figure 6



439.9 Elevation, top of damp zone
Damp Drillhole
433.9 Elevation, base of damp zone

—440— Contours: Base of Kaolinite

Pit Cells

Fig. 6 _Base of Kaolinite.srf

CLIENT: Tellus Holdings

PROJECT: Sandy Ridge

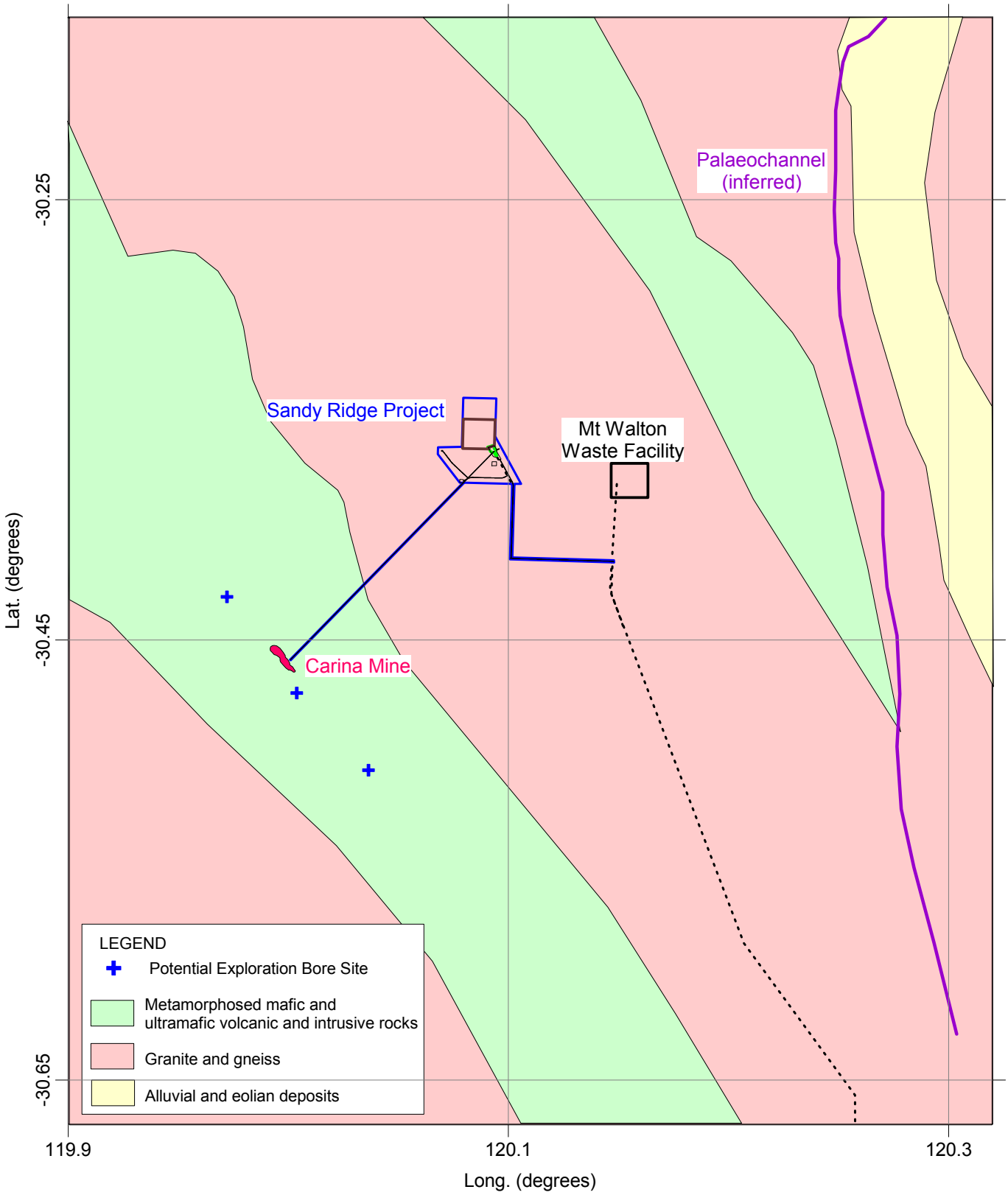
DATE: October 2015

Dwg. No: 454-0/15/01-6

ELEVATION (m AHD) BASE OF KAOLINITE AND DAMP ZONES

Rockwater PROPRIETARY LIMITED

Figure 7



454-0/Surfer/15-001/Fig. 7.srf

Base: State Geological map from Department of Mines and Petroleum

CLIENT: Tellus Holdings	POTENTIAL WATER SOURCES
PROJECT: Sandy Ridge	
DATE: October 2015	
Dwg. No: 454-0/15/01-7	

Rockwater PROPRIETARY LIMITED

APPENDIX I

BORE COMPLETION DATA

MONITORING BORE DATA – SRMB146

PROJECT:	SANDY RIDGE
Bore No:	**SRMB146**
Location:	Mt Walton
GDA Coordinates:	219,888 mE 6,637,794 mN
Status:	Monitoring bore
Date Commenced:	15/03/2015
Date Completed:	16/03/2015
Drilling Contractor:	Wallis Drilling
Drilling Rig:	Mantus 300
Depth Drilled:	31 m
Drilling Details:	0 to 7 m, 191 mm air-hammer 7 to 31 m, 152 mm air-core
Casing Details:	+0.88 to 0.42 m, 150 mm ND galvanised well cover with lockable lid +0.73 to 1.27 m, 145 mm OD, 127 mm ID inner steel casing +0.66 to 24.5 m, 61 mm OD, 55 mm ID, Class 9 uPVC blank casing . 24.5 to 30.5 m, 61 mm OD, 55 mm ID, Class 9 uPVC machine slotted casing, 1 mm aperture slots
Pack Interval:	23.3 to 30.5 m graded gravel pack (1.6 – 3.2 mm) 19.3 to 23.3 m bentonite seal 0.2 to 19.3 m backfill 0 to 0.2 m concrete
Reference Point Description:	top of galvanised lid
Height of Casing Above Ground:	+0.88 m

MONITORING BORE DATA – SRMB146 (continued)

Reference Point Elevation: 467.7 mAHD

Pumping Tests: Nil

Static Water Level: 30.55 m btoc or 437.1 m AHD (6/5/2015)

Lithology:

Depth		Lithology	Description
From	To		
0	2	Sand	Sandy cover
2	3	Laterite	Ferricrete/iron rich zone +/- pisolites
3	6	No sample returns	
6	7	Silcrete	Siliceous zone
7	10	Mottled Zone	Iron oxide stained saprolite
10	26	Kaolinite	White clay rich saprolite zone
26	30	Saprock	Strongly weathered zone with some original feldspar, non-white
30	31	Granite	Moderately weathered to fresh granite
		End of Hole	

NB: Lithology log provided by Terra Search as Rockwater was not onsite for drilling of this hole.

MONITORING BORE DATA – SRMB147

PROJECT:	SANDY RIDGE
Bore No:	**SRMB147**
Location:	Mt Walton
GDA Coordinates:	219,890 mE 6,638,007 mN
Status:	Monitoring bore
Date Commenced:	15/03/2015
Date Completed:	16/03/2015
Drilling Contractor:	Wallis Drilling
Drilling Rig:	Mantus 300
Depth Drilled:	21 m
Drilling Details:	0 to 8 m, 191 mm air-hammer 8 to 21 m, 152 mm air-core
Casing Details:	+0.88 to 0.42 m, 150 mm ND galvanised well cover with lockable lid +0.86 to 1.14 m, 145 mm OD, 127 mm ID inner steel casing +0.88 to 14.6 m, 61 mm OD, 55 mm ID, Class 9 uPVC blank casing . 14.6 to 20.6 m, 61 mm OD, 55 mm ID, Class 9 uPVC machine slotted casing, 1 mm aperture slots
Pack Interval:	13.5 to 20.6 m graded gravel pack (1.6 – 3.2 mm) 9.5 to 13.5 m bentonite seal 0.2 to 9.5 m backfill 0 to 0.2 m concrete
Reference Point Description:	top of galvanised lid
Height of Casing Above Ground:	+0.88 m

MONITORING BORE DATA – SRMB147 (continued)

Reference Point Elevation: 466.6 mAHD

Pumping Tests: Nil

Static Water Level: 20.55 m btoc or 446.0 m AHD (6/5/2015)

Lithology:

Depth		Lithology	Description
From	To		
0	2	Sand	Sandy cover
2	3	Laterite	Ferricrete/iron rich zone +/- pisolites
3	6	No sample returns	
6	8	Mottled Zone	Iron oxide stained saprolite
8	21	Kaolinite	White clay rich saprolite zone
		End of Hole	

NB: Lithology log provided by Terra Search as Rockwater was not onsite for drilling of this hole.

MONITORING BORE DATA – SRMB148

PROJECT:	SANDY RIDGE
Bore No:	**SRMB148**
Location:	Mt Walton
GDA Coordinates:	219,702 mE 6,637,808 mN
Status:	Monitoring bore
Date Commenced:	16/03/2015
Date Completed:	16/03/2015
Drilling Contractor:	Wallis Drilling
Drilling Rig:	Mantus 300
Depth Drilled:	24 m
Drilling Details:	0 to 10 m, 191 mm air-hammer 10 to 24 m, 152 mm air-core
Casing Details:	+1.00 to 0.3 m, 150 mm ND galvanised well cover with lockable lid +0.90 to 1.1 m, 145 mm OD, 127 mm ID inner steel casing +0.89 to 18.3 m, 61 mm OD, 55 mm ID, Class 9 uPVC blank casing 18.3 to 24.3 m, 61 mm OD, 55 mm ID, Class 9 uPVC machine slotted casing, 1 mm aperture slots
Pack Interval:	16.3 to 24.3 m graded gravel pack (1.6 – 3.2 mm) 12.3 to 16.3 m bentonite seal 0.2 to 12.3 m backfill 0 to 0.2 m concrete
Reference Point Description:	top of galvanised lid
Height of Casing Above Ground:	+1.0

MONITORING BORE DATA – SRMB148 (continued)

Reference Point Elevation: 464.9 mAHD

Pumping Tests: Nil

Static Water Level: Dry or <438.6 m AHD (6/5/2015)

Lithology:

NB: Lithology log from 0 to 12 m provided by Terra Search as Rockwater was not onsite for the upper section of this hole.

Depth		Lithology	Description
From	To		
0	2	Sand	Sandy cover
2	6	No sample returns	
6	12	Mottled Zone	Iron oxide stained saprolite
12	24	Weathered granite	White clay (kaolinite), with minor to major medium to coarse grained angular quartz with trace black minerals (biotite?), moderately hard to hard, trace vugs, @ 18 m slightly damp
		End of Hole	

MONITORING BORE DATA – SRMB149

PROJECT:	SANDY RIDGE
Bore No:	**SRMB149**
Location:	Mt Walton
GDA Coordinates:	220,238 mE 6,637,886 mN
Status:	Monitoring bore
Date Commenced:	16/03/2015
Date Completed:	16/03/2015
Drilling Contractor:	Wallis Drilling
Drilling Rig:	Mantus 300
Depth Drilled:	23 m
Drilling Details:	0 to 23 m, 152 mm air-core
Casing Details:	+1.15 to 0.15 m, 150 mm ND galvanised well cover with lockable lid +0.92 to 1.08 m, 145 mm OD, 127 mm ID inner steel casing +1.06 to 16.9 m, 61 mm OD, 55 mm ID, Class 9 uPVC blank casing . 16.9 to 22.9 m, 61 mm OD, 55 mm ID, Class 9 uPVC machine slotted casing, 1 mm aperture slots
Pack Interval:	15.5 to 22.9 m graded gravel pack (1.6 – 3.2 mm) 11.5 to 15.5 m bentonite seal 0.2 to 11.5 m backfill 0 to 0.2 m concrete
Reference Point Description:	top of galvanised lid
Height of Casing Above Ground:	+1.15 m

MONITORING BORE DATA – SRMB149 (continued)

Reference Point Elevation: 472.8 mAHD

Pumping Tests: Nil

Static Water Level: Dry or <447.6 m AHD (6/5/2015)

Lithology:

Depth		Lithology	Description
From	To		
0	2	Sand	Orange, fine to very coarse, poorly sorted, sub-angular to angular, minor silt, soft
2	3.5	Sand	Orange, fine to very coarse, poorly sorted, sub-angular to angular, minor silt and lateritic gravel (0.5 to 4 cm) sub-rounded to well-rounded, soft
3.5	5	Silcrete	Mid brown/cream silicified kaolin, major very coarse sub-angular to very angular quartz, minor orange and red mottling, trace to minor weak fragmented quartz veins, hard, @ 4.5 m core has small vugs
5	6	Silcrete	Pink silicified kaolin, major very coarse sub-angular to very angular quartz, heavy red mottling, trace to minor weak fragmented quartz veins, hard
6	9	Silcrete	White silicified kaolin, major very coarse to granular, sub-angular to very angular quartz, hard
9	11	Silcrete	Red silicified kaolin, very heavy red (hematite) mottling, major very coarse to granular, sub-angular to very angular quartz, hard, minor small vugs
11	14	Silcrete?	Red silicified kaolin?, completely iron stained, major very coarse to granular, sub-angular to very angular quartz, minor goethite, hard
14	17	Weathered Granite	White/grey weathered granite with goethite staining, medium to granular, sub-angular to angular grey quartz, traces black/silver micaceous mineral flecks, moderately hard
17	23	Weathered Granite	Green weathered granite with goethite staining, medium to granular, angular to very angular grey quartz, minor to major black/silver micaceous mineral flecks, moderately hard to hard
		End of Hole	

MONITORING BORE DATA – SRMB150

PROJECT:	SANDY RIDGE
Bore No:	**SRMB150**
Location:	Mt Walton
GDA Coordinates:	219,372 mE 6,638,392 mN
Status:	Monitoring bore
Date Commenced:	17/03/2015
Date Completed:	17/03/2015
Drilling Contractor:	Wallis Drilling
Drilling Rig:	Mantus 300
Depth Drilled:	49 m
Drilling Details:	0 to 49 m, 152 mm air-core
Casing Details:	+1.07 to 0.13 m, 150 mm ND galvanised well cover with lockable lid +0.96 to 1.04 m, 145 mm OD, 127 mm ID inner steel casing +0.92 to 40.0 m, 61 mm OD, 55 mm ID, Class 9 uPVC blank casing 40.0 to 49.0 m, 61 mm OD, 55 mm ID, Class 9 uPVC machine slotted casing, 1 mm aperture slots
Pack Interval:	39.0 to 49.0 m graded gravel pack (1.6 – 3.2 mm) 35.0 to 39.0 m bentonite seal 0.2 to 35.0 m backfill 0 to 0.2 m concrete
Reference Point Description:	top of galvanised lid
Height of Casing Above Ground:	+1.07 m

MONITORING BORE DATA – SRMB150 (continued)

Reference Point Elevation: 465.0 mAHD

Pumping Tests: Nil

Static Water Level: 36.1 m btoc or 428.9 m AHD (6/5/2015)

Airlift Yield: ~0.03 L/s

Salinity: 6,570 mg/L TDS (calculated from field electrical conductivity)

Lithology:

Depth		Lithology	Description
From	To		
0	3	Sand	Orange, fine to very coarse, poorly sorted, sub-angular to angular, major lateritic gravel up to very large pebbles, soft
3	9	Silcrete	White silcrete with major kaolinite, minor to major iron mottling, minor to major fine to very coarse, sub-angular to angular quartz, hard, trace small vugs
9	18	Clay (kaolinite)	White/cream clay (kaolinite) with slight green tinge (chlorite?), minor fine to coarse grained, sub-angular to angular quartz, trace to minor red iron mottling, soft to moderately hard
18	31	Weathered Granite	Cream, major very coarse to granular, very angular to angular quartz with white clay (kaolinite), minor pink feldspars, trace to minor green mottles (chlorite?), moderately hard
31	46	Weathered Granite	Brown, major very coarse to granular, very angular to angular quartz with white clay (kaolinite), major iron staining, minor pink feldspars and green staining (chlorite?), moderately hard, @ 39 m damp
46	49	Granite	White, relatively fresh granite, hard
		End of Hole	

MONITORING BORE DATA – SRMB151

PROJECT:	SANDY RIDGE
Bore No:	**SRMB151**
Location:	Mt Walton
GDA Coordinates:	219,681 mE 6,638,402 mN
Status:	Monitoring bore
Date Commenced:	17/03/2015
Date Completed:	17/03/2015
Drilling Contractor:	Wallis Drilling
Drilling Rig:	Mantus 300
Depth Drilled:	45 m
Drilling Details:	0 to 12 m, 191 mm air-hammer 12 to 45 m, 152 mm air-core
Casing Details:	+0.58 to 0.72 m, 150 mm ND galvanised well cover with lockable lid +0.58 to 1.42 m, 145 mm OD, 127 mm ID inner steel casing +0.58 to 38.7 m, 61 mm OD, 55 mm ID, Class 9 uPVC blank casing . 38.7 to 44.7 m, 61 mm OD, 55 mm ID, Class 9 uPVC machine slotted casing, 1 mm aperture slots
Pack Interval:	32.3 to 44.7 m graded gravel pack (1.6 – 3.2 mm) 28.3 to 32.3 m bentonite seal 0.2 to 28.3 m backfill 0 to 0.2 m concrete
Reference Point Description:	top of galvanised lid
Height of Casing Above Ground:	+0.58 m

MONITORING BORE DATA – SRMB151 (continued)

Reference Point Elevation: 465.9 mAHD

Pumping Tests: Nil

Static Water Level: 36.65 or 429.2 m AHD (6/5/2015)

Lithology:

Depth		Lithology	Description
From	To		
0	3	Silcrete	Mid brown silcrete with minor iron mottling, minor to major medium to very coarse, sub-angular to sub-rounded quartz, hard
3	6	Silcrete	Cream silcrete with major kaolinite and medium, sub-angular to sub-rounded quartz, hard
6	27	Clay (kaolinite)	White clay (kaolinite) with minor to major medium to very coarse sub-angular quartz, trace green staining (chlorite?), minor small vugs, soft, slightly damp
27	30	Clay (kaolinite)	White clay (kaolinite) with major medium to coarse, sub-angular to angular quartz, trace small vugs, soft, slightly damp
30	36	Weathered granite	White, medium to pebble, sub-angular to very angular quartz, minor clay (kaolinite), trace black minerals and silver micas, moderately hard, damp
36	39	Weathered granite	White, medium to granular, sub-angular to angular quartz, minor white clay (kaolinite) and pink feldspar, moderately hard, moist
39	42	Weathered granite	White, medium to pebble, sub-angular to very angular quartz, minor clay (kaolinite) and orange stained quartz, moderately hard
42	45	Granite	White, relatively fresh granite with minor iron staining and trace black minerals, hard
		End of Hole	

MONITORING BORE DATA – SRMB152

PROJECT:	SANDY RIDGE
Bore No:	**SRMB152**
Location:	Mt Walton
GDA Coordinates:	219,499 mE 6,637,606 mN
Status:	Monitoring bore
Date Commenced:	17/03/2015
Date Completed:	17/03/2015
Drilling Contractor:	Wallis Drilling
Drilling Rig:	Mantus 300
Depth Drilled:	38 m
Drilling Details:	0 to 9 m, 191 mm air-hammer 9 to 38 m, 152 mm air-core
Casing Details:	+0.54 to 0.76 m, 150 mm ND galvanised well cover with lockable lid +0.56 to 1.44 m, 145 mm OD, 127 mm ID inner steel casing +0.54 to 32.4 m, 61 mm OD, 55 mm ID, Class 9 uPVC blank casing . 32.4 to 38.4 m, 61 mm OD, 55 mm ID, Class 9 uPVC machine slotted casing, 1 mm aperture slots
Pack Interval:	31.3 to 38.4 m graded gravel pack (1.6 – 3.2 mm) 27.3 to 31.3 m bentonite seal 0.2 to 27.3 m backfill 0 to 0.2 m concrete
Reference Point Description:	top of galvanised lid
Height of Casing Above Ground:	+0.54 m

MONITORING BORE DATA – SRMB152 (continued)

Reference Point Elevation: 464.6 mAHD

Pumping Tests: Nil

Static Water Level: 34.35 m or 430.3 m AHD (6/5/2015)

Airlift Yield: ~0.01 L/s

Salinity: 6,030 mg/L TDS (calculated from field electrical conductivity)

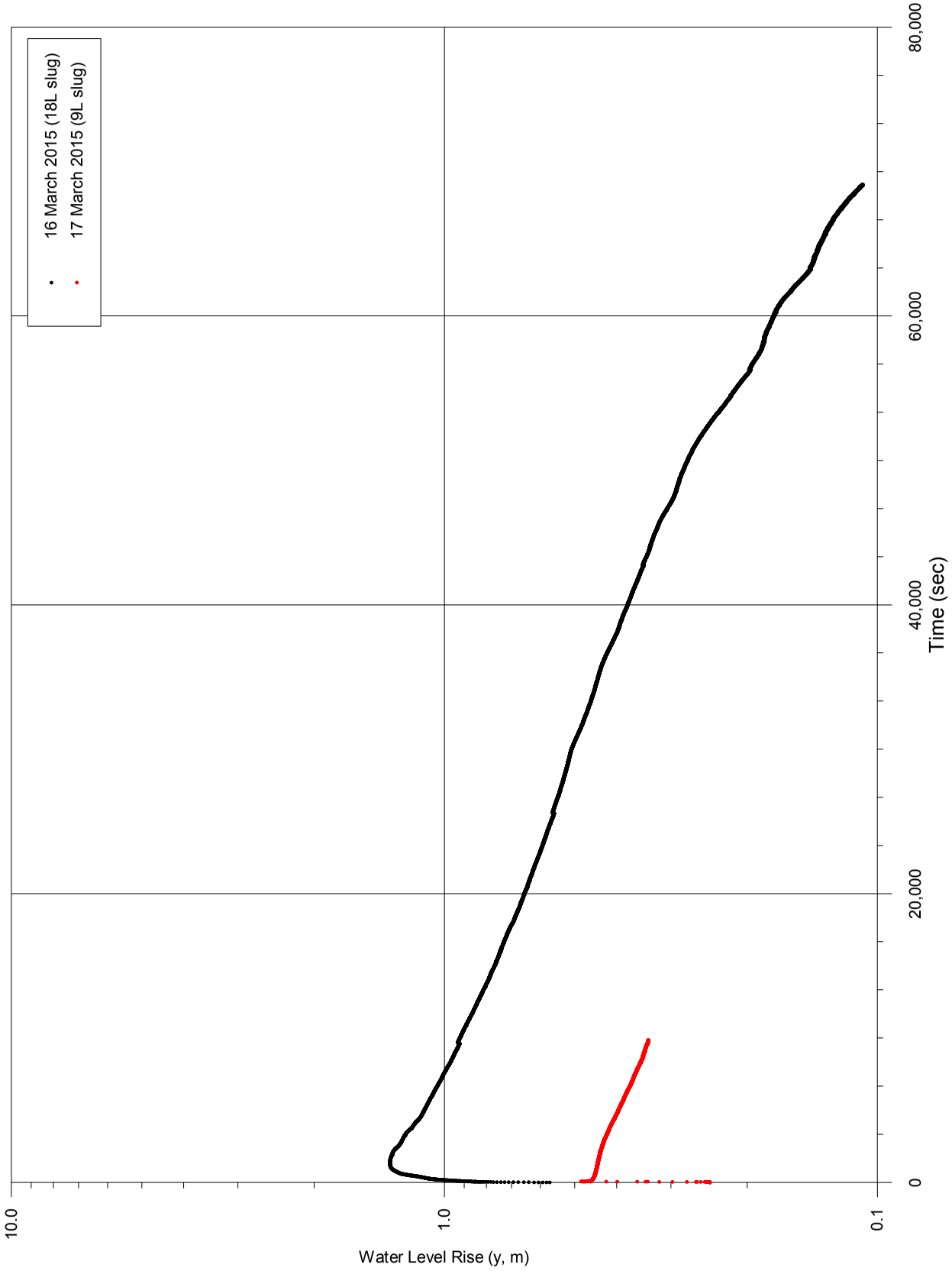
Lithology:

Depth		Lithology	Description
From	To		
0	3	Sand	Orange medium to coarse grained moderately sorted sand, minor clay, soft
3	9	Silcrete	White silcrete, minor lateritic gravel and medium grained angular quartz, minor red iron mottling, hard
9	15	Clay (kaolinite)	White clay (kaolinite) with major pale pink iron mottles and minor yellow mottles, minor fine to coarse, sub-angular quartz, soft to moderately hard, trace small vugs
15	27	Weathered Granite	White clay (kaolinite) with major medium to granular, sub-angular quartz, moderately hard, trace small vugs
27	38	Weathered Granite	Cream clay (kaolinite) with slight green tinge (chlorite?), major medium to granular, sub-angular quartz, trace black mineral flecks, moderately hard to hard, trace small vugs, @ 36 m moist
		End of Hole	

APPENDIX II

PERMEABILITY TEST PLOTS AND CALCULATIONS

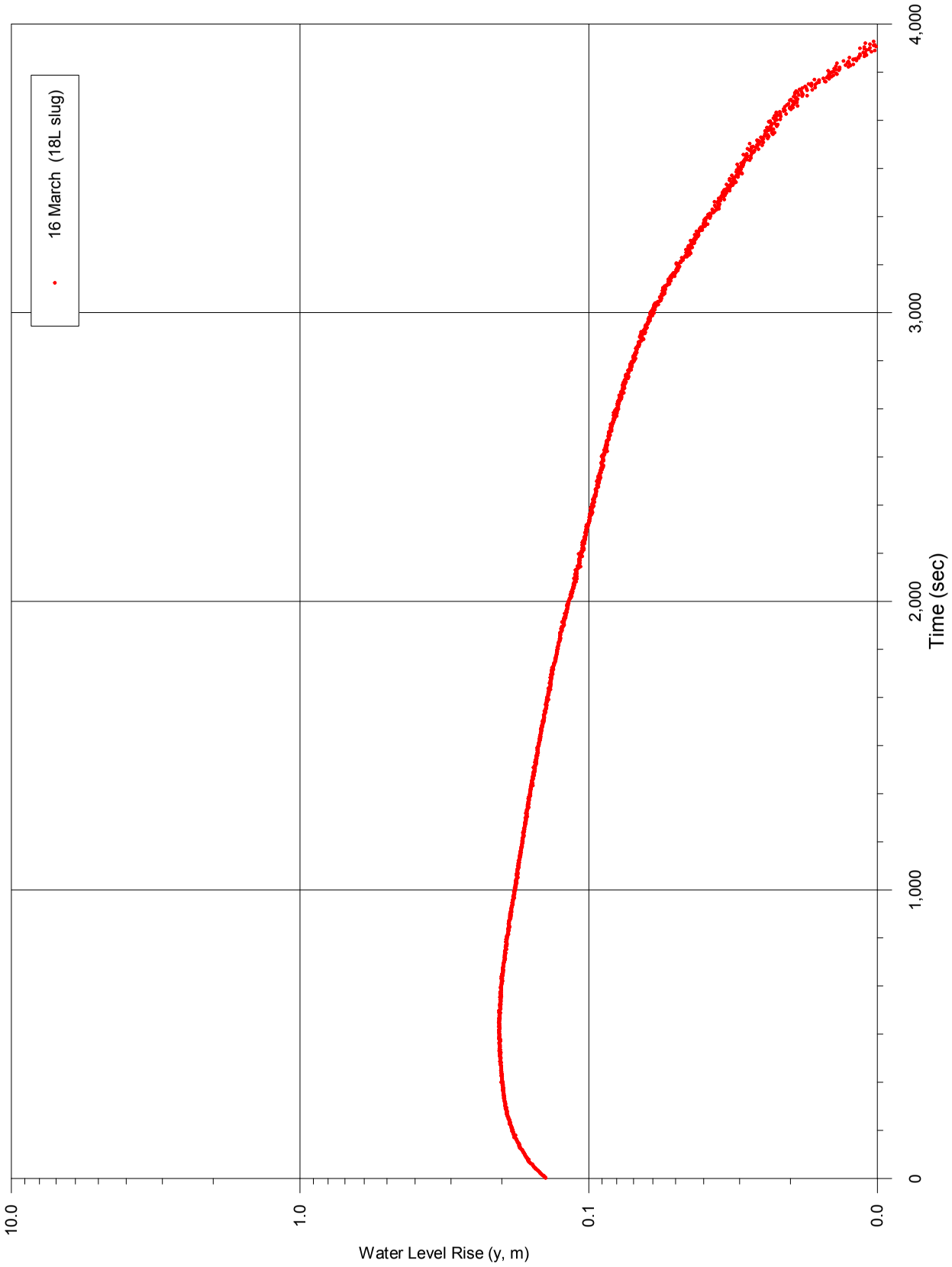
Figure AII-1



I:\454-0\Grapher\Slug Tests\SRMB146 Falling Head.grf

Client: Tellus Holdings	SRMB146 FALLING HEAD TESTS
Project : Sandy Ridge Drilling, Permeability Testing and Potential Water Sources Report	
Date : June 2015	
Dwg. No: 454-0/15/01-AI-1	

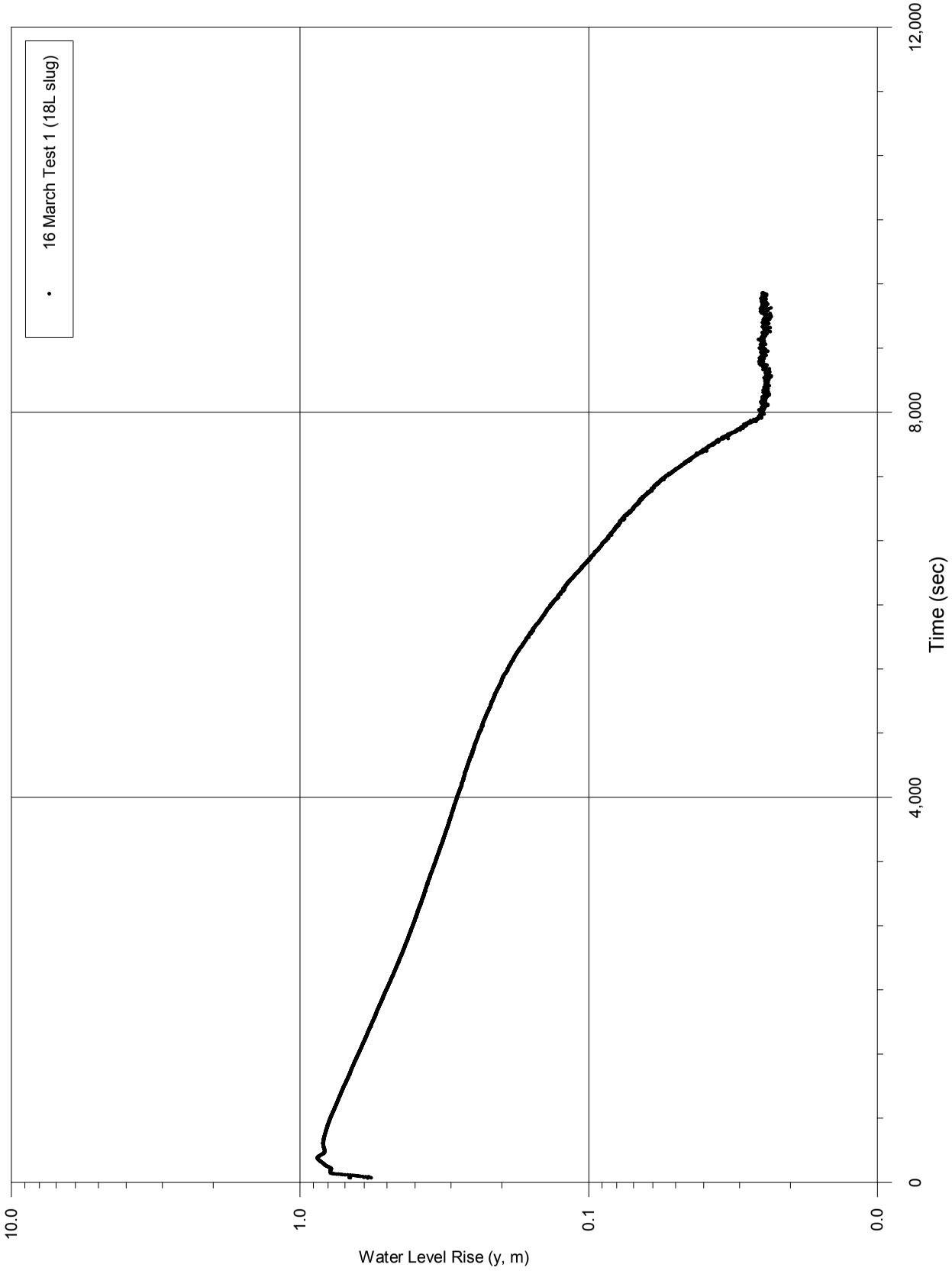
Figure AII-2



I:\454-0\Grapher\Slug Tests\SRMB147 Falling Head.grf

Client: Tellus Holdings	SRMB147 FALLING HEAD TEST
Project : Sandy Ridge Drilling, Permeability Testing and Potential Water Sources Report	
Date : June 2015	
Dwg. No: 454-0/15/01-AII-2	

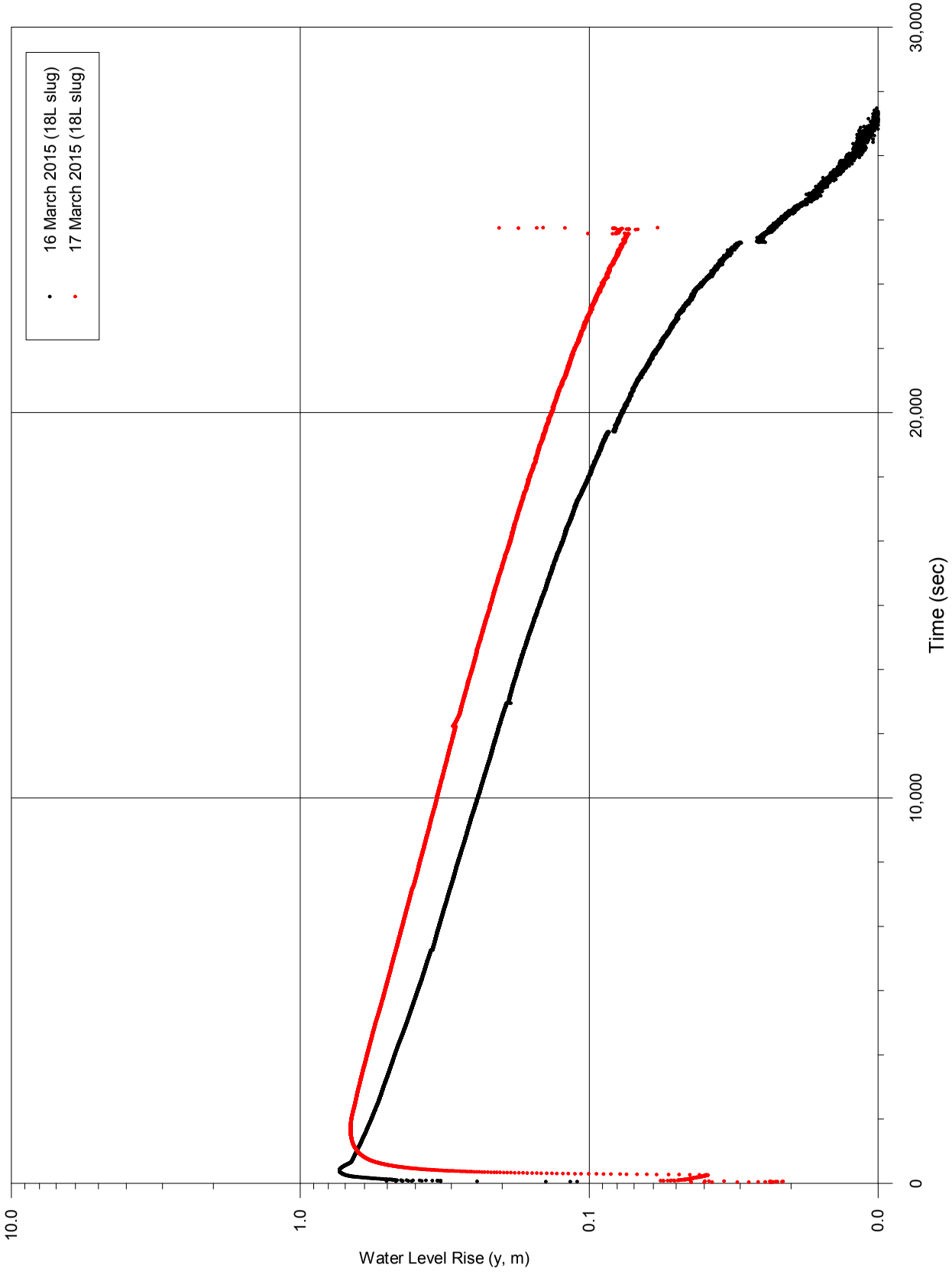
Figure AII-3



I:\454-0\Grapher\Slug Tests\SRMB148 Falling Head.grf

Client: Tellus Holdings	SRMB148 FALLING HEAD TEST
Project : Sandy Ridge Drilling, Permeability Testing and Potential Water Sources Report	
Date : June 2015	
Dwg. No: 454-0/15/01-AII-3	

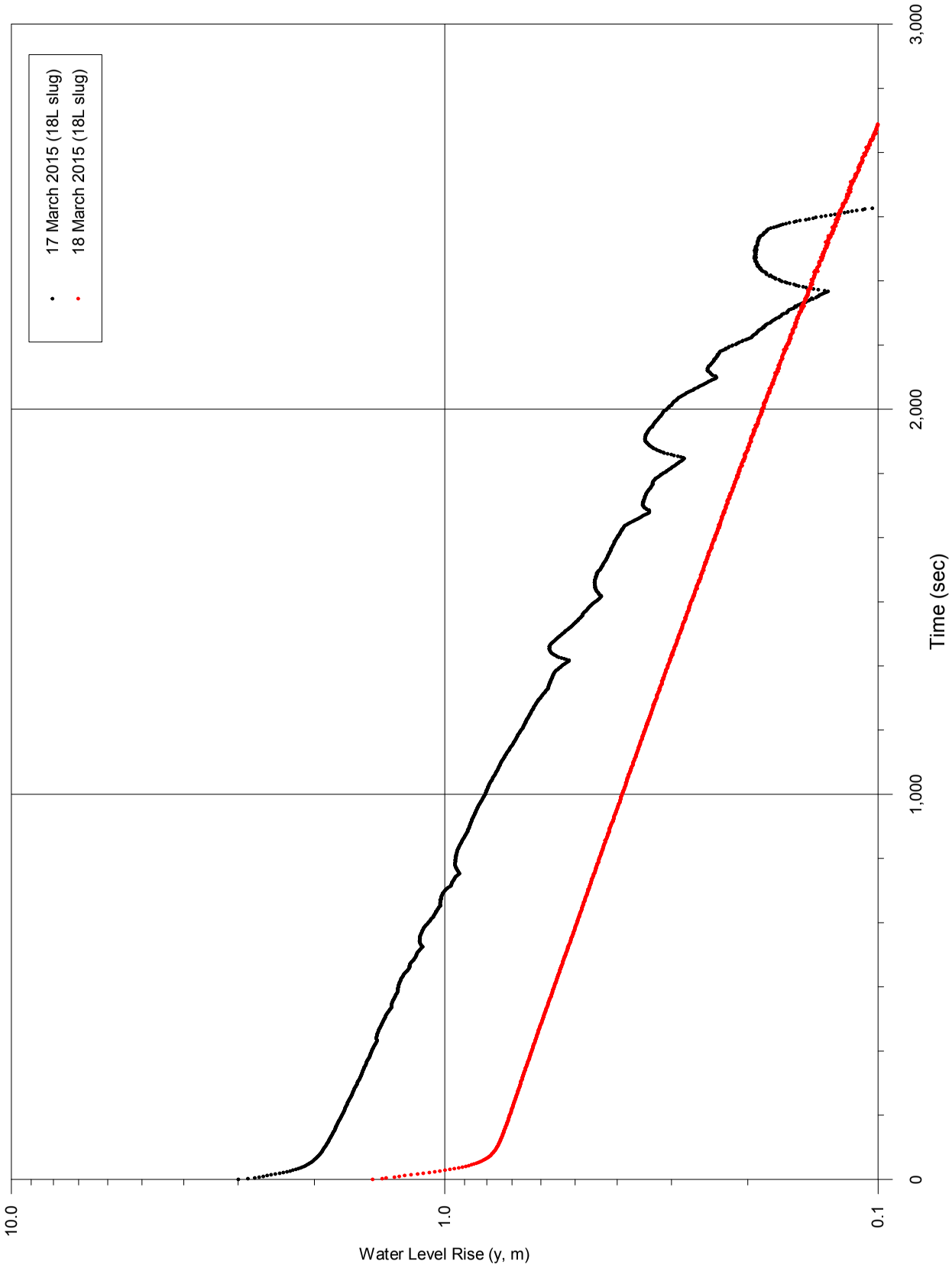
Figure AII-4



I:\454-0\Grapher\Slug Tests\SRMB149 Falling Head.grf

Client: Tellus Holdings	SRMB149 FALLING HEAD TESTS
Project : Sandy Ridge Drilling, Permeability Testing and Potential Water Sources Report	
Date : June 2015	
Dwg. No: 454-0/15/01-AII-4	

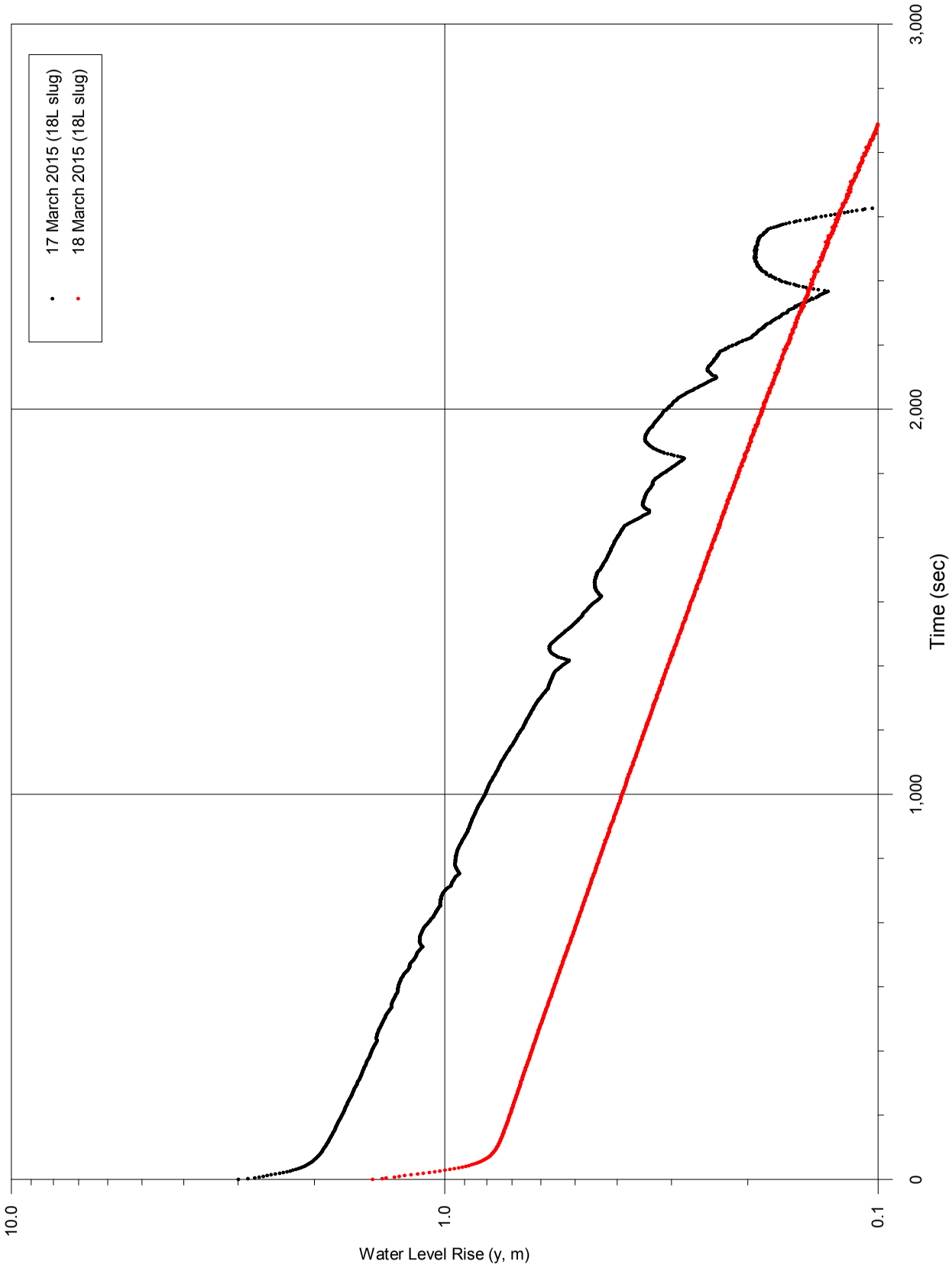
Figure AII-5



I:\454-0\Grapher\Slug Tests\SRMB150 Falling Head.grf

Client: Tellus Holdings	SRMB150 FALLING HEAD TESTS
Project : Sandy Ridge Drilling, Permeability Testing and Potential Water Sources Report	
Date : June 2015	
Dwg. No: 454-0/15/01-AII-5	

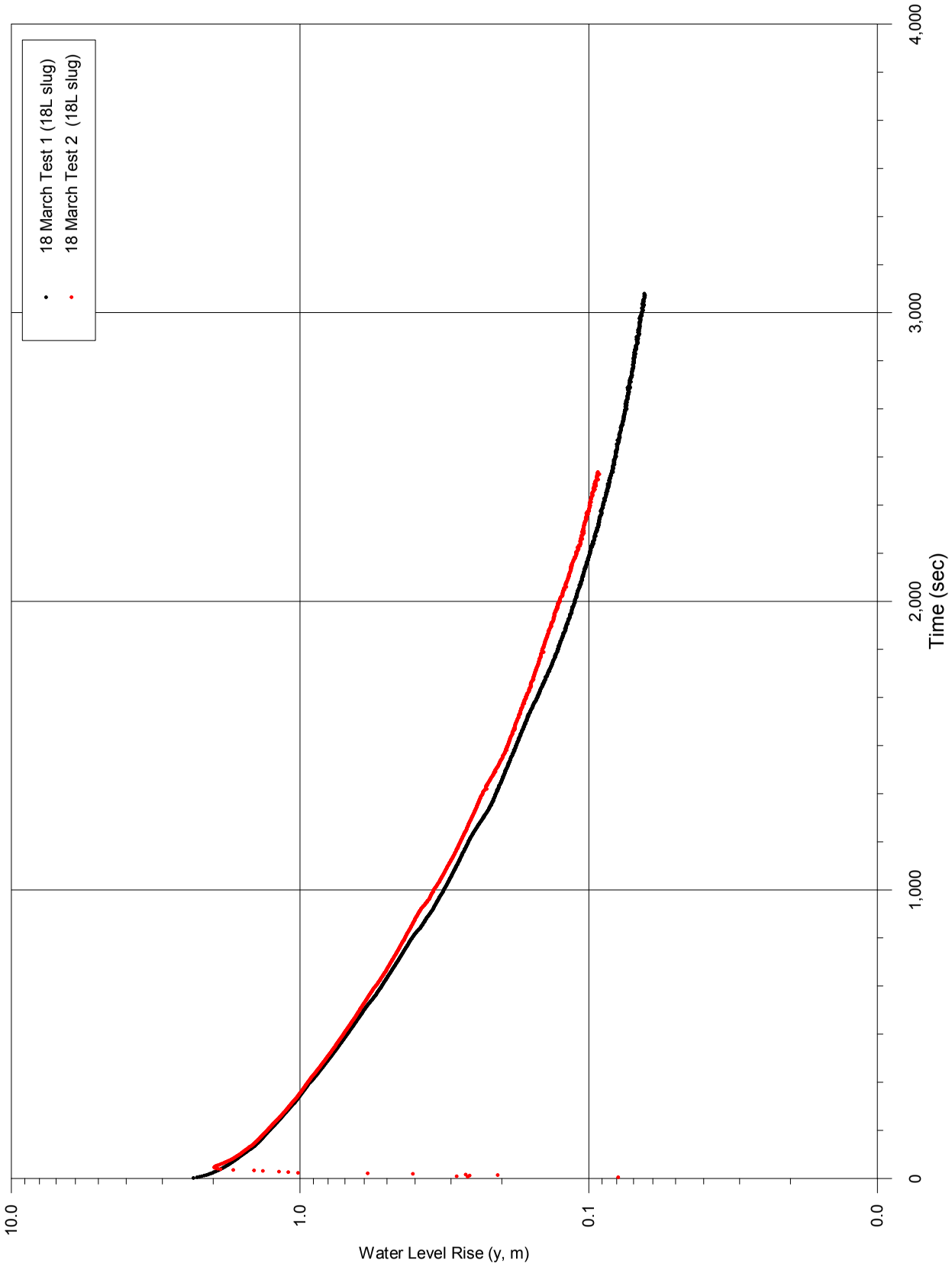
Figure AII-5



I:\454-0\Grapher\Slug Tests\SRMB150 Falling Head.grf

Client: Tellus Holdings	SRMB150 FALLING HEAD TESTS
Project : Sandy Ridge Drilling, Permeability Testing and Potential Water Sources Report	
Date : June 2015	
Dwg. No: 454-0/15/01-AII-5	

Figure AII-7



I:\454-0\Grapher\Slug Tests\SRMB152 Falling Head.grf

Client: Tellus Holdings	SRMB152 FALLING HEAD TESTS
Project : Sandy Ridge Drilling, Permeability Testing and Potential Water Sources Report	
Date : June 2015	
Dwg. No: 454-0/15/01-AII-7	

Bore SRMB146 (Falling Head Test 1)

(Using Oosterbaan & Nijland (1994) Method For Holes Above Water Table)

Using early-time data

Formula:			Enter (Overwrite)		
K = 1.15*r*	(log (h_o+r/2)-log (ht+r/2))/(t-t_o)		Variables:	0.076	(Hole radius, m)
			h_o =	1.340	(Head at $t_{o,m}$)
			h_t =	1.230	(Head at $t_{,m}$)
			t_o=	0.00	(Time at h_o in secs)
			t =	2000	(Time at h_t in secs)
			to- t =	2000.0	
Term 1	0.0874	Term 4	0.038		
Term 2	0.13924922				
Term 3	0.10311925				
K=	**1.579E-06**	**m/sec**			
	0.136	m/d			

Bore SRMB146 (Falling Head Test 2)

(Using Oosterbaan & Nijland (1994) Method For Holes Above Water Table)

Using early-time data

Formula:			Enter (Overwrite)		
K = 1.15*r*	(log (h_o+r/2)-log (ht+r/2))/(t-t_o)		Variables:	0.076	(Hole radius, m)
			h_o =	0.471	(Head at $t_{o,m}$)
			h_t =	0.436	(Head at $t_{,m}$)
			t_o=	0.00	(Time at h_o in secs)
			t =	2000	(Time at h_t in secs)
			to- t =	2000.0	
Term 1	0.0874	Term 4	0.038		
Term 2	-0.2932822				
Term 3	-0.3242217				
K=	**1.352E-06**	**m/sec**			
	0.117	**m/d**			

Appendix II - Permeability Test Calculations

Bore SRMB147 (Falling Head Test 1)

(Using Oosterbaan & Nijland (1994) Method For Holes Above Water Table)

Using early-time data

Formula:

$K = 1.15*r* (\log (h_o+r/2)-\log (ht+r/2))/(t-t_o)$

Enter (Overwrite)		
Variables:-	0.076	(Hole radius, m)
h_o =	0.203	(Head at $t_{o,\ m}$)
h_t =	0.162	(Head at $t_{,m}$)
t_o=	628.00	(Time at h_o in secs)
t =	1284	(Time at h_t in secs)
to- t =	656.0	

Term 1	0.0874	Term 4	0.038
Term 2	-0.617983		
Term 3	-0.69897		

K= 1.079E-05 m/sec

0.932 m/d

Appendix II - Permeability Test Calculations

Bore SRMB148 (Falling Head Test 1)

(Using Oosterbaan & Nijland (1994) Method For Holes Above Water Table)

Using early-time data

Formula:

$K = 1.15*r* (\log (h_o+r/2)-\log (ht+r/2))/(t-t_o)$

Enter (Overwrite)		
Variables:-	0.076	(Hole radius, m)
h_o =	0.870	(Head at $t_{o,\ m}$)
h_t =	0.460	(Head at $t_{,m}$)
t_o=	0.00	(Time at h_o in secs)
t =	2000	(Time at h_t in secs)
to- t =	2000.0	

Term 1	0.0874	Term 4	0.038
Term 2	-0.041914151		
Term 3	-0.302770657		

K= 1.140E-05 m/sec

0.985 m/d

Bore SRMB149 (Falling Head Test 1)

(Using Oosterbaan & Nijland (1994) Method For Holes Above Water Table)

Using early-time data

Formula:					Enter (Overwrite)		
K = 1.15*r*	(log (h_o+r/2)-log (ht+r/2))/(t-t_o)				Variables:	0.076	(Hole radius, m)
					h_o =	0.700	(Head at $t_{o,m}$)
					h_t =	0.545	(Head at $t_{,m}$)
					t_o=	0.00	(Time at h_o in secs)
					t =	2000	(Time at h_t in secs)
					to- t =	2000.0	
Term 1	0.0874		Term 4	0.038			
Term 2	-0.13194364						
Term 3	-0.23433145						
K=	**4.474E-06**	**m/sec**					
	0.387	**m/d**					

Bore SRMB149 (Falling Head Test 2)

(Using Oosterbaan & Nijland (1994) Method For Holes Above Water Table)

Using early-time data

Formula:					Enter (Overwrite)		
K = 1.15*r*	(log (h_o+r/2)-log (ht+r/2))/(t-t_o)				Variables:	0.076	(Hole radius, m)
					h_o =	0.670	(Head at $t_{o,m}$)
					h_t =	0.583	(Head at $t_{,m}$)
					t_o=	0.00	(Time at h_o in secs)
					t =	2000	(Time at h_t in secs)
					to- t =	2000.0	
Term 1	0.0874		Term 4	0.038			
Term 2	-0.14996674						
Term 3	-0.2069084						
K=	**2.488E-06**	**m/sec**					
	0.215	**m/d**					

Mt Walton

Bore SRMB150 Falling-Head Test Calculations (Logger Data)

(Using Bouwer and Rices' Method (1989))

TEST 1

$k = \frac{r_c^2 \ln (R_e/r_w)}{2L_e} \times 1/t \ln (y_o/y_t)$

$\ln R_e/r_w = \left[\frac{1.1}{\ln(L_w/r_w)} + \frac{C}{L_e/r_w}\right]^{-1}$

(Assumes base is impervious)

Where L_e	9.0	(Slotted Length)
r_w =	0.076	(Hole Radius)
r_c =	0.026	(Casing Radius)
L_w =	3.0	(Depth from SWL to Base of Slots)
L_e/r_w =	118.421	
A =	4.600	(Parameter from graph)
B =	0.8	(Parameter from graph)
C =	4.6	(Parameter from graph)
y_o =	1.916	(Head at t = 0)
y_t =	1.402	(Head at time t)
t =	326	(Time t - secs)

$\ln R_e/r_w = \left[\frac{1.1}{3.68} + \frac{4.6}{118.42}\right]^{-1}$

$= \left[0.299 + 0.039\right]^{-1}$

$= 2.96$

$k = \frac{0.0007}{2} \times \frac{2.9576}{9.0} \times 0.0031 \times 0.3123$

$= 0.0001 \times 0.0010$

= 1.06E-07 m/sec

Hydraulic Conductivity

= 0.0092 m/day

= **0.0276** **m^2/day** Transmissivity

TEST 2

$k = \frac{r_c^2 \ln (R_e/r_w)}{2L_e} \times 1/t \ln (y_o/y_t)$

$\ln R_e/r_w = \left[\frac{1.1}{\ln(L_w/r_w)} + \frac{C}{L_e/r_w}\right]^{-1}$

(Assumes base is impervious)

Where L_e	9.0	(Slotted Length)
r_w =	0.076	(Hole Radius)
r_c =	0.026	(Casing Radius)
L_w =	3.0	(Depth from SWL to Base of Slots)
L_e/r_w =	118.42	
A =	4.6	(Parameter from graph)
B =	0.8	(Parameter from graph)
C =	4.6	(Parameter from graph)
y_o =	0.751	(Head at t = 0)
y_t =	0.601	(Head at time t)
t =	308	(Time t - secs)

$\ln R_e/r_w = \left[\frac{1.1}{3.68} + \frac{4.6}{118.42}\right]^{-1}$

$= \left[0.299 + 0.039\right]^{-1}$

$= 2.96$

$k = \frac{0.0007}{2} \times \frac{2.9576}{9.0} \times 0.0032 \times 0.2228$

$= 0.0001 \times 0.0007$

= 8.04E-08 m/sec

Hydraulic Conductivity

= 0.0069 m/day

= **0.0208** **m^2/day** Transmissivity

Mt Walton
Bore SRMB151 Falling-Head Test Calculations (Logger Data)

(Using Bouwer and Rices' Method (1989))

TEST 1

$$k = \frac{r_c^2 \ln (R_e/r_w)}{2L_e} \times 1/t \ln (y_o/y_t)$$

$$\ln R_e/r_w = \left[\frac{1.1}{\ln(L_w/r_w)} + \frac{C}{L_e/r_w}\right]^{-1}$$

(Assumes base is impervious)

Where L_e =	6.0	(Slotted Length)
r_w =	0.076	(Hole Radius)
r_c =	0.026	(Casing Radius)
L_w =	8.2	(Depth from SWL to Base of Slots)
L_e/r_w =	78.95	
A =	3.8	(Parameter from graph)
B =	0.6	(Parameter from graph)
C =	3.6	(Parameter from graph)
y_o =	3.300	(Head at t = 0)
y_t =	2.609	(Head at time t)
t =	100	(Time t - secs)

$$\ln R_e/r_w = \left[\frac{1.1}{4.68} + \frac{3.6}{78.95}\right]^{-1}$$

$$= \left[0.235 + 0.046\right]^{-1}$$

$$= 3.56$$

$$k = \frac{0.0007}{2} \times \frac{3.5609}{6.0} \times 0.0100 \times 0.2350$$

$$= 0.0002 \times 0.0023$$

= 4.71E-07 m/sec

= 0.0407 m/day

Hydraulic Conductivity

= **0.3323** **m^2/day** Transmissivity

Mt Walton

Bore SRMB152 Falling-Head Test Calculations (Logger Data)

(Using Bouwer and Rices' Method (1989))

TEST 1

$k = \frac{r_c^2 \ln (R_e/r_w)}{2L_e} \times \frac{1}{t} \ln (y_o/y_t)$

$\ln R_e/r_w = \left[\frac{1.1}{\ln(L_w/r_w)} + \frac{C}{L_e/r_w}\right]^{-1}$

(Assumes base is impervious)

Where L_e	6.0	(Slotted Length)
r_w =	0.076	(Hole Radius)
r_c =	0.026	(Casing Radius)
L_w =	4.2	(Depth from SWL to Base of Slots)
L_e/r_w =	78.95	
A =	3.8	(Parameter from graph)
B =	0.6	(Parameter from graph)
C =	3.6	(Parameter from graph)
y_o =	2.006	(Head at t = 0) use early time
y_t =	1.187	(Head at time t) use early time
t =	180	(Time t - secs)

$\ln R_e/r_w = \left[\frac{1.1}{4.02} + \frac{3.6}{78.95}\right]^{-1}$

$= \left[0.274 + 0.046\right]^{-1}$

$= 3.13$

$k = \frac{0.0007}{2} \times \frac{3.1336}{6.0} \times 0.0056 \times 0.5247$

$= 0.0002 \times 0.0029$

= 5.15E-07 m/sec

= 0.0445 m/day (Hydraulic Conductivity)

= 0.1885 m^2/day (Transmissivity)

TEST 2

$k = \frac{r_c^2 \ln (R_e/r_w)}{2L_e} \times \frac{1}{t} \ln (y_o/y_t)$

$\ln R_e/r_w = \left[\frac{1.1}{\ln(L_w/r_w)} + \frac{C}{L_e/r_w}\right]^{-1}$

(Assumes base is impervious)

Where L_e	6.0	(Slotted Length)
r_w =	0.076	(Hole Radius)
r_c =	0.026	(Casing Radius)
L_w =	4.2	(Depth from SWL to Base of Slots)
L_e/r_w =	78.95	
A =	3.8	(Parameter from graph)
B =	0.6	(Parameter from graph)
C =	3.6	(Parameter from graph)
y_o =	1.981	(Head at t = 0) use early time
y_t =	1.116	(Head at time t) use early time
t =	200	(Time t - secs)

$\ln R_e/r_w = \left[\frac{1.1}{4.01} + \frac{3.6}{78.95}\right]^{-1}$

$= \left[0.274 + 0.046\right]^{-1}$

$= 3.13$

$k = \frac{0.0007}{2} \times \frac{3.1257}{6.0} \times 0.0050 \times 0.5739$

$= 0.0002 \times 0.0029$

= 5.05E-07 m/sec

= 0.0437 m/day (Hydraulic Conductivity)

= 0.1829 m^2/day (Transmissivity)

Hydrogeology Assessment

TELLUS

Rockwater
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TELLUS HOLDINGS LTD
SANDY RIDGE KAOLINITE PROJECT

SUSTAINABILITY OF CARINA MINE AS A WATER SOURCE

February 2016

1 BACKGROUND

Tellus Holdings Limited (Tellus) is proposing to develop a kaolin mine at its Sandy Ridge project at Mount Walton, approximately 140 km north-west of Kalgoorlie. It plans to utilise mined-out pits for a complementary storage and waste-disposal business.

A water supply of 180,000 kL per annum (~495 kL/d or about 6 L/s) will be required when mining and mineral processing is ramped-up to full production. Initially a much smaller volume would be required. It is planned to obtain the water required from the Carina iron ore mine owned by Polaris Metals Pty Ltd, located 12 km south-west of Sandy Ridge.

The Environmental Scoping Document for the Sandy Ridge project requires Tellus to:

- Assess the impacts on water quality of sourcing water from the Carina mine over 25 years; and
- Assess the viability of using the Carina mine as a water source for 25 years.

This memorandum addresses the above items which concern the sustainability of the water source.

2 VIABILITY OF USING CARINA MINE PIT AS WATER SOURCE

The Carina mine pit intersects vuggy goethitic iron ore that has moderate to high permeability.

A review of dewatering progress by Rockwater in 2014 showed that pumping from the pit increased from about 1,200 to 1,400 kL/d in 2011 to about 2,250 kL/d in March 2014. A numerical model was calibrated to historical pumpage and water levels, and was run to predict future pumping requirements; rates of up to 3,000 kL/d were indicated to be needed.

The water pumped from the pit is currently stored in a series of turkeys nest dams and is used for dust suppression, ore processing and camp use. An unknown quantity is evaporated or lost as seepage back into the ground.

The same numerical model was used to estimate steady-state groundwater inflows for several pit water levels, to be used as one component of the post-mining pit water balance. The water balance is used to assess the viability and potential impact of using water from the pit for the Sandy Ridge water supply.

Post-mining, the water in the pit will recover until groundwater inflows plus rainfall accumulation balance evaporation losses. As the water level rises, groundwater inflows decrease and the area for evaporation increases. The following were also assumed:

- Rainfall accumulation = 80% of the average annual rainfall for Southern Cross, falling within the perimeter bunds;
- Evaporation is dam evaporation for Southern Cross, given in Luke, Burke and O'Brien, 1988, reduced by 20% to allow for the lower rate of evaporation for saline water; and
- Water areas at each elevation were measured from contours from the planned pit design.

The water balance for several pit water levels is given in the table below.

Water Level (m AHD)	Area (m^2)	Inflows (kL/d)	Evap (kL/d)	Rainfall (kL/d)	Balance (kL/d)	extraction (kL/d)	New Balance (kL/d)
412	274,590	0	1,211	332	-879	495	-1,374
370	149,040	564	657	332	239	495	-256
350	93,150	707	411	332	628	495	133
300	12,150	979	54	332	1,257	495	762

Without extraction, the balance (at 0 kL/d) indicates that the pit water level will stabilise at about 379 m AHD. Extraction at the maximum rate needed (495 kL/d) would lower the pit water level until it stabilises at about 357 m AHD. Even without allowing for the water available from pit storage, this indicates that the water supply is sustainable.

3 POTENTIAL IMPACT ON WATER QUALITY

The water in the Carina pit has salinity of about 33,000 mg/L TDS. The original static water level was at about 412 m AHD.

The water balance above shows that even without groundwater extraction, the post-mining pit water level will be about 33 m below the original static water level, and so the pit will become a permanent groundwater sink, with evaporation losses exceeding rainfall accumulation. Consequently, the salinity of the pit water will gradually increase.

Pumping water from the pit will lower the pit water level and so will reduce both evaporation losses and the rate of salinity increase. This positive impact will be enhanced by removing water from the pit that is more saline than the groundwater inflows.

Water in the pit is alkaline (pH 7.5 to 8.0) and there are no indications that lowering water levels in the pit will have any impact on the alkalinity of the water.

4 CONCLUSIONS

Our assessment is that water from the Carina mine pit should be a suitable water source for the Sandy Ridge project, and that a water supply of up to 495 kL/d will be easily sustainable.

Post-mining, the pit will become a permanent sink, resulting in a gradual increase in the salinity of the pit water, and there will be no potential for the pit water to flow back into surrounding rocks. Pumping water from the pit will have the beneficial impact of reducing the rate of salinity rise.

Dated: **4 February 2016** **Rockwater Pty Ltd**

P H Wharton
Principal

REFERENCE

Luke, G.J., Burke, K.L., and O'Brien, T.M., 1988, Evaporation data for Western Australia. Tech. Report No. 65 (2nd Ed), W.A. Dept. of Agriculture.

Infiltration & Seepage Modelling

TELLUS

The Assessment of Long-term Recharge to Encapsulated Waste Isolation Cells – Sandy Ridge Project

Tellus Holdings Ltd

The Assessment of Long-term Recharge to Encapsulated Waste Isolation Cells Sandy Ridge Project

Prepared For

Tellus Holdings

August 2016

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EXECUTIVE SUMMARY

Tellus Holdings Limited (Tellus) is proposing to develop the Sandy Ridge Project (the Proposal) located approximately 75 kilometers (km) north east of Koolyanobbing, in the Shire of Coolgardie, within the Goldfields Region of Western Australia. The Proposal is to develop a kaolin open cut mine and use the mine voids as are repository for the secure storage and isolation of hazardous, intractable and low level radioactive waste in a near surface geological repository using best practice storage and isolation safety case. As part of obtaining regulatory approval for the Proposal, Tellus needs to quantitatively assess what water movement (if any) will occur in the repository over an extended period of time (i.e. greater than 25 years).

Tellus recognised that the proposed repository configuration needed to be assessed using unsaturated flow modelling to confirm the design of the encapsulation, with respect to long term infiltration and seepage. Tellus contracted CyMod Systems to undertake selected unsaturated flow modelling to quantify the likely magnitude of infiltration and seepage of water through the proposed repository. This report describes the models used in the assessment of infiltration and seepage, and makes conclusions and recommendations based on the results of that modelling.

To meet the above objectives, CyMod Systems used the two-dimensional unsaturated flow program Vadose/W, as developed by GeoSlope (GeoSlope, 2012), to construct column models of part of an encapsulated waste storage cell (the 'cell'). Note that these models, with respect to applicable modelling guidelines, are characterised as Class 1, in that they are uncalibrated and are constrained to two-dimensional vertical and horizontal flow (Barnett et al., 2012).

Rockwater Pty Ltd, (Rockwater) drilled seven investigation holes in the development envelope, all of which intersected a granite weathering profile consisting of:

- 2 to 3 metres (m) of surficial aeolian sand;
- overlying up to 8 m of silcreted clay and/or laterite;
- mottled and pallid zone clays/weathered granite; and
- slightly weathered to fresh granite at depth in the deep holes, at a depth of 26 to 31 m.

Rockwater concluded that little or no groundwater has been intersected within the project area, in either the mineral exploration drilling or the 2015 investigation programme, indicating that there is no effective aquifer in the area.

The low rainfall recharge implied by the lack of groundwater in the area is also supported by the prevailing climatic conditions. The area is characterised as semi-arid, with annual average rainfall in the area of less than 300 mm, and evaporation exceeding 2400 mm/annum. Under these conditions, the sporadic rainfall events (which may be intense) result in local runoff, and infiltration of rainfall into the thin aeolian surface sand. However, during subsequent dry periods, evaporation and evapotranspiration act to remove this rainfall infiltration from the top few metres of soil, which results in little if any net recharge.

Based on a chloride mass balance, existing rainfall recharge is estimated to range from 0.0023 mm/annum to 0.07 mm/annum.

A number of flow models were constructed as part of the assessment of infiltration and seepage to the repository. These models included:

- Existing in situ hydrogeological models with historical rainfall;
- Column models of the proposed capping design with different lower boundary conditions; and
- Column models of the proposed capping design with different surface boundary geometry and material properties.

To represent conservative estimates, rainfall input to modelling assessments was based upon repeated cycles of the 10 wettest years since 1890 as worst-case climatic conditions. Seven of the wettest 20 years have occurred since 1990, suggesting conditions may be getting wetter in the future. Consequently, using the wettest 10 years as an analogue for climate change is consistent with recent historical trends.

None of the models presented in this report have been calibrated against measured data, reflecting the absence of time series hydrogeological information in the area. Models were verified by comparing simulated results to similar capping designs in semi-arid climates that have measured data or have been modelled using unsaturated flow and heat transfer. In the case of the simulations of natural ground, the model was compared to prevailing condition, and measured soil moisture profiles in the area, and was found to be consistent with the conceptual hydrogeological model.

In the case for the cells, the results were compared to data in published literature of similar containment cells and the results found to be consistent and reasonable.

Conclusions

The results of the simulations indicate that the infiltration of rainfall into the repository is limited by:

1. A lack of recharge due to runoff from the relatively low hydraulic top soil/subsoil and kaolinised granite, due to the sloping of the cell's clay cap; and
2. evaporation and evapotranspiration of infiltrated water from the top 4 metres of soil that is retained above the cell cap.

The simulations indicate that it is important to retain the water near the surface, allowing it to be evaporated/evapotranspired, which given the semi-arid nature of the prevailing environment, is sufficient to reduce recharge to less than 0.20 mm/year below the clay cap. If the top soil cover is too thick (i.e. greater than 4 metres depending on the grading of the cover material), infiltration may collect on the surface of the clay cap to form a thin saturated layer, which would significantly increase the infiltration reaching the compacted kaolinised granite seal.

Based on the model results, it is likely that less than 0.008 mm/year of infiltration will occur through the Kaolin seal in the waste storage cell. This seepage will enter the in situ kaolinised granite which has an estimated hydraulic conductivity of $4x10^{-6}$ m/sec, which is significantly higher than the capping system. It is anticipated that this seepage will vertically migrate to the water table which in this area is at depth, or be stored in the unsaturated zone, below the repository.

Given the volume of seepage estimated from the simulation, the hydraulic conductivity of the kaolinised granite, the inferred depth to the water table, and the in situ saturation of the unsaturated zone below the repository, it is unlikely that any groundwater mounding or lateral flow of seepage will occur in the vicinity of a cell, as seepage will be stored in the unsaturated zone or enter the water table at depth and flow laterally to the northwest.

Recommendations

Groundwater and climate monitoring should be undertaken to establish base line conditions in the area of the Project. This will allow the impact of mining and waste storage to be quantitatively assessed.

The unsaturated hydraulic properties of the silcrete and backfill material should be determined quantitatively, and used to reduce the uncertainty in future modelling.

Soil moisture probes and other instrumentation should be installed at various depths above the silcrete to establish soil moisture profiles during rainfall events and subsequent dry periods. This data should be used to calibrate any unsaturated flow models that are developed in the future.

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LIST OF ABBREVIATIONS

Abbreviation	Definition
cell	encapsulated waste storage cell
Cl_p	Chloride concentration in rainfall
Cl_g	Chloride concentration in groundwater
CMB	Chloride-mass balance
EWSC	encapsulated waste storage cell
EVT	Evapotranspiration
$J/m^3.C$	Specific Heat Capacity
J/s.m.C	Heat transfer coefficient
k	horizontal hydraulic conductivity
kL	kilolitre
m	meters
m^2	Square meters
m^3	Cubic meters
mbgl	metres below ground level
mbtoc	metres below top of casing
mm	millimetres
m/d	meters per day
m/s	meters per second
mg/L	milligrams per litre
P	Annual Precipitation
Q_r	Recharge due to rainfall, mm/annum
R_c	recharge coefficient
Rockwater	Rockwater Pty Ltd
TDS	Total Dissolved Solids
Vadose/W	2-D unsaturated flow model as developed by GeoSlope

1 INTRODUCTION

Tellus Holdings Limited (Tellus) is proposing to develop the Sandy Ridge Project (the Proposal) located approximately 75 kilometers (km) north east of Koolyanobbing, in the Shire of Coolgardie, within the Goldfields Region of Western Australia. The Proposal is to develop a kaolin open cut mine and use the mine voids for the secure storage and isolation of hazardous, intractable and low level radioactive waste in a near surface geological repository using best practice storage and isolation safety case. As part of obtaining regulatory approval, Tellus needs to quantitatively assess what water movement (if any) will occur in the repository over an extended period of time (i.e. greater than 25 years).

Tellus recognized that the proposed cell configuration as shown in Figure 1, needed to be assessed using unsaturated flow modelling to confirm the design of the encapsulation, with respect to long term infiltration and seepage. The objectives of this modelling are:

- To estimate long term seepage and recharge rates for a typical cell using measured and estimated material properties and historical rainfall sequences;
- Undertake a qualitative sensitivity analysis to better quantify the risks and uncertainties in the cell design due to recharge and seepage;
- Optimize the proposed design to minimize or eliminate recharge into the cell, and
- Provide a report presenting the results of the near surface hydrogeology modelling of the repository.

Tellus contracted CyMod Systems to undertake selected unsaturated flow modelling of a typical encapsulated waste storage cell, to quantify the likely magnitude of infiltration and seepage of water through each cell. This report describes the models used in the assessment of seepage, and makes conclusions and recommendations based on the results of that modelling.

2 MODELLING APPROACH

The objective in developing an unsaturated flow model of the shallow (less than 50 m thick) hydrogeological environment in the vicinity of the repository is to provide a quantitative tool that can be used to assess the likely rainfall recharge into the cells over long time frames (i.e. in excess of 25 years). The modelling of unsaturated flow is typically computer resource intensive, which generally precludes undertaking full three-dimensional unsaturated flow modelling. Consequently, simplified two-dimensional cross sectional models are used to assess vertical flow in and around the repository. This simplification is justified given the absence of significant horizontal flow and focus is on vertical unsaturated flow processes.

The models are required to simulate the rainfall recharge processes that affect the volume of recharge that may enter a cell and must account for the:

- thickness and material properties of soils that may be used in constructing the cell;
- semi-arid climate and irregular nature of rainfall in the area;
- potential revegetation of the surface of the cell; and
- climate uncertainty.

2.1.1 Model Confidence Level Classification

To meet the above objectives, CyMod Systems used the two-dimensional unsaturated flow program Vadose/W, as developed by GeoSlope (GeoSlope, 2012), to construct column models of an encapsulated waste storage cell (EWSC, and referred to as a cell). Note that these models, with respect to applicable modelling guidelines are characterised as Class 1, in that they are uncalibrated and are constrained to two-dimensional vertical and horizontal flow (Barnett et al., 2012).

2.1.2 System of Units

The system of units used for modelling in this report is shown in Table 1, by model component.

Model	Length	Time	Mass	Energy	Temperature
Vadose/W 2012	metres (m)	seconds (s)	gram (g)	joules (J)	Celsius (C)

Table 1: Systems of Units

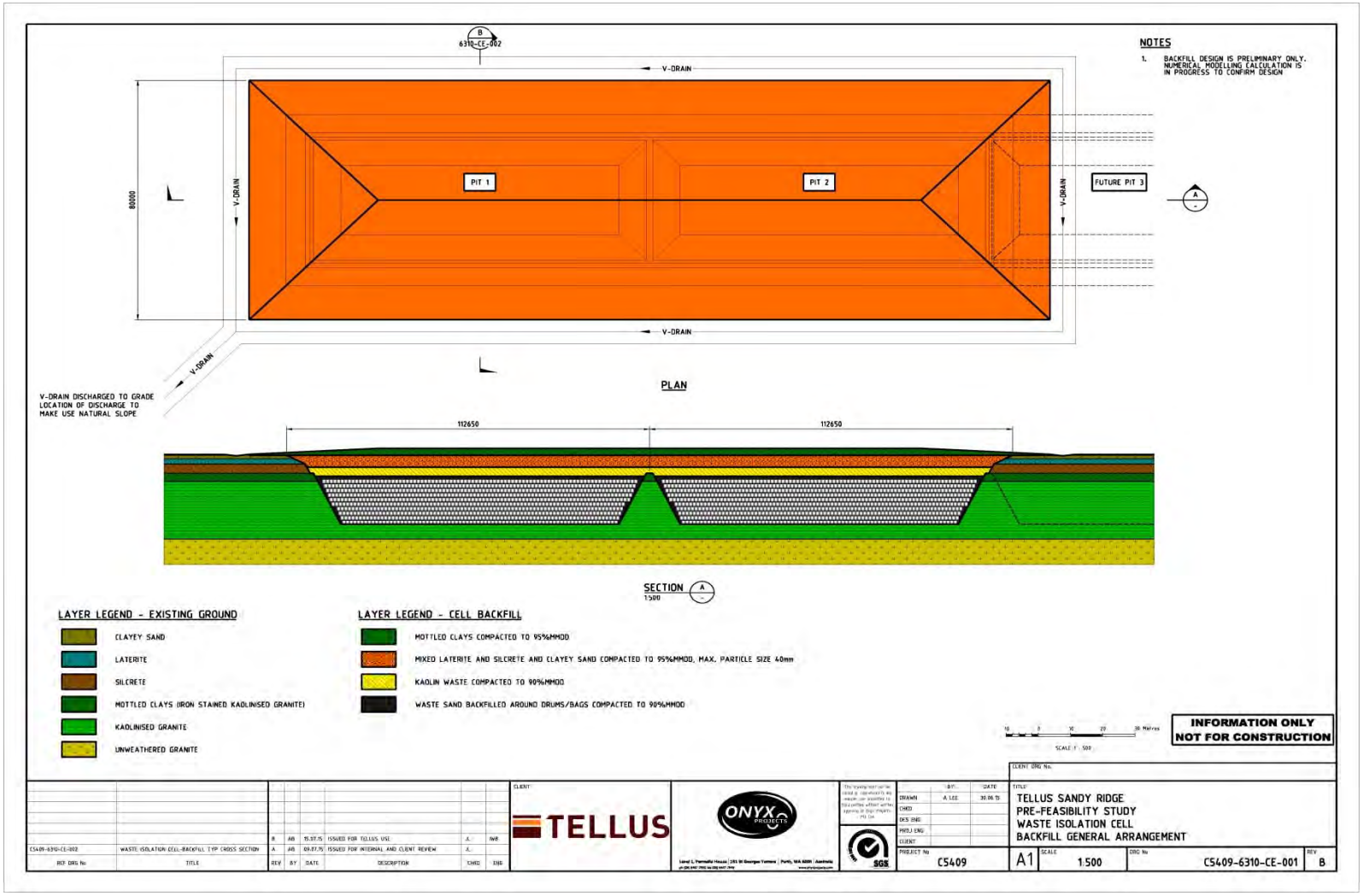

Figure 1: Proposed Cells – Sandy Ridge Project

3 CONCEPTUAL HYDROGEOLOGICAL MODEL

3.1 Geology

Rockwater Pty Ltd, (Rockwater) drilled seven investigation holes in the development envelope, all of which intersected a granite weathering profile consisting of:

- 2 to 3 m of surficial aeolian sand;
- overlying up to 8 m of silcreted clay and/or laterite;
- mottled and pallid zone clays/weathered granite; and
- slightly weathered to fresh granite at depth in the deep holes, from 26 to 31 m in depth.

Minor vugs were noted in the silcrete, clay, kaolinite and weathered granite. A typical geological cross section is shown in Figure 2.

3.2 Hydrogeology

The drilling investigation program undertaken by Rockwater in 2015 showed that of seven groundwater exploration holes drilled in the proposed storage area, four were dry, in that they did not intersect the water table (Rockwater 2015). In addition, all of the kaolinite resource exploration holes drilled by Tellus were dry in the proposed pit/cells area. Of the water exploration holes, five of them intersected some damp kaolinite/weathered granite, but only two were within the proposed pits/cells area.

The water from bores SRMB150 and SRMB152 is saline, with salinities of 6,570 and 6,030 mg/L TDS (total dissolved solids), respectively. All three bores that intersected groundwater had a water level at a depth lower than the planned excavation depth of 30 m. Bore SRMB150 had the shallowest water level (34.23 metres below top of casing, mBTOC) on 6 May 2015, but this bore is located outside of the repository area.

Rockwater concluded that the low airlift yields from investigation bores and low permeability of the weathered profile suggest that the zones containing groundwater do not constitute an aquifer.

3.2.1 Moisture Content

Resource samples were acquired during exploration drilling of the kaolin orebody, that indicate that for weathered granite below 6mbgl (metres below ground level); moisture content is typically between 10-12% by weight.

This suggests:

- the soil is very dry,
- the area has limited recharge,
- the depth to the water table is well below the base of weathered granite, and
- the material is free draining (i.e. water flows vertically under a unit gradient due to gravity).

3.2.2 Material Properties

A program of testing was undertaken on selected bores to estimate the saturated hydraulic conductivity (k) of the weathered granite. Table 2 shows the results of those tests, which characterize the weathered granite as having low hydraulic conductivity.

Bore	Test No.	k	k	Lithology of Screened Interval
		(m/d)	(m/s)	
SRMB146	1	0.14	1.62×10^{-6}	Kaolinite, & deeply weathered granite
SRMB146	2	0.12	1.39×10^{-6}	
SRMB147	1	0.93	1.08×10^{-5}	Kaolinite (saprolite)
SRMB148	1	0.99	1.15×10^{-5}	Kaolinite (weathered granite)
SRMB149	1	0.39	4.51×10^{-6}	Weathered granite
SRMB149	2	0.22	2.55×10^{-6}	
SRMB152	2	0.18	2.08×10^{-6}	

Table 2: In Situ Hydraulic Conductivity Test Results (Rockwater 2015)

Note that most in situ hydraulic conductivity tests are considered to have an accuracy of about one order of magnitude, and hence they should only be used for relative comparison of hydraulic conductivity (Nagy et al, 2013).

In addition to in situ pumping tests, eleven core samples from 4 bores were recovered from the silcrete and unweathered granite for laboratory testing. The selected cores were chosen to provide representative estimates of bulk saturated hydraulic conductivity (k_v) for the silcrete and unweathered granite. The results of the testing showed that:

- Silcrete k_v was 5×10^{-8} m/s;
- Unweathered granite k_v ranged from 4×10^{-8} to 31×10^{-8} m/s,

The saturated hydraulic conductivity represents the maximum hydraulic conductivity of the material. Consequently, the saturated hydraulic conductivity is greater than the unsaturated hydraulic conductivity, as shown for each soil type in Appendix A, as defined by a conductivity and matric suction relationship, with matric suction dependent on water content.

3.2.3 Recharge

The lack of a saturated aquifer in the Project area suggests that the low rainfall, high evaporation rate and lithology of the site mitigates against the formation of an aquifer. Consequently, rainfall recharge may be insufficient to cause groundwater to accumulate and saturate the weathered granite to form an aquifer. This conclusion is consistent with the prevailing hydraulic conductivity of the geological formations making up the stratigraphic sequence in the area, which limits the rate of deep infiltration, while increasing the exposure of soil moisture to high evapotranspiration rates in shallow soils.

The low rainfall recharge implied by the lack of groundwater aquifers in the area is also supported by the prevailing climatic conditions. The area is characterized as semi-arid, with annual average rainfall in the area of less than 300 mm, and evaporation exceeding 2400 mm/annum. Under these conditions, sporadic rainfall events (which may be intense) result in local runoff, and infiltration of rainfall into the thin aeolian surface sand. However, during subsequent dry periods, evaporation and evapotranspiration act to remove this rainfall infiltration from the top few metres of soil, which results in little if any net recharge.

The geology of the area enhances the store and release nature of the natural recharge processes. Figure 2 shows there are 2-4 metres of top soil and laterite, underlain by 3-8 metres of hard, dense silcrete which is inferred to have a hydraulic conductivity of $5x10^{-8}$ m/s. Therefore, in the instance of a large, intense storm event, any significant surface infiltration will be temporally stored in the unsaturated top soil and laterite, within 4 metres of the surface. In this instance, when infiltration is sufficient, an increase in water storage in the unsaturated layer will develop in the top soil/laterite on top of the less permeable silcrete.

Given the thickness of the top soil and laterite, and the shallow depth of the silcrete, it is likely that any rainfall recharge that infiltrates below the shallow topsoil would be subsequently evaporated, or evapotranspired by deep-rooting vegetation, resulting in the drying of the material lying above the silcrete, between rainfall events. This process results in limited infiltration of rainfall recharge to depth, and is consistent with the lack of either perched water or a saturated zone at depth in the weathered granite profile.

Below the silcrete is weathered kaolinised granite, grading to fresh granite. If the silcrete is absent or more permeable (i.e. vuggy - containing macropores for preferential flow), in the above instance of an extreme rainfall event, infiltration may extend through the weathered granite profile to form a damp to saturated zone lying on top of the fresh granite. The absence of a water table in the weathered kaolinised granite on top of the fresh granite, suggests any such deep infiltration would subsequently migrate into low permeability fresh granite (hydraulic conductivity of $4.5x10^{-8}$, and porosity 0.1 – 1%, Cook, 2003), with storage of water in fresh granite forming localised fractured rock aquifers.

3.3 Recharge Estimated using a Chloride Mass Balance

A chloride-mass balance (CMB) is a widely used technique that provides a direct estimate of rainfall recharge based on readily attainable data. However, the following assumptions must be satisfied to accurately apply the CMB method as an estimate of long term, average groundwater recharge:

- All chloride in the groundwater originates only from direct rainfall recharge to the aquifer;
- The chloride-mass flux is in steady state (i.e. invariant with time); and
- There are no processes that result in the loss or concentration of chloride in the aquifer (i.e. no mineral dissolution, adsorption or precipitation).

Based on the conceptual hydrogeology of the area the following observations can be made:

- the limited groundwater is at depth, and has minimal interaction with other groundwater processes:
- There are no other sources of groundwater in the area, suggesting rainfall is the primary source of this water;
- Given the geological stability of the lithology in the area, there are no geochemical processes in the area that would react with chloride, thus it can be considered conservative; and
- Given the prevalence of a semi-arid climate for a long period, it is likely that the chloride mass flux is in steady state.

Therefore, based on the conceptual hydrogeological model, it is likely that the stated assumptions above are applicable to the project area and justify use of a CMB.

Under the above conditions, the spatially averaged recharge flux to the aquifer under natural rainfall recharge can be expressed as:

$Q_r = (P)(Cl_p)/Cl_g$ (Wood, 1999).

Where:

Q_r is the average ground water recharge flux (mm/annum);
P is the average annual precipitation (mm/annum);
Cl_p is the average precipitation-weighted chloride concentration (mg/L); and
Cl_g is the average chloride concentration in the groundwater (mg/L).

For the project area the variables defined above are as indicated below:

1. P is 287 mm/annum;
2. Cl_p is 0.05 to 1.5 mg/L (Turner et al, 1995); and
3. CL_g is estimated as 4050 mg/l (Rockwater 2015, assuming same composition as seawater and a TDS of 6300 mg/L).

Based on these parameter estimates, rainfall recharge to the project area may range from 0.0035 to 0.106 mm/annum, with the lower estimate more applicable to the project area.

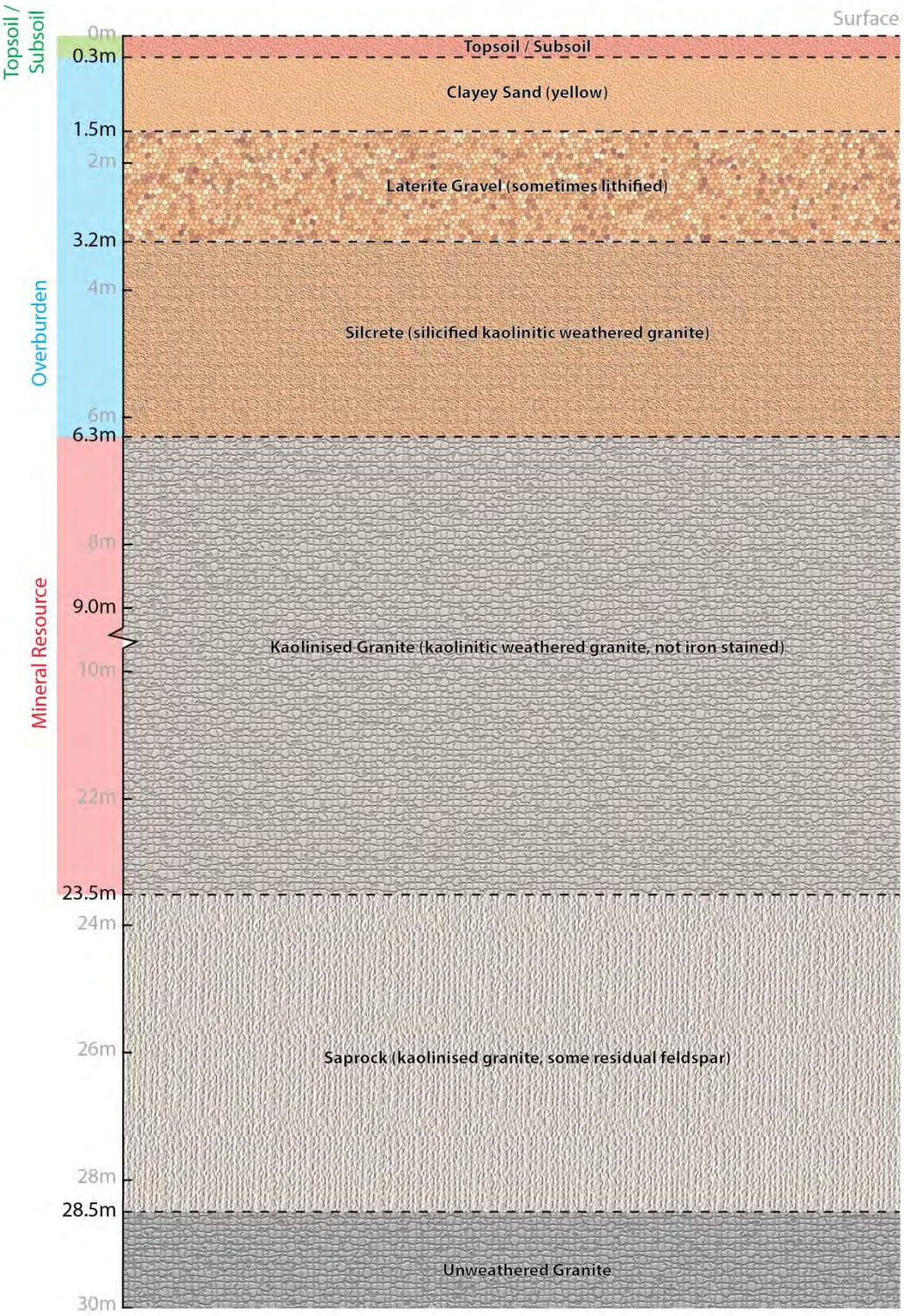

Figure 2: Geological Cross-section

4 MODEL CONSTRUCTION

A number of flow models have been constructed as part of the assessment of infiltration and seepage into/out of a cell. These models include:

- Existing in situ hydrogeological models with historical rainfall;
- Column models of the proposed capping design with different lower boundary conditions; and
- Column models of the proposed capping design with different surface boundary geometry and material properties.

The column models are all based on information provided by Tellus with respect to the proposed cell configuration. Figure 3 shows a cross-section through a single cell that was used to construct the unsaturated column models. Consequently, all the models use the same environmental inputs and are based on the same conceptual hydrogeological model, as described in Section 3. These common components of the unsaturated flow models are described below.

4.1 Material Properties

The material properties, as used in the models, describe the unsaturated flow properties that determine how water flows through both natural and engineered ground. Tables 3 and 4 list the hydraulic properties of the materials used in the models, and their corresponding saturated properties. The saturated hydraulic conductivity of the materials is as provided by Tellus (Ingram, 2015). The hydraulic conductivity of in-situ materials were estimated from:

- in situ testing (i.e. slug test); or
- based on Hazen's formula, and
- assumed in the case of silcrete.

For made ground (i.e. capping and kaolinised granite seals) saturated hydraulic conductivity was based on laboratory measurements of remoulded samples (Douglas Partners, 2015). Appendix A shows the relationships used to model hydraulic conductivity and saturation as a function of matric suction pressure.

In the absence of measured data (i.e. measured saturation at different pore pressures, and measured hydraulic conductivity at different pore pressures or saturation) generic curves, as provided by GeoSlope based on a material's grain size classification, were used to approximate the unsaturated flow material properties.

The Vadose/W models presented here use the full thermal model (required for climate boundary conditions). The thermal properties were modelled using material types as shown in Table 5. The estimates of thermal conductance and thermal storage for the in-situ materials and cap were taken from the literature (Abu-Hamdeh et al., 2000; Farouki, 1981).

Material	Generic Material	Saturated Hydraulic Conductivity (m/s)	Water Content at Saturation (fraction)	Comments
Clayey Sand	Silty Sand	$1x10^{-6}$	0.35	
Laterite	Silty Sand	$2.5x10^{-5}$	0.35	
Silcrete	Sand/gravel	$5x10^{-8}$	0.10	Silicified with poorly connected vugs, as measured from selected cores
Mottled Clays	Clay	4.62×10^{-6}	0.45	
Kaolinised Granite	Clay	4.62×10^{-6}	0.45	
Fresh Granite	Sand/gravel	$4.5x10^{-8}$	0.02	Base of model, assumed to be fractured

Table 3: Hydraulic Properties of Natural Materials

Material	Generic Material	Saturated Hydraulic Conductivity (m/s)	Water Content at Saturation (fraction)	Comments
Kaolinised Granite – uncompacted	Silty Sand	$1x10^{-6}$	0.35	Used as cover over compacted mottled clay
Mottled Clays - compacted	Clay	6.13×10^{-8}	0.40	
Kaolinised Granite - compacted	Clay	6.13×10^{-8}	0.40	
Mixed Laterite, silcrete and clayey sand compacted	Silty Sand	$1x10^{-7}$	0.35	
Kaolin Waste Compacted	Silty Sand	$2.2x10^{-8}$	0.45	May not be available, replaced with compacted Kaolinised granite
Granular material backfilled around waste packages	Sand	5×10^{-5}	0.35	

Table 4: Unsaturated Flow Material Properties - Cell Construction

Material	Generic Material	Thermal Conductivity Dry (J/sec• m•C)	Volumetric Specific Heat Capacity Dry (J/m^3•C)
Clayey Sand/Top Soil/ Granular material backfilled around waste packages	Silty Sand	0.5	2.3×10^6
Laterite	Silty Sand	0.3	2.5×10^6
Silcrete	Sand	0.3	2×10^6
Mottled Clays natural and compacted Kaolinised Granite	Clay	0.3	2.5×10^6
Kaolinised Granite Kaolin Waste	Clay	0.3	2.5×10^6
Unweathered Granite	Sand	0.3	2×10^6

Table 5: Thermal Model Material Properties

4.2 Vertical Discretisation

The model layers are defined by digital cross-sections of the inferred geology that is likely to be encountered in the area. The cross-sections have all been constructed from data as shown in Figure 3. Each geological layer is defined as polygonal region, in which material properties are uniform. These regions are subdivided (i.e. discretised) into quadrilateral cells, that are used to solve the state equations describing unsaturated water and energy flow in the region using a finite element approach.

Vadose/W uses two types of finite elements, standard and surface elements as defined by a surface region. For standard finite element regions, the actual gridding of cells is automatically done by Vadose/W, using a specified characteristic length (i.e. 1 m), that determines the scale of the finite elements. In the case of the surface elements, the region is automatically applied to the top surface of the model when a transient climatic boundary condition is used. Due to the steep temperature and pressure gradients near the soil surface, the surface region has enhanced vertical discretisation, through the use of automatically generated thin cells. The thickness of the surface layer is manually specified by defining the number of layers; dependent on the nature of the problem, and the thickness of the surface layer. The surface region is then solved for the flow and thermal equations using enhanced numerical and spatial resolution.

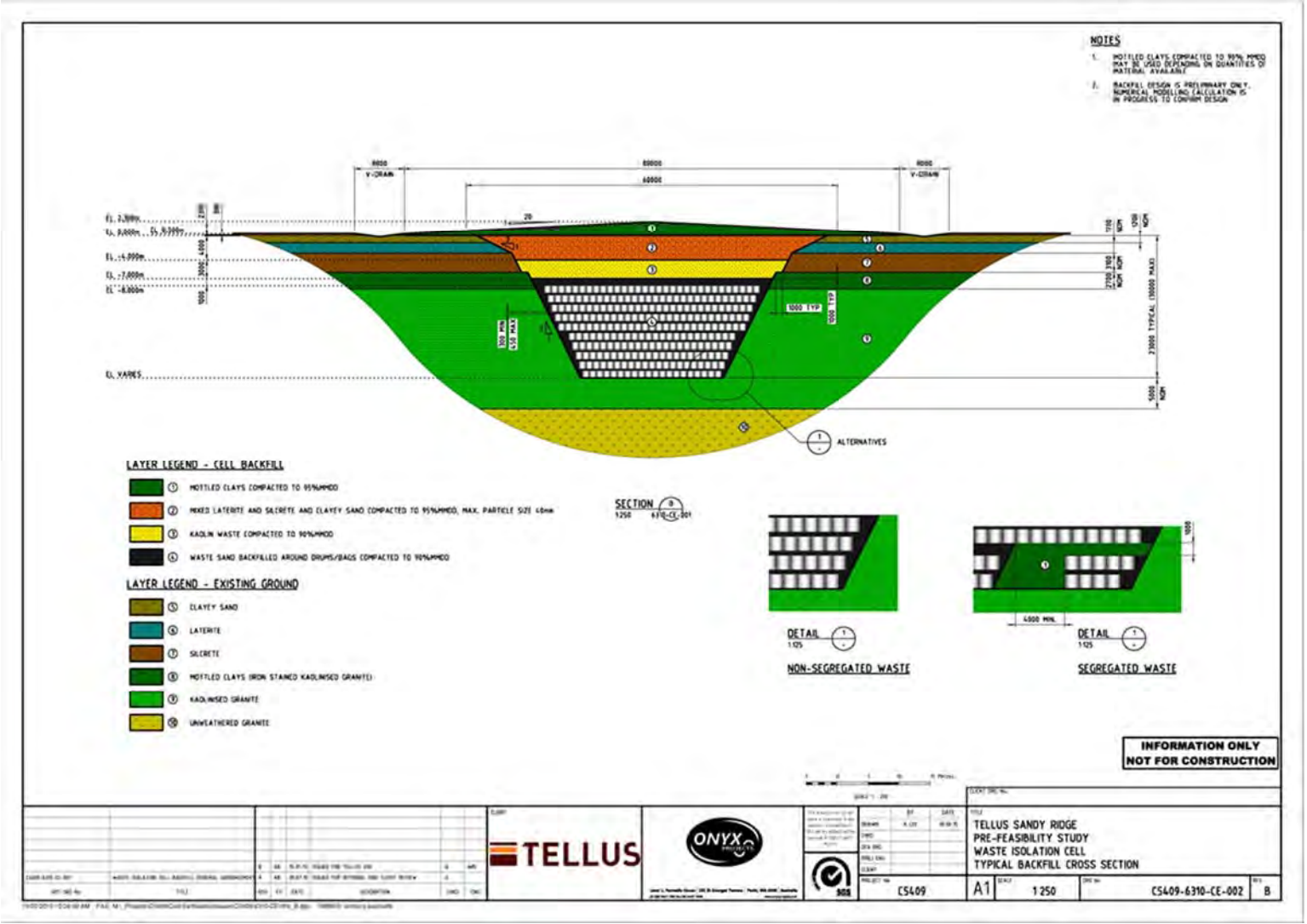

Figure 3: Cross-section of Cell

4.3 Initial Conditions

The initial conditions for the model simulations are generated by assuming average climate conditions and running a steady state model. The steady state model calculates the saturation and pressure distribution assuming no change in water storage, which is consistent with time invariant recharge conditions. However, average climate conditions may not be representative of typical conditions in the area, as these will depend on preceding rainfall conditions.

To limit the impact of the initial conditions on model results, the models were also run for an initial 80 years using time-varying climate inputs so as to minimize model artefacts due to the use of average conditions in a semi-arid climate, in the steady state model. The 80-year conditioning time is limited by the computational resources required for long transient simulations, and may result in estimates of vertical fluxes still being influenced by the initial conditions.

4.4 Boundary Conditions

All of the models employ boundary conditions on the top and bottom horizontal extents of the model domain. The vertical boundaries of the models are considered stream lines, which by definition do not allow flow across them: these boundaries are defined as no flow both for water and energy.

4.4.1 Bottom of the Model

The hydrogeological conditions at the bottom of the model are ambiguous in the area of the proposed pits/cells, as no saturated aquifer exists, and the extent of saturation is spatially variable. Consequently, for the purposes of this study, the nature of the boundary on the bottom of the models is addressed using a sensitivity analysis.

There are three viable boundary conditions that are used for the bottom of the model:

- Unit gradient boundary condition;
- A specified pore pressure boundary condition; and
- No flow boundary condition.

The effects of these boundary conditions have been assessed as part of a sensitivity analysis of the results, and reflect the ambiguous conditions associated with the fresh/weathered granite basement. Rockwater found in some areas that the fresh granite was saturated, indicating likely localised fractured rock aquifers, while in the vicinity of the proposed cells the fresh/weathered granite was dry, with only 3 areas indicated as damp.

Consequently, the three boundary conditions are used to model:

- Gravity drainage through the fresh bedrock from the weathered granite, where the flow is controlled by the unweathered granite;
- Potential for elevated soil moisture, causing dampness; and
- Impermeable bedrock resulting in a saturated zone and horizontal flow in the weathered bedrock.

Subsequently, the unit gradient flow boundary condition was used to report results as this was considered most representative of the prevailing conditions in the proposed pit/cells area.

4.4.2 Ground Surface – Top of Model

The top surface of the model has three important boundary processes that directly affect the amount of recharge that can occur:

- Rainfall;
- Runoff; and
- Evapotranspiration (EVT).

All of the models used a transient climate model to simulate these conditions at ground surface, which may include a thermal model, a runoff model, and an evapotranspiration model. In order to simulate these environment components, the models use daily climate data, applied to Vadose/W surface elements with a full thermal model.

4.5 Recharge and Evapotranspiration

The surface zone in Vadose/W calculates net flux (recharge) to the unsaturated zone, accounting for water and vapour movement, utilizing a full thermal model. This results in a computational intensive simulation, which can effectively simulate evapotranspiration and the heating of the soil due to insolation and high ambient temperatures. Numerically, the surface zone can experience very high negative pore pressures due to high surface temperatures which rapidly decrease with depth, resulting in steep hydraulic and thermal gradient in this region.

The application of a climate-based boundary condition for recharge, runoff and evaporation and evapotranspiration allows the model to more accurately simulate the processes that are relevant to estimating recharge at the site by constraining the solution to respect the physical limits of pore pressure (which drives water flow) and available energy which limits evaporation and hence pore saturation. Note that evapotranspiration was not included in some of the models as excluding EVT is a conservative assumption with respect to estimating the risk of infiltration/recharge.

4.5.1 Rainfall and Evaporation

The drilling results (Section 3) showed that the proposed cells area does not have a saturated aquifer, and dampness was only found in three bores at depth. This indicates rainfall recharge in the area is small, and insufficient to cause the accumulation of groundwater to form a saturated layer. The lack of recharge is due to:

- Low average rainfall;
- Large intermittent rainfall events that are typically followed by long periods of no rainfall;
- High ambient temperature and high potential evaporation; and
- Runoff from relatively low hydraulic conductivity top soil.

These conditions are also consistent with the assessment of the area against the Thornthwaite Moisture Index (TMI). The use of this climatic parameter is a predictor of the depth of seasonal moisture change and is widely accepted as a method to categorise aridity in Australia and the depth of the drying on soils. The estimated TMI for the site is -45, suggesting that seasonal moisture changes can occur to a depth of 4 m below ground level. This depth extends to below the top of silcrete in natural ground, which effectively acts as an aquitard.

In the case of the proposed cell, the compacted mottled clay cap will be about 2 metres below the surface, given the thickness of the top soil and subsoil. Consequently, the compacted mottled clay cap, which has a hydraulic conductivity similar to the silcrete (6.13×10^{-8} m/s versus 5×10^{-8} m/s), will act in the same manner by delaying vertical flow, and increasing soil saturation in and above the cap, thereby providing more time for evaporation to occur.

The average climate parameters as estimated for the project location are given in Table 6.

Max Temp (C)	Min temp (C)	Max Relative Humidity (%)	Min relative Humidity (%)	Wind Velocity (m/s)	Rainfall (mm/annum)	Evaporation (mm/annum)
25.5	11.4	80	35	3	252	2467

Table 6: Interpolate Average Annual Climate Parameters 1890-2015

For the purposes of this study an interpolated dataset of daily climate time series data was generated for the location using SILO data (Jefferies et al, 2001). This data was then used as input into the models, using the climate boundary condition in Vadose/W. Figure 4 shows the interpolated monthly rainfall in the area from 1990 to 2015.

To account for some of the uncertainty in the model and rainfall dataset, daily rainfall input for the forward modelling assessments were constructed using repeated cycles of the 10 wettest years since 1890. This climate sequence

was used as it may result in a conservative (i.e. larger than will actually occur) estimate of infiltration and seepage under high rainfall conditions for the predictive scenario assessments (Scenarios 2 through 4) of the proposed cell design. The initial scenario assessment (Scenario 1) to establish existing conditions used 20 years of historic climate data starting in 1995 as shown in Figure 4.

Table 7 summarizes the wettest 20 years since 1890, with the wettest 10 years of these used for the rainfall data set in forward scenarios (Scenarios 2 through 4). The wettest 20 years listed in Table 7 is also shown in Figure 5 as monthly rainfall. It is interesting to note that seven out of the wettest 20 years have occurred since 1990, suggesting conditions may get wetter in the future.

Year	Max Temp (C)	Min temp (C)	Max Relative Humidity (%)	Min relative Humidity (%)	Wind Velocity (m/s)	Rainfall (mm/annum)
1992	23.72	11.19	41.87	82.37	3	553.8
1999	25.16	11.82	36.97	78.55	3	521.2
1995	24.41	11.29	42.22	86.82	3	499.6
1963	24.83	11.86	40.68	81.81	3	476.6
1974	24.34	11.17	40.58	82.76	3	443.2
1975	24.23	10.47	39.31	83.28	3	412.9
2011	25.26	12.23	38.34	80.42	3	411.6
1915	25.37	11.92	39.02	83.64	3	405.6
2000	24.82	10.39	38.31	84.43	3	399.8
2006	26.02	11.42	34.63	80.78	3	386.9
1942	24.46	10.88	36.67	79.60	3	385.8
1917	24.01	10.39	39.15	84.85	3	382.7
1930	26.22	11.76	36.48	82.29	3	366.6
1980	25.78	11.96	35.08	74.81	3	348.9
1955	24.03	10.89	40.20	83.94	3	347.7
1918	25.73	11.65	38.31	84.71	3	347.2
1943	24.60	10.81	37.01	80.75	3	343
2014	26.57	12.28	33.16	74.54	3	341.5
1892	25.42	11.47	35.03	80.76	3	337
2004	26	11	36	81	3	333.8

Table 7: 20 Highest Rainfall Years Since 1890

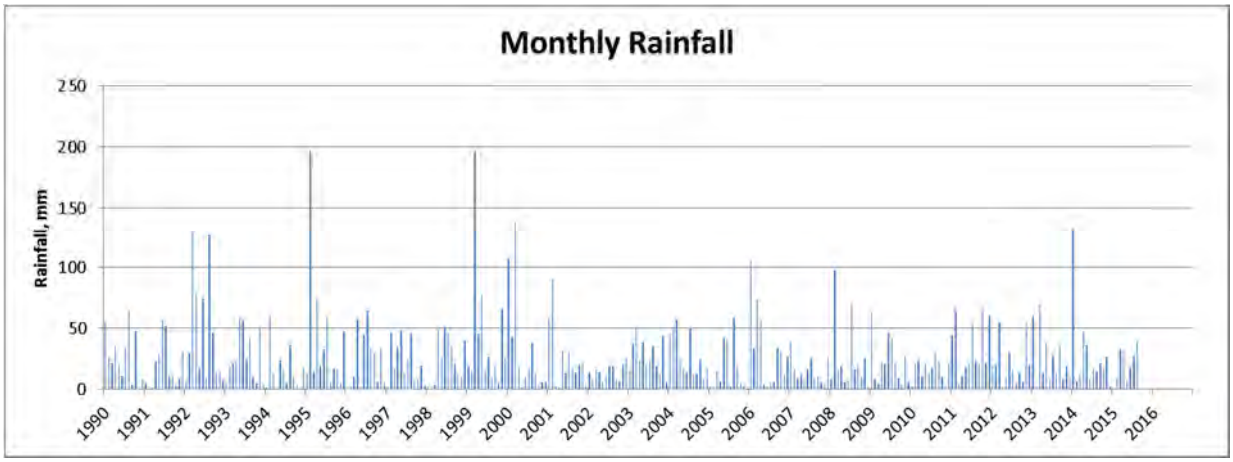

Figure 4: Monthly Rainfall – Sandy Ridge

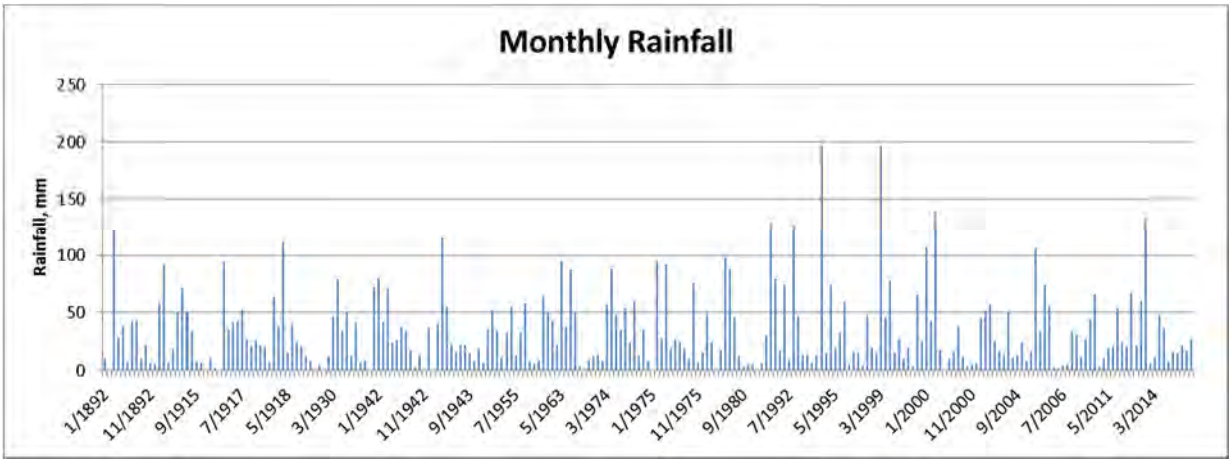

Figure 5: Monthly Rainfall – 20 Highest Rainfall Years

5 MODEL CALIBRATION AND VERIFICATION

None of the models presented in this report have been calibrated against measured data, reflecting the absence of time series hydrogeological information in the area. However, the models were verified by comparing simulated results to similar situations that have measured data or that have been modelled using unsaturated flow and heat transfer. In Scenario 1, for natural ground, the modelling results were compared to the prevailing conditions in the area, and were found to be consistent with the conceptual hydrogeological model. Additionally, seasonal soil temperatures were compared to data in published literature and found to be consistent, for the climatic conditions.

A review of measured moisture content in samples deeper than 6 m below ground level (mbgl) indicates that soil moisture is typically between 10-12%. A review of modelling results for Scenario 1 show similar soil moisture conditions as those measured. These results support the model's implementation of the proposed conceptual hydrogeological model of the area.

In the case for the a cell, the results were compared to data in published literature of capping systems in similar climatic conditions and the results found to be consistent and reasonable and are discussed in Section 6.

6 MODEL SCENARIOS

All of the scenarios were simulated using a vertical column 1 m thick, by either 12 or 20 m wide. Vertically, the column represents approximately 40 m of soil, and was constructed from the information contained in Figure 3. Results of the scenario water balances are reported as totals for the entire model, and as normalized vertical fluxes passing through a one square metre area, specified as mm per year. The normalized flux is used to calculate infiltration and seepage estimates for an entire cell.

6.1 Run Parameters

All of the scenarios modelled were simulated using transient conditions, with the following Vadose/W options:

- Initial conditions for saturation and temperature taken from previous model simulations;
- Minimum pressure head difference for convergence of 0.01 kPa, and minimum temperature difference of 0.01 C.
- Maximum of 100 iterations with 10 reviews; and
- Adaptive time stepping with a minimum time step of 60 seconds and a maximum time step of 720 seconds.

Using the above model options, the execution times for a 20-year run ranged from 12 to 24 hours, using a parallel solver (40 cores).

The results of the unsaturated modelling are presented as soil moisture in decimal percent (i.e. 0.1 = 10%). This soil moisture can then be compared to the graphed curves of soil hydraulic properties, for the relative soil type, as shown in Appendix A. The corresponding matric suction then implies the estimated suction pressure holding soil moisture in the soil unit. Water content held at matric suction above 100kPa (approximate atmospheric pressure) is held against gravity and thus is no longer freely draining. The matric suction pressure can be used to estimate the unsaturated hydraulic conductivity of the soil type at a specific soil moisture, which can result in k being orders of magnitude less than the saturated hydraulic conductivity for the same material.

6.2 Scenario 1: Existing Conditions

A one-dimensional column model, shown in Figure 6, was constructed to simulate the existing conditions at the site. Two cases were simulated:

- Case A - uses estimated material properties based on soil characteristics
- Case B – material properties are adjusted to account for no runoff for rainfall on the order of 50 mm in twelve hours.

The objective of scenario 1 (S1A and S1B) is to establish that the model can replicate known conditions, thereby confirming that the model correctly simulates the conceptual hydrogeology, which will reduce the uncertainty in subsequent model simulations. This approach is used in lieu of model calibration, as there is no quantitative data available for calibration.

The Scenario 1A model uses the soil properties as defined in Tables 3, 4 and 5, and has the following boundary conditions:

- 20 years of historic climate data starting in 1995;
- Evapotranspiration from sparse vegetation;
- lower boundary is specified as a unit gradient which is typically recommended for one-dimensional column models that do not have a water table; and
- ponding of water is allowed, which eliminates runoff, as the top of the model is flat.

Scenario 1B is the same as Scenario 1A, but has modified topsoil material properties to allow rainfall to infiltrate given very dry preceding conditions and includes evapotranspiration. This scenario is based on anecdotal evidence that under some conditions, rainfall does not runoff but infiltrates into the ground.

The twenty-year simulations are run five times, with subsequent runs using the results from the previous model run as the initial condition. This effectively makes the scenario run 100 years long. The concatenating of runs was required due to the relatively long runtimes of a single twenty-year run. Results of the simulations are

presented below for the last 20 years of the simulation.

6.2.1 Scenario 1A - Model Results

Figures 7 and 8 show the predicted soil moisture (as the volumetric fraction of water in a unit volume of soil) and the fractional saturation (volumetric soil moisture divided by soil porosity) as a function of depth at the end of 100 years. From the figures, all of the geological materials remain unsaturated (i.e. fractional saturation is less than 1), though there is increased saturation at the top of the silcrete, due to the low hydraulic conductivity of this material. The saturation profile confirms that for the climatic conditions simulated and the characteristics of the soil column, it is unlikely that a saturated aquifer will occur either perched atop the silcrete or at the interface between weathered and fresh granite. The low moisture content of the soils results in very low unsaturated hydraulic conductivity (i.e. due to very large suction pressures > 10,000 kPa), which reduces water flow in these soils.

These results are consistent with measured water content in sampled soil from exploration holes drilled in the area, which showed soil moisture ranging from 10-12%, below 6 mbgl.

The SA1 results are consistent with the conceptual hydrogeology and confirm that the model is a reasonable analogue of the existing conditions at the project site. Note that the model does predict increased soil moisture on top of the unweathered granite, which is due to its low assumed hydraulic conductivity. A review of available bore logs does indicate that water occurs in the vicinity of the interface between the fresh granite and the overlying weathered granite in the area of the proposed cells. There were no soil samples taken above 6 mbgl, so no comparison of simulated soil moisture to measured data can be made above the silcrete.

6.2.1.1 Water Balance

Table 8 and 9 shows the water balance for S1A, for the last 20 years of the simulation. Figure 9 shows the water balance error, which in this case is the difference between the cumulative water balance versus the change in storage. For transient models, the water balance error is generally defined as the change in storage (as indicated by the difference in moisture content between the start and the end of the model) divided by the cumulative water balance (net fluxes) for the same period. Figure 10 shows the cumulative boundary fluxes for the model, as a function of time. Figure 13 shows the evapotranspiration of water by deep rooted vegetation, with a maximum leaf area index (LAI) of 0.5.

Based on a change in storage of -0.25 m^3, versus a water balance error of 0.012 m^3, the percentage water balance error is 5% which is acceptable for this type of groundwater model (Barnett et al., 2012).

Table 10 shows the annual fluxes passing vertically through the topsoil/subsoil, silcrete and weathered granite, in terms of infiltration and seepage over the last 20 year simulation period.

Based on the water balance, most rainfall is evaporated with some evapotranspired after heavy rainfall, with infiltration into the topsoil/subsoil layer of 0.20 mm/annum. The infiltration below the silcrete layer, which is indicative of rainfall recharge, is on average 0.19 mm/annum. This modelling result is consistent with, but larger than the average rainfall recharge based on a chloride mass balance (section 3.3), which indicated a range from 0.0036 to 0.10 mm/annum. The larger recharge estimated by the model is likely due to the use of measured silcrete vertical hydraulic conductivity of $5.x10^{-8}$ m/s from cores which may not characterize the spatial variability of the silcrete accurately.

Run Duration	Model Area	Rainfall	EVT	Evaporation	Change in Storage	Water Balance Error	Water Balance Error
Years	m^2	m^3	m^3	m^3	m^3	m^3	%
20	20	111.5	-2.27	-109.36	-0.25	-0.013	5

Table 8: S1A - Model Water Balance

Rainfall	EVT	Evaporation	Change in Storage	Water Balance Error	Water Balance Error
mm	mm	mm	mm	mm	%
279	-5.7	-273.4	-0.6	0.03	5

Table 9: S1A – Annual Water Balance

Rainfall	Infiltration to Top Soil/Subsoil	Infiltration Below Silcrete
mm	mm	mm
279	0.20	0.19

Table 10: S1A – Annual Rainfall, Infiltration and Seepage

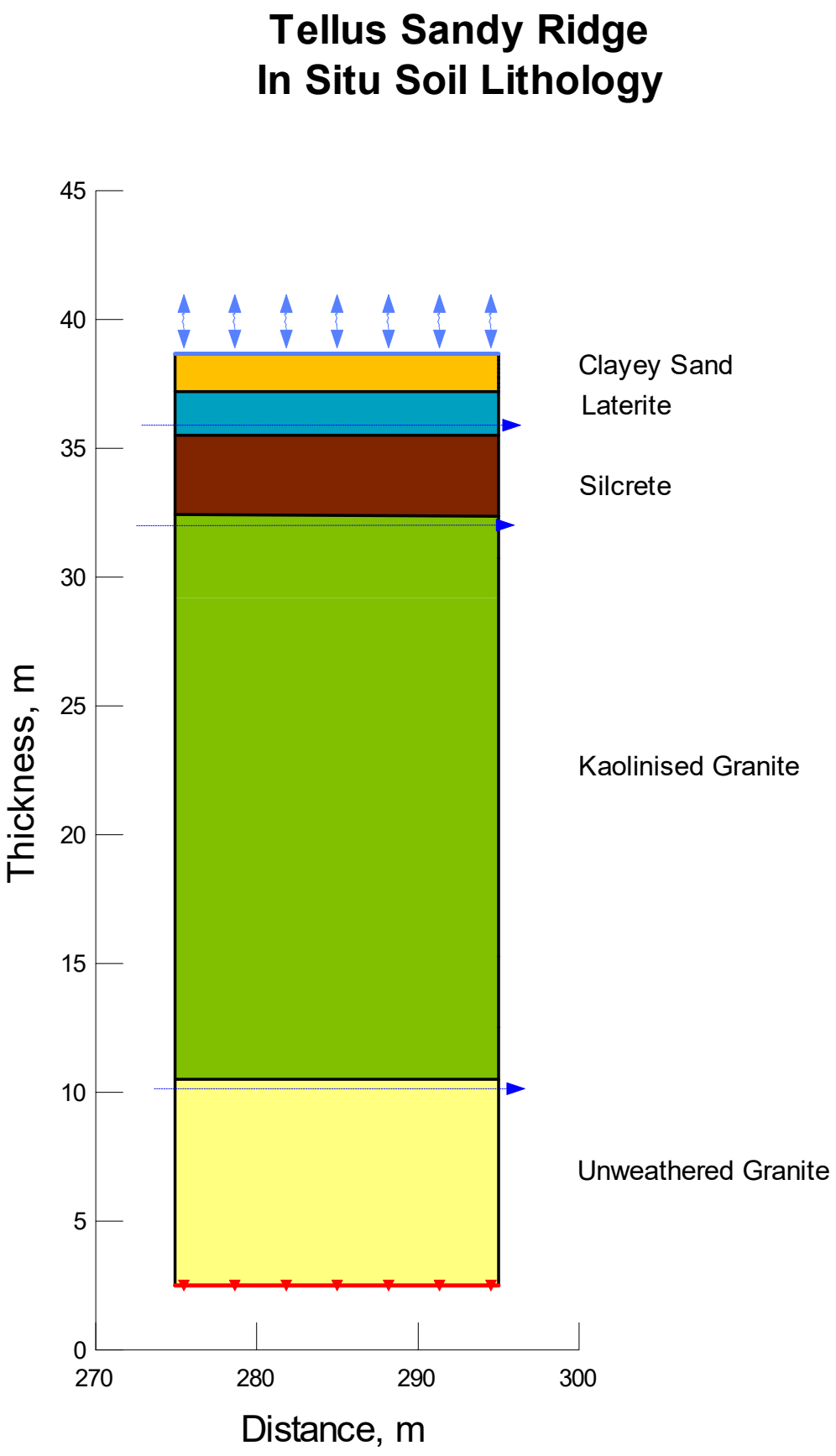

Figure 6: SA1 – Model Structure (Natural Ground)

Tellus Sandy Ridge
In Situ Soil LIthology

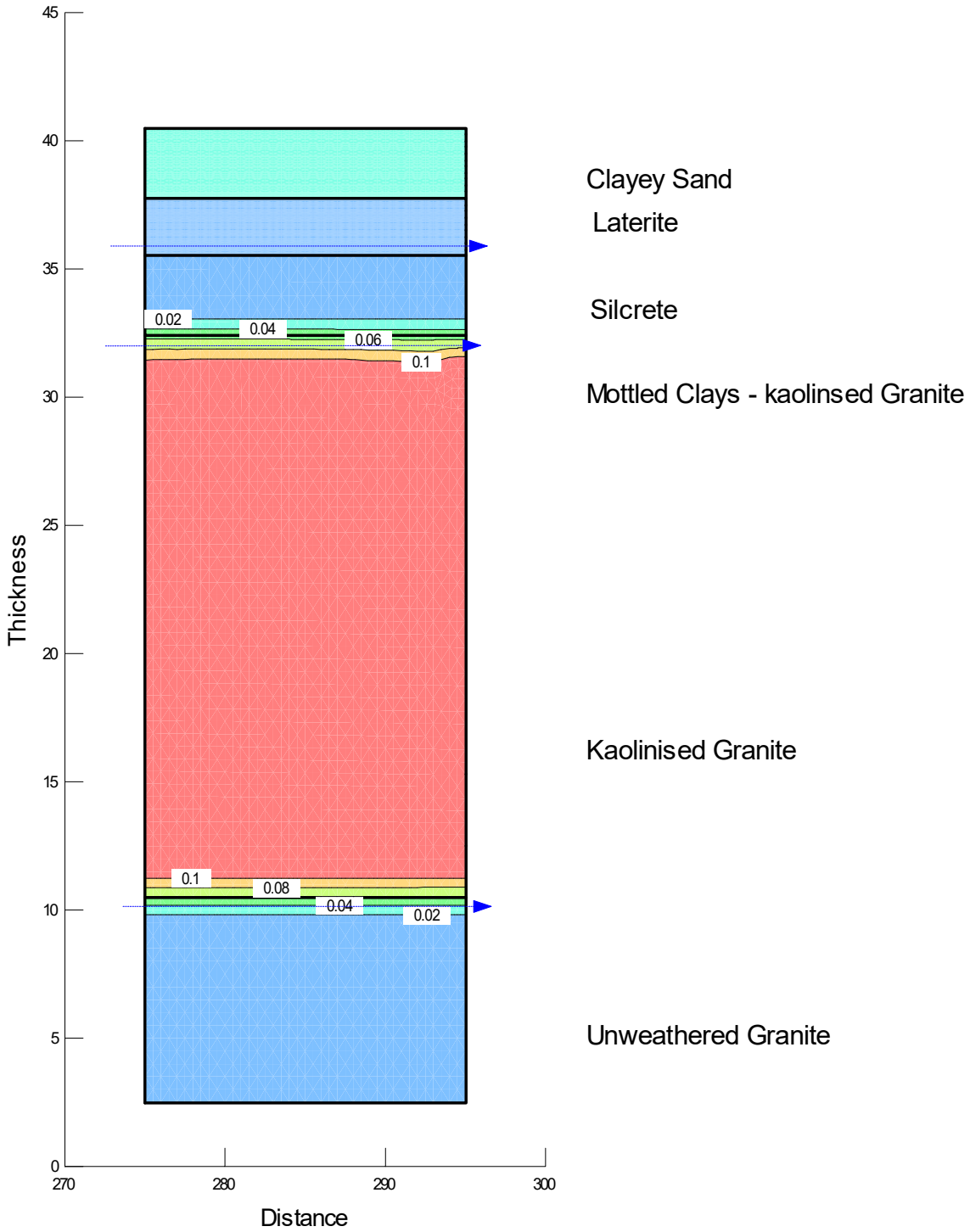

Figure 7: S1A - Predicted Soil Moisture after 100 years

Tellus Sandy Ridge
In Situ Soil Lithology

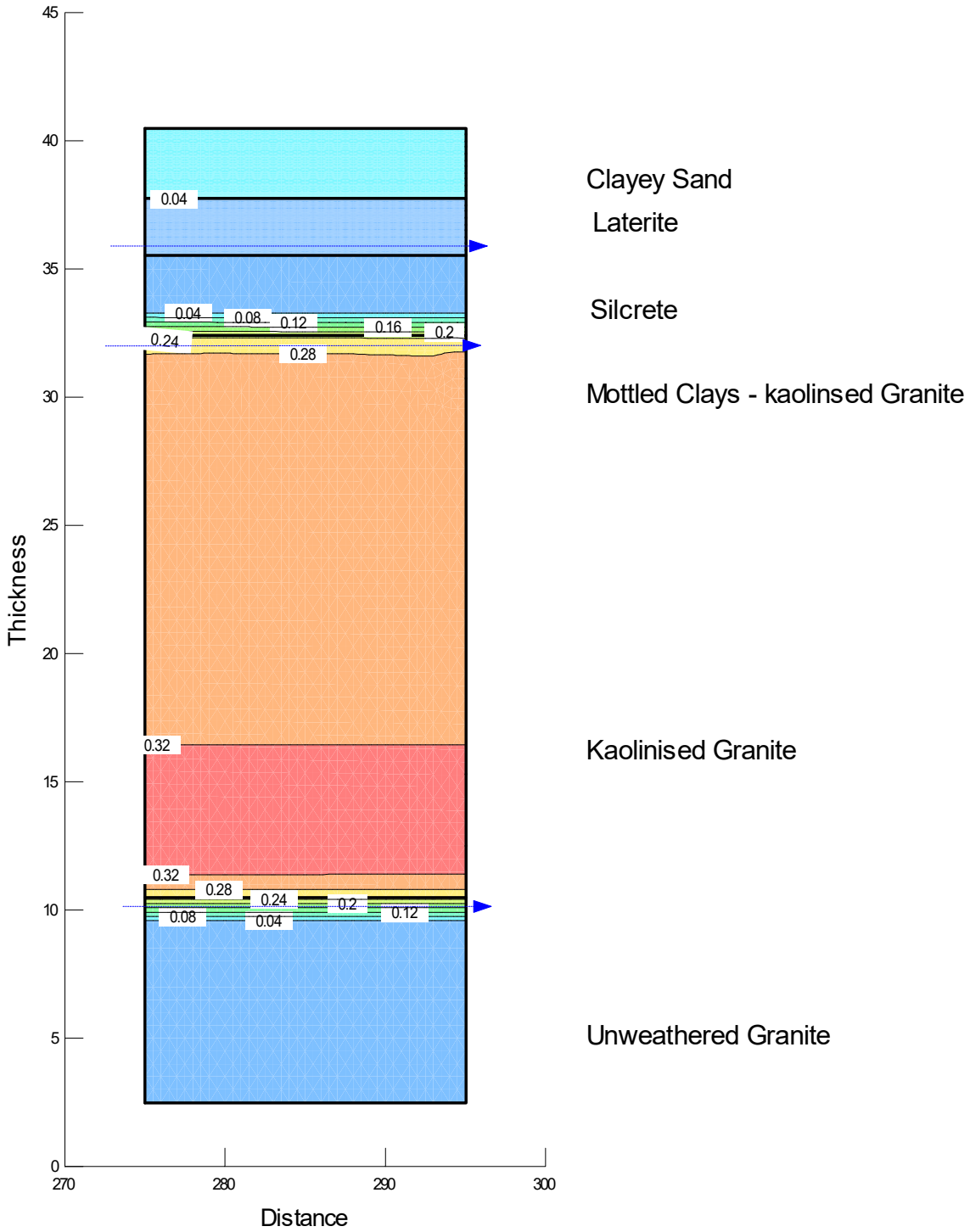

Figure 8: S1A - Predicted Soil Saturation after 100 years

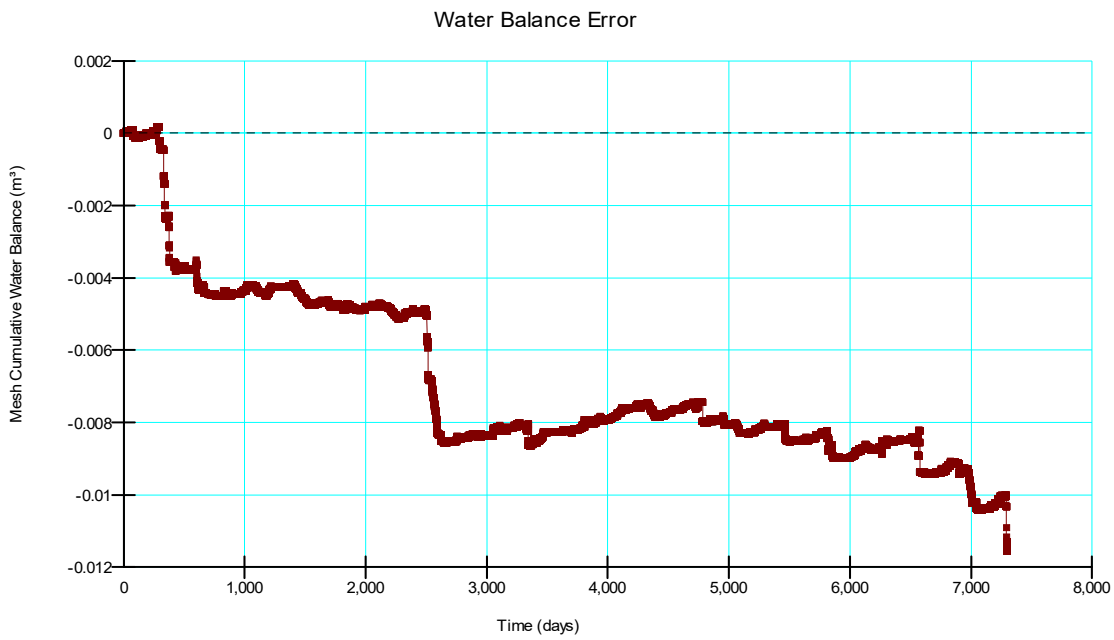

Figure 9: S1A Cumulative Water Balance

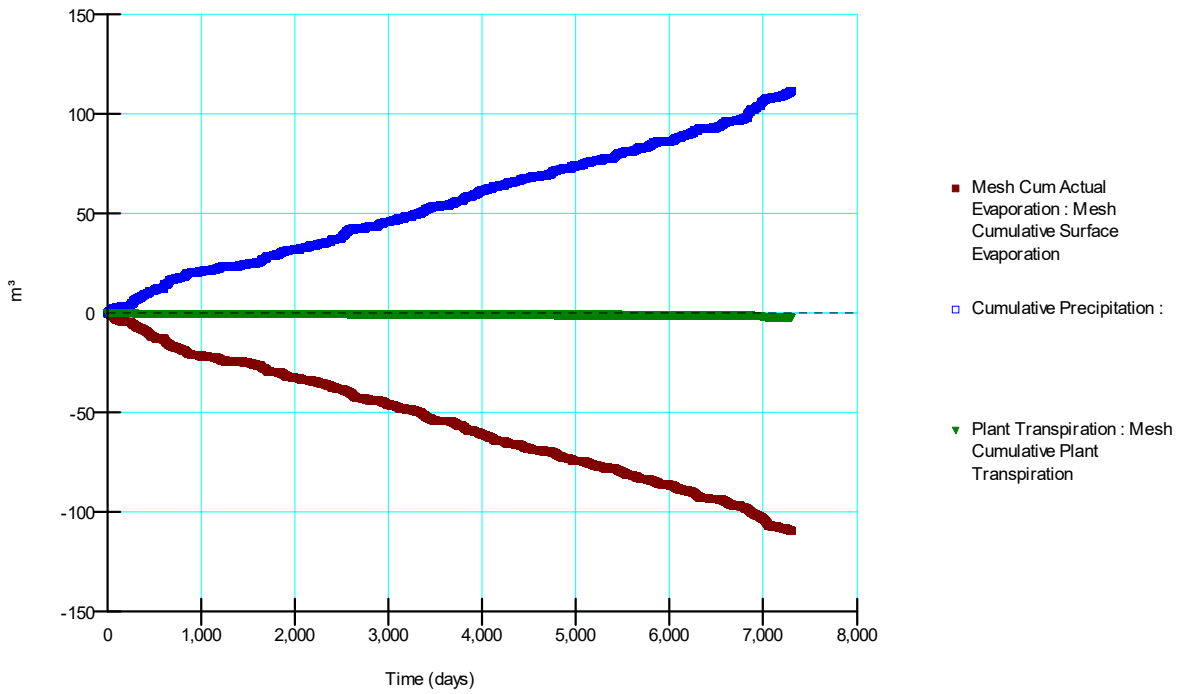

Figure 10: S1A - Boundary Fluxes

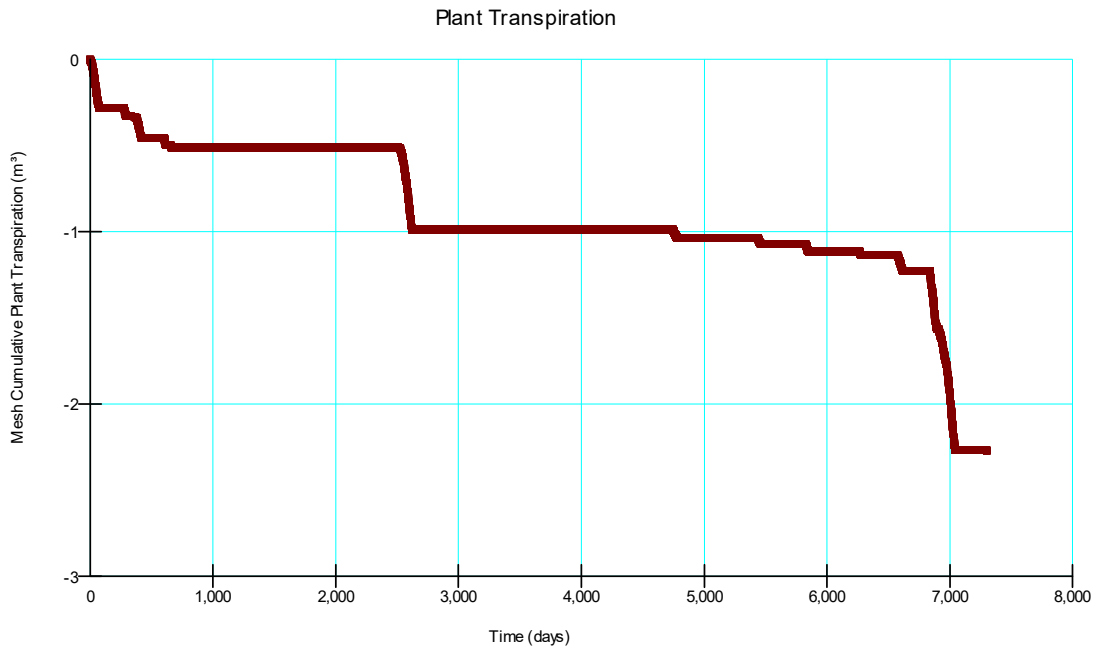

Figure 11: Plant Evapotranspiration

6.2.2 Scenario 1B – Model Results

Figures 12 and 13 shows the predicted soil moisture (as the volumetric fraction of water in a unit volume of soil) and the fractional saturation (volumetric soil moisture divided by soil porosity) as a function of depth at the end of 100 years for Scenario 1B. From the figures, all of the geological materials remain unsaturated (i.e. fractional saturation is less than 1), though there is increased saturation at the top of the silcrete, due to the lower hydraulic conductivity of this material. The saturation profile confirms that for the climatic conditions simulated and the characteristics of the soil column, it is unlikely that a saturated aquifer will occur either perched atop the silcrete or at the interface between weathered and fresh granite. The low moisture content of the soils results in very low unsaturated hydraulic conductivity (i.e. due to very large suction pressures greater than 10,000 kPa), which reduces water flow in these soils.

These results are consistent with measured water content in sampled soil from exploration holes drilled in the area, which showed soil moisture ranging from 10-12% below 6 mbgl. Consequently, even with increased infiltration into the surface soils, recharge below the silcrete layer is still relatively small at 0.21 mm/annum or about 0.07% of average rainfall.

6.2.2.1 Water Balance

Table 11 and 12 shows the water balance for S1B, for the last 20 years of the simulation.

Figure 14 shows the water balance error, which in this case is the difference between the cumulative water balance versus the change in storage. For transient models, the water balance error is generally defined as the change in storage (as indicated by the difference in moisture content between the start and the end of the model) divided by the cumulative water balance (net fluxes) for the same period. Figure 15 shows the cumulative boundary fluxes for the model, as a function of time.

Based on a change in storage of 1.6 m^3, versus a water balance error of 0.01 m^3, the percentage water balance error is 0.6% which is acceptable for this type of groundwater model (Barnett et al., 2012). Given the magnitude in the change in storage, and the small water balance error this error has limited impact on the quality of the solution.

Table 10 shows the annual fluxes passing vertically through the topsoil/subsoil, silcrete and weathered granite, in terms of infiltration and seepage over the last 20 year simulation period.

Based on the water balance, most rainfall is evaporated, with infiltration into the topsoil/subsoil layer of 0.21 mm/annum. The infiltration below the silcrete layer, which is indicative of rainfall recharge, is on average 0.0.20 mm/annum.

This scenario shows the sensitivity of recharge to changes in the hydraulic conductivity of the top soil, and how quickly rainfall can infiltrate the soil column. From the results, it is suggested recharge is not sensitive to top soil saturated hydraulic conductivity when it is greater than $1x10^{-6}$ m/sec. This is consistent with the conceptual hydrogeological model, where the low hydraulic conductivity of the silcrete layer acts to impede downward flow, and allow evaporation and evaporation to occur over a longer time.

Run Duration	Model Area	Rainfall	EVT	Evaporation	Change in Storage	Water Balance Error	Water Balance Error
Years	m^2	m^3	m^3	m^3	m^3	m^3	%
20	20	111.5	-2.27	-109.4	-0.16	-0.012	7.5

Table 11: S1B - Model Water Balance

Rainfall	EVT	Evaporation	Change in Storage	Water Balance Error	Water Balance Error
mm	mm	mm	mm	mm	%
279	-5.7	-273.4	-0.4	0.03	7.5

Table 12: S1B – Annual Water Balance

Rainfall	Infiltration to Top Soil/Subsoil	Infiltration Below Silcrete
mm	mm	mm
279	0.21	0.20

Table 13: S1B – Annual Rainfall, Infiltration and Seepage

Tellus Sandy Ridge
In Situ Soil LIthology

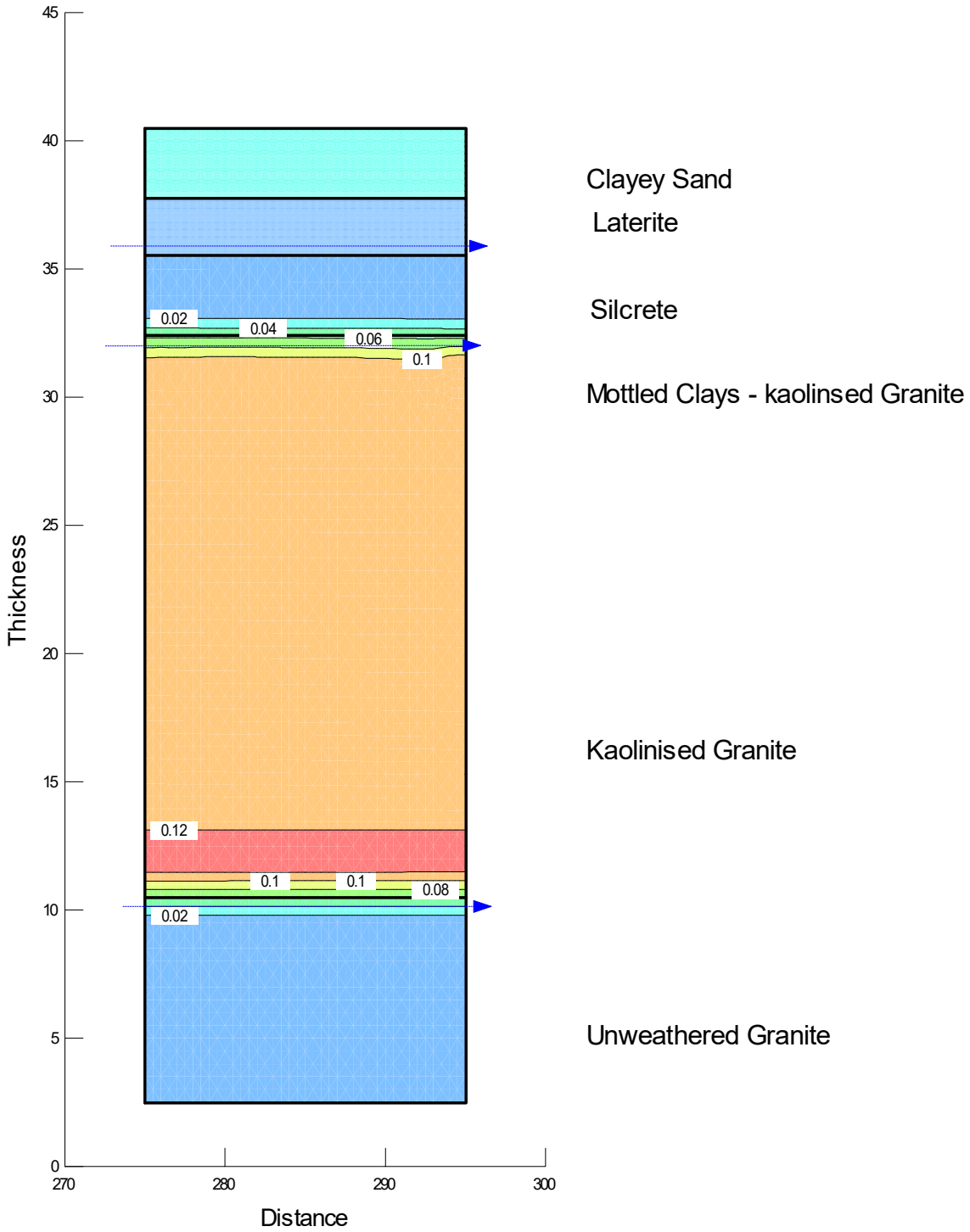

Figure 12: S1B - Predicted Soil Moisture after 100 years

Tellus Sandy Ridge
In Situ Soil LIthology

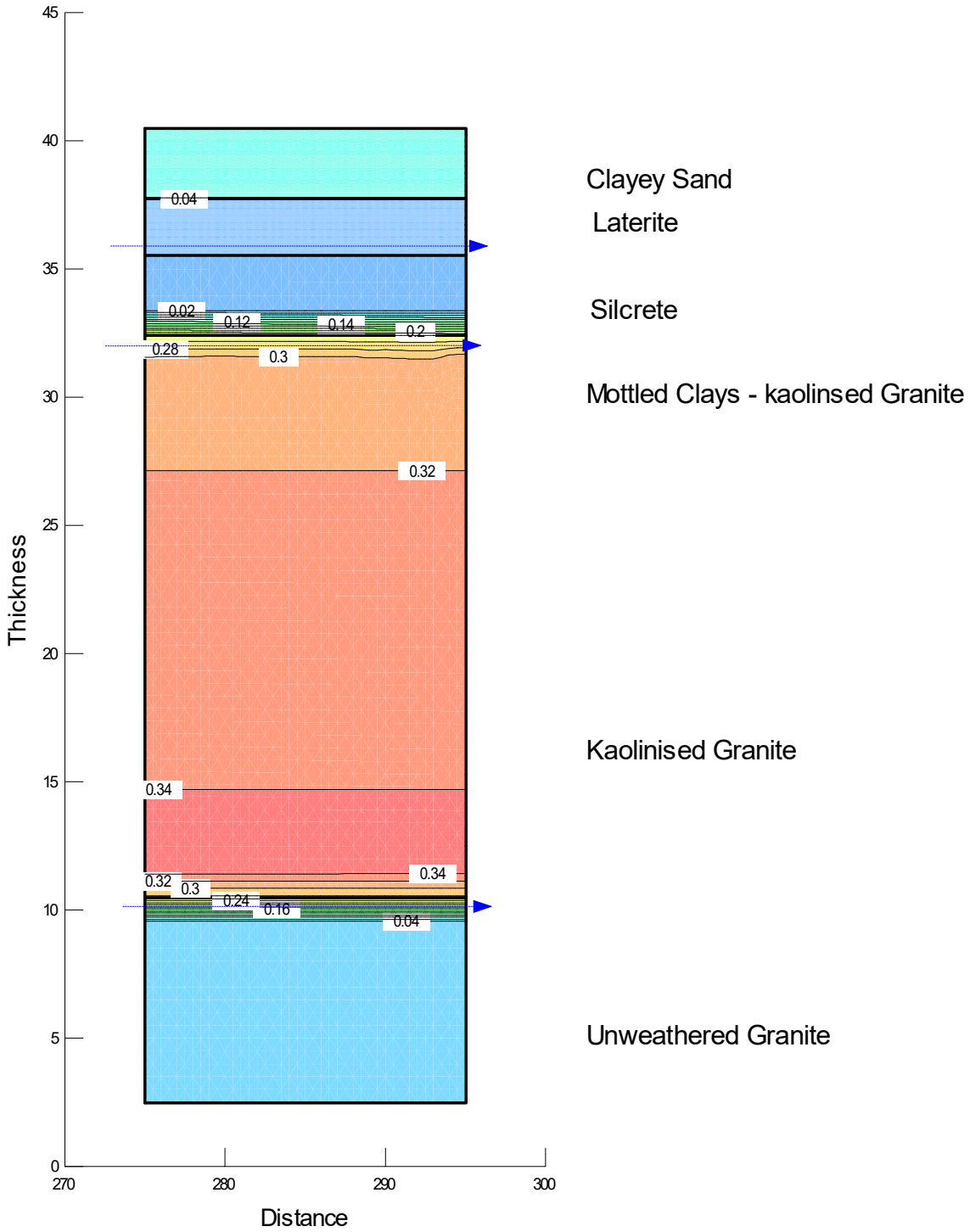

Figure 13: S1B - Predicted Soil Saturation after 100 years

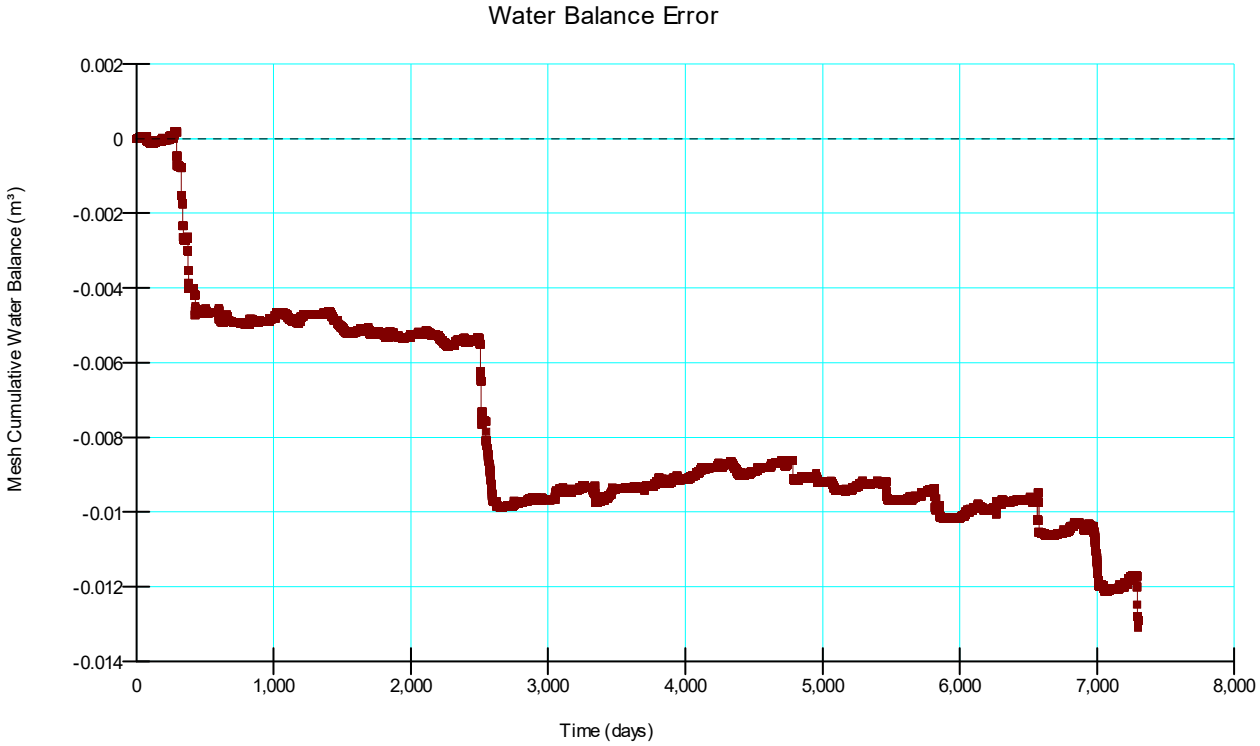

Figure 14: S1B Cumulative Water Balance

6.3 Scenario 2 – Backfilled and Capped Cell: Lower Boundary Sensitivity

A one-dimensional column model, shown in Figure 15, was constructed to simulate the backfilled and capped cell. The model, referred to as S2, was used to quantitatively assess the sensitivity of infiltration and seepage to changes in the lower boundary condition. The model was also used to estimate the infiltration and seepage through the compacted mottled clay cap (the cap) and the compacted kaolinised granite seal (the seal), into the granular material surrounding waste packages, which is further described in Scenario 3. Consequently, S2 was run using the three different lower boundary conditions as described below:

1. No flow boundary condition representing impervious fresh granite;
2. A specified pore pressure boundary condition to represent elevated saturation at the base of the model (sitting atop or emanating from fresh granite); and
3. Unit gradient boundary condition to represent low topographical gradient of the fresh granite for drainage to depth.

The S2 models uses soil properties as defined in Tables 3, 4 and 5, and the 10 wettest years of climate data as described in Section 4.

6.3.1 S2 – Results

Figures 16, 17 and 18 show the predicted soil moisture at the end of the 100 year simulation period for the three different boundary conditions. The figures show that all of the geological materials remain unsaturated. Given that the materials are unsaturated, the simulated pressure heads are negative, consistent with the materials being unsaturated.

6.3.2 Water Balance

Table 14 shows the water balance for the column models for the last 20 years of the simulation. The water balance shows that the lower boundary condition has no significant impact on the surface boundary flows, but does affect the change in storage. The change in storage is consistent with the different boundary conditions:

- For the no flow lower boundary, the change in storage is associated with evapotranspiration of water from shallow soils;
- For the specified pressure boundary, the saturation in the weathered granite has increased from 12% to 22% due to the lower suction pressure at the boundary over the 20 years compared to the initial condition; and
- For the unit gradient, storage has decreased due to drainage and evapotranspiration.

Table 15 shows the sensitivity of the vertical fluxes in the column models to the lower boundary condition.

In general, the lower boundary condition has limited effect on the vertical fluxes, other than for the unit gradient, which tends to increase the vertical flux below the compacted kaolinised granite seal due to the lower saturation in this region and deep drainage.

Case	Rainfall	Runoff	Evaporation	Bottom Flow	Change in Storage	Water Balance Error	Water Balance Error
	m^3	m^3	m^3	m^3	m^3	m^3	%
No flow	104.3	72	33	0	-0.52	0.037	7
Specified Pressure	104.3	72	33	0.38	0.98	0.12	12
Unit Gradient	104.3	72	33	0.39	-0.51	0.05	10

Table 14: Scenario 2 Water Balances

Case	Infiltration to Top Soil	Infiltration Below Clay Cap	Infiltration below kaolinised Granite Seal
	m^3	m^3	m^3
No flow	0.4	0.046	0.001
Specified Pressure	0.4	0.045	0.0007
Unit Gradient	0.3	0.03	0.0017

Table 15: Sensitivity of Vertical Flux to Lower Boundary Condition

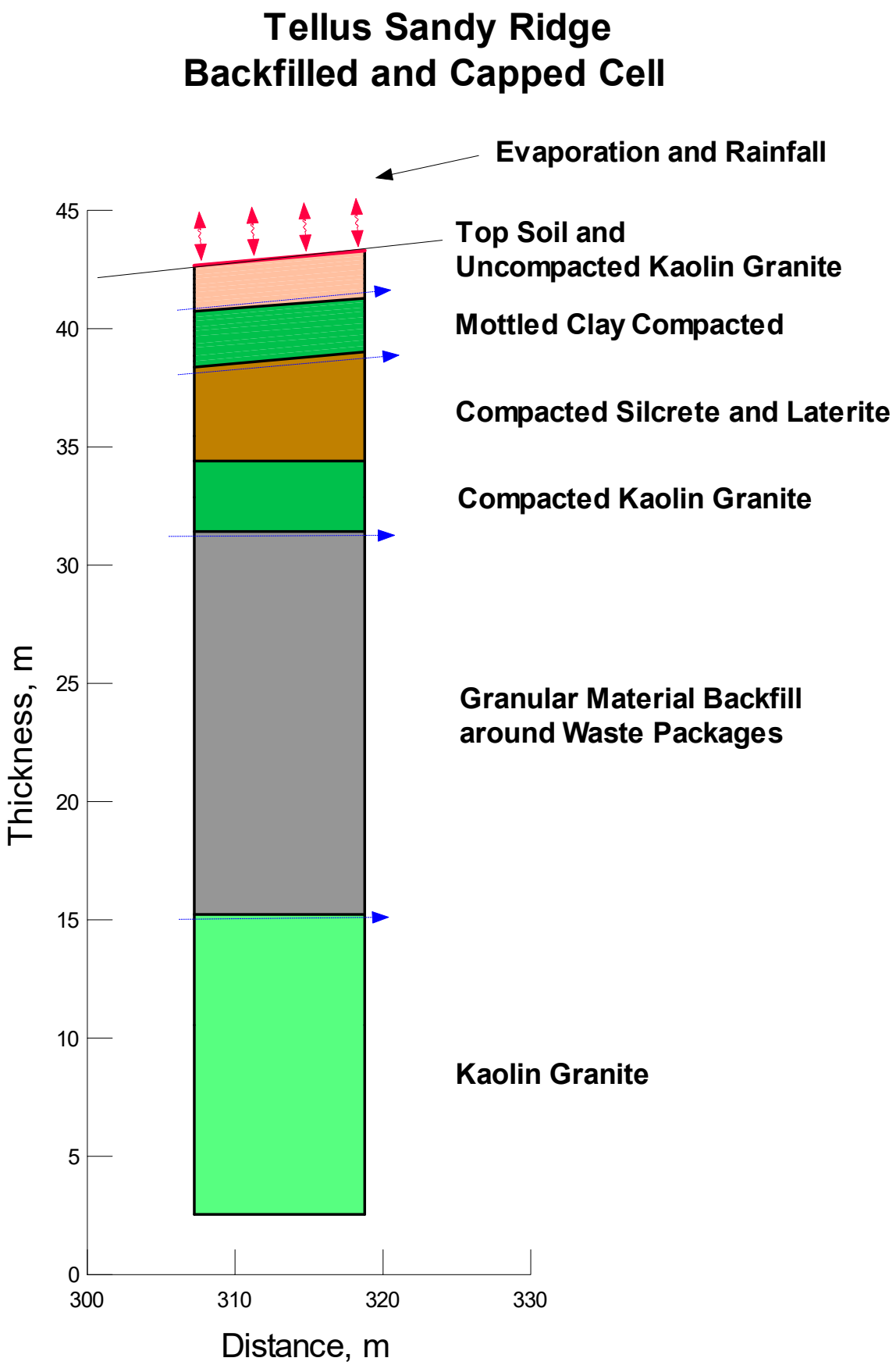

Figure 15: Backfilled and Capped Cell – Column Model

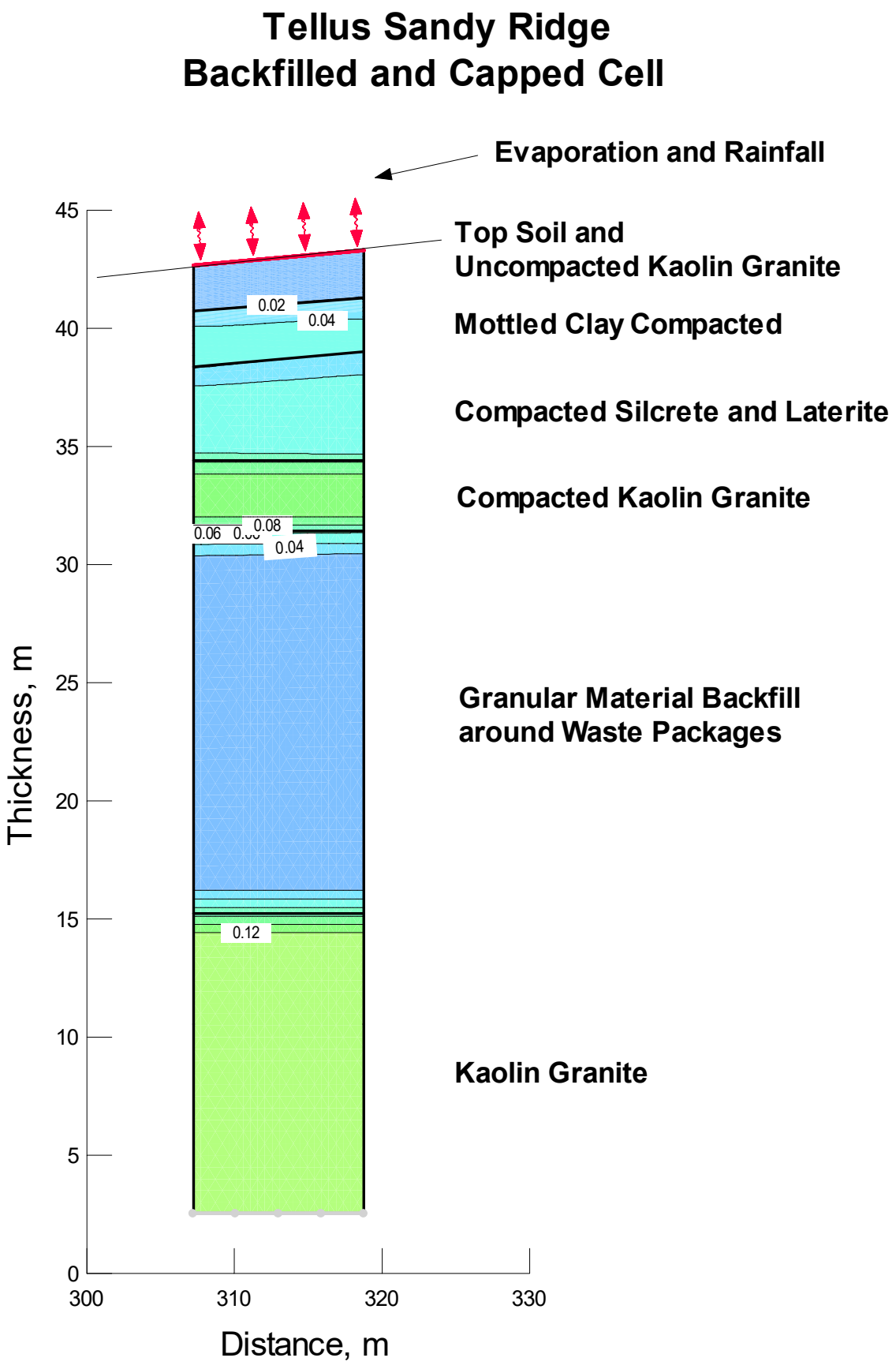

Figure 16: Moisture Content – No Flow Lower Boundary

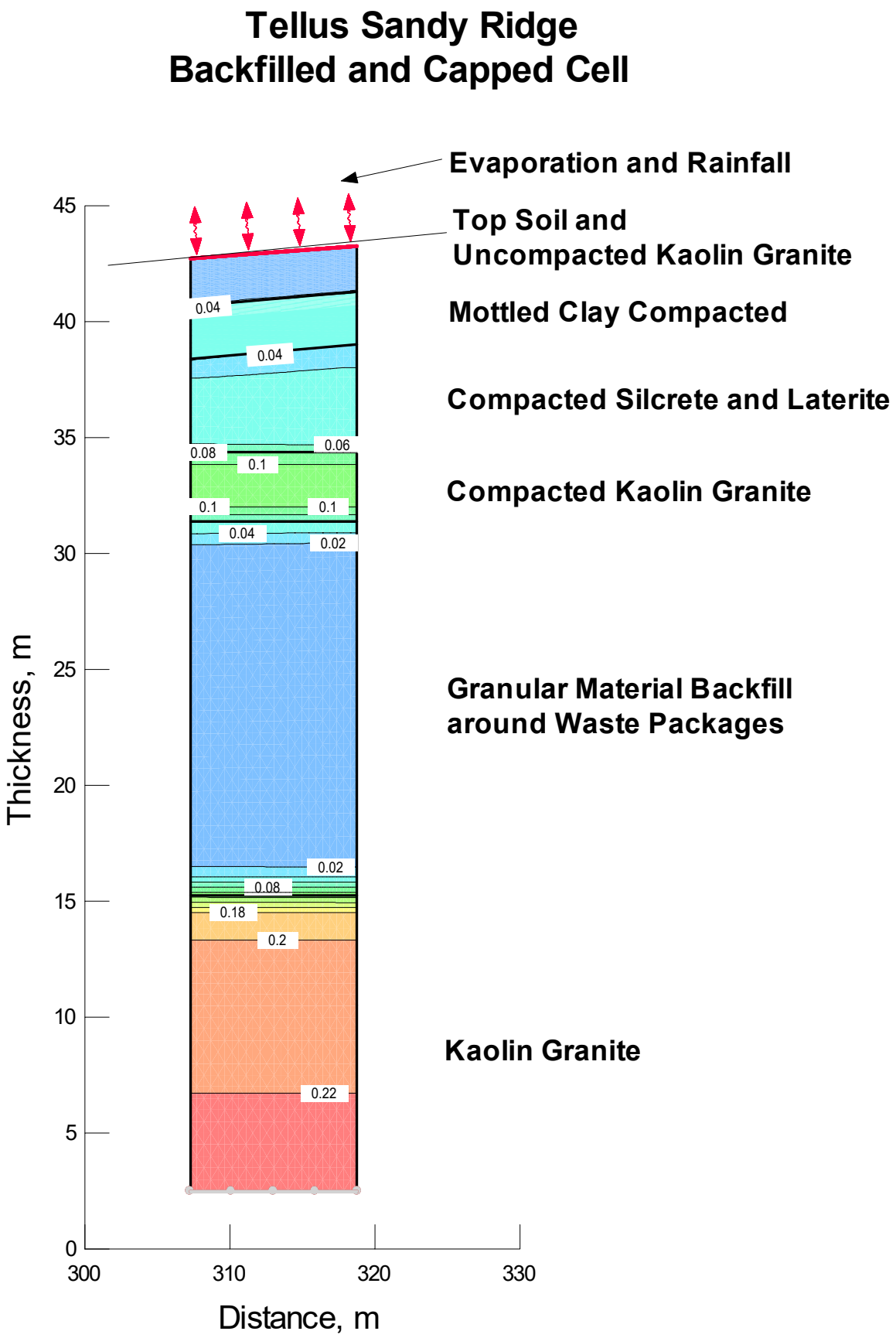

Figure 17: Moisture Content – Specified Pressure Lower Boundary

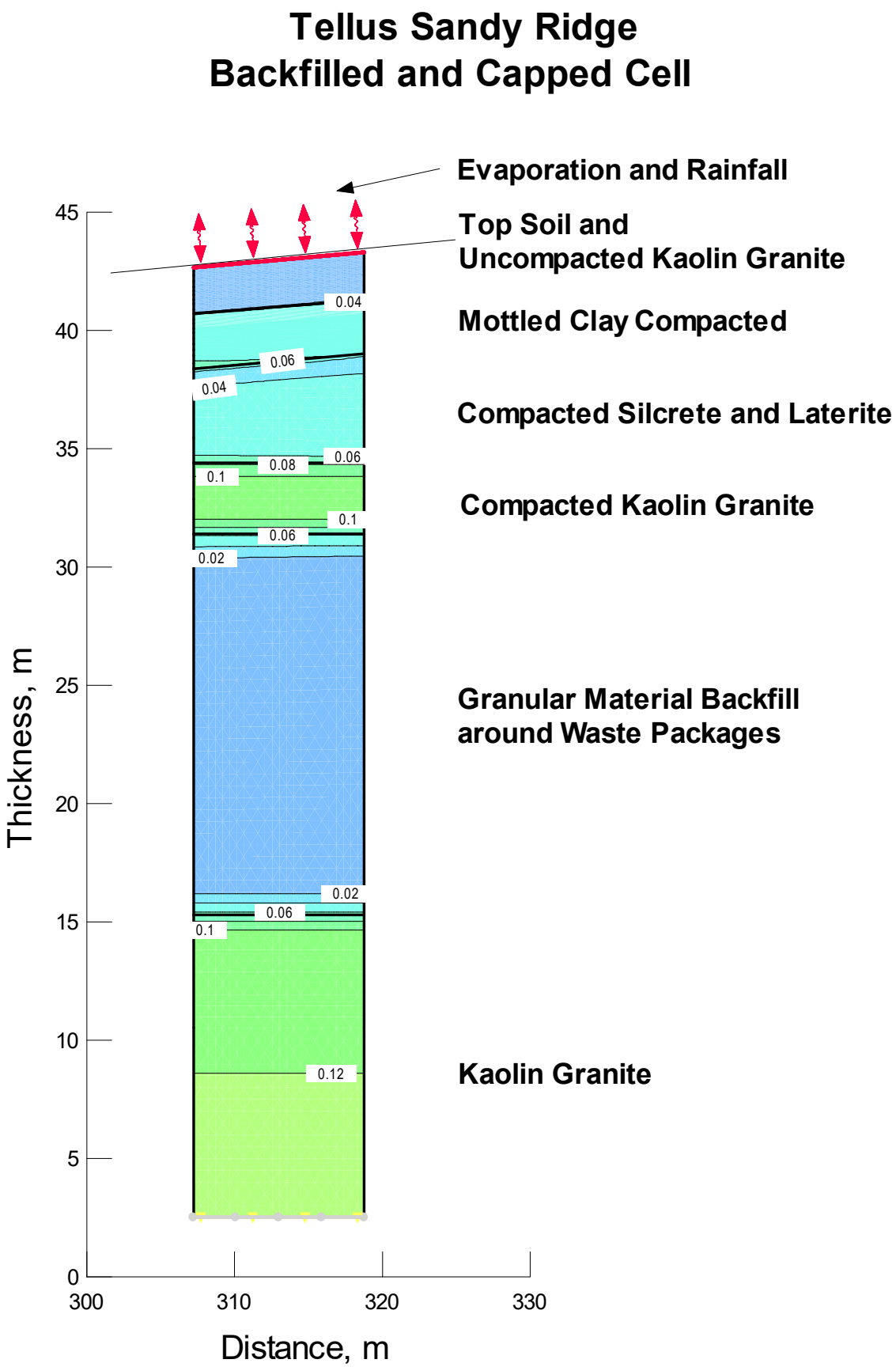

Figure 18: Moisture Content – Unit Gradient Lower Boundary

6.4 Scenario 3 – Backfilled and Capped Cell: Estimate of Infiltration and Seepage

A one-dimensional column model, shown in Figure 19, was constructed to simulate the backfilled and capped cell. The model, referred to as S3, was used to estimate the infiltration (also referred to as percolation) through the compacted mottled clay cap, and seepage through the kaolinised granite seal into the granular material that surrounds waste packages. Scenario S3 uses the soil properties as defined in Tables 3, 4 and 5 and repeated sequences of the 10 wettest years of climate data as described in Section 3 to estimate vertical fluxes. As a result of the S2 analyses, S3 also applies the unit gradient lower boundary condition.

6.4.1 S3 – Results

Figures 20 and 21 show that all of the geological materials remain unsaturated, though there is increased saturation at the top of the compacted mottled clay cap, and in the compacted kaolinised granite seal, due to the low hydraulic conductivity of these materials. Given that the materials are unsaturated the simulated pressure head is negative, consistent with the materials being unsaturated.

These figures confirm that for the climatic conditions simulated and the characteristics of the soil column, it is unlikely that a saturated aquifer will occur perched atop the compact clay cap, on the compacted kaolinised granite seal or at the interface between weathered and fresh granite, given that seepage is sufficiently small to move vertically downwards under gravity drainage.

6.4.2 Water Balance

Tables 16 and 17 show the water balance for the column model at the end of 100 years. Table 18 shows the predicted cumulative infiltration and seepage over the 20 year simulation period normalized to annum fluxes. Figure 22 shows the cumulative water balance. Figure 23 shows the boundary fluxes, in terms of rainfall, runoff and evaporation over the last 20 years of the simulation. Based on a change in storage of -1.2 m^3, the percentage water balance error is 10% which is larger than the typically accepted error of 1% (Barnett et al., 2012) for groundwater models. However, given the magnitude of the boundary flows, this error is unlikely to have a significant effect on the results.

Based on the water balance, 69% of rainfall runs off, with 31% recharging the shallow surface soils, as shown graphically in Figure 19. Infiltration, as net recharge to the top soil/subsoil, is 1.4 mm/year. Vertical flow below the clay cap is 0.8 mm/year, which flows vertically via the compacted silcrete and laterite backfill to the compacted kaolinised granite seal. The vertical flux below the compacted kaolinised granite seal is 0.008 mm/year. This seepage is smaller than that estimated for the natural system (0.017 mm/year).

6.4.3 S3 – Seepage

Based on a seepage of 0.008 mm/annum into the waste storage area, over an area of 7200 m^2, indicates about 0.058 m^3/annum of seepage may enter a storage cell as vertical leakage, and drain vertically into the weathered granite. This vertical leakage can:

- Go into storage within the weathered or fresh granite and form a groundwater mound; and
- flow laterally to the northwest following the topography of the fresh granite.

Assuming that most of the seepage is retained in the unsaturated weathered granite, which is about 10 m thick directly beneath the cell, has a porosity of 0.35 and an initial saturation of 0.1 suggests that this material would become fully saturated in after 300,000 years given the estimated seepage rate.

Conversely, this seepage may flow as a thin saturated layer in the fresh granite;

- horizontally to the northwest;
- under a prevailing hydraulic gradient of 0.001;
- through fractures having 1% porosity; and
- with an average hydraulic conductivity of $4x10^{-6}$ m/sec;

This gives a groundwater velocity of $4x10^{-7}$ m/s, indicating a travel time of about 6000 years to the most likely exposure point (75 km to the north). In the absence of connected fractures, and flow in the porous weathered granite, the travel time would increase to more than 200,000 years, assuming the fresh granite has a saturated hydraulic conductivity of $1x10^{-8}$ m/s. In either case, the model results suggest the magnitude of seepage potentially emanating from the cell under wet conditions is unlikely to mound or move far from the site for a long (centuries) period of time.

Run Duration	Model Area	Rainfall	Runoff	Evaporation	Bottom Flow	Change in Storage	Water Balance Error	Water Balance Error
Years	m^2	m^3	m^3	m^3	m^3	m^3	m^3	%
20	12	104.3	-72.2	-32.9	0.33	-0.9	-0.09	10

Table 16: S3 - Model Water Balance

Run Duration	Model Area	Rainfall	Runoff	Evaporation	Bottom Out Flow	Change in Storage
Years	m^2	mm	mm	mm	mm	mm
20	12	435	300	137	2	5

Table 17: S3 – Annual Water Balance

Infiltration to Top Soil	Infiltration Below Clay Cap	Infiltration Below Compacted Kaolinised Granite Seal
Mm	mm	mm
1.3	0.8	0.008

Table 18: S3 – Model Predicted Cumulative Infiltration and Seepage – 20 Years

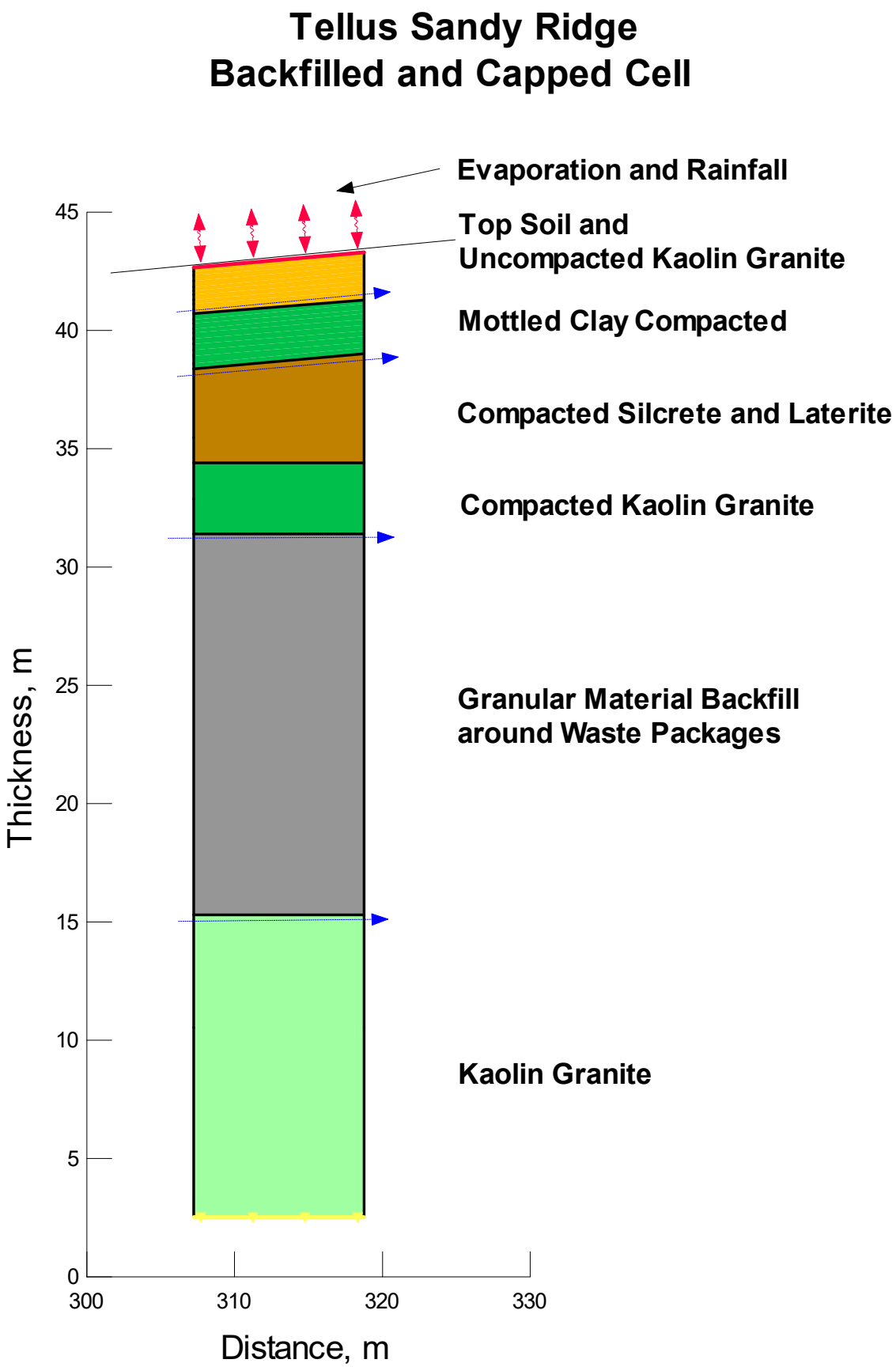

Figure 19: S3 Column Model – Proposed EWSC

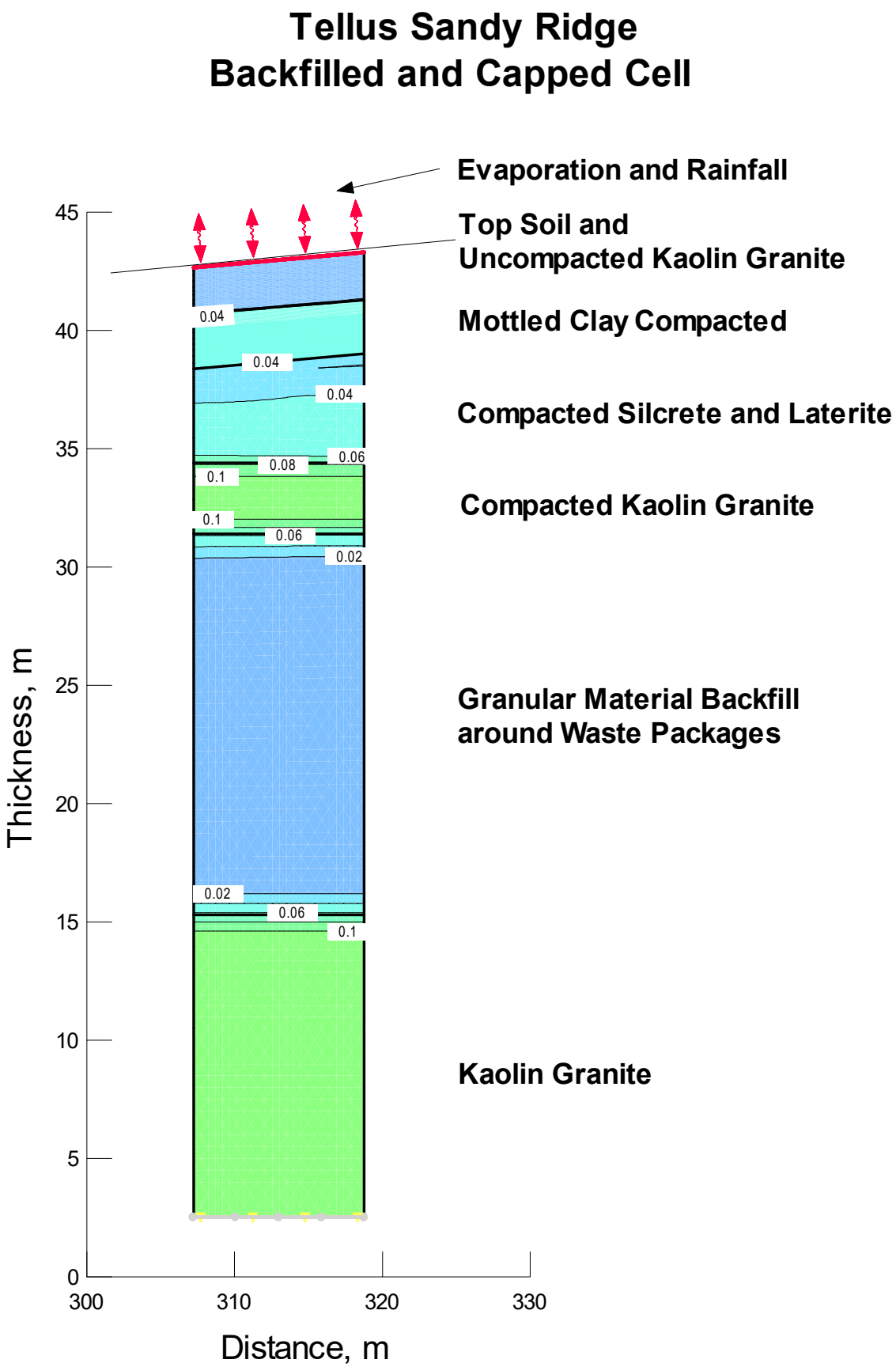

Figure 20: Predicted Moisture Content after 100 Years

Tellus Sandy Ridge
Backfilled and Capped Cell

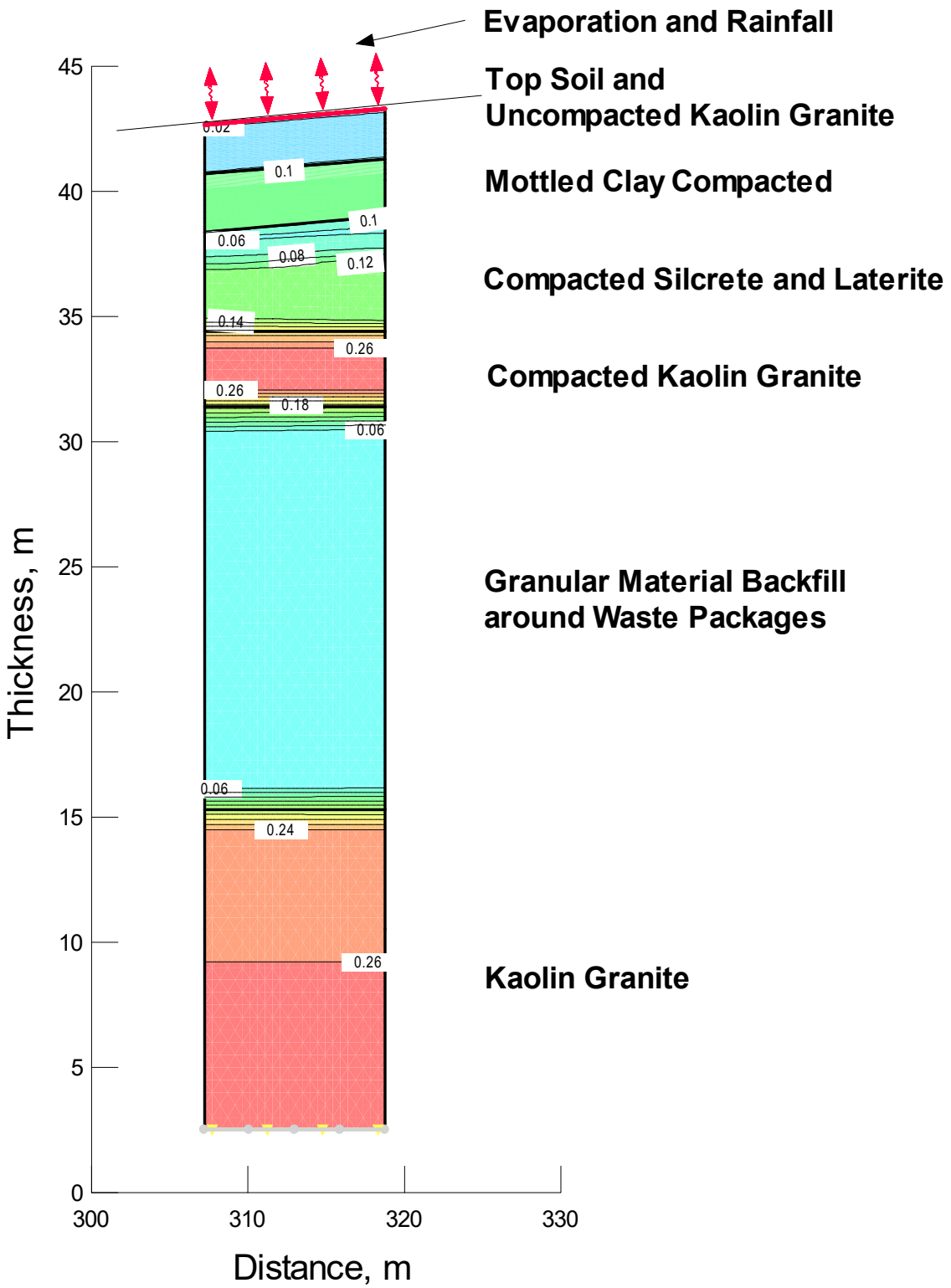

Figure 21: Predicted Saturation after 100 Years
(fraction of material porosity, see Appendix A)

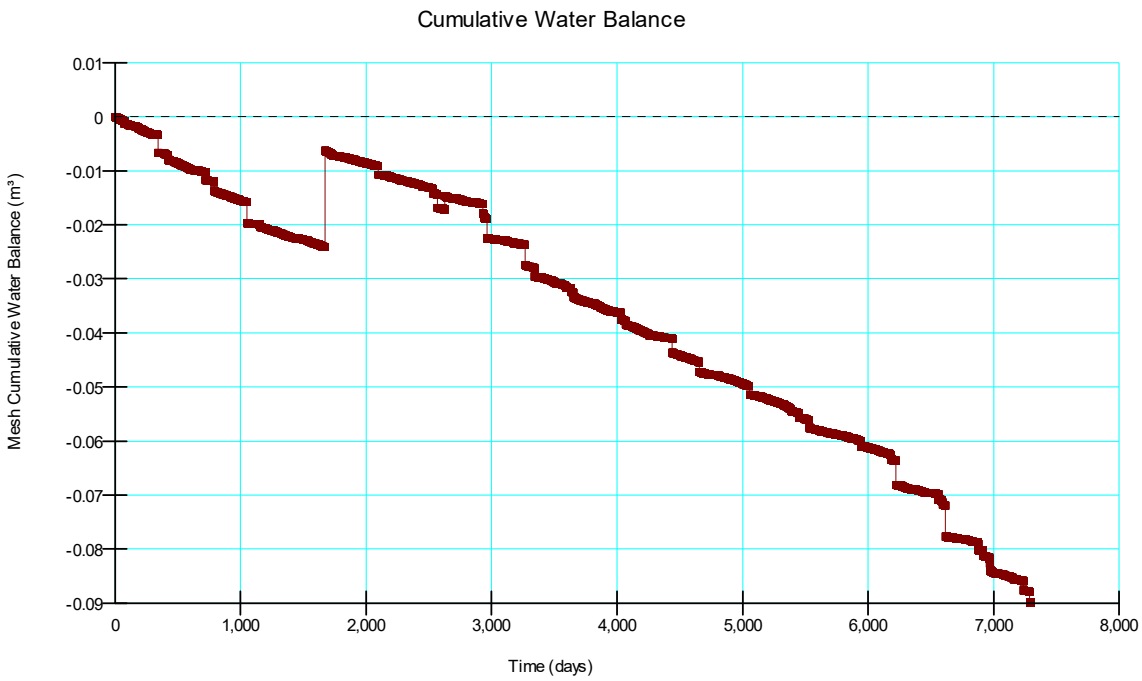

Figure 22: S3 Water Balance Error

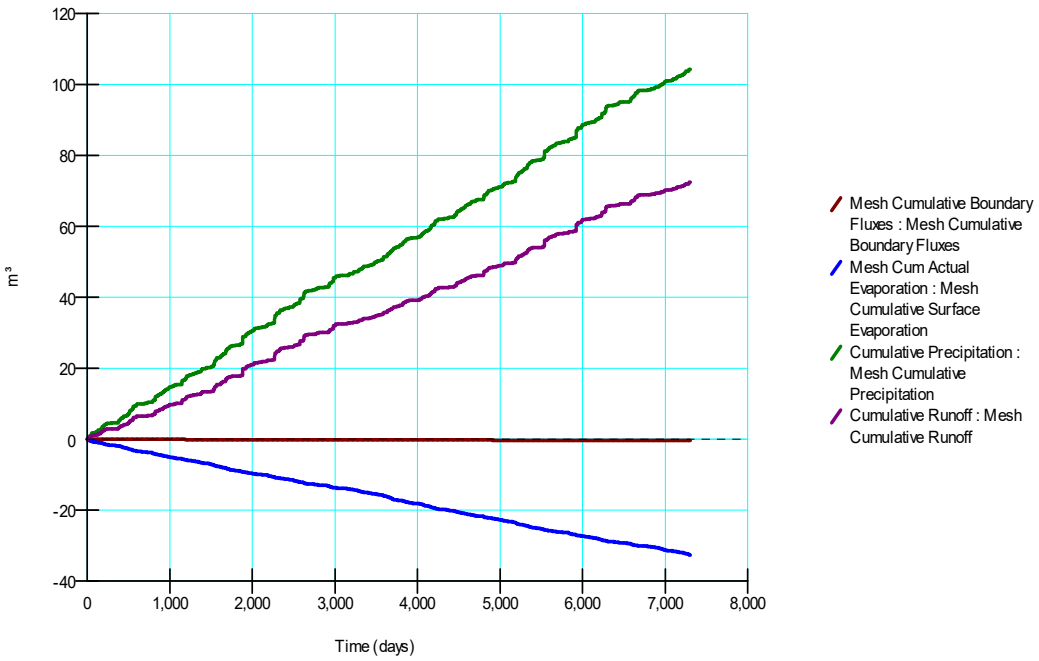

Figure 23: Major Water Balance Components

6.5 Scenario 4 – Backfilled and Capped Cell: High Conductivity Top Soil and Waste Rock

A one-dimensional column model, shown in Figure 24, was constructed to simulate the backfilled and capped cell. The model, referred to as S4, was used to estimate the infiltration (also referred to as percolation) through the compacted mottled clay cap, and seepage from the kaolinised granite seal into the granular material that surrounds waste packages, and in that respect is the same as S3. However, S4 uses a higher hydraulic conductivity of $5x10^{-5}$ m/sec for the top soil and waste rock protective layer which sits on top of the compacted clay cap. In addition, the top of the cell is modelled as flat, which eliminates runoff. Other than these changes, the scenarios are the same with S4 using the soil properties as defined in Tables 3, 4 and 5 and repeated sequences of the 10 wettest years of climate data as described in Section 3.

6.5.1 S4 – Results

Figures 25 and 26 show the moisture content and saturation in the soil column, respectively at the end of 100 years. The figures indicate that all geological materials remain unsaturated, though there is increased saturation at the top of the compacted mottled clay cap, and in the compacted kaolinised granite seal, due to the low hydraulic conductivity of these materials. Given that the materials are unsaturated the simulated pressure head is negative, consistent with the materials being unsaturated.

The modelling results confirm that for the climatic conditions simulated and the characteristics of the soil column, it is unlikely that a saturated aquifer will occur either perched atop the compact clay barriers or at the interface between weathered and fresh granite.

6.5.2 S4 - Water Balance

Tables 19 and 20 show the water balances for the S4 column model at the end of 100 years. Tables 21 and 22 show the predicted cumulative infiltration and seepage over the 20 year simulation period, and the normalized annual fluxes. Figure 27 shows the cumulative water balance. Figure 28 shows the boundary fluxes, in terms of rainfall, runoff and evapotranspiration over the last 20 years of the simulation. Based on a change in storage of -3.1 m^3, the percentage water balance error is 2% which is consistent with the typically accepted error of 1% (Barnett et al., 2012) for groundwater models.

Note that in this case there is no runoff, as the top of the model is flat, and ponding of water is allowed, if rainfall exceeds the rate of infiltration. Hence, all rainfall recharge is either removed as evaporation, or infiltrates into soil storage and becomes seepage into the fresh granite.

Due to the increased saturation in the clay cap and kaolin seal resulting from higher hydraulic conductivity in the top soil, infiltration below the clay cap of 0.5 mm/annum is larger than in either S1 or S3. More importantly, seepage into the granular material that surrounds waste packages is 0.4 mm/annum compared to less than 0.008

mm/annum in S3. This result highlights the significant sensitivity of seepage to higher hydraulic conductivity of the top soil and kaolin waste rock, as well as the importance of maintaining a sloping surface to encourage rapid runoff and minimize infiltration.

Run Duration	Model Area	Rainfall	Runoff	Evaporation	Bottom Flow	Change in Storage	Water Balance Error	Water Balance Error
Years	m^2	m^3	m^3	m^3	m^3	m^3	m^3	%
20	12	104.3	0	105.6	1.87	-3.1	-0.065	2

Table 19: S4 - Model Water Balance

Run Duration	Model Area	Rainfall	Runoff	Evaporation	Bottom Out Flow	Change in Storage
Years	m^2	mm	mm	mm	mm	mm
20	12	435	0	-440	-7.8	12.9

Table 20: S4 – Annual Water Balance

Infiltration to Top Soil	Infiltration Below Clay Cap	Infiltration Below compacted Kaolinised Granite Seal
m^3	m^3	m^3
0.47	0.11	0.105

Table 21: S4 – Model Predicted Cumulative Infiltration and Seepage over the 20 year simulation period

Infiltration to Top Soil	Infiltration Below Clay Cap	Infiltration Below Compacted Kaolinised Granite Seal
mm	mm	mm
2.0	0.5	0.4

Table 22: S4 – Model Predicted Annual Infiltration and Seepage over the 20 year simulation period

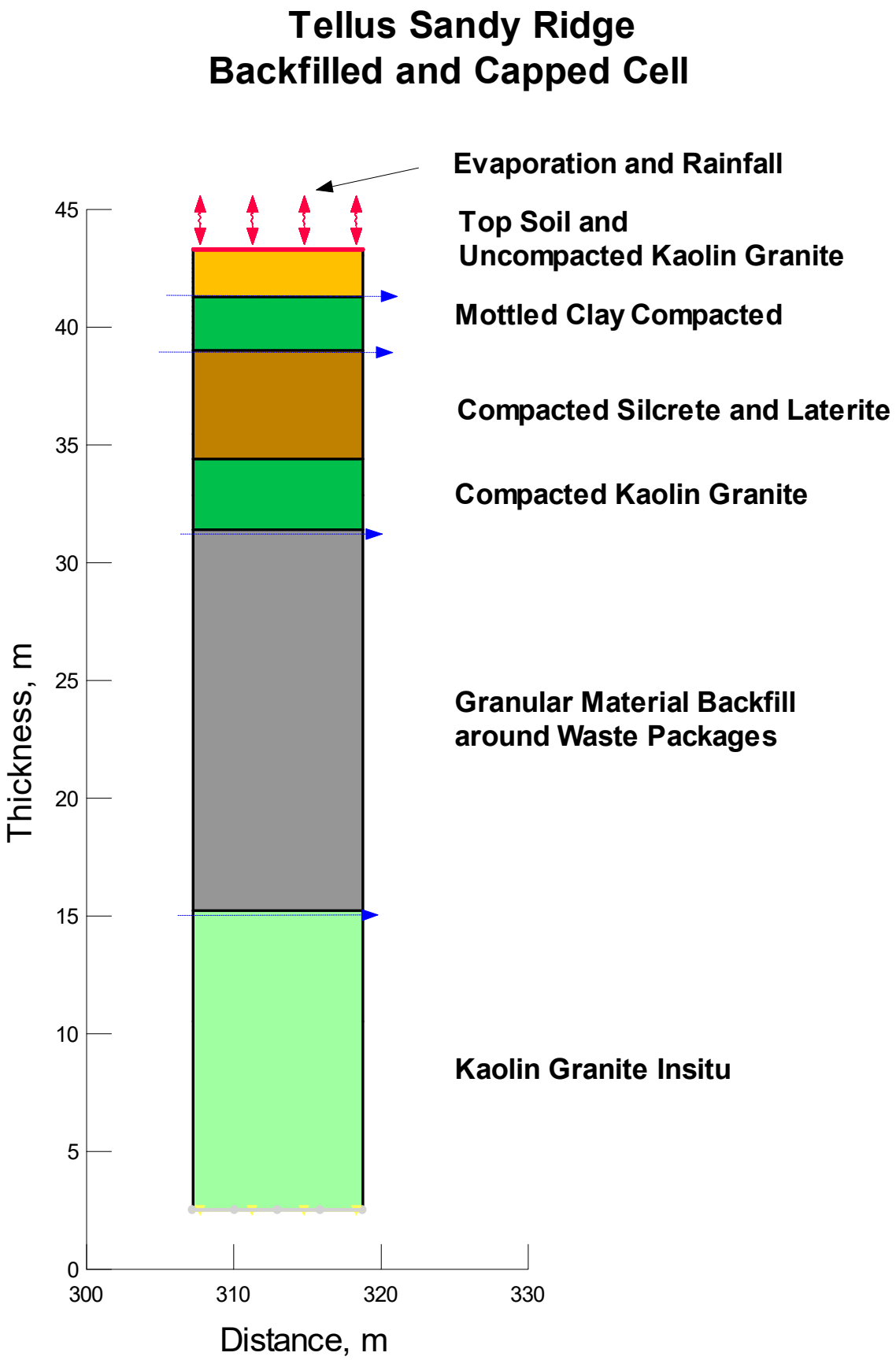

Figure 24: S4 Column Model

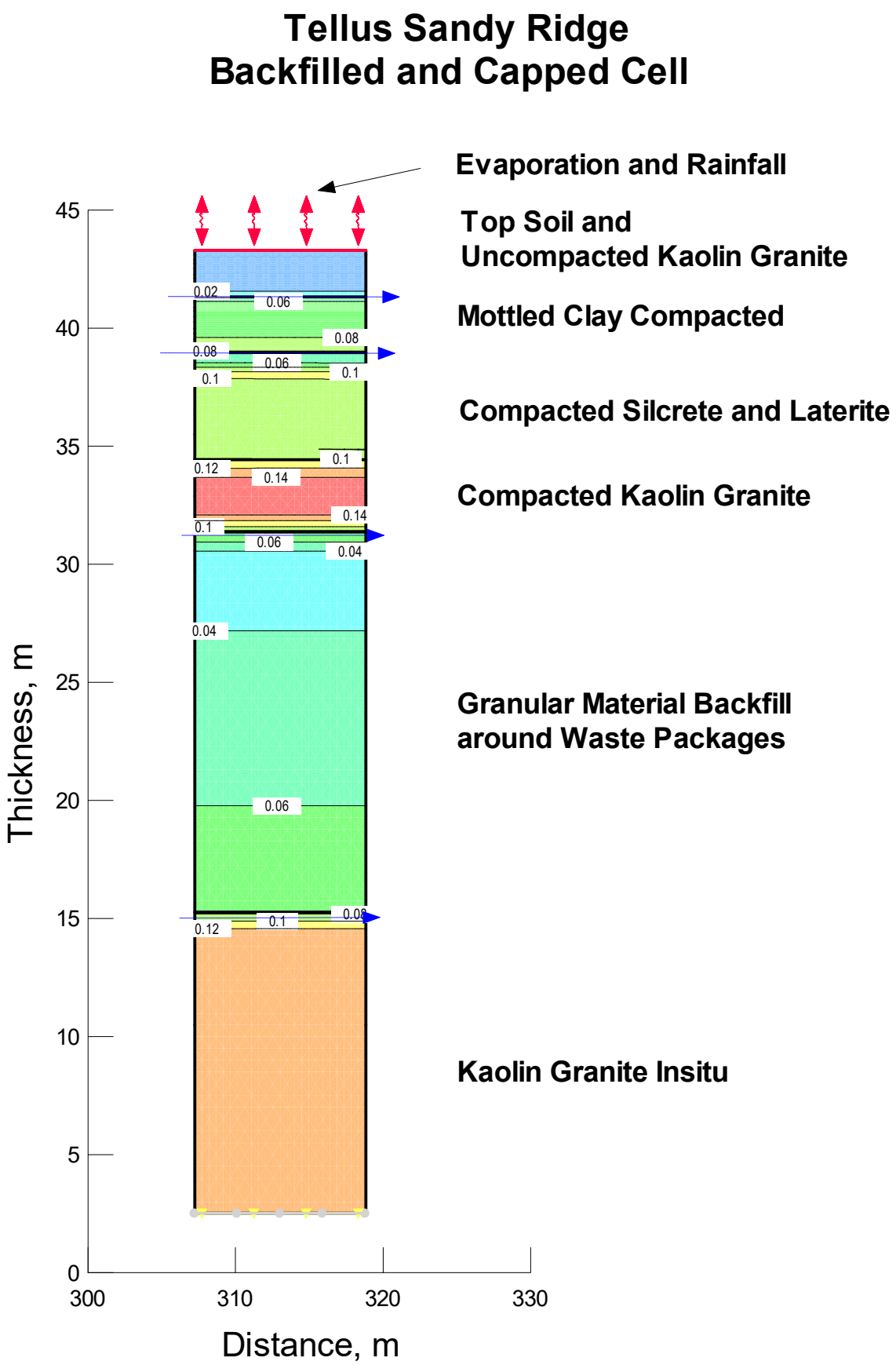

Figure 25: S4 Predicted Moisture Content after 100 Years

Tellus Sandy Ridge
Backfilled and Capped Cell

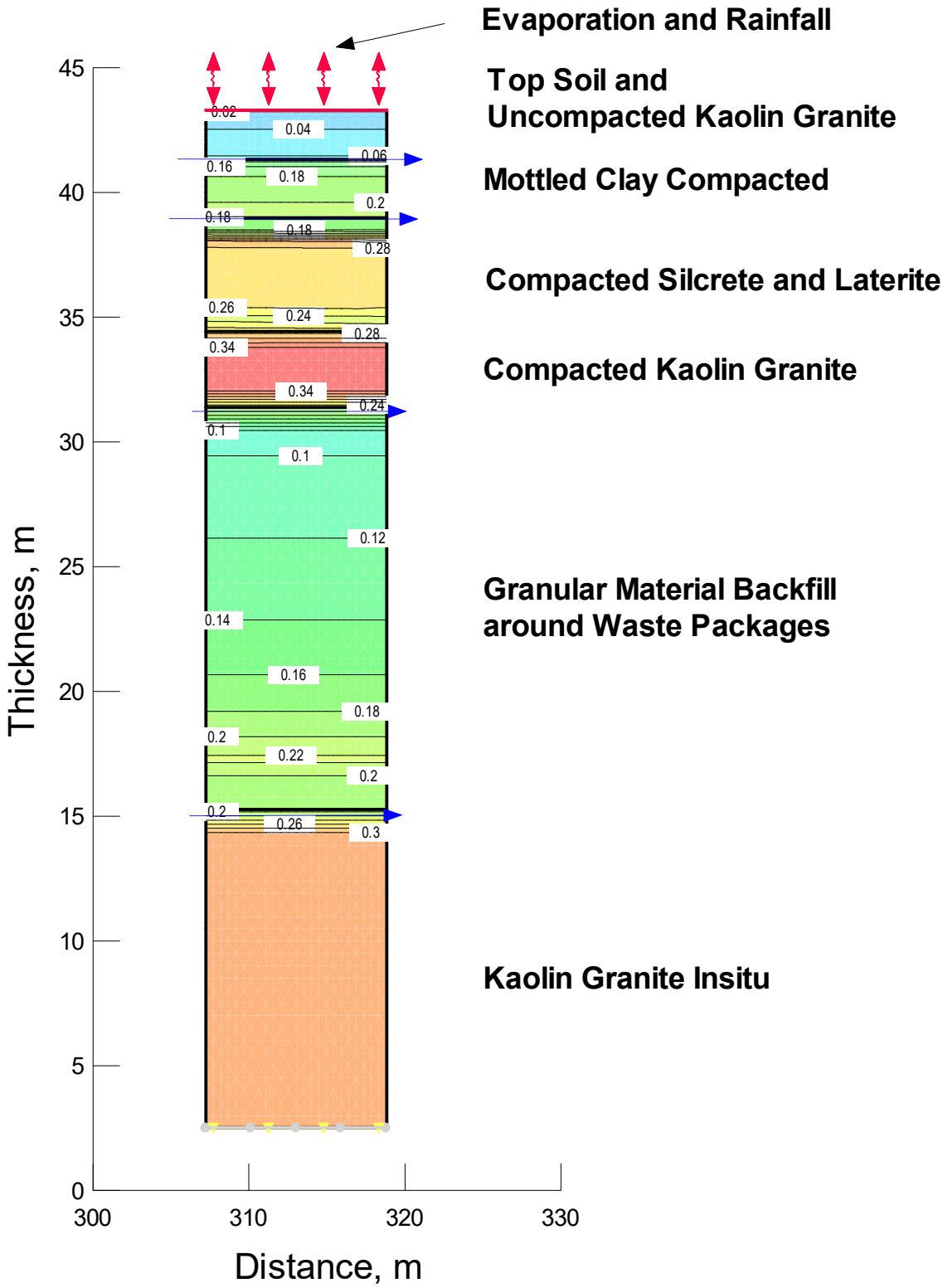

Figure 26: S4 Predicted Saturation after 100 Years
(fraction of material porosity, see Appendix A)

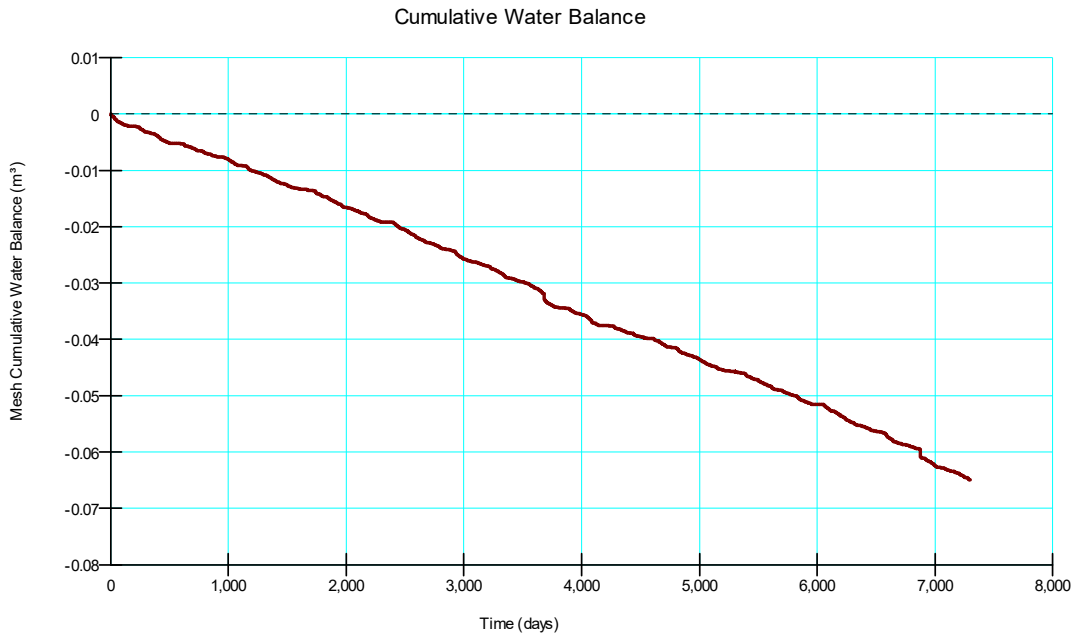

Figure 27: S4 Cumulative Water Balance

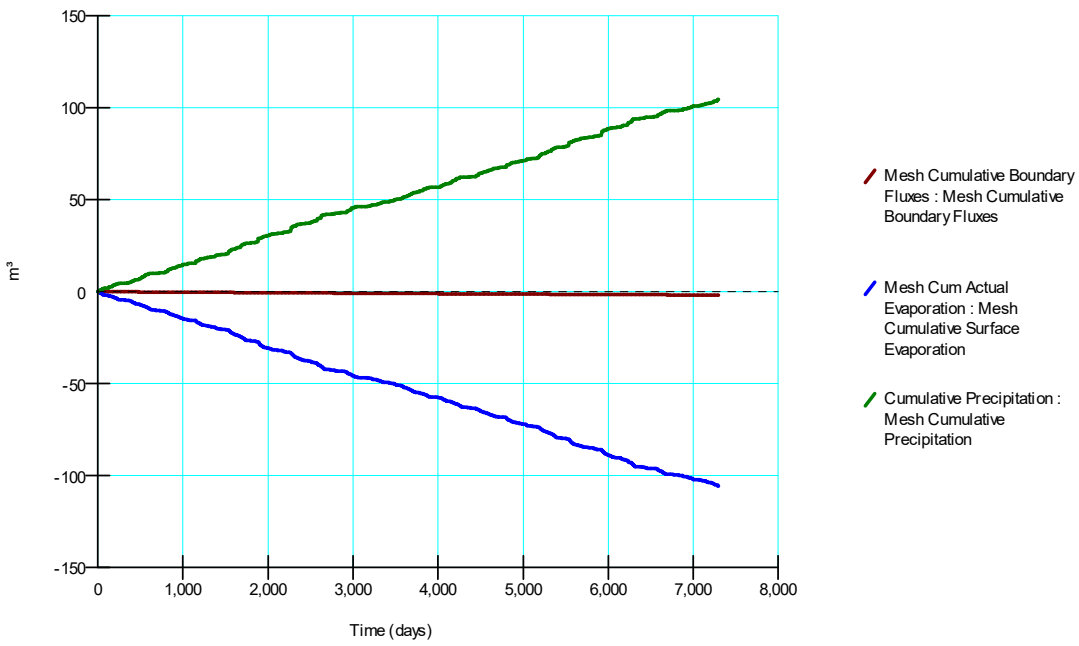

Figure 28: S4 Major Water Balance Components

6.6 Discussion of Results

The results of the simulations, as described above, indicate that the infiltration of rainfall into a cell is limited by:

1. Runoff from the relatively low hydraulic top soil and waste rock (kaolinised granite), due to the sloping of the cell cap; and
2. Evaporation of infiltrated water from the shallow top soil and waste rock that is retained above the compacted mottled clay cap, and thereby subject to evaporation/evapotranspiration between rainfall events.

The runoff process is important as it limits the residence time of rainfall on the surface of the cell, which in turn limits the time for infiltration of rainwater into the top soil/waste rock cover. The second process of evaporation is analogous to what is occurring naturally in the undisturbed ground where:

- Rainfall infiltrates and vertically migrates to the silcrete layer where it accumulates due to the silcrete being relatively impermeable.
- The silcrete is typically within 3 metres of the surface, which maintains the infiltrated water close to the surface where it is subject to evapotranspiration.

In the case of the designed cap for the cells:

- Rainfall infiltrates the top soil and subsoil, and vertically migrates to the compacted mottled clay cap where it accumulates due to the reduced hydraulic conductivity of the capping material;
- The compacted mottled clay cap is typically within 2 metres of the surface, which maintains the infiltrated water close to the surface where it is subject to evaporation/evapotranspiration;
- Water that infiltrates the clay cap is subsequently retarded by the kaolinised granite seal, which provides additional time for some evaporation and storage.
- Infiltration to depth is higher in the capped cell due to the higher hydraulic conductivity of the compacted clay cap and the compacted clay seal, when compared to the in situ silcrete.

Consequently, the simulations of both systems indicate that it is important to retain the water near the surface, allowing it to be evaporated, which given the semi-arid nature of the prevailing environment, is sufficient to reduce recharge to less than 0.1 mm/year below the clay cap. If the top soil cover is too thick, infiltration may collect on the surface of the clay cap to form a thin saturated layer, which would significantly increase the infiltration reaching the compacted kaolinised granite seal.

A review of capping systems in the United States showed that those in semi-arid to arid environments typically demonstrated zero infiltration for monolithic clay caps or store and release designs (Benson, 2002). Both of these designs were able to achieve percolation/infiltration rates equivalent to that of a composite capping system (geomembrane/clay). These results are consistent with the results from S1 and S3 and can be considered a verification of the model.

Similar results for a semi-arid climate were recorded at waste rock dumps in the Pilbara, where store and release systems with a 4 m thick cover of waste rock with a hydraulic conductivity of $5x10^{-5}$ m/s showed zero infiltration for annual rainfall similar to that measured at the project (Meiers et al, 2010).

Consequently, it is important that the encapsulation system be constructed to prevent saturated zones being formed on top of the clay barriers (i.e. the mottled clay cap and the kaolinised granite seal on the cell) by promoting runoff and having sufficient thickness of material to allow evaporation, and caps having low hydraulic conductivity to limit infiltration into the cell area.

6.6.1 Seepage

Based on the model results, it is likely that less than 0.008 mm/year of seepage will emanate from the base of a capped and sealed cell. Assuming a 7,200m^2 surface area of a cell, this flux equates to 57L/year of seepage averaged across the entire cell area, assuming the modelled rainfall conditions of continuous wettest years recorded for 100 years. This seepage will enter the in situ kaolinised granite which has an estimated hydraulic conductivity of $4x10^{-6}$ m/sec, which is significantly higher than the capping system. It is anticipated that this seepage will vertically migrate to depth, or be stored in the unsaturated zone below the repository as discussed in section 6.4.3. In the model, the vertical migration of seepage is via a unit gradient boundary condition, which is equivalent to simulating a water table at depth and is consistent with the actual conditions at the site.

Given the volume of seepage estimated from the simulation, the hydraulic conductivity of the kaolinised granite, the inferred depth to the water table, and the unsaturated storage below the repository, it is unlikely that any groundwater mounding will occur in the vicinity of each cell. This is because seepage flow laterally upon entering the water table at depth in the fresh granite (which is consistent with the existing conditions in the Project area).

7 MODEL LIMITATIONS

The application of the model is constrained by the assumptions and limitations inherent in the underlying conceptual model, as well as the approximations made in realizing the conceptualization as a numerical model. The following assumptions and limitations have been made for this study:

1. Flow through all of the modelled formations conforms to Darcy's Law, which explicitly assumes flow through a porous medium. While these conditions are satisfied in the top soil, laterite and weathered granite, it may not apply to the silcrete and fresh granite. Flow in the silcrete and fresh granite may occur through preferential flow paths such as macro pores, vugs/cavities and fractures. In these areas, the model solution for groundwater flow may be in error and not reflect actual conditions. This may result in groundwater velocity being underestimated in these areas.
2. There is no effective aquifer in the model area, and groundwater flow is primarily vertical;
3. All groundwater is locally sourced from rainfall recharge.
4. Any saturated zone is at depth and is not important with respect to estimating recharge.

Model Applicability is shown in Table 20. Based on modelling guidelines (Barnett, 2014), all the models presented in this report are assessed as Class 1 models.

Objective	Achieved	Comments
Simulate groundwater flow within and between all hydrogeological units in the site.	Yes	Models are limited to 1 and 2 dimensions representations, where flow is predominantly vertical.
Establish water budgets for each geological / hydrogeological unit.	Yes	Subject to non-uniqueness of recharge/ hydraulic conductivity distributions.
Provide results that will support the assessment cell designs with respect to recharge.	Yes	
Estimate the likely range and uncertainty of groundwater recharge changes as a result of the construction of cells.	Yes	

Table 23: Model Applicability to Stated Objectives

Given the lack of measured material properties the results of the modelling are indicative, and should be used for the relative assessment of alternatives, rather than the absolute estimate of vertical flows.

8 CONCLUSIONS AND RECOMMENDATIONS

8.1 Conclusions

The results of the column simulations of unsaturated flow indicate that the infiltration of rainfall into each cell is limited by:

1. Runoff from the relatively low hydraulic conductivity of the top soil and subsoil, due to the sloping of the cell cap; and
2. Evaporation and evapotranspiration of infiltrated water from the shallow top soil/subsoil that is retained above the compacted mottled clay cap.

The simulations indicate that it is important to retain the water near the surface, allowing it to be evaporated/evapotranspired, which given the semi-arid nature of the prevailing environment, is likely to reduce recharge to less than 0.1 mm/year below the clay cap. If the top soil/subsoil cover is too thick, infiltration may collect on the surface of the clay cap to form a thin saturated layer, which would significantly increase the infiltration reaching the compacted kaolinised granite seal.

Based on the model results, it is likely that less than 0.01 mm/year of seepage will infiltrate into the waste storage area. Based on a cell area of 7200 m^2, the annual potential seepage out of the waste storage area is 0.057m^3/annum (57 L/year). This seepage will enter the in situ kaolinised granite which has an estimated hydraulic conductivity of $4x10^{-6}$ m/sec, which is significantly higher than the capping system. It is anticipated that this seepage will vertically migrate to the water table which in this area is at depth, or be stored in the unsaturated zone below the repository.

Given the volume of seepage estimated from the simulation, the hydraulic conductivity of the kaolinised granite, the inferred depth to the water table, and the unsaturated storage below the repository, it is unlikely that any groundwater mounding will occur in the vicinity of each cell. This is because seepage will be either stored in the unsaturated zone or flow laterally upon entering the water table at depth.

Sensitivity analysis showed that the lower boundary condition has limited effect on the magnitude of the vertical fluxes, other than for the unit gradient, which tends to increase the vertical flux below the compacted kaolinised granite seal.

There is some sensitivity of infiltration to the topsoil/waste rock cover hydraulic conductivity and runoff, both of which tend to increase infiltration and subsequently the saturation in the clay cap and kaolin seal. Under these conditions annual infiltration (seepage) into the granular material that surrounds waste packages increases to 0.4 mm/annum compared to 0.008 mm/annum in S3. The lack of runoff also increases the infiltration as well as the amount of water that must be evapotranspired, indicating that it is important to maintain a sloping surface on the cell surface to encourage rapid drainage.

The results of S4 highlight the sensitivity of seepage to higher hydraulic conductivity of the top soil/subsoil and waste rock, increased saturation in the clay cap and seal and the ponding of water on flat ground.

8.2 Recommendations

Groundwater and climate monitoring should be undertaken to establish base line conditions. This will allow the impact of mining and waste storage to be objectively assessed.

The unsaturated hydraulic properties of the silcrete and backfill material should be determined quantitatively, and used to reduce the uncertainty in future modelling.

Soil moisture probes and other instrumentation should be installed at various depths above the silcrete to establish soil moisture profiles during rain events and subsequent dry periods. This data should be used to calibrate any unsaturated flow models that are developed in the future.

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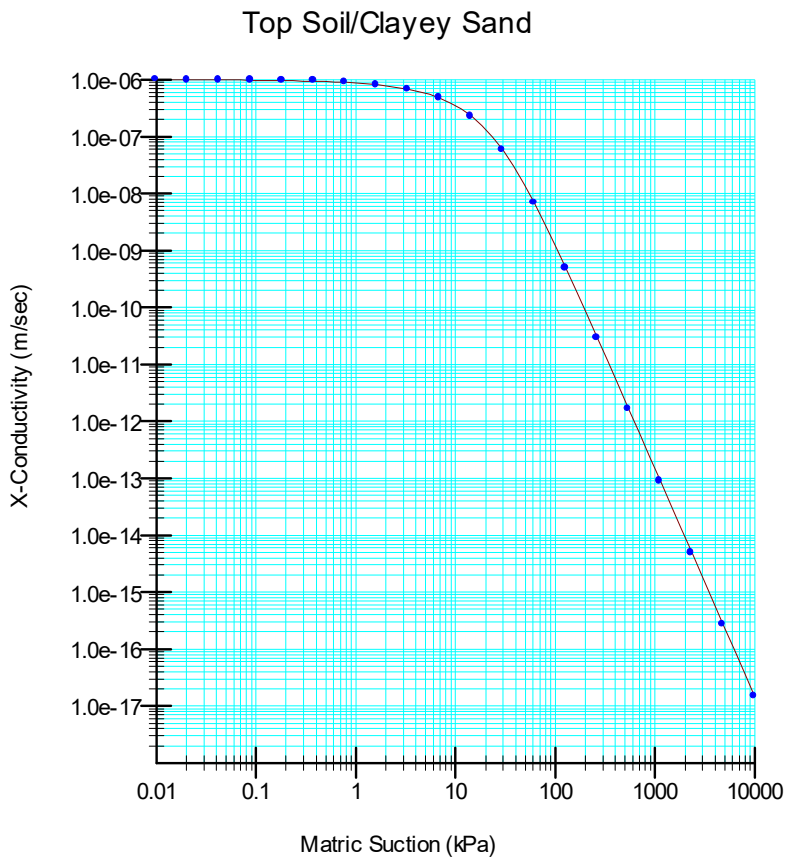
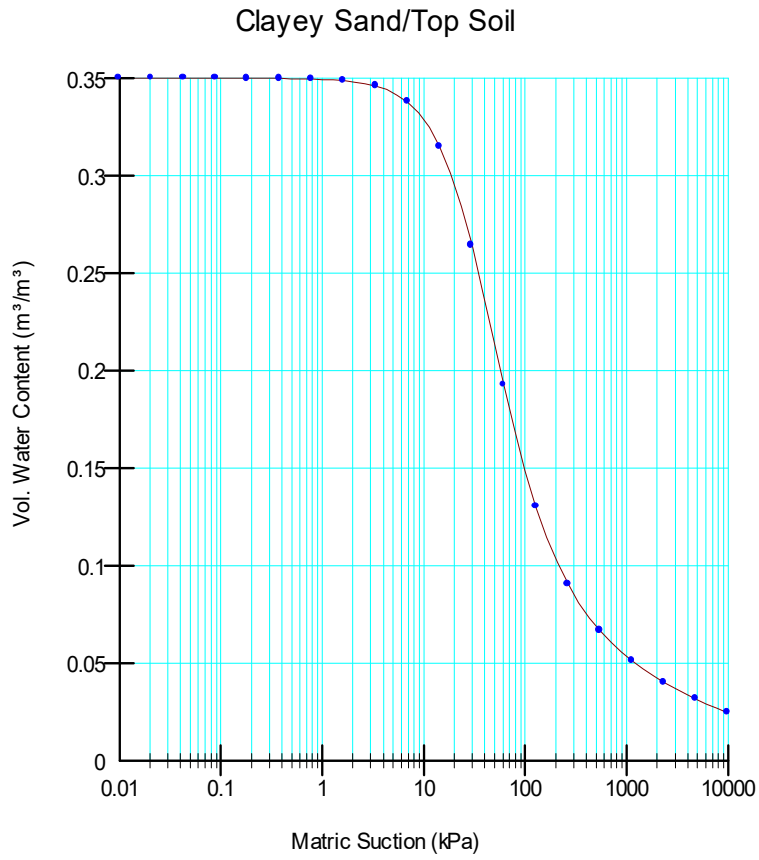
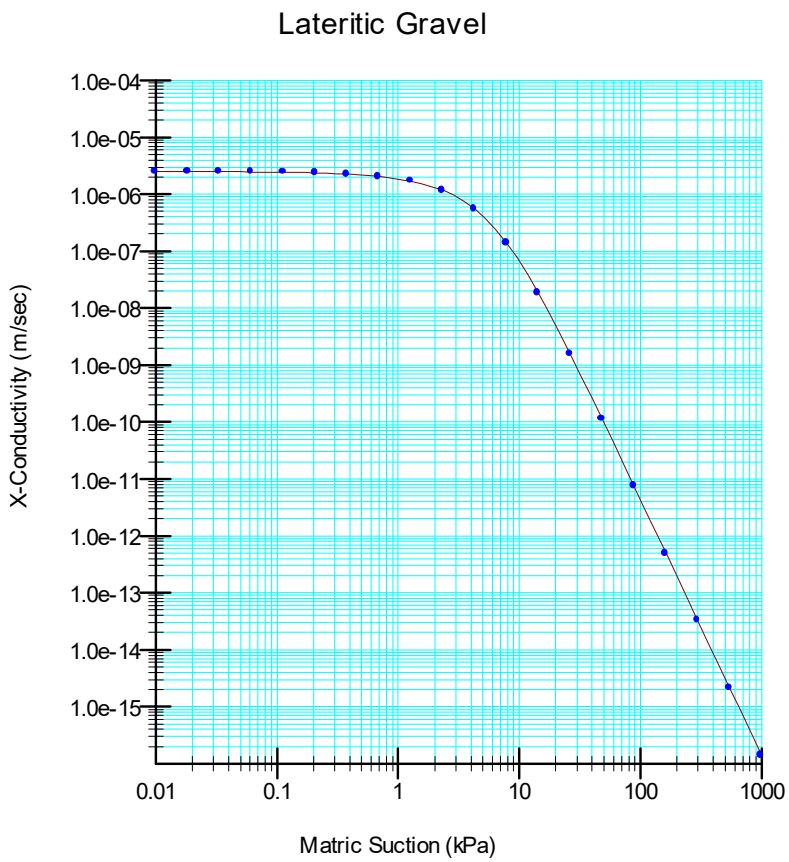
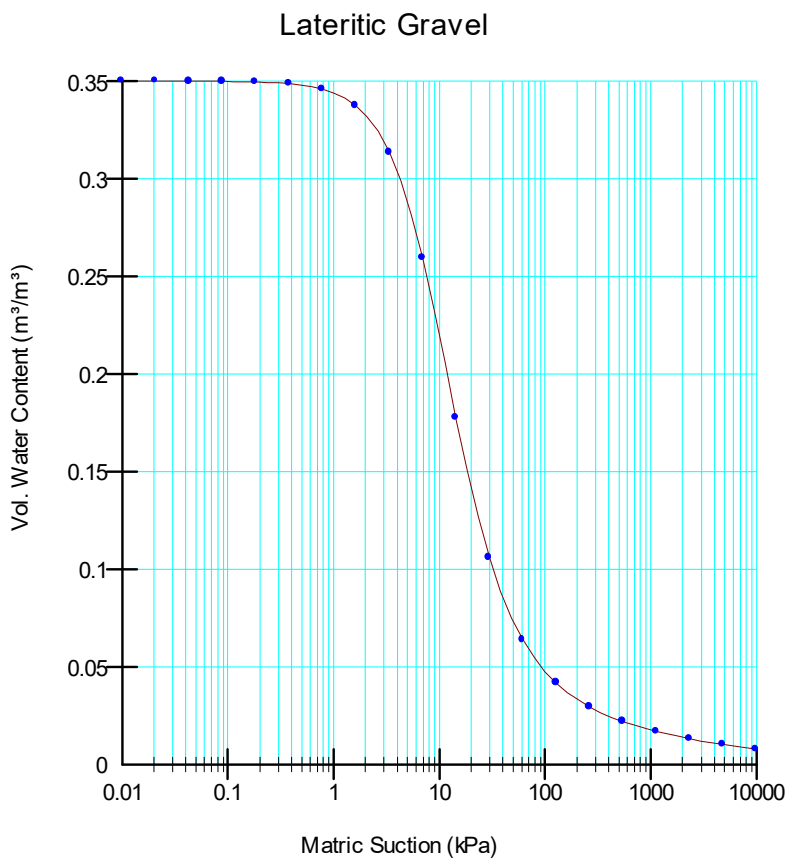
APPENDIX A: MATERIAL PROPERTY FUNCTIONS



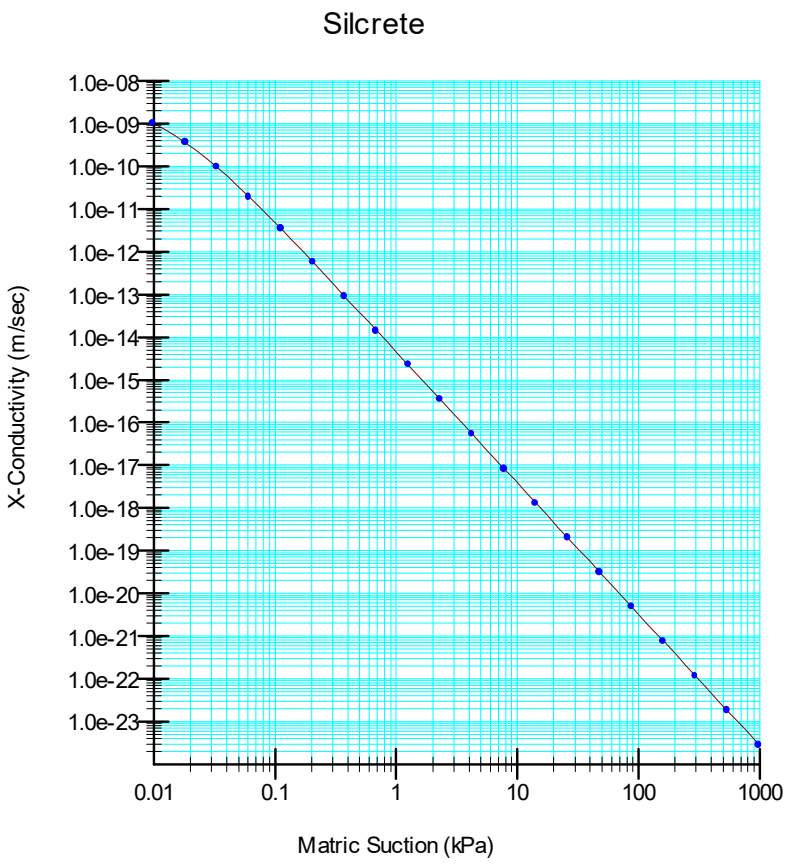


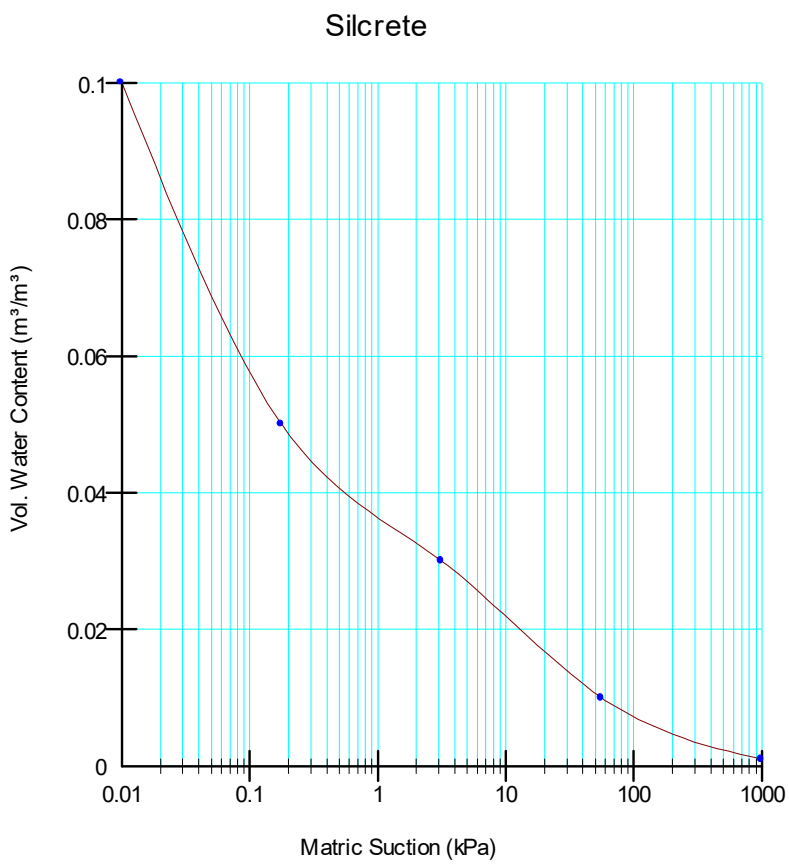
Top Soil/Clayey Sand – Material Properties



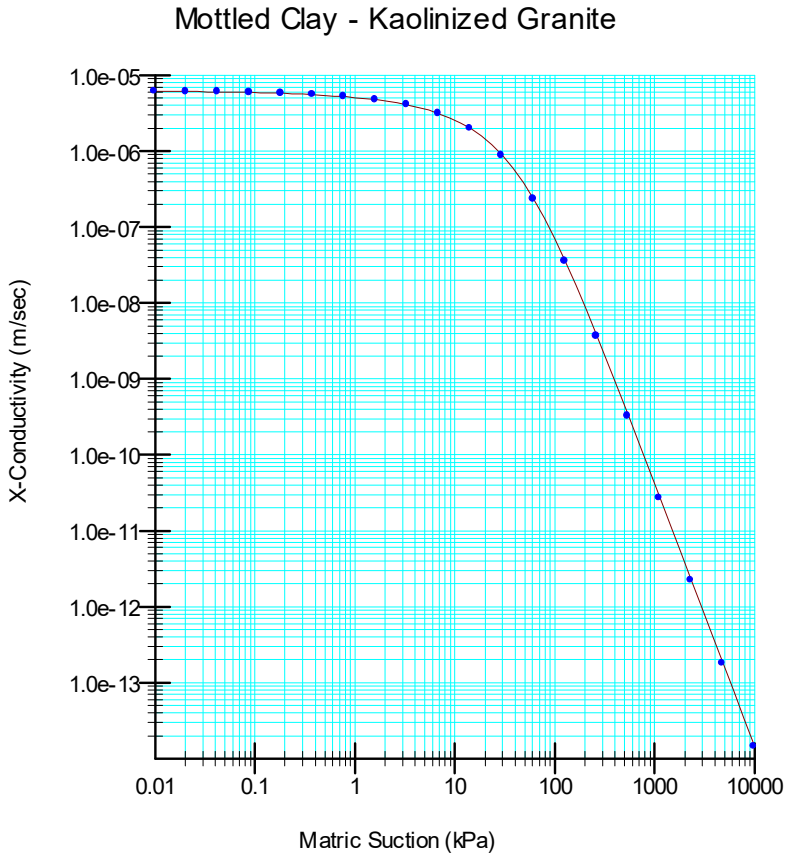


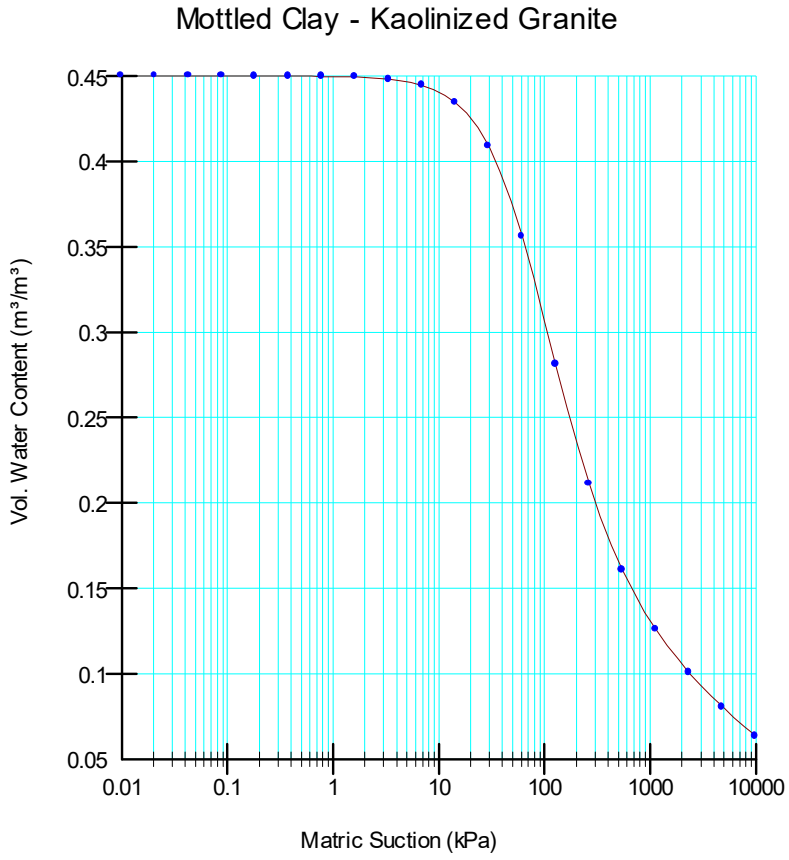
Laterite Gravel – Material Properties



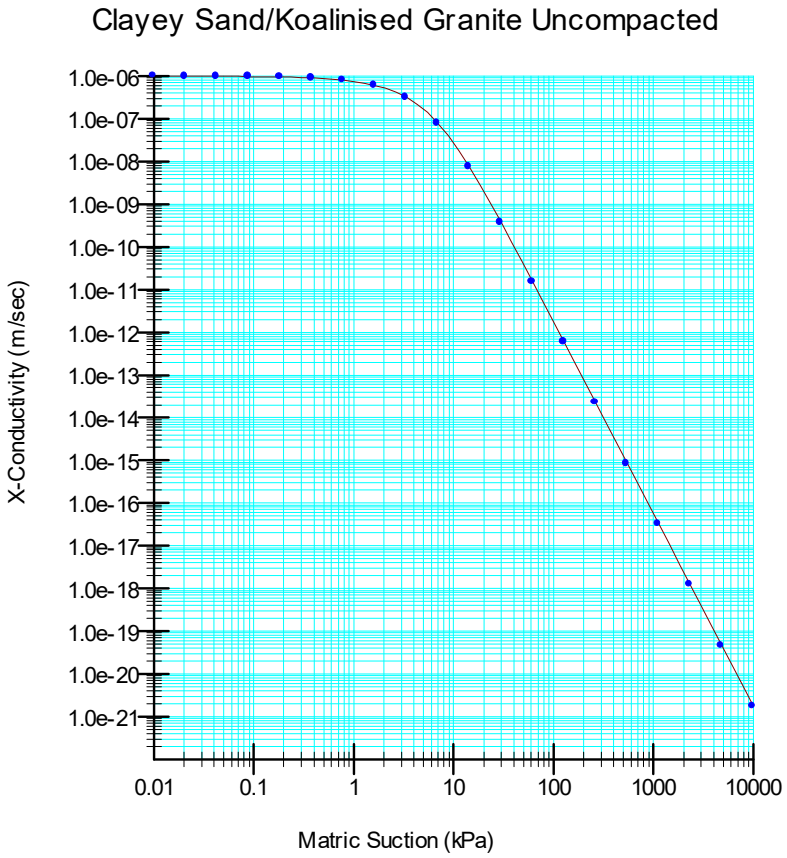


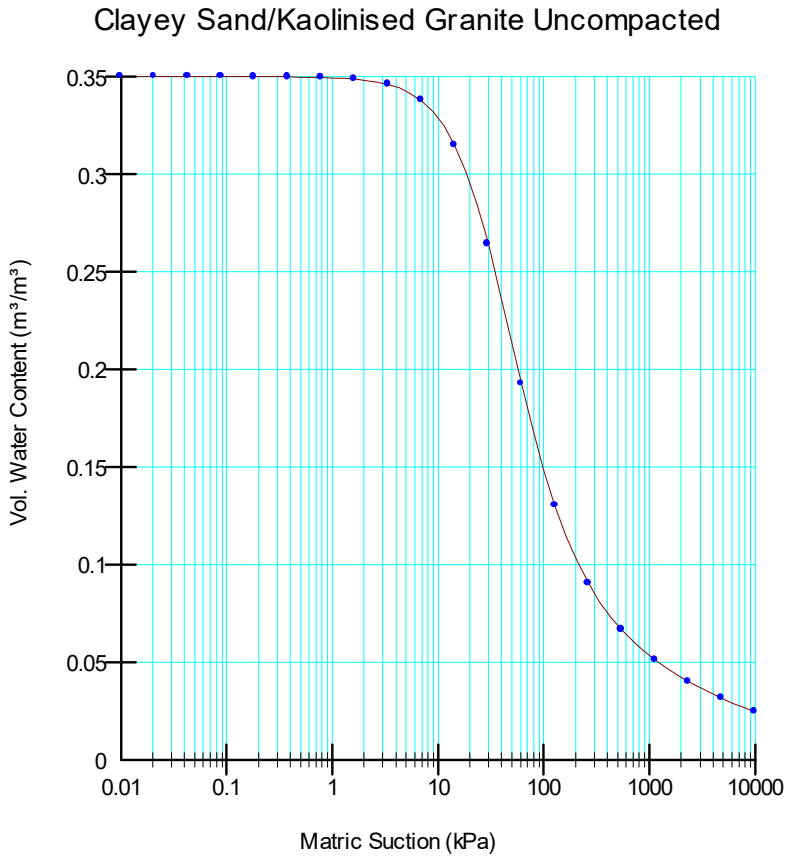
Silcrete – Material Properties





Mottled Clays/Kaolinised Granite – Material Properties





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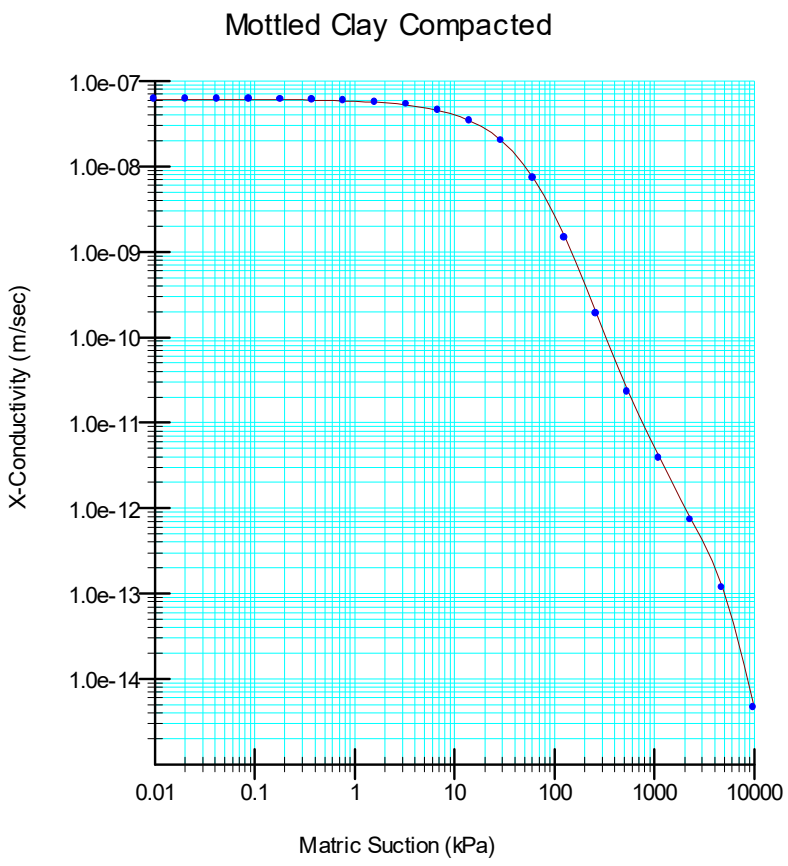
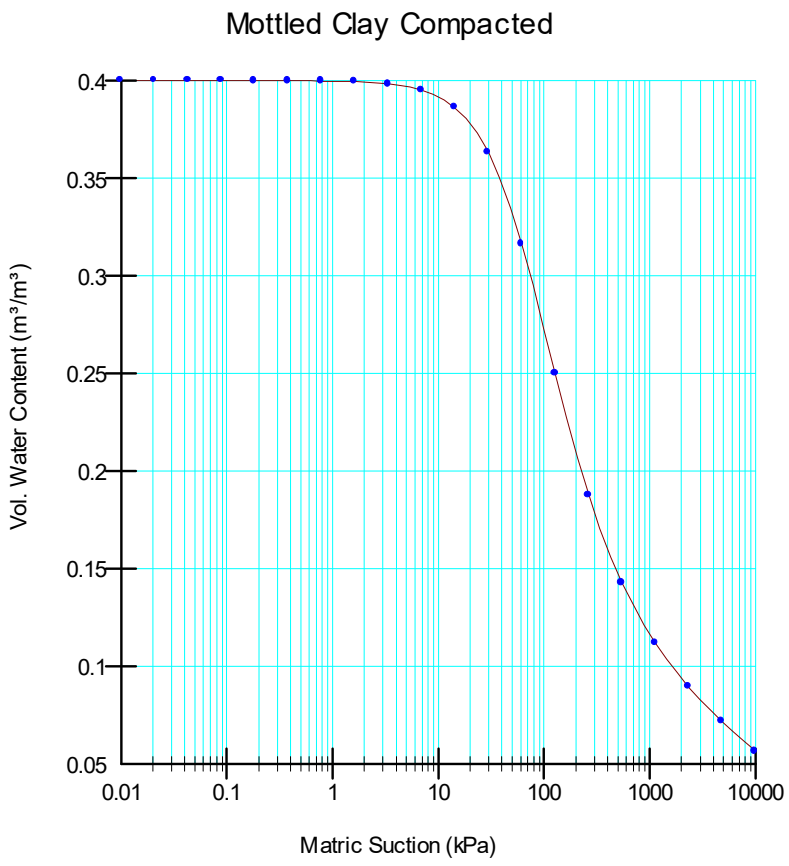
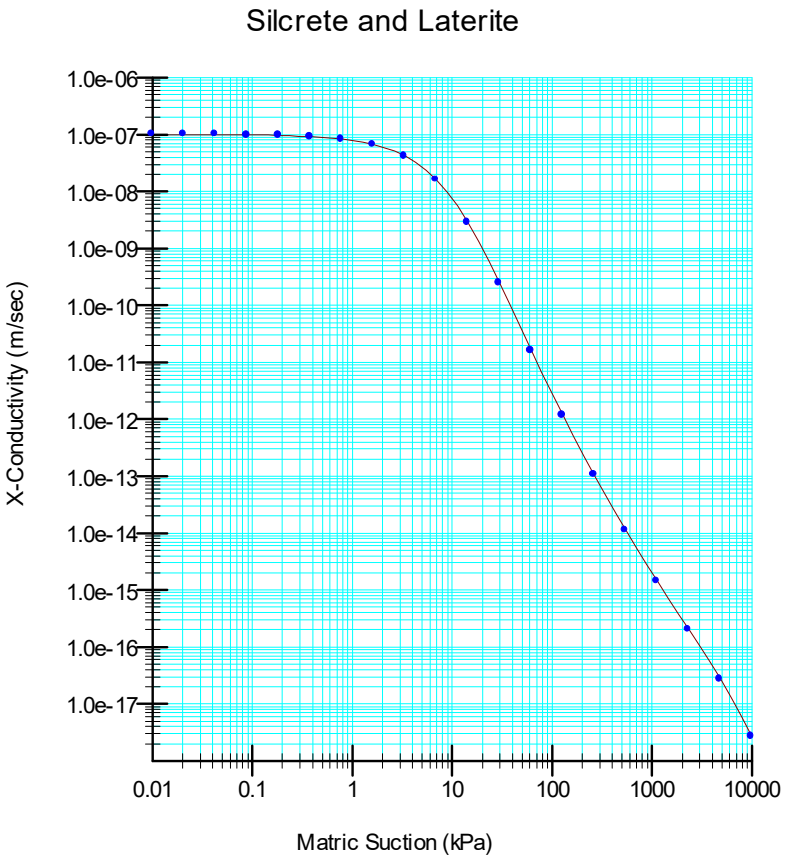
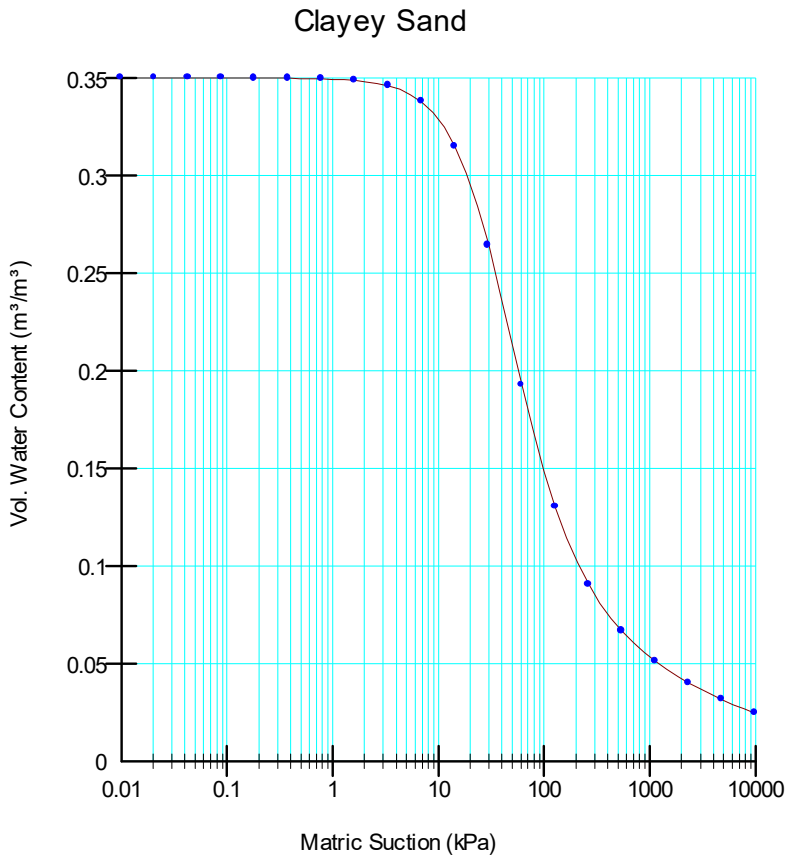


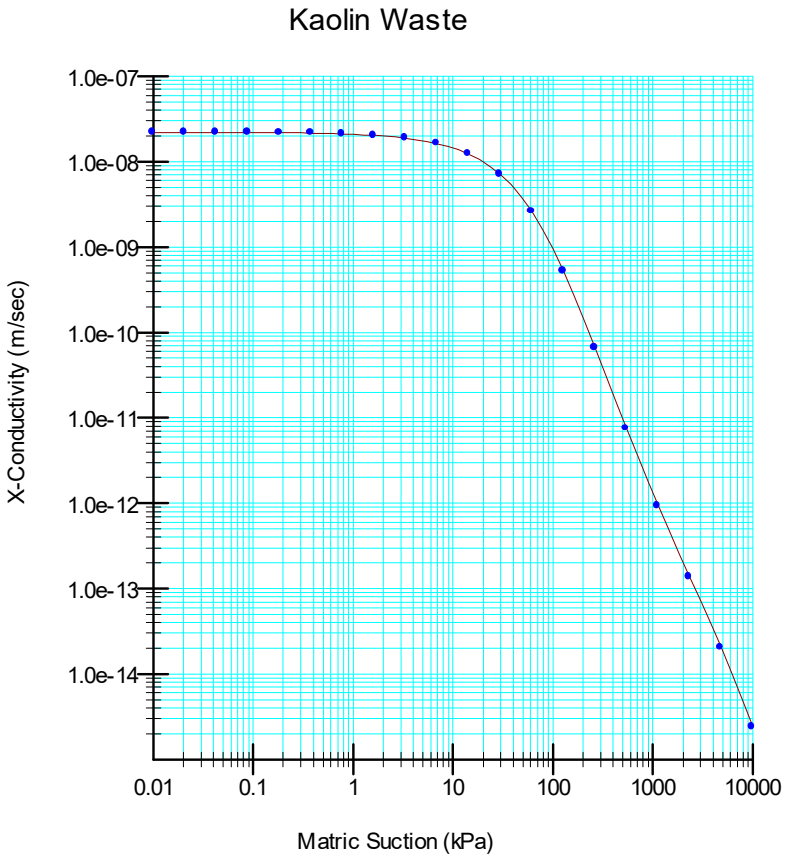


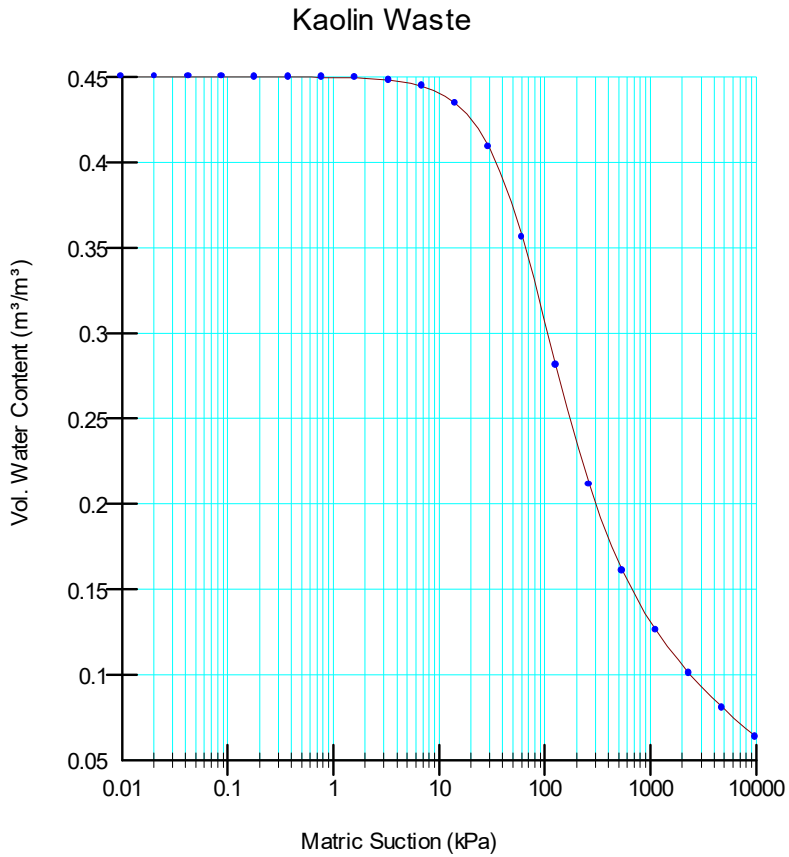
Mottled Clays/Kaolinised Granite Compacted – Material Properties



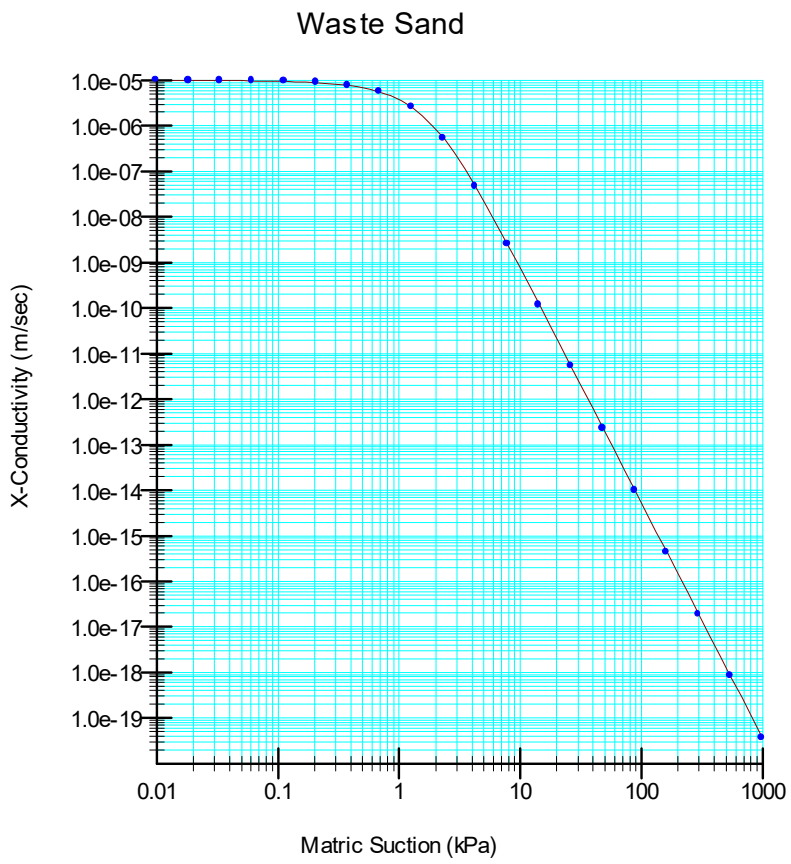


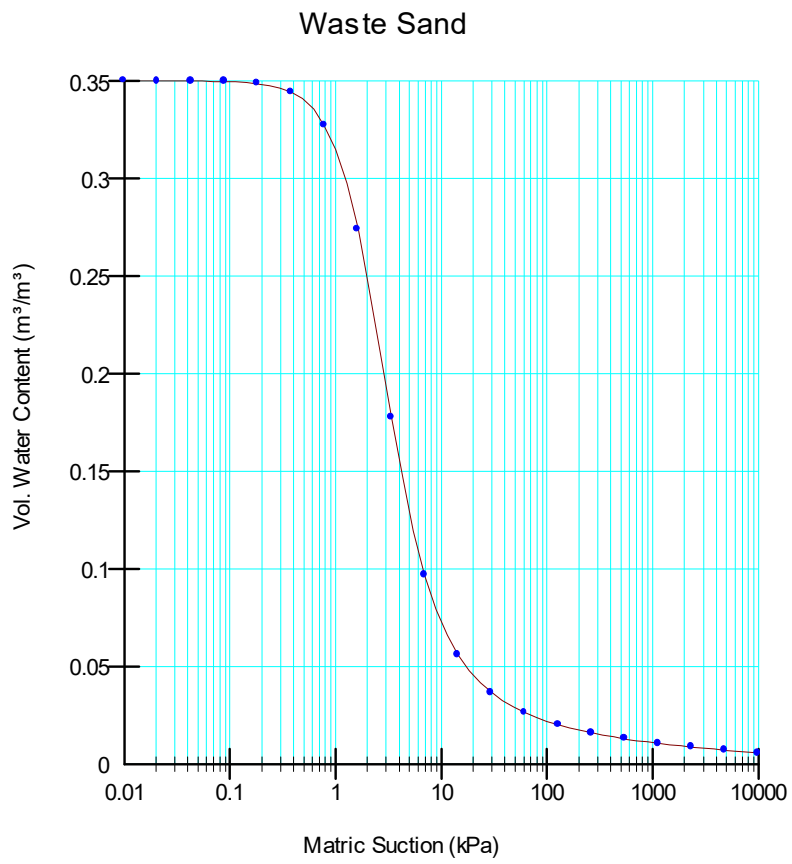
Mixed Laterite, Silcrete and Clayey Sand – Material Properties





Kaolin Waste Compacted


Waste Sand
X-Conductivity (m/sec)
1.0e-05
1.0e-06
1.0e-07
1.0e-08
1.0e-09
1.0e-10
1.0e-11
1.0e-12
1.0e-13
1.0e-14
1.0e-15
1.0e-16
1.0e-17
1.0e-18
1.0e-19
0.01
0.1
1
10
100
1000
Matric Suction (kPa)


Waste Sand
Vol. Water Content (m³/m³)
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
0.01
0.1
1
10
100
1000
10000
Matric Suction (kPa)

Waste Sand

Heritage Survey

TELLUS

JCHMC

REPORT ON AN ABORIGINAL HERITAGE SURVEY OF TELLUS SANDY RIDGE PROJECT

JUNE 2015

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EXECUTIVE SUMMARY

Tellus Holdings Limited (Tellus) is proposing to develop its Sandy Ridge Project, situated 140 kilometers northwest of Kalgoorlie. R. & E. O'Connor Pty Ltd was employed to undertake Aboriginal heritage surveys in order to consult with Aboriginal stakeholders and provide Tellus with suitable heritage management recommendations. The survey was carried out by John Cecchi of John Cecchi Heritage Management Consultancy in May 2015, on behalf of R. & E. O'Connor Pty Ltd. The field survey was conducted in consultation with representatives of the Kaparn Native Title Group, Kelamaia Kabu(d)n and Widji Group via pedestrian transects aligned north-south, spaced fifty meters apart. No sites of Aboriginal heritage were identified during the survey. Two isolated artefacts were identified and recorded within the Project. These do not constitute sites and no further action is recommended in their regard.

Given that no sites of ethnographic or archaeological significance were identified within the Project, the Aboriginal representatives approve the Project. The potential for stratified archaeological deposits was assessed as low given the local geology and predictive site patterning. It is therefore recommended that the Project proceed as planned.

Given that the Act applies to sites whether previously reported or not, should ground works encounter Aboriginal cultural material, further archaeological and ethnographic consultation may be warranted. Should any skeletal material be uncovered, the Western Australian Police should be contacted.

i. Copyright

This report is subject to the provisions of the *Copyright Act 1968* (Cth).

ii. Spatial Accuracy Statement

The GPS Co-ordinates in this report are MGA Zone 51 referenced to WGS 84, which approximates to GDA 94, and are accurate to 10 meters.

iii. Acronyms and Definitions

ACMC	Aboriginal Cultural Material Committee
Act	*Aboriginal Heritage Act 1972* (WA)
AHIS	Aboriginal Heritage Inquiry System
BP	Before Present
DAA	Department of Aboriginal Affairs
HSR	Heritage Survey Report
JCHMC	John Cecchi Heritage Management Consultancy
Project	Sandy Ridge Kaolin Mine Project

iv. Acknowledgements

The author gratefully acknowledges Rory O'Connor of R. & E. O'Connor Pty Ltd, Tellus Sandy Ridge Project Leader Michael Ingram, Terra Search Geologist Jamie Williams and the Aboriginal participants.

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1.0 INTRODUCTION

Tellus is proposing to undertake kaolin mining in Western Australia's Goldfields Region. The Project encompasses nearly nine kilometers square of land within tenement E16/440 and a haul road connecting the proposed mine to the existing Mount Dimer Road. The Project is situated twenty kilometers north of Mt Walton, some 140 kilometers northwest of Kalgoorlie. R. & E. O'Connor Pty Ltd was employed to undertake Aboriginal heritage surveys in order to consult with Aboriginal stakeholders and provide Tellus with suitable heritage management recommendations. The surveys were carried out by John Cecchi of John Cecchi Heritage Management Consultancy in May 2015.

1.1 Scope Of Heritage Survey

As stated by the DAA the purpose and scope of an Aboriginal archaeological heritage survey is to:

- Establish whether the study area contains physical evidence of past Aboriginal occupation and use;
- Record, assess and make recommendations regarding the management of these sites, with specific reference to the proposed development;
- Analyse the above information against the development proposal to provide the basis for the development of planning recommendations; and
- Collate all information required for the purpose of reporting a site to the Aboriginal Site Register (if applicable).

The scope of an ethnographic survey is to:

- Undertake consultation with all people who have a valid interest in, are knowledgeable about and/or who have traditional rights and obligations in the study area;
- Document all discussions and decisions by groups or individuals, including any limitations to information;
- Identify sites;
- Document any recommendations and conditions voiced by the Aboriginal consultants;
- Document any other relevant Aboriginal heritage issues; and
- Analyse the above information against the development proposal to provide the basis for the development of planning recommendations.

2.0 SURVEY AREA

The survey area covers nearly nine square kilometers of land twenty kilometers north of Mt Walton and 140 kilometres northwest of Kalgoorlie (Figures One and Two).

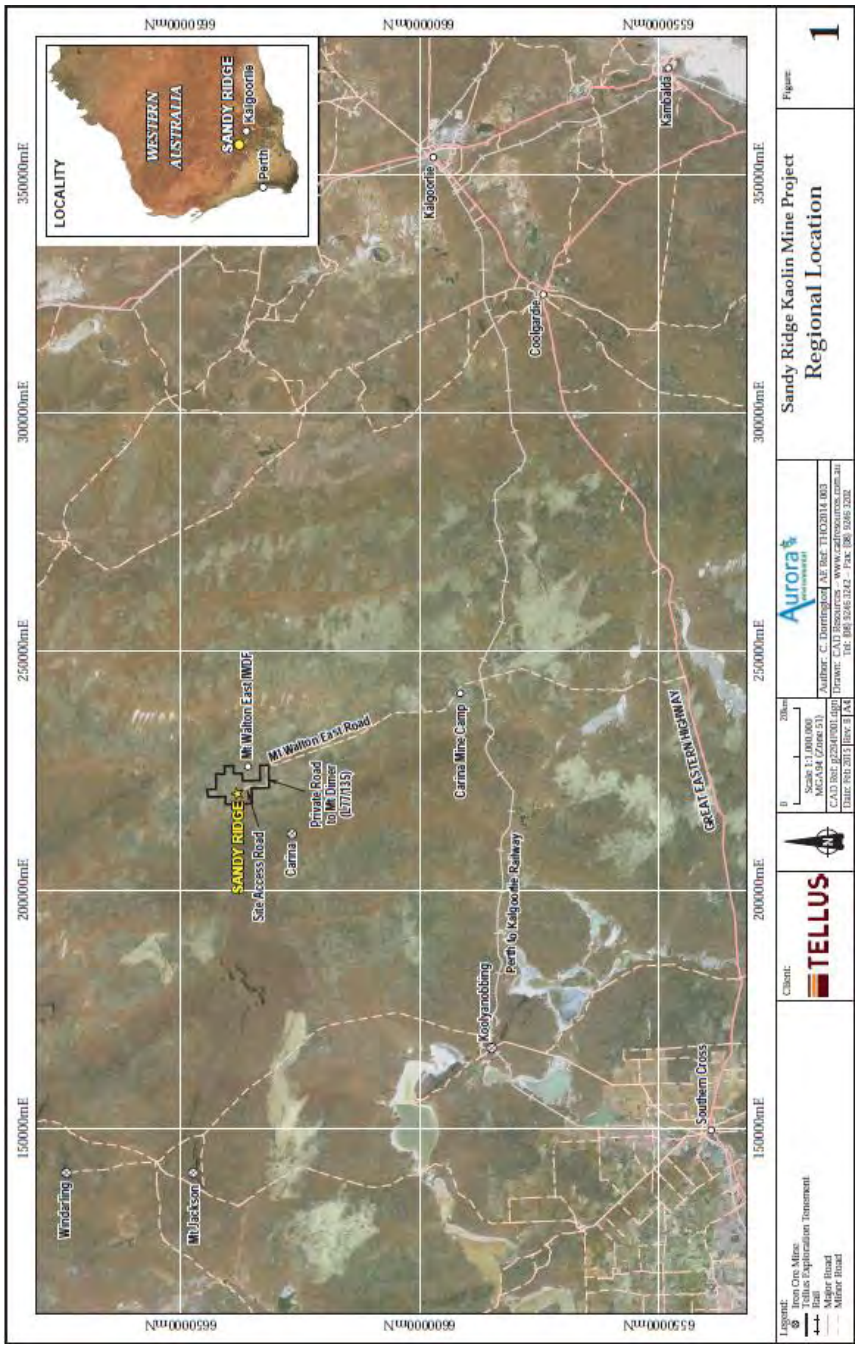

Figure 1. Survey Area Locality Map.

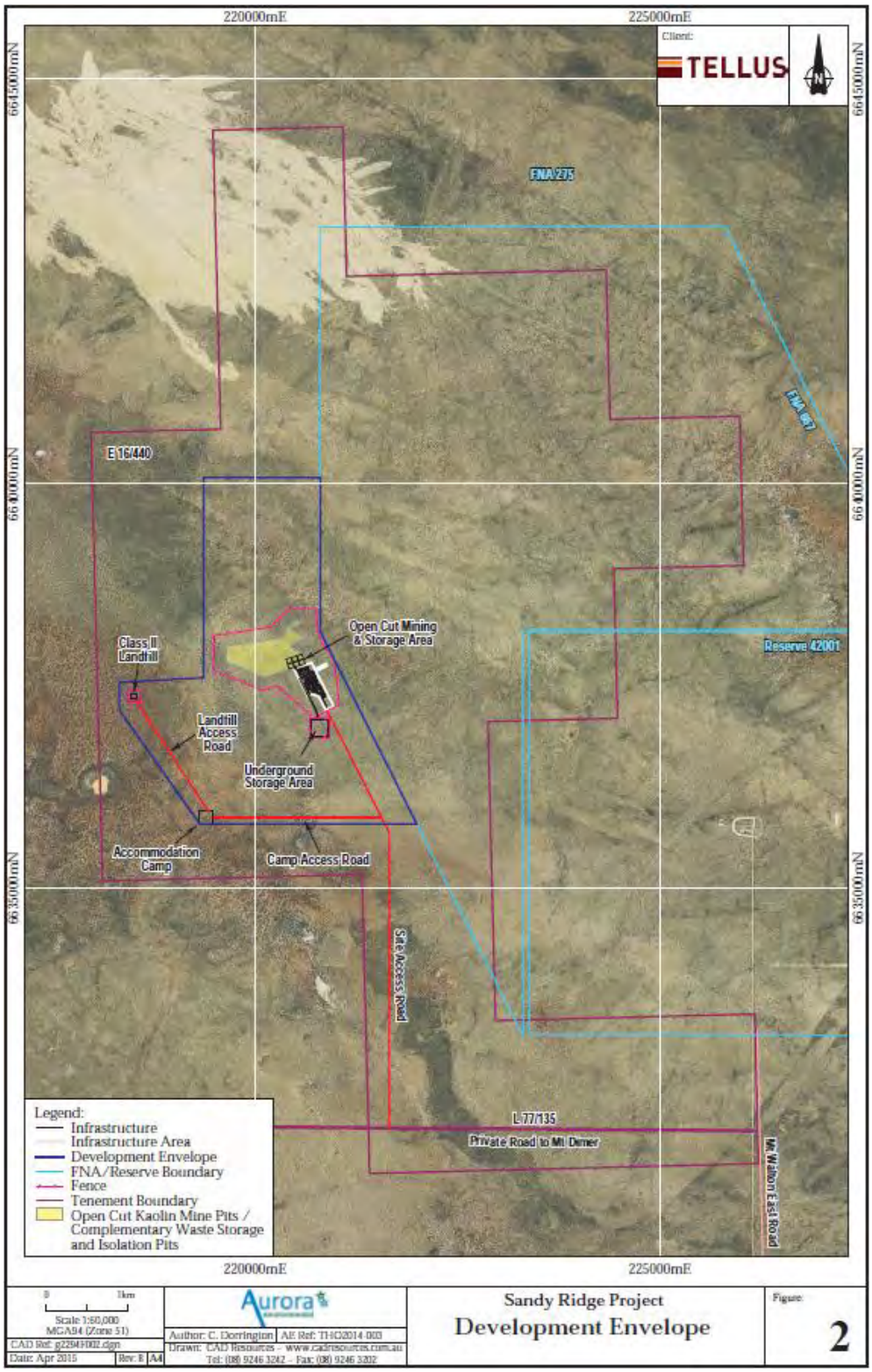

Figure 2. Map of Survey Area.

3.0 ETHNOGRAPHIC BACKGROUND

Pre-European settlement in the general area in which the Project area is located was a transition zone between the Bibbulmun people of the Southwest and the tribal groups who inhabited the Desert regions of Australia's interior (collectively known nowadays as "Wangkayis" or "Wongis"). Thus, Bates (1944) notes that:

> *"...Southern Cross was the eastern border of Bibbulmun country. In 1909 all remaining members of its group had been drawn into the circumcised tribes on their eastern boundary, the last natives of Merredin and Burracoppin also having being circumcised before they died out."*

Tindale (1974) refers to these intermediate people as the *Kelamaia*, but his field notes reveal that this was the name for the language spoken in that region, whereas *Kubrun* was the name of the people which he collected. In her field notes, published in 1985 by the National Library of Australia, Bates gives more detail in their regard, collected during a visit to that region in the early years of the century:

> *"...the name Karratjibbin has been applied to this nation as it was the term supplied by my Southern Cross informants, for their chief camping ground in that locality...the area over which this group extended ran from Mount Jackson in the north (about Lat. 30*20') through the Southern Cross district towards the Dundas area...The peculiar organisation existing amongst these people differentiates them from every other known tribe in the West. They possess a two-moiety system, which in this respect links them with their south-*

> *western neighbours, but with the important difference amongst the Karratjibbin people of each moiety marrying within itself and producing the other moiety...Whether the area of these people extends further than the limits mentioned, could not be ascertained in the short time allowed for investigation...I found the system among the Norseman district natives and in the Mount Jackson group. Their social organisation, customs, laws, initiation, etc., coincide with those of their eastern, north-eastern and south-eastern neighbours, with whom they have traded their local products...The various groups composing the "nation" held rights of possession to certain water-holes, hills, soaks, springs, etc., the chief of which appeared to be Karratjibbin, Wilgauin (Mt. Jackson), Yogguragain (west of Karratjibbin), Kammining (north-west of Karratjibbin), Malyorning (?), Juwardain (near Mt. Jackson)...The Karratjibbin Nation borders the Bibbulmun on the north-east, and several of the latter were adopted into and circumcised by the Karratjibbin people."*

To the east of the above groups, as noted above, were found the lands of the most westerly groups who inhabited the desert interior. In that area, social and linguistic similarity stretched in a wide arc from Oodnadatta in present-day South Australia, through the Great Victoria and Great Sandy Deserts, to the Fitzroy River in the northwest and the vicinity of Purnululu National Park in the northeast, extending partially into the present-day Northern Territory. To the south, and centered upon Norseman, Balladonia and Frasers Range, were located the Ngadju people.

Cultural practices and religious stories in the general Goldfields region were shared between neighbouring groups, although names of spiritual entities tended to be changed with transition from one culture-group to another. Aboriginal traditional religion is based on the land; its shrines, hymns and religious objects refer to topographic and other natural features. In such a religion, a degree of permanence and stability exists, which would not be the case were the religion based in man-made structures. In the general region in which the present study was carried out, the hymns and stories which are the link which binds the human to the natural (viewed, from an emic perspective, as supernatural) have been retained by a pivotal generation of elderly Aboriginal people. The existence and location of religious sites is therefore still known to the Aboriginal people. These sites, in the Kalgoorlie/Coolgardie/Menzies area are related mainly to four mythic sagas, which are commemorated in song and story, namely:

(i) the Yina Kutjarra, two mythic human ancestors, carriers of Law and religion (known to neighbouring Wangkayi groups as *Wati Kutjarra*), who pursued an emu ancestor through the Kalgoorlie region;

(ii) the Tjilkamarta or echidna ancestor, a creative being;

(iii) the Nganamarra or mallee fowl ancestor, a creative being;

(iv) the Milyura or Pleiades, creative women ancestors (known to neighboring Wangkayi groups as *Kungkarangkara*).

Generally, sites associated with these mythic sagas are either prominent rocky outcrops or water-sources.

3.1 Native Title Groups And Stakeholders

The first application for determination of native title lodged over lands which include the Project was the Gubrun Application, representing the Donaldson, Wilson, Champion and Sambo families. All of these families were and are members of the larger culture-group named as Kubrun. Following that application, the Kabul, Kelamaia Kabu(d)n, Mingarwee and Kalaako Applications were lodged by members of the same four families, who felt that they had been omitted from the Gubrun claimant group; or at least from its decision-making processes. The matter was resolved for a short time by the Goldfields Land and Sea Council, which brought together some, but not all, of the disputing parties under the umbrella of a group called the Central West Goldfields People and lodged an application for determination of native title on their behalf. Gubrun, Kabul, Mingarwee and Kalaako Applications were then either withdrawn or struck out by the Federal Court of Australia. The Central West Goldfields People Application was struck out by the Court and at approximately the same time, the Widji Group, comprising initially the grandchildren of the Central West elders, made a separate application and, through the efforts of their accountant, achieved registration under Section 190A of the *Native Title Act 1993*, thereby obtaining the Right to Negotiate under the Future Act provisions of that legislation. The State of Western Australia took action against the Widji Application in the Federal Court of Australia and it also was ultimately struck out. In 2011, the Kelamaia Kabu(d)n Application was withdrawn to two small areas – one at Ularring Rock to the north of Davyhurst, and another near Widgiemooltha. In late 2013, the Kaparn Application was lodged. It is currently being considered for registration by the National Native Title Tribunal. Accordingly, at this stage there is one unregistered native title application

covering the Project and one such application awaiting a decision regarding its registration.

Paragraph 2.18 of the *Due Diligence Guidelines* issued by DAA are relevant to deciding which persons or groups should be included in Aboriginal heritage surveys and consultations, as follows.

Information about the Aboriginal heritage of a particular area is best obtained in consultation with the relevant Aboriginal people for that area. Whilst there is no definitive list of Aboriginal people who should be consulted for an area, the Aboriginal Cultural Material Committee suggests that the following people at least should be consulted:

(a) those who are determined native title holders;

(b) those who are registered native title claimants;

(c) persons named as informants on Aboriginal site recording forms held in the Register at DIA;

(d) any other Aboriginal persons who can demonstrate relevant cultural knowledge in a particular area.

As noted above, there are no relevant registered native title claimants (and no determined native title holders). As there are no Aboriginal sites registered within the Project, there are no relevant site recording forms and therefore no registered informants. Relevant cultural knowledge of the general area in which the Project will occur has been demonstrated in the Federal Court of Australia in the course of native title hearings and in numerous previous heritage surveys by the following family groups:

- The Sambo family as members of the former Central West Goldfields People and

current Kaparn groups.

- The Champion family, as members of the former Gubrun and Kelamaia Kabu(d)n groups.
- The Donaldson family, as members of the former Central West Goldfields People and Widji groups.

Inclusion of these participants will achieve the two required outcomes, as follows:

- Certainty in regard to the presence or otherwise of known Aboriginal sites within the survey area;
- Certainty that no relevant persons or families have been omitted from the consultative process and that therefore no complaints over such omission will arise after survey completion.

There remains, of course, the possibility of hitherto unknown Aboriginal sites being within the areas of proposed works associated with the Project and for this matter it was formulated that the Aboriginal representative participate in the archaeological field investigation.

4.0 ENVIRONMENTAL BACKGROUND

4.1 Climate

The study area experiences a semi-arid climate with hot, dry summers and mild winters. Mean maximum temperature for the hottest month occur in January at 33.6 °C with mean minimum of 18.3 °C. Maximum temperatures exceeding 46 °C have been recorded for the region. Temperatures in July reach a mean maximum of 16.7 °C and a mean minimum of 5 °C (BOM 2015).

The area receives on average 267mm of rain annually, fairly evenly distributed throughout the year, with slightly higher falls in the winter months between June and August. Winter rainfall is usually associated with cold fronts, whilst thunderstorms provide the area with localised and variable rainfall during the summer months. The area is also subject to droughts given high temperatures and high evaporation rates (Beard 1981).

4.2 Geology

The study region is situated within the Yilgarn Craton comprising basements of Archaean greenstone and granites and Proterozoic granite and gneiss intrusions (Beard 1990). Undulating uplands on granite pavements and low valleys of greenstone hills typify the geology of the region with granite outcrops commonly occurring. Red-brown loams and Aeolian sands occur in the broad valley floors interspersed with Eocene marine limestone plains. Gravelly sand plains and laterite breakaways occur in upper levels stemming from erosion of the lateritic duricrust (Cowan et al 2001).

4.3 Vegetation

The Project lies within the Coolgardie Botanical District of the South-western Interzone, in the Eremean Botanical Province (Beard 1981). The vegetation is characterised by an open sclerophyll woodland dominated by Salmon Gum (*E. salmonaphloia*) and Gimlet *(E. salubris*) within valley floors, with a variety of mallee species colonising the slopes between the valley floors and sandy uplands. The latter are characterised by acacia scrub. The majority of the survey area is situated on yellow sands with some gravel with typical sand plain vegetation. A few pockets of mallee and gum woodlands are also present.

5.0 ARCHAEOLOGICAL BACKGROUND

Early Aboriginal occupation of arid and semi-arid regions of Australia has been dated to 25,000 BP from sites such as the Newman Rockshelter in the Pilbara (Maynard 1980). Other excavations at Puntutjarpa in the Gibson Desert (Gould 1977) and at Walga Rock (Bordes et al 1983) have yielded dates of around 10,000 BP.

Researchers (Gould 1980) have elaborated a rain-chasing model to describe the type of Aboriginal adaptation to arid and semi-arid regions. The model proposes an opportunistic water exploitation system, where ephemeral and semi-permanent water sources were utilised prior to the more reliable and permanent sources (Gould 1980, Veth 1989).

Aboriginal colonisation theories for arid and semi-arid ecosystems have been widely debated. Smith (1988) has suggested that availability of water during an earlier lacustral

phase would have allowed Aboriginal occupation of the interior of Australia by 12,000 BP. Occupation of desert lowlands before and during the last glacial maximum would have been abandoned until the amelioration in climate c.15,000 to 7,000 BP.

Veth (2000) postulated a different model whereby the initial colonisation of the arid regions occurred during the more favourable climatic period of the late Pleistocene, from approximately 25,000 BP, with a retreat to less arid areas during the 22,000 to 13,000 BP period, and a re-occupation of marginal lands between 13,000 to 5,000 BP. From 5,000 to 1,500 BP all desert ecosystems are thought to have been inhabited due to a re-establishment of regional networks and an intensification of site occupation, ceremonial gatherings and long distance exchange (Veth 2000).

Several dated sites within the survey region have yielded Holocene dates in the range of 2,000 BP near Leinster (Liberman et al 1977) to 500 BP near Hyden (Bowdler 1989) and 1570 BP at Windimurra (Harris 2002).

According to previous research, the archaeological mark of a rain-chasing model of occupation includes a higher number of low-density artefact scatters around ephemeral water sources and larger sites associated with more permanent water bodies.

5.1 Regional Archaeology

In the wider region several Aboriginal heritage surveys have been conducted (Cecchi 2014a, 2014b, 2014c, 2013, 2012a, 2012b, 2011, 2009 and O'Connor 2012a, 2012b 2009, 2008, 1987). From these studies the following generalisations can be made:

- Artefacts scatter sites are the most common site type recorded. These sites are usually located in the vicinity of water sources such as creeks, drainage lines, claypans, rockholes and granite outcrops or within rockshelters. The size, density and raw material variability is proportional to the size and nature of the water source with which it's associated or the distance to the closest potential water source;
- Surface scatters commonly exhibit artefacts manufactured from a variety of lithics including quartz, chert, chacedony, fine grained sedimentary (mudstone, siltstone), silcrete, tuff, ironstone, BIF, quartzite, dolerite and basalt;
- Surface artefact scatters exhibit assemblage's characteristic of the Australian Small Tool tradition. Backing and tool types such as scrapers, blades and backed blades have been recorded. Few grinding implements have been identified, usually within larger sites;
- Quartz, silcrete, chert and chalcedony quarry sites have been recorded previously;
- Stone arrangements and scarred trees have been previously recorded in the region; and
- Stone arrangements usually occur in association with granite outcrops and water sources, or where suitable cobbles and stones can be found at the surface.

6.0 DEPARTMENT OF ABORIGINAL AFFAIRS SITE REGISTER

A search of the DAA AHIS indicated that there are no Registered Sites or Other Heritage Places within the Project (Appendix 5). From the author's private library one Aboriginal heritage survey was identified as been previously conducted within the Project.

6.1 Previous Heritage Survey Reports

Tellus commissioned Aboriginal heritage surveys prior to undertaking exploratory drilling of the Sandy Ridge Project (Cecchi 2014b). Representatives of the Kaparn Group, Kelemaia Kubu(d)n and Widji groups were consulted and participated in a field survey for the drill lines. No sites were identified and the report recommended further consultation and field surveys should the Project proceed in order to identify and record any sites outside the drill lines cleared.

7.0 SURVEY METHODOLOGY

The field survey was conducted via pedestrian transects aligned north-south, spaced fifty meters apart. Representatives of the following Aboriginal Groups were consulted with regards to the Project:

- Kaparn Native Title Group: Elizabeth Sambo, Gina Sambo, Jamarl Sambo, Isabel Richards, Mark Richards and Trevor Johns; and
- Kelamaia Kabu(d)n: George Champion (snr), Tim Champion, Charles Coleman and Travis Champion; and
- Widji Group: Dianne Logan, Rodney Edwards, Corey Logan and Betty Logan.

8.0 SURVEY RESULTS

No sites of Aboriginal heritage were identified during the survey.

8.1 Isolated Artefacts

Two isolated artefacts were identified and recorded within the survey area (Appendix 1). Given that studies have evidenced the fact that Aboriginal people travelled, hunted and gathered throughout much of the region it is not uncommon to find isolated stone artefacts. Within the survey area artefact densities were very low and the potential for stratified deposits was assessed as negligible due to the local geology and predictive site patterning. The Aboriginal people and the author do not deem these artefacts to constitute 'sites' under the Act.

Figure 3. Isolated Flake.

9.0 DISCUSSION AND CONCLUSION

Tellus commissioned Aboriginal heritage surveys of its Sandy Ridge Project, 140 kilometres northwest of Kalgoorlie. The Project encompasses nearly nine square kilometers of land some twenty kilometers north of Mt Walton. The survey was carried out by John Cecchi of John Cecchi Heritage Management Consultancy in May 2015, on behalf of R. & E. O'Connor Pty Ltd, in consultation with representatives of the Kaparn Native Title Group, Kelamaia Kabu(d)n and Widji Group. The field survey was conducted via pedestrian transects aligned north-south, spaced fifty meters apart. Ground visibility was good, with an average of 50%. Given the survey methodology and ground visibility it is postulated that any sites with surface expressions would have been identified during the survey.

The majority of the survey area comprises sandplain vegetation with no reliable water sources present. Given that no sites of ethnographic or archaeological significance were identified within the Project the Aboriginal representatives approve the Project (Appendix 2). The potential for stratified archaeological deposits was assessed as negligible given the local geology and predictive site patterning. It is therefore recommended that the Project proceed as planned.

Given that the Act applies to sites whether previously reported or not, should ground works encounter Aboriginal cultural material, further archaeological and ethnographic consultation may be warranted. Should any skeletal material be uncovered, the Western Australian Police should be contacted.

10.0 RECOMMENDATIONS

- No sites of Aboriginal heritage were identified during the survey.
- The Aboriginal representatives consulted approve the Project.
- The Project should proceed as planned.
- The Act applies to sites whether previously reported or not. Should ground works encounter Aboriginal cultural material, further archaeological and ethnographic consultation may be warranted. Should any skeletal material be uncovered during ground works, the Western Australian Police should be contacted.

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APPENDIX 1 ISOLATED ARTEFACTS RECORDING

Artefact Type	Lithic Type	Size (Length x Width x Thickness) mm	Location (MGA Zone 51) mE mN	Geographical Context	Land Integrity	Potential for Stratified Archaeological Deposit
Flake	Quartz	22 x 15 x 7	219968 6638229	Sandplain	High	Negligible
Core	Quartz	55 x 41 x 30	221654 6633218	Sandplain	High	Negligible

APPENDIX 2

DEFINITION OF ARCHAEOLOGICAL TERMS

Scarred Trees

Aboriginal scarred trees reflect several traditional activities involving the removal of bark and wood. A significant amount of Aboriginal cultural material was sourced from the bark and wood of trees to make implements such as shields, sacred boards, shelters and containers. Other scars have been recorded as toe holds made in order to climb trees, or holes within trunks used to smoke out and hunt mammals (Long 2005). Aboriginal scars occur on a variety of tree types and given the variety of purposes for which they were used, appear in a diverse range of sizes and shapes.

Scars on trees formed after the piece of bark or wood is extracted and damage to the cambium results in a drying out of the sapwood, where bark will not be able to grow back again. Overgrowth of bark surrounding the scar may occur and to such an extent to eventually close or apparently seal the wound, although this new growth will never join with the dry face underneath.

A scar on a tree can also derive from other injuries the bark receives, for example via lighting strike, fire damage, collapse of branches or other trees onto trunk, vehicle collision, surveyors marks, ring barking and faunal damage. Given these considerations, it is sometimes difficult to accurately identify a scarred tree as of Aboriginal, European or natural origin.

Long (2005) provides the following guidelines to assess the whether a scar on a tree is from natural or incidental types of scarring:

- What impacts have occurred in the vicinity of the scar?

- How old is the tree on which the scar occurs, and how long has the scar been there?

- What impacts have occurred to the tree, and can you work out the order in which they have occurred?

-Can you identify the form and size of the original scar on the tree?

An epicormic shoot or stem will be located immediately below a section of damaged trunk which interrupts the connection between the roots and the canopy and is a common feature associated with cultural scars (Long 2005).

If the scar occurs on a dead tree, an arborist could perhaps indicate when the tree died, how old the tree was at the time of death and provide an estimate of the time between scarification and death of the tree. This information would provide a possible time span for the production of the scar on the tree. C-14 dating and growth ring counting can provide accurate dates for the age of the tree.

A **Quarry** may occur wherever outcrops of suitable stone are found. These exhibit a concentration of primary flakes in the artefact assemblage with a relative dense concentration, and may contain the original quarried stone exhibiting hundreds of flake scars.

Because rocks and minerals can fracture as a result of geomorphic or other natural processes flaked stones are classified as **stone artefacts** if they exhibit one or more of the following features (Holdaway & Stern 2004: 108-9):

A positive or negative ring crack

A negative or positive bulb of percussion

An érraillure scar below the point of percussion

Negative flake scars or ridges

Flakes, Cores and Retouched flakes (Tools), are the three main categories of artefacts and their features are detailed below (Hiscock 1984: 129):

Flakes must exhibit at least one of the following traits:

A ring crack

A positive bulb of percussion

An érraillure scar below the point of percussion

Cores exhibit negative flake scars marking the place where previous flakes were struck. A core may be described as Unidirectional, Bidirectional, Bifacial or Multidirectional

depending on the orientation of the flake scars and location of the striking platform (Holdaway & Stern 2004:180-2).

Retouched Flakes, also classified as Tools, are stones that show signs of flake scars across their ventral surface and display a ring crack.

APPENDIX 3

EXTRACT FROM *ABORIGINAL HERITAGE ACT* 1972

Part II — Application and traditional use

5. Application to places

This Act applies to —

(a) any place of importance and significance where persons of Aboriginal descent have, or appear to have, left any object, natural or artificial, used for, or made or adapted for use for, any purpose connected with the traditional cultural life of the Aboriginal people, past or present;

(b) any sacred, ritual or ceremonial site, which is of importance and special significance to persons of Aboriginal descent;

(c) any place which, in the opinion of the Committee, is or was associated with the Aboriginal people and which is of historical, anthropological, archaeological or ethnographical interest and should be preserved because of its importance and significance to the cultural heritage of the State;

(d) any place where objects to which this Act applies are traditionally stored, or to which, under the provisions of this Act, such objects have been taken or removed.

[Section 5 inserted by No. 8 of 1980 s. 2; amended by No. 24 of 1995 s. 6.]

APPENDIX 4 DAA AHIS RESULTS

Search Criteria

0 Registered Aboriginal Sites in Coordinates search area; 217803.00mE, 6641248.00mN z51 (MGA94) : 223854.00mE, 6641469.00mN z51 (MGA94) : 227965.00mE, 6630161.00mN z51 (MGA94) : 217258.00mE, 6631050.00mN z51 (MGA94)

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Accuracy is shown as a code in brackets following the coordinates. Map coordinates (Latitude/Longitude and Easting/Northing) are based on the GDA 94 Datum. The Easting/Northing map grid can be across one or more zones. The zone is indicated for each Easting on the map, i.e. '500000mE:Z50' means Easting=500000, Zone=50.

Terminology (NB that some terminology has varied over the life of the legislation)

Place ID/Site ID: This a unique ID assigned by the Department of Aboriginal Affairs to the place

Status:

- **Registered Site**: The place has been assessed as meeting Section 5 of the *Aboriginal Heritage Act 1972*
- **Other Heritage Place which includes:**
  - **Stored Data / Not a Site:** The place has been assessed as not meeting Section 5 of the *Aboriginal Heritage Act 1972*
  - **Lodged:** Information has been received in relation to the place, but an assessment has not been completed at this stage to determine if it meets Section 5 of the *Aboriginal Heritage Act 1972*

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- **Boundary Restricted = No:** place location is shown as accurately as the information lodged with the Registrar allows.
- **Boundary Restricted = Yes:** To preserve confidentiality the exact location and extent of the place is not displayed on the map. However, the shaded region (generally with an area of at least 4km²) provides a general indication of where the place is located. If you are a landowner and wish to find out more about the exact location of the place, please contact DAA.
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  - **Female Access Only:** Only females can view restricted information

Legacy ID: This is the former unique number that the former Department of Aboriginal Sites assigned to the place. This has been replaced by the Place ID / Site ID.

List of Registered Aboriginal Sites with Map

No Results

Legend

Selected Heritage Sites

- Registered Sites
- Aboriginal Community Occupied
- Aboriginal Community Unoccupied
- Town
- Search Area

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Search Criteria

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List of Other Heritage Places with Map

No Results

Legend

Selected Heritage Places

- Other Heritage Places
- Aboriginal Community Occupied
- Aboriginal Community Unoccupied
- Town
- Search Area

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Radiation Assessments

TELLUS

TELLUS

SANDY RIDGE FACILITY
RADIATION WASTE MANAGEMENT PLAN

Final Report| November 2016

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Document control

Rev	Issue date	Description	Originator	Checked	Approved
1	08/11/2016	Radiation Management Plan	H Rossouw	R Phillips	

Disclaimer

This Public Environmental Review (PER) has been prepared for submission to the Western Australian Environmental Protection Authority for the purpose of the Minister for Environment making a determination regarding whether to approve Tellus Holding Limited's Proposal under the Western Australian Environmental Protection Act 1986. This PER has been developed for this purpose only, and no one other than the Environmental Protection Authority or the Minister should rely on the information contained in this PER to make any decision.

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ABBREVIATIONS

ADT	Articulated Dump Truck
ALARA	As Low as Reasonably Achievable
ARPANSA	Australian Radiation Protection and Nuclear Safety Agency
Bq	Becquerel
Bq/cm^2	Becquerels per square centimetre
Bq/g	Becquerels per gram
Bq/kg	Becquerels per kilogram
Bq/m^3	Becquerels per cubic metre
°C	degrees Celsius
Gv	gray (unit)
HAZOP	hazard and operability
HLW	High level radioactive waste
IAEA	International Atomic Energy Agency
ICRP	International Commission on Radiological Protection
ILW	intermediate level waste
IWDF	Intractable Waste Disposal Facility
L	litre
LLW	low level radioactive waste
m	metre
mSv	Millisieverts
mSv/y	Millisieverts per year
NOHSC	National Occupational Health and Safety Commission
NORM	naturally occurring radioactive material

PPE	personal protective equipment
RWMP	Radiation Waste Management Plan
TC	Transport contractor
TLD	Thermoluminescent Dosimeter
VLLW	very low level waste
VSLW	very short lived waste
WA	Western Australia
WAC	Waste acceptance criteria
µGy/h	micro gray per hour

GLOSSARY

Absorbed dose	Quantity of energy imparted by ionizing radiation to unit mass of matter such as tissue. Unit gray, symbol Gy. 1 Gy = 1 joule per kilogram.
Activity	Attribute of an amount of a radionuclide. Describes the rate at which transformations occur in it. Unit becquerel, symbol Bq. 1 Bq = 1 transformation per second.
Alpha particle	A particle consisting of two protons plus two neutrons. Emitted by a radionuclide.
Anthropogenic	As an adjective - caused by humans. Anthropogenic radiation is radiation caused by human activity.
Atom	The smallest portion of an element that can combine chemically with other atoms.
Atomic mass	The mass of an isotope of an element expressed in atomic mass units, which are defined as one-twelfth of the mass of an atom of carbon-12.
Atomic number	The number of protons in the nucleus of an atom. Symbol Z.
Becquerel (Bq)	See activity.
Beta particle	An electron emitted by the nucleus of a radionuclide. The electric charge may be positive, in which case the beta particle is called a positron.
Cosmic rays	High energy ionizing radiations from outer space. Complex composition at the surface of the earth.
Cosmogenic radionuclides	The cosmic radiation which strikes the earth induces radioactivity in the atmosphere. Most of this radioactivity is very short-lived. Some radionuclides however survive to eventually reach the surface of the earth. Among these are H (tritium), Be (beryllium-7) and C (carbon-14) which has the longest half-life (5730 years).
Decay	The process of spontaneous transformation of a radionuclide. The decrease in the activity of a radioactive substance.
Decay product	A nuclide or radionuclide produced by decay. It may be formed directly from a radionuclide or as a result of a series of successive decays through several radionuclides.
Diagnostic radiology	Term usually applied to the use of x-rays in medicine for identifying disease or injury in patients.
Disposal	In relation to radioactive waste, dispersal or emplacement in any medium without the intention of retrieval.
Dose	General term for quantity of ionizing radiation. See absorbed dose, equivalent dose, effective dose and collective effective dose. Frequently used for effective dose.

Effective dose	The quantity obtained by multiplying the equivalent dose to various tissues and organs by a weighting factor appropriate to each and summing the products. Unit sievert, symbol Sv. Frequently abbreviated to dose.
Electromagnetic field	The region in which electromagnetic radiation from a source exerts an influence on another object with or without there being contact between them.
Electromagnetic radiation	Radiation that can be considered as a wave of electric and magnetic energy travelling through a vacuum or a material. Examples are gamma rays, x-rays, ultraviolet radiation, light, infrared radiation and radiofrequency radiation.
Electromagnetic spectrum	All electromagnetic radiations displayed as a continuum in order of increasing frequency or decreasing wavelength.
Electromagnetic wave	See electromagnetic radiation.
Electron	An elementary particle with low mass, 1/1836 that of a proton, and unit negative electric charge. Positively charged electrons, called positrons, also exist. See also beta particle.
Electron volt	Unit of energy employed in radiation physics. Equal to the energy gained by an electron in passing through a potential difference of 1 volt. Symbol eV. 1 eV = 1.6 × 10-19 joule approximately.
Element	A substance with atoms all of the same atomic number.
EMF	Electromagnetic field. Not to be confused with the initials for electromotive force.
Equivalent dose	The quantity obtained by multiplying the absorbed dose by a factor to allow for the different effectiveness of the various ionizing radiations in causing harm to tissue. Unit sievert, symbol Sv.
Excitation	A process by which radiation imparts energy to an atom or molecule without causing ionisation. Dissipated as heat in tissue.
Fission	Nuclear fission. A process in which a nucleus splits into two or more nuclei and energy is released. Frequently refers to the splitting of a nucleus of uranium-235 into two approximately equal parts by a thermal neutron with emission of other neutrons.
Free radical	A grouping of atoms that normally exists in combination with other atoms but can sometimes exist independently. Generally very reactive in a chemical sense.
Frequency	The number of complete cycles of an electromagnetic wave in a second. Unit hertz, symbol Hz. 1 Hz = 1 cycle per second.
Gamma ray	A discrete quantity of electromagnetic energy without mass or charge. Emitted by a radionuclide. See x-ray.
Gray	See absorbed dose.
Half-life	The time taken for the activity of a radionuclide to lose half its value by decay. Symbol t½.

Infrared radiation	Electromagnetic radiation capable of producing the sensation of heat and found between light and radiofrequency radiations in the electromagnetic spectrum. Has subregions IRA, IRB and IRC.
Instability	Having the property of being unstable.
Ion	Electrically charged atom or grouping of atoms.
Ionisation	The process by which a neutral atom or molecule acquires or loses an electric charge. The production of ions.
Ionising radiation	Radiation that produces ionisation in matter. Examples are alpha particles, gamma rays, x-rays and neutrons. When these radiations pass through the tissues of the body, they have sufficient energy to damage DNA.
Isotope	Nuclides with the same number of protons but different numbers of neutrons. Not a synonym for nuclide.
Laser	Device which amplifies light and usually produces an extremely narrow intense beam of a single wavelength.
Light	Electromagnetic radiation capable of producing the sensation of vision and found between ultraviolet and infrared radiations in the electromagnetic spectrum.
Mass number	The number of protons plus neutrons in the nucleus of an atom. Symbol A.
Molecule	The smallest portion of a substance that can exist by itself and retain the properties of the substance.
Neutron	An elementary particle with unit atomic mass approximately and no electric charge.
Non-ionising radiation	Radiation that does not produce ionisation in matter. Examples are ultraviolet radiation, light, infrared radiation and radiofrequency radiation. When these radiations pass through the tissues of the body they do not have sufficient energy to damage DNA directly.
Nucleus	The core of an atom, occupying little of the volume, containing most of the mass, and bearing positive electric charge.
Nucleus of a cell	The controlling centre of the basic unit of tissue. Contains the important material DNA.
Photon	A quantum of electromagnetic radiation.
Positron	See beta particle.
Probability	The mathematical chance that a given event will occur.
Proton	An elementary particle with unit atomic mass approximately and unit positive electric charge.
Radiation	The process of emitting energy as waves or particles. The energy thus radiated. Frequently used for ionizing radiation except when it is necessary to avoid confusion with non-ionizing radiation.
Radioactive	Possessing the property of radioactivity.

Radioactive waste	Useless material containing radionuclides. Categorised in according to activity (and other criteria such as half-life) as exempt, low level, intermediate level and high level waste.
Radioactivity	The property of radionuclides of spontaneously emitting ionizing radiation.
Radiofrequency radiation	Electromagnetic radiation used for telecommunications and found in the electromagnetic spectrum at longer wavelengths than infrared radiation.
Radiological protection	The science and practice of limiting the harm to human beings from radiation.
Radionuclide	An unstable nuclide that emits ionizing radiation.
Radiotherapy	Term applied to the use of radiation beams for treating disease, usually cancers, in patients.
Risk	The probability of injury, harm or damage.
Risk factor	The probability of cancer and leukaemia or hereditary damage per unit equivalent dose. Usually refers to fatal malignant diseases and serious hereditary damage. Unit Sv-1.
Sensitive receiver	Can be a natural feature, such as a water source, a rare, threatened or endangered flora or fauna. It can also be a human feature such as a school or a hospital.
Sievert (Sv)	See effective dose.
Specific energy absorption rate	The rate at which energy is absorbed by unit mass of tissue in an electromagnetic field. Unit watt per kilogram, symbol W kg-1.
Stable	An isotope or nuclide is considered stable if it has a half-life longer than the age of the universe i.e. a half-life longer than about 13.7 billion years.
Ultraviolet radiation	Electromagnetic radiation found between x-rays and light in the electromagnetic spectrum. Has subregions UVA, UVB, UVC.
Unstable	An isotope or nuclide is considered to be unstable if it has a half-life less than the age of the universe i.e. a half-life less than about 13.7 billion years.
UV radiation	See ultraviolet radiation.
Visible radiation	See light.
Waste management	The control of waste from creation to disposal.
Wavelength	The distance between successive crests of an electromagnetic wave passing through a given material. Unit metre, symbol m.
X-ray	A discrete quantity of electromagnetic energy without mass or charge. Emitted by an x-ray machine. See gamma ray.

1 SCOPE

This Radiation Management Plan (RMP) has been prepared to document management systems and procedures to be implemented at the Tellus Holdings Ltd (Tellus), Sandy Ridge waste disposal project to mitigate the risks associated with radioactive waste. This will include details of how radioactive waste is handled, stored and monitored in accordance with relevant legislation and policies.

The RMP has been prepared to address the regulatory requirements of the:

- *Australian Radiation Protection and Nuclear Safety (ARPANS) Act 1998*.
- Australian Radiation Protection and Nuclear Safety Regulations 1999.
- *Radiation Safety Act 1975*.
- Radiation Safety (General) Regulations 1983.
- Radiation Safety (Qualifications) Regulations 1980.
- Radiation Safety (Transport of Radioactive Substances) Regulations 2002.

It also acknowledges the *Nuclear Waste Storage and Transportation (Prohibition) Act 1999*.

2 INTRODUCTION

Tellus is planning to develop the Sandy Ridge Project (the Proposal). The Proposal is comprised of two main business components, mining of kaolin clay for export and storage and permanent isolation (disposal) of hazardous and intractable waste in mine voids.

The proposed commodity business involves mining kaolin mostly in an open cut methodology, processing on site and then exporting the kaolin via Fremantle Port to Asia where it would be used in various industrial sectors (e.g. paper, ceramics, fiberglass and paint). Kaolinite is a clay mineral also known as 'Kaolin clay', with the chemical composition $Al_2Si_2O_5(OH)_4$.

The waste aspect of the Proposal involves disposing of up to 100,000 tpa of intractable, hazardous and low level radioactive wastes in the mine voids (herein referred to as 'cells') over a 25 year period (i.e. 2,500,000 tonnes in total). The conceptual infrastructure layout of the waste disposal

Tellus recognised Australia's need for an operational geological repository; which is able to store intractable and hazardous wastes long-term, rather than having wastes stored in more than 100 locations across Australia, often in unsecured and temporary locations.

Cells would be filled in layers with multiple sections in each layer. Each layer would be divided into sections containing wastes of similar characteristics. Each section would be backfilled, compacted and all air pockets/voids excluded. Each layer would be compacted, until approximately 7m below the ground surface, where a thick capping layer of low permeability clay would be installed to prevent water ingress into the cell. Following this, more backfilling and a clay domed cap would be situated on the top of the cell, to shed any landing rainfall. During the waste disposal process, a roof canopy is positioned over the cell to exclude rainfall prior to the thick capping layer being installed.

Waste acceptance criteria (WAC) developed for this facility is described in the waste acceptance criteria (document reference: TCO-5-05). The radionuclide concentration limits is set taking into account the actual siting, design and planning of the facility (e.g. Natural geological barrier, arid climate, remoteness, engineered multi layered shielding and barriers, duration of institutional control, site specific management plans and operating procedures) and exposure dose constrains to ensure no person is exposed above the dose limit (as defined in Schedule I of the Radiation Safety (General) Regulations). These radioactive wastes are generally generated by medical research and industry, operation of research facilities (e.g. laboratory coats, overshoes, gloves), Naturally Occurring Radioactive Materials (NORMs), NORMs occurring on pipework and scale from industry, oil spills containing NORMs and orphan sources (i.e. gauges and instrumentation). Wastes which would not be disposed of into cells include: infectious materials, nuclear material, uncertified waste, putrescible waste and gases.

Tellus operations are underpinned by utilising a combination of engineered and natural barriers, known as a multi barrier system, which provides long term containment and isolation of the waste.

After the placement of waste in the cell has been completed, the following protection measures would be implemented:

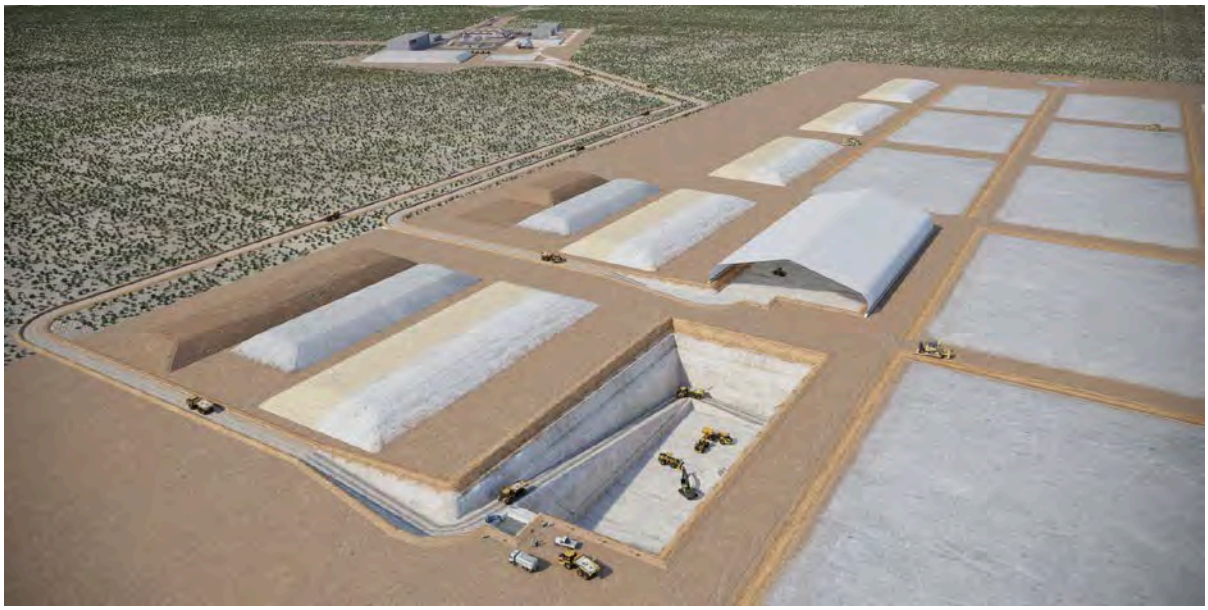
- An all-weather cover would be maintained over the cell until it is backfilled and capped to allow for protection from all weather conditions, without the possibility of creating leachates or contaminated surface water.
- Any airspace surrounding the placed waste would be backfilled with kaolin processing plant waste product (low value kaolin and quartz sand) to fill all void space and provide stability.
- The cell would then be backfilled with compacted clay, silcrete, laterite and yellow sand.
- The surface of the cell would be covered with a domed clay cap to exclude rainfall.

After a period of subsidence monitoring to confirm the stability and integrity of the clay capping, topsoil would be placed over the cap and the area re-vegetated with species of local provenance. Local species would be selected based on their root system penetration (depth), ensuring that the capping design is not compromised.

Tellus would monitor and manage the site for an extended period following closure before returning ownership to State, a period termed institutional control. Further information on management of the Facility is provided in the Waste Facility Decommissioning and Closure Plan.

The institutional control period (ICP) will ensure the wastes stored and disposed of in the geological repository are undisturbed for a period of time until they no longer pose a risk to human health and the local environment.

Figure 2-1 Infrastructure area conceptual layout



2.1 Location

The Proposal is located approximately 75 kilometres (km) north-east of Koolyanobbing, Western Australia. Access is via a 100 km road to the Intractable Waste Disposal Facility (IWDF) Mount Walton East (Crown Reserve No. 44102) that extends northward from the Boorabbin Siding on Great Eastern Highway; a 4.5 km westwards section along an existing road; and a 5.3 km northwards section of new site access road into the development envelope (See Figure 2-2)

There are no sensitive receptors within 5 km of the location of the Proposal. The nearest operation is the Class V IWDF Mount Walton East located approximately 6 km to the east, which operates on a campaign basis and does not have permanent residents. The nearest mining camp is the Carina Iron Ore Mine Accommodation Camp located approximately 52 km to the south east of Sandy Ridge.

The location of the Sandy Ridge Project has been specifically chosen to meet the requirements of International and National codes relating to the siting of a near surface geological repository. These site characteristics include:

- **Geologically stable** — the development envelope sits within the Archean Yilgarn Block and is geologically typical of areas overlying deeply weathered granite domes. It has very low seismicity (no earthquakes have been recorded at Sandy Ridge) and no volcanic or tectonic activity.
- **Natural geological barrier** — the clay bed is laterally extensive (80 km long and 40 km wide), has been stable for approximately 20 million years and is up to 36 m thick. This is capped by erosion resistant silcrete and laterite layers typically 4 to 6 metres thick in total.
- **Semi-arid desert Mediterranean climate** — averages just over 250 mm of rainfall per annum and evaporation is greater than 2,000 mm per annum. This means very little rainfall occurs across the site and generally water will evaporate before it infiltrates.
- **No surface water receptors** - there are no channels or creeks in the development envelope.
- **Very little (if any) surface water runoff** – Due to the low rainfall, high evaporation, permeable upper soil profile and gently sloping topography, significant rainfall events infiltrate quickly. There is a low likelihood of surface flows in the local catchments and any flows are short-lived and local in nature.
- **Lack of commercial mineral deposits** – there is no evidence to suggest that there is potential for economic mineral or hydrocarbon deposits beneath the kaolin deposit.
- **Topography** – the development envelope is flat to gently undulating and suitable for the construction of infrastructure and heavy vehicle movement.
- **Absence of Population** – located in an area with no population, the nearest population centre is a non-permanent camp approximately 52 km away.
- **Agricultural land use** – there is no potential for medium to high value agriculture.

- **Environmental values** – the environmental values of the development envelope are currently unknown and will be determined through investigation.
- **Heritage** – no special cultural or historical significance has been identified through a completed heritage study and consultation with stakeholders familiar with the area.
- **No flooding** – the development envelope is not subject to flooding, nor is it predicted to be in the future. The site is at very low risk of encountering cyclones.
- **Very low rates of erosion** – the development envelope is not subject to the erosive forces of high winds or rain due to the climate, soil types and topography and has been stable for thousands of years.

2.2 Access to appropriate technical expertise, facilities and operating procedures

Tellus Holdings has engaged Hygiea Consulting to provide technical expertise and support for the radiological aspects of the project. Henriette Rossouw; Hygiea Principal Consultant has over 12 years' experience in radiation protection and has been involved in the provision of radiological services to the mining, government and industrial sectors in the Commonwealth and State regulatory framework. Support will include:

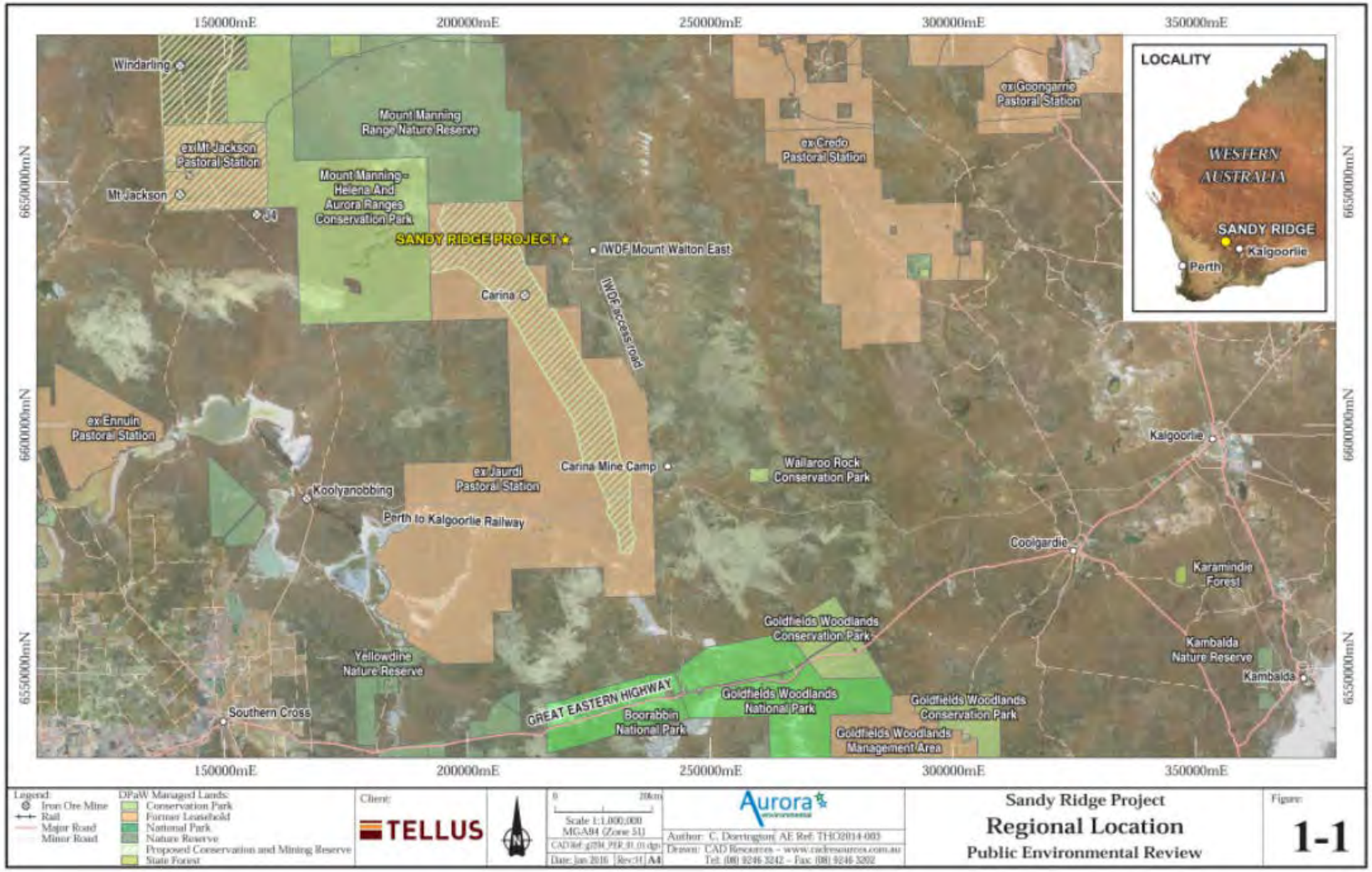
- Acting as Radiation Safety Officer.
- Assistance in preparation of reports and documentation.
- Provision of advice on monitoring equipment, programs and data interpretation.
- Development of systems and procedures relating to radiation safety.
- In co-operation with other consultants, undertake background, environmental and occupational monitoring.

With respect to non-radiological issues Tellus has employed or retained through consultancy agreements a wide range of technical personnel with considerable experience in all aspects of the proposed project.

Equipment used for the evaluation, measurement and assessment of radiological impacts would be provided by Tellus. The equipment would be either, owned and maintained by Tellus, or hired or provided by sub-contractors.

Documented operating procedures, work instructions and maintenance and calibration procedures would be provided in accordance with Tellus documentation policy prior to the commencement of any work.

Figure 2-2 Site location map



3 SYSTEM OF RADIATION MANAGEMENT

3.1 Introduction

The system of radiation management during operation of the proposed Facility is based on the justification, optimisation and limitation principles established by the International Commission on Radiological Protection (ICRP), standardized by the International Atomic Energy Agency (IAEA) and adopted in a joint Australian Radiation Protection and Nuclear Safety Agency (ARPANSA) and National Occupational Health and Safety Commission (NOHSC) document.

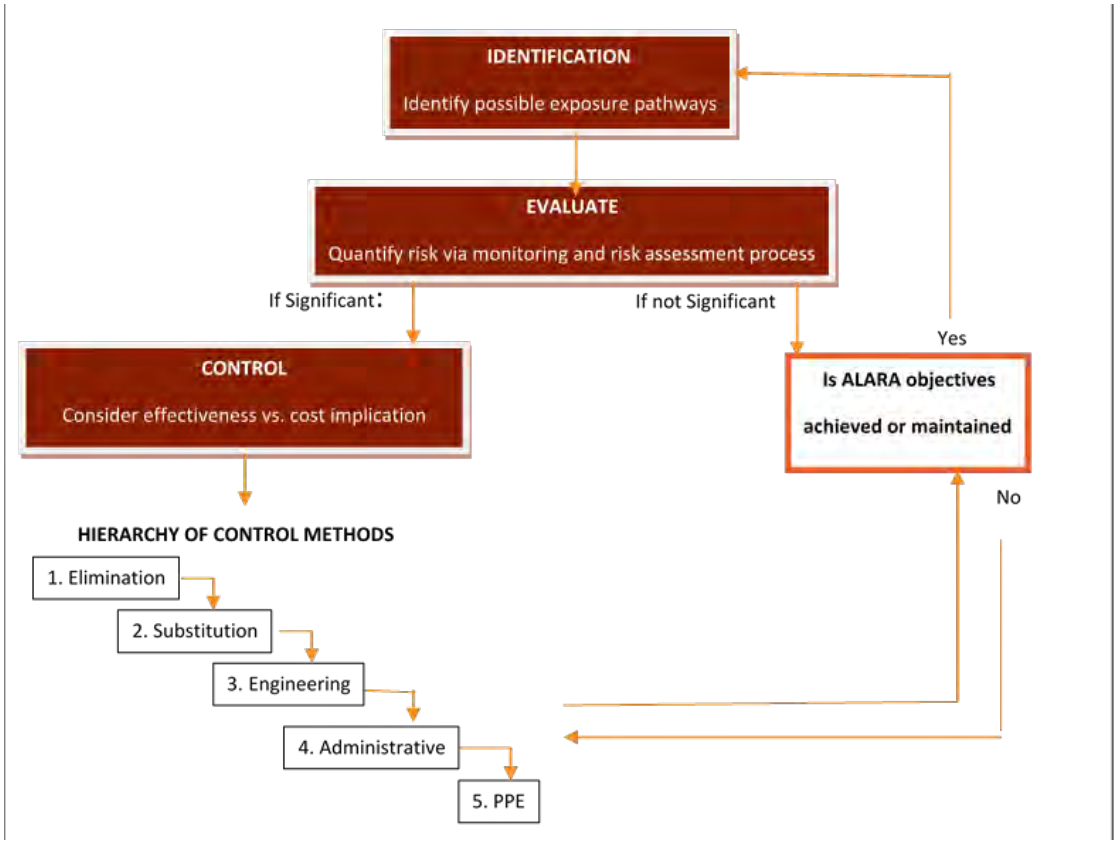
The application of the system and the justification, optimisation and limitation principles are discussed below.

The primary steps in the radiation management process include:

- Identifying and quantifying the sources of radiation.
- Defining possible candidate radiation protection that would reduce the exposure or doses.
- Quantifying the economic factors (cost of systems, operations, maintenance).
- Quantifying exposures and doses to individuals and to populations in the vicinity of the facility.
- Estimating the health risk and identifying non-health detriment.
- Selecting the candidate radiation protection systems or combination of systems with the preferred ALARA (As Low as Reasonably Achievable) outcome.

These steps are illustrated in Figure 3-1 below.

Figure 3-1 System of radiation management



3.2 System process

3.2.1 Justification of the Practice

Tellus recognises that a practice involving exposure to radiation should be adopted only if the benefits of the practice outweigh the risks associated with the radiation exposure. Any decision that alters the radiation exposure situation should do more good than harm. The Justification Principle has been adopted in the design of the facility, control systems and administrative procedures.

3.2.2 Optimisation of protection

Protection from radiation was aimed to keep the likelihood of incurring exposures, the number of people exposed, and the magnitude of their individual doses as low as reasonably achievable, taking into account economic and societal factors (ALARA principle).

The principle of optimisation of radiation protection is a cornerstone of the system for radiation protection and is the key driver for ensuring that radiation doses are not just maintained below

standards, but are kept to the lowest feasible level throughout the life cycle of a practice involving radioactive materials.

Optimisation commenced at the design stage of the project. At the design stage, the cost-benefit analysis was conducted to achieve a balanced design, which is not only optimised for radiation protection, but all other health, safety and environmental requirements.

In design, optimisation will be facilitated by:

- Specifying the radiation protection design criteria in terms of dose action levels at 50% of derived limits.
- Specifying engineering control features, such as dust extraction and or suppression equipment, radon gas control, shielding, facility design, roster systems and automation of processes.
- Undertaking formal hazard assessments, such as hazard and operability (HAZOP) studies at various stages of design.
- Ensuring design engineers were aware of relevant radiation protection measures through appropriate training and instruction.
- Applying the hierarchy of risk control principles (i.e. preference to elimination and control of hazards rather than use of operational procedures and PPE) to achieve exposure control.

Some of the administrative operational principles used for optimization involve the:

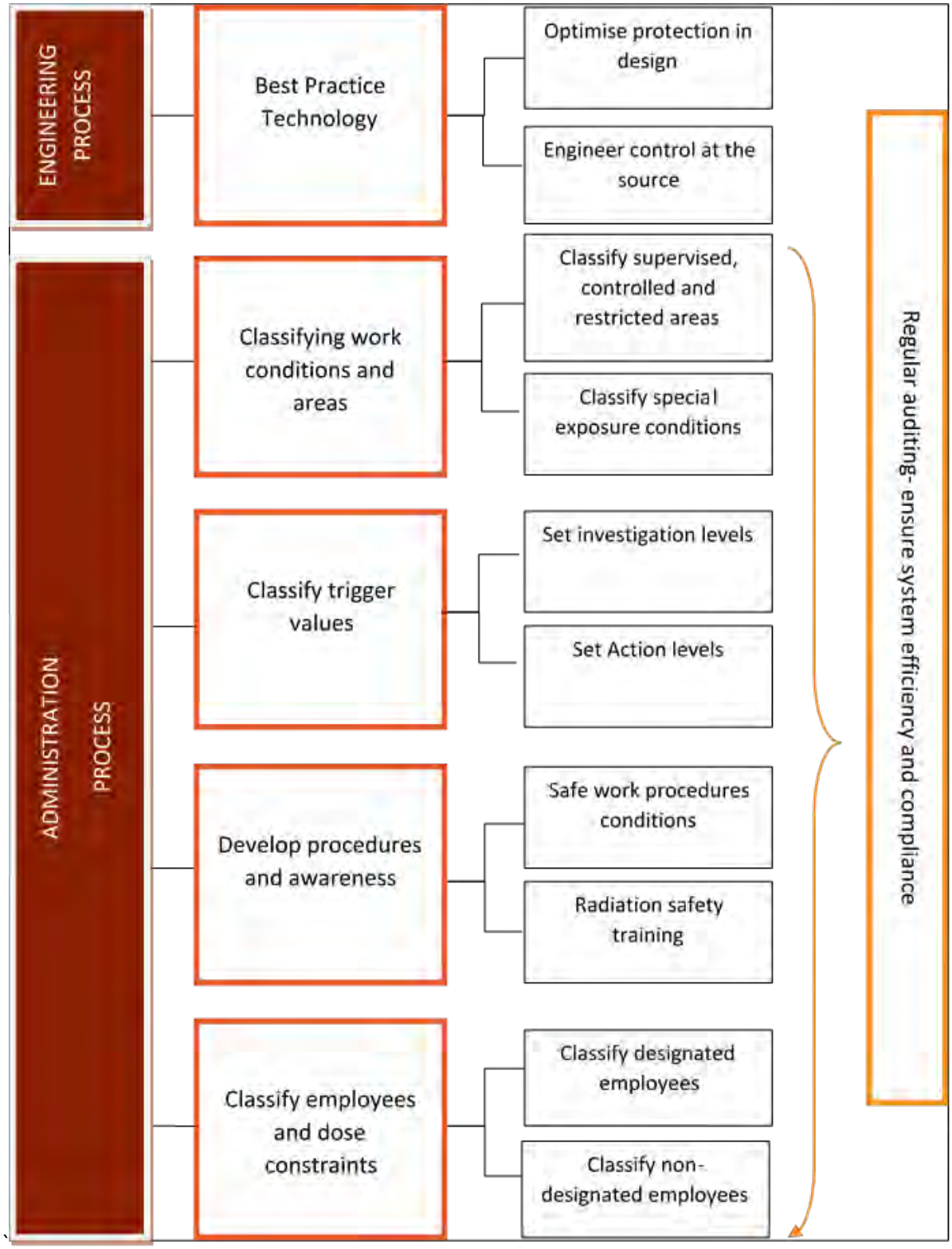
- Classification of working conditions and workplaces.
- Implementation of a risk based radiation monitoring program.
- Application of a recording, analysing and reporting system for the results of the radiation monitoring program.
- Formulation, distribution and implementation of adequate descriptions for the safe conduct of certain work procedures.
- Audit of system to ensure it is efficient in reducing the exposures.

3.2.3 Dose limitation in occupational protection

Individuals should not receive radiation doses greater than the recommended limits. To ensure the dose limits are below the dose limits recommended by the ICRP, ARPANSA and NOHSC an action level of 50% of the stated dose limit was established and used as a design specification.

The diagram in Figure 3-2 Application of system protection illustrates the overall approach that would be followed to ensure that radiation doses at the site are is low as practicable.

Figure 3-2 Application of system protection



4 FACILITY DESIGN

During the feasibility stage of the project consideration were given to engineering best practice as well as socio economic considerations to determine the most suitable design that would meet the safety requirements at acceptable cost. The current proposal is open cut pit with In-cell vertical shaft disposal of radioactive wastes. During the waste disposal process a roof canopy is positioned over the cell to exclude rainfall prior to the capping layer being installed. There may be instances (for non-soluble waste types) where a cell may be filled with waste without a roof canopy. In addition, any potential stormwater surface flows would be diverted away from the cells by bund walls or levee banks.

4.1 Design considerations

The location and design of the mining operations is primarily driven by the requirements of the waste cell.

The design criteria for the open cut mine were:

- Fit within the available span of the covering clear-span building (65 m).
- Cells to be arranged in parallel lines, so as to simplify the relocation of the cover building between pits on lightweight rails.
- Sufficient but minimum separation distance between cells (approximately 20m) to maximise kaolin resource recovery but also allow independent and safe waste and mining activities in adjacent pits.
- Be of maximum available depth, the limiting depth being 5m above un-weathered granite or 30 metres, whichever comes first. Maximising the depth increases the storage capacity and decreases the overburden mining and backfill and capping completion costs per tonne of waste.
- Have the capacity to contain approximately 50,000 tonnes of waste materials. This is not an essential criteria as the length of the covering building is not set, however it does make for easier planning at feasibility study level.
- Ramp access by 40 tonne capacity six wheel drive articulated dump trucks (ADT) and a 30 tonne articulated dump truck carrying a 20 foot ISO container.
- As much of the ramp to be contained within the building footprint as possible, to prevent the ramp becoming a rainfall catchment.
- Safe batter angles for short-term use (<15 months).
- Depth of final cover and capping is based on the existing IWDF practices and near-surface water modelling conducted by Cymod Systems.

- Maximising the availability of kaolin ore.
- Only one mining pit in operation at a time and the pit being left open for as short a time as reasonably practical, as it would be a collection point for rainfall and potential water infiltration.

No detailed site-specific geotechnical data is available yet, but a limited amount of data from the IWDF site investigations and knowledge of similar deep weathering profiles in Western Australia was used to establish the geotechnical parameters for the design. The Design of the cell is illustrated in Figure 4-1..

Figure 4-1 Covered cell design

4.2 Waste storage and isolation business

From a waste storage and isolation perspective (ignoring kaolin sales), there is a vast amount of area with suitable geology for waste placement at Sandy Ridge. The only limits on the amount of area suitable for storage is tenure; a few areas of thicker silcrete (increasing mining costs); or thin kaolinisation. The area of disturbance being applied for with the EPA at present is probably capable of accepting 100 years of waste placement at 50,000 tonnes per year. This could easily be further expanded with additional permitting to accept a further 100 plus years of waste at the same rate per year, and beyond if required.

A solution identified for the storage of radioactive wastes which cannot be placed in an open-cell with other chemical wastes is the construction of shafts within the planned open-cell storage. As demonstrated by Figure 4-2., a number of shafts can be constructed within a cell using pre-formed cylindrical shaft segments. As the cell is progressively filled with other wastes, more segments are

stacked upon each other to create a shaft. A buffer of compacted kaolinised granite is placed around each segment to provide further isolation from chemical waste at the same level.

Figure 4-2 In-cell vertical shafts shown in bottom right hand corner

Waste can be placed into the shaft at any time, but it is expected that the shaft would progress to several metres of depth before a campaign of waste placement takes place, so as to provide a level of physical separation and a shield between the radioactive waste and workers on the active surface. Waste drums are lowered into the shaft and each later is backfilled with earthen material to fill void spaces. Higher activity wastes can be backfilled with cementitious slurry if required. A fabricated steel or pre-cast concrete lid is used on the shaft to prevent un-authorised human entry. Upon the shaft reaching and being filled with waste to the base of cap level, the lid is left in place and the structure is covered by the cell cap materials.

Once all wastes are placed in the cell and the area is ready for closure, an engineered cap consisting of compacted backfill materials is placed into the remaining void. This cap serves several purposes; preventing surface or meteoric water from entering the waste storage area and mobilising soluble waste chemicals, preventing erosion, acting as a barrier to un-authorised access of the isolated waste materials, and providing a barrier to radioactive emissions. The construction of the cap is completed by an earthmoving contractor whilst new waste placement activities occur in the next cell. After a monitoring period (currently being negotiated), further overburden and soils are placed over the cap and progressive rehabilitation commences.

The long term (10,000 plus years) performance of the cap has been modelled using both near-surface hydrogeological and erosion modelling software. The modelling has indicated that the cap design is robust from both water infiltration and erosion aspects.

4.3 Mine rehabilitation

Rehabilitation is progressive during the life of the facility Monitoring of the clay caps over each cell takes place for a period before the final placement of any surplus overburden, sub-soil and topsoil over the cap. The soil is then revegetated.

At completion of the project, the infrastructure is removed and the remainder of the site rehabilitated in accordance with normal mine-closure practices.

4.4 Security

The facility security design will be in accordance with ARPANSA RPS 11 in order to decrease the likelihood of the unauthorised access to or acquisition of the radioactive source by persons with malicious intent.

This includes:

- Source security plan would be developed and implemented based on the category of source that requires storage.
- Entire site is security fenced.
- Radiation store building would be physically secure to prevent un-authorised entry
- Access control system to radiation store. (Unique swipe cards required for entry, recording who/when entered.)
- Exterior surveillance cameras on the Radiation Store building that would be linked to a remote recording system.
- Cameras and alarm system on the Radiation store building would be linked to on site office location as well as the accommodation village 3 km away to raise an alarm. Response on alarm would be attended to by trained person from accommodation village if the working site is not manned at the time.
- During site induction all workers on site and Responsible Person are made aware of security issues and response procedures would be developed in accordance with guidelines (RPS 11).

5 WASTE MANAGEMENT

5.1 Waste types accepted

Intractable wastes do not have commercially viable recycling, reuse or disposal options and include wastes that need time to breakdown and chemical wastes that are not readily destroyed. These wastes need long-term management. The Facility provides a location where intractable wastes can be permanently isolated to protect the community and the environment.

Likely chemical wastes to be disposed of in the cells include; arsenic or arsenic containing compounds, cyanide inorganic compounds, chromium (VI) compounds, lead or lead compounds, spent pot liners, soils contaminated with heavy metals, asbestos and pesticides, hydrocarbon wastes and phosphates from the agricultural industry.

The type of industrial materials to be stored or permanently isolated are intractable and hazardous materials generated in the; mining, oil and gas, heavy industry, agricultural and government (emergency service) sectors.

Examples of wastes that may be accepted at Sandy Ridge include:

- **Mining Industry**
  - Waste process streams, e.g. arsenic from the gold industry.
  - Demolition waste produced during the decommissioning of mining and processing radioactive ore operations, such as pipework, concrete, machinery and PPE.
- **Oil and gas** — for example hydrocarbons in contaminated soil or from processing from upstream, midstream and downstream. Note: some waste from the oil and gas industry contains naturally occurring radioactive materials (NORMs). NORM containing scale and equipment would be accepted at the facility.
- **Heavy industry** — For example spent catalyst wastes (Aluminium slag).
- **Agricultural** — for example pesticides.
- **Government** (state emergency service) — waste generated due to man-made or natural disasters that need to be removed safely by Government out of the community. For example - asbestos clean ups.
- **Medical isotopes** — those used in medical research, equipment, contaminated PPE and X rays used by dentists/doctors.
- **Industrial radioactive equipment** – such as grain moisture meters, smoke alarms and gauges.

The classification of radioactive waste has been defined in international standards developed by the IAEA. ARPANSA Safety Guide for Classification of Radioactive Waste (2010) largely reflects the international guidance referred to above. As such, it does not include quantitative values of allowable activity content for each significant radionuclide. Radioactive waste generated in Australia generally falls within the Very Short Lived Waste (VSLW), Very Low Level Waste (VLLW), Low Level Waste (LLW)

or Intermediate Level Waste (ILW) classifications. Australia does not generate any electricity from nuclear power and therefore currently does not generate any used fuel that would be classified as High Level Waste (HLW).

Waste acceptance criteria (WAC) developed for this facility is described in the waste acceptance criteria document. The radionuclide concentration limits is set taking into account the actual siting, design and planning of the facility (e.g. Natural geological barrier, arid climate, remoteness, engineered multi layered shielding and barriers, duration of institutional control, site specific management plans and operating procedures) and exposure dose constrains to ensure no person is exposed above the dose limit (as defined in Schedule I of the Radiation Safety (General) Regulations).

5.1.1 Industrial and medical radioactive source

A sealed radioactive source is a container of encapsulated radioactive material. The capsule or material of a sealed source is strong enough to maintain leak tightness under the conditions of use for which the source was designed, and also under foreseeable mishaps. In more technical terms, it is radioactive material that is:

- Permanently sealed in a capsule or;
- Closely bonded and in a solid form.

The source is designed to contain the radioactive material under normal operating conditions and, usually has high concentration of radioactive material in a small volume.

Sealed radioactive sources are used in various applications in medicine, agriculture, industry, transportation, construction, geology, mining, research, etc. For example high activity cobalt sources are used to treat cancer. In most of these areas the use of sealed radioactive sources either cannot be replaced by other methods or provides results that are unmatched by other methods.

Radioactive sources with half-lives of less than about 100 days will decay to safe levels in a few years. From a waste management point of view such sources can be safely allowed to decay in storage or in near surface disposal facilities. This does not mean that short half-life radioactive sources are without hazard. The radionuclides in the strongest source category (Co_{60}, Sr_{90} and Cs_{137}) are those with moderate half-lives between about 5 and 30 years. With such high strengths and moderate half-lives these sources require isolation for hundreds to thousands of years. Sources used for the calibration of instruments may contain extremely long lived radionuclides such as C_{14} (half-life = 5700 years), Cl_{36} (half-life = 300 000 years) and I_{129} (half-life = 17 million years), but their activity is generally low and of negligible radiological significance.

Table 5-1 summarises such radioisotopes relevant to the medical and industrial sectors.

Table 5-1 Industrial and medical radioisotopes

Isotope	Half Life	Common uses
Radioisotopes commonly used in medical and laboratory settings		
Americium 241	432 years	Research. Check source for instruments
Caesium 137	30.1 years	Irradiators. Teletherapy. Brachytherapy. Check source for instruments and Cameras. Also used in radiotracing to identify sources of soil erosion and depositing, also for nuclear gauges.
Carbon 14	5730 years	Used to measure the age of organic material, diagnose certain bacteria in people.
Chromium 51	27.71 days	Chromium [Cr_{51}] Edetate Injection BP is used to determine the amount of fluid flowing through your kidneys (glomerular filtration rate) and to assess the function of your kidneys. Sodium Chromate [Cr_{51}] Sterile Solution BP is used for in-vitro/ex-vivo red blood cell labelling and is intended only for diagnostic use.
Cobalt 60	5.27 years	Irradiators. Teletherapy. Industrial Radiography. Brachytherapy.
Copper 64	12.7 hours	Used to study genetic disease affecting copper metabolism.
Fluorine 18	110 min	Used in Positron Emission Tomography (PET) to study brain physiology and pathology, detect heart problems and diagnose certain types of cancer.
Gallium 67	78.3 hours (3.26 days)	Infection scans, the most common use is to investigate whether there is an area of localised infection in the body or to detect the location of certain types of tumours.
Gold 198	2.696 days	Wire implants for cancer therapy. Can be used to trace sewage and liquid waste movements.
Iodine 123	13.2 hours	Used in imaging to monitor thyroid function and detect adrenal dysfunction.
Iodine 125	59.4 days	Brachytherapy. Used for treatment of thyroid diseases and cancer and scanning.
Iodine 131	8 days	Used for treatment of thyroid diseases and cancer and scanning.
Iridium 192	74 days	Industrial Radiography. Brachytherapy. Supplied in wire form for use as an internal radiotherapy source, also used as a radiography source.
Molybdenum 99	66.02 hours	Used as the 'parent' in a generator to produce technetium 99m
Phosphorus 32	14.28 days	Used most commonly in the treatment of Polycythemia Rubra Vera. I.e. an overproduction of red blood cells. Labelling DNA.
Phosphorus 33	19 days	RTGs. Labelling DNA
Plutonium 238	87.8 years	Pacemakers.
Radium 226	1600 years	Brachytherapy.

Samarium 153	46.7 hours	Used to help in relieving the pain caused by tumour deposits in the bone
Selenium 75	120 days	Industrial Radiography
Sulphur 35	87.2 days	Labelling DNA
Strontium 90	28.6 years	RTGs Used for pain relief therapy for men with the spread of bone cancer (metastases)
Tritium	12.32 years	Measure the age of young groundwater and used as a tracer to study sewage and liquid wastes. Labelling in labs.
Technetium 99m	6 hours	Used to image the brain, thyroid, lungs, liver, spleen, kidney, gall bladder, skeleton, blood pool, bone marrow, salivary and lachrymal glands and heart blood pool and to detect infection. Can be used to trace sewage and liquid waste movements.
Thallium 201	73.1 h	Used in imaging to detect the location of damaged heart muscle.
Thulium 170	129 days	Industrial Radiography
Ytterbium 169	32 days	Industrial Radiography
Yttrium 90	2.7 days	Used for therapy in knee joints and liver cancer.
Radioisotopes commonly used in industrial settings		
Caesium 137	30.1 years	Industrial gauges. Well logging / moisture gauges. Transmission Gauges – can penetrate thickness of steel up to 100mm, contents of pipelines, well logging gauges, density gauges, thickness gauge, level gauge, Industrial Radiography.
Californium 252	2.645 years	Industrial gauges. Well logging / moisture gauges.
Cobalt 60	5.27 years	Industrial gauges, level gauge, thickness gauge.
Curium 244	18.1 years	Industrial gauges
Americium 241	432 years	Industrial gauges. Smoke Detectors, Am_{241} & $9Be_9$ combined (neutron source) used in portable moisture and density gauges, well logging gauges.
Strontium 90	28.6 years	Backscatter gauges – thickness of plastics, rubber, glass, thin light alloys.
90 Yttrium 90	2.7 days	Backscatter gauges – thickness of plastics, rubber, glass, thin light alloys.
Iridium 192	74 days	Industrial radiography (imaging)
Radium 226	1600 years	Was used some years ago in transmission gauges for density measurements, this isotope is no longer used.
Krypton 82	10.7 years	Industrial gauges. Transmission gauge – thickness of cardboard.
Thallium 204	3.799 years	Thickness gauge for paper & plastic.
Promethium 147	2.63 years	Transmission gauge – density of paper, backscatter gauge – thickness of paper, thin metal coatings.

5.1.2 Waste containing NORM

The waste rock, from certain mining operations, may contain elevated levels of naturally occurring radionuclide material (NORM) and may need to be managed as radioactive waste for radiation protection purposes and safety reasons.

Waste material containing or contaminated with NORM can contain long lived radionuclides at relatively low concentrations that may exceed the levels for exempt waste can be found in the mining and processing of:

- Phosphate minerals.
- Mineral sands.
- Some gold bearing rocks.
- Coal.
- Hydrocarbons.

Waste containing naturally occurring radionuclides can vary considerably in its characteristic and could hence fall into several classes for disposal. Some could have very low activity concentration levels and not require disposal as radioactive waste. Other waste with higher, but limited concentrations could be appropriate for near surface disposal and such waste with higher concentrations were specific radionuclides may have been concentrated may require disposal at greater depth than typical for near surface disposal.

Some NORM contaminated wastes such as those found during the decommissioning of facilities that mine and process radioactive ores, such as pipework, concrete, machinery and PPE, may also require disposal as LLW or ILW.

Some waste, such as some scales arising in the oil and gas industry may have high activity concentration levels. These may necessitate the management of such waste as LLW, or in some cases ILW. Typical industry waste activity concentrations is given in Table 5-2.

Table 5-2 Typical industry wastes activity concentration ranges

Nuclide	Activity concentration (Bq/g)			
	U & Th sands	Radium scale	Radium sludge	Oil & gas+
Pa-231	0.7			
Pb-210	10	0.02-75	0.1-1300	
Po-210	4	0.02-1.5	0.004-160	
Ra-226	10	0.1-15000	0.05-800	1400
Ra-228	70	0.05[!]-2800	0.5-50	1587
Th-227	0.5			
Th-228	70			
Th-230	11			
Th-232	60	0.001-0.002	0.002-0.01	
U-234				
U-235	0.5			
U-238	10	0.001-0.5	0.005-0.01	
[#] It is not foreseen that radium scale & sludge would be disposed of in bulk				

5.2 Waste acceptance procedure

Before a waste can be accepted Tellus must be satisfied that the waste meets the Waste Acceptance Procedures (WAP) and Waste Acceptance Criteria (WAC). The waste acceptance procedure is summarised below and in the flowchart (Figure 5-1).

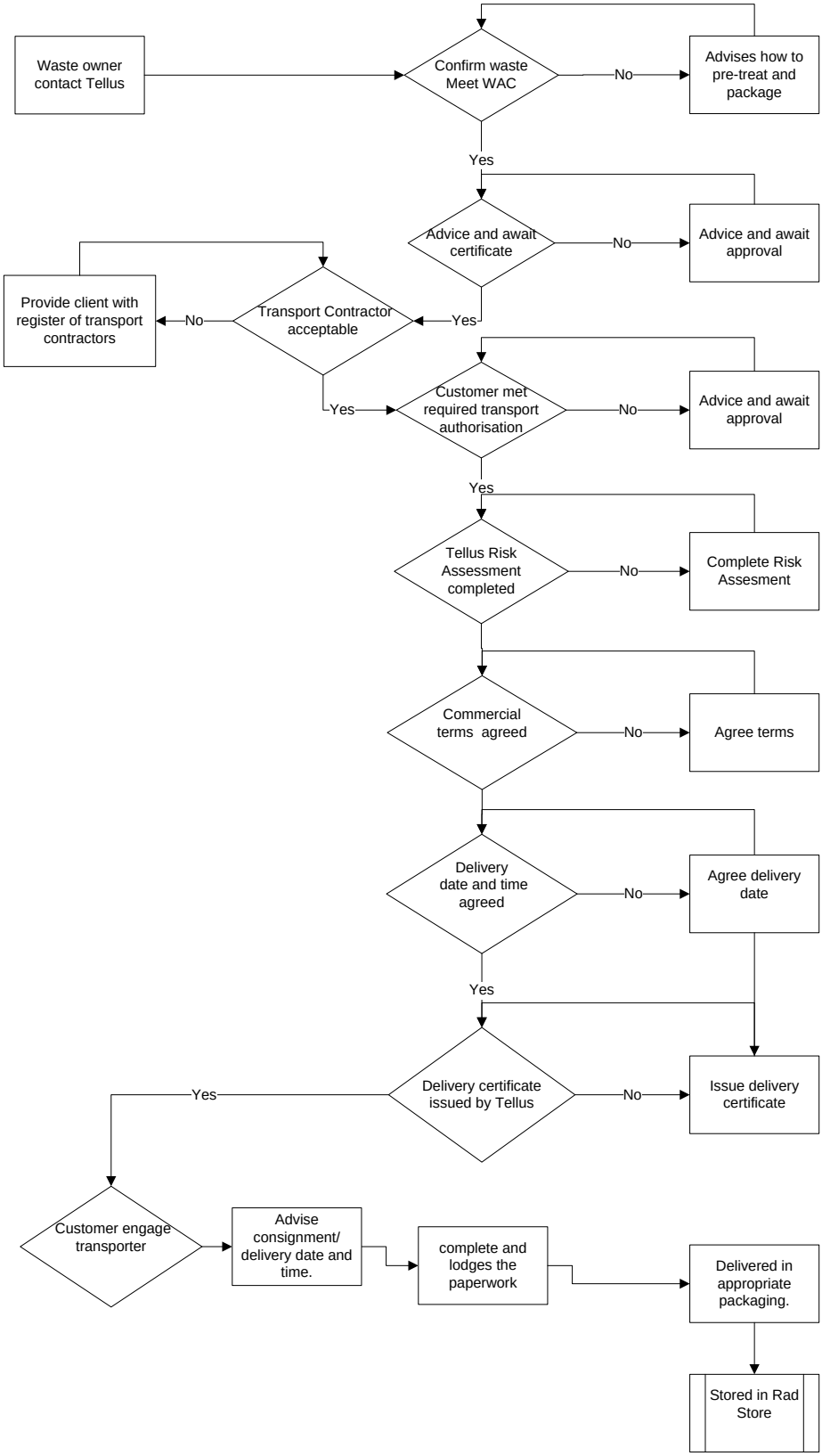
A Customer holding radioactive waste which they want to send to Sandy Ridge contacts Tellus to:

- Advise of the type, form, and quantity of the waste.
- Advise of any requirements for surface storage and potential future recovery.
- Advise of the preferred time and date of delivery.
- Identify any requirements for pre-treatment and packaging.
- Confirm the gate price,
- Confirm any other contractual issues pertaining to storage or permanent isolation certificates.
- Tellus would confirm that the waste meets the WAC, or alternatively advises the Customer how to pre-treat and / or package the waste so that it does meet Tellus' WAC. Sealed sources shall be packaged so that the serial number of the source can be inspected by Tellus upon arrival at the Sandy Ridge site. I.e., encasement in concrete shall not take place prior to an inspection by Tellus.
- If the waste does require pre-treatment or packaging which the Customer cannot carry out themselves, they would be directed to use the services of an established and reputable Waste Management Contractor.

- The customer shall obtain and provide a copy to Tellus of a "Disposal Permit" obtained from the Department of Health, - Radiation Health Western Australia.
- When the waste is in a suitable form and packaging for transport, the Customer advises Tellus of the proposed Transport Contractor. Tellus would maintain a Register of Transport Contractors who has been regularly audited by Tellus for compliance with various levels of hazardous waste transport licencing across all States and Territories of Australia. A new Transport Contractor may be placed on the Register at any time subject to having demonstrated its licences and safe work practices to Tellus. If the customer does not already have established service contracts with an acceptable Transport Contractor, Tellus would be able to recommend one.
- The Customer (or their Transport Contractor) must then obtain and complete all required State, Territory and Federal authorisations and notifications for transport of the waste. These may vary from State to State, and more than one State's authorisation may be required if the transport route passes through more than one State.
- The Customer shall complete and submit a Risk Assessment for the transport of the waste to Tellus. Tellus would provide a standard format risk assessment.
- Only when:
    - the Customer can confirm that the waste does meet Tellus' WAC; and
    - a Disposal Permit has been obtained from Radiation Health (WA); and
    - the proposed Transport Contractor is acceptable to Tellus; and
    - all State and Federal transport requirements have been proven to be met; and
    - a Tellus Risk Assessment has been completed and mitigating actions (if required) are ready to be implemented; and
    - commercial terms have been agreed;

  would a certificate be issued by Tellus to the Customer for the delivery of the waste to the Sandy Ridge site. The date and time of delivery to Sandy Ridge would be mutually agreed at this point.
- The Customer then engages their nominated Transport Contractor to transport the waste to Sandy Ridge.
- The Transport Contractor advises Tellus of when the consignment has departed the Customer's premises, and confirms the expected delivery date and time.
- Upon delivery and inspection at Sandy Ridge, the Transport Contractor and Tellus complete and lodge the paperwork.

Figure 5-1 Radioactive waste acceptance procedure



5.3 Requirements of the waste transport contractor

The following requirements are proposed on transport contractors:

- The Transport Contractor (TC) is licenced to carry the type of waste in each State, which may be transited on the journey between the customer and the Sandy Ridge site. Different States and Territories have differing legislation and requirements pertaining to the transport of hazardous materials and wastes. The TC includes the principal company, all vehicles and operators regardless of whether or not they are independent sub-contractors. If a TC sub-contracts part of the transport service to another party (e.g. railway or shipping service), the principal contractor shall ensure that any subcontractors are identified to Tellus and that they also meet Tellus' TC requirements.
- The TC shall demonstrate to Tellus that it has suitable licences, approvals, permits, management systems and operational practices and they operate in line with the Australia Code for the Transport of Dangerous Goods by Road and Rail to ensure the safe transport of radioactive wastes. The systems and practices shall be appropriate for the type of waste being carried.
- Tellus would maintain a Register of TC and their demonstrated capabilities for various types of waste. A TC would only remain on the Register for a limited period of time before being required to re-qualify and hence be re-instated onto the register.
- Tellus reserves the right to carry out an audit of a TC licences, systems and practices at any time in order for the contractor to remain on Tellus' Register. Failure to comply would result in that TC being removed from the Register, but does not preclude the TC from being re-instated to the Register upon passing of an audit in the future.
- Tellus may use the services of independent auditors or agents to carry out compliance audits of TC.
- Tellus reserves the right to remove a TC from the Register at any time and for any reason.

5.4 Waste handling

Once waste is delivered on site in appropriate transport packaging, it would be treated or stored as required.

5.4.1 Sealed sources

Once delivered to site, sealed sources would be stored in the radiation store building, preferably on pallets in racking. In campaigns, these sources would then be unpacked, inspected and verified. The most used packing configuration is a 60 L drum inside a 200 L drum. Cement slurry would be added to the 60 L to fill all the void spaces and to cover all the items. The cement filled 60 L drums would be placed in the centre of a 200 L drum, which is then filled with concrete. The 200 L drum would be marked with its identification number and labelled.

These drums would be stored until the shaft is prepared for disposal. Drums would then be transferred to the cell, loaded into the shaft and covered with fill/grout.

If any packaging activity is undertaken outside of the radiation compound then the extended area would be designated as a supervised area with appropriate barricades and signage erected. All workers coming into close proximity to the radioactive waste shall wear personal radiation monitors, as supervised by the Responsible Site Office (RSO).

5.4.2 NORM containing pastes / sludges / liquids

Once delivered to site it would be stored in the Radiation Store building or in sea containers on hardstand (location dependent upon activity). In campaigns it would be unpacked, inspected and verified by laboratory testing. It would then be treated with absorbent and pozzolanic materials to form a slurry which would solidify and stabilise the waste. The slurry can then be poured either into drums, moulds, or contained sections of the cell where it would set. If using drums or moulds, the set slurry (solidified) material would be transferred into waste cell.

5.4.3 Contaminated solid materials

Contaminated solid material would be stored in Radiation warehouse building or in sea containers on hardstand (location dependent upon activity) until suitable space is available in cell. In campaigns, depending upon physical size and shape of materials, type and activity of radiation, either;

- Place (compacted) in drums and fill with kaolin or cement grout then disposal in cell or shaft.
- Crush, cut or otherwise (if needed) to remove void space in object and fill remaining voids in object with cement grout or kaolin solids and place in cell or shaft.
- If necessary, place entire sea-container in cell, cut holes in top and fill all void space with cement grout.

5.4.4 Contaminated soil or sands (bulk)

Depending on the volume and physical characteristics of material it would be delivered to site in either bulka bags, shipping containers or as wetted down sand. Practical transport would be arranged to coincide with a disposal campaign; If not possible (as might be the case after an emergency clean-up operation) the material would be stored the radiation store; If too bulky separate demarcated stockpile areas would be set up. Dust control would be applied to material to prevent any spread of contamination and the area would be screened after removal of the stockpile to ensure the contamination levels are back to background radiation. The bulk material can be disposed of directly in the cell, diluted or mixed with other material, or set in concrete if required.

6 CONTROLLING RADIATION EXPOSURE

6.1 Introduction

When examining options in an endeavour to rectify an undesirable situation, Tellus would adopt the following hierarchy of control measures:

- Eliminate the hazard.
- Substitute a work process for one in which exposure levels are decreased.
- Engineering control to prevent or reduce contact between the hazard and people (e.g. shielding, ventilation, isolation).
- Apply administrative controls such as placarding, time restrictions, work procedures and training.
- Personal Protective Equipment. Tellus considers the use of personal protective equipment such as respirators, acceptable whilst engineering controls are being developed and implemented, or where such controls are not practicable.

In eliminating and reducing hazards, Tellus believes that 'due regards' should be given to best practicable technology. This would take into account:

- Prevailing circumstances and conditions.
- Current state of technological knowledge.
- Safe working conditions and whether these are being compromised by introducing the control.
- Social and economic factors and consequences.

6.2 Engineering design controls

During the disposal operations the exposure to external γ-radiation is kept to a reasonable minimum by:

- The cell design.
- Radiation warehouse design.
- Ventilation.
- Packaging.

The disposal cell is designed in such a manner that radioactive waste can be placed after the other waste. The most radioactive waste can also be placed at the bottom of the shaft to reduce exposure risk. This reduces the exposure time; increases the distance between radioactive waste and workers and provides shielding between waste and potential receptors.

Potential exposure to γ-radiation from radiation gauges is minimised by setting those sources in concrete inside steel drums. This provides shielding, additional security of sources and reduces risk of exposure.

The radiation warehouse is designed and would be built to provide shielding and reduce risk of exposure. It would also be demarcated and access controlled to prevent unauthorised entry and exposure. It would also be built to ensure security sources kept.

If NORM wastes are stored with a risk of Radon gas build-up, ventilation systems would be used to ensure the risk is reduced to ALARA.

6.3 Dust control system

If there are stockpiles stored on site and material can be spread by wind the following practices are implemented:

- Ad Hoc stockpile are would be designed with a concrete slab and bunding. It can also be closed off with tarp or mesh material to ensure no generation of dust.
- Maintaining a minimum open air stock level to minimise drying and dust generation.
- A watering system and wind breaks to prevent the generation of dust.
- Shade cloth mesh barriers can be used in areas best suited to their application to prevent the generation of dust ad form wind breaks if needed.
- A dust suppression agent can be applied to non-active stockpiles to prevent dust emissions leaving the premises during periods of high winds; and
- A Comprehensive dust monitoring program, consisting of both personal and environmental dust monitoring, are in place to monitor and report on the efficiency of the existing control measures.

6.4 Contamination control

The site boundary is screened at least annually to confirm the efficiency of controls in place to prevent contamination of neighbouring properties.

All equipment that may be contaminated with radioactive material is screened to ensure they are within the release limits. Surface radiation contamination on plant and equipment must be less than 0.4 Bq/cm^2 averaged over 300 cm^2, otherwise plant and equipment is not released from site.

6.5 Institutional Control

6.5.1 Responsibilities of key personnel

The duties of key personnel for the implementation and maintenance of the RMP are detailed in Table 6-1.

Table 6-1 Duties of key personnel

Item	Action	Responsible person
1	Provide advice to the management on the implementation of the RMP.	Radiation Safety Officer
2	Provide advice in matters in relation to radiation protection of employees, public and environment.	Radiation Safety Officer
3	Accountability of all radiation sources on site.	Radiation Safety Officer
4	Monitoring of radiation hazards in accordance with the Standard job procedures.	Monitoring technicians/ Radiation Safety Officer
5	Ensuring that the nominated radiation monitoring is carried out and that the results are reported to appropriate employees, management and government departments.	Radiation Safety Officer
6	Following the nominated safe working practices policies, procedures and appropriate requirements for radiation monitoring.	All employees
7	Ensuring all incidents is immediately reported to the responsible person.	All employees
8	Authorising all Company policies, including those relating to radiation protection.	Site Manager
9	Implementation of the Company's policy on radiation safety.	Area Co-ordinators and Supervisors

6.5.2 Areas classification and work rules

To ensure ALARA principles are maintained, classification of areas is done based on the potential annual radiation exposure in excess of the natural background and the following work rules apply to those areas:

- **"Radiation supervised area"**: an area to which access by members of the public should be minimised and restricted.
    - General awareness of elevated radiation levels in the area is required both for employees and for visitors. Visitors to the site must be accompanied at all times.
- **"Radiation Controlled area"**: an area to which access by employees should be limited or minimised;
    - Only employees who have attended radiation safety training are allowed to work in these areas. Employees who have not attended this training are allowed to work only in exceptional circumstances.
- **"Radiation restricted area"** is an area where the potential for the radiation exposure of employees is above 75% of the annual dose limit.

- Only employees who have attended radiation safety training are allowed to work in these areas and wearing of a personal radiation monitor (a thermoluminescent dosimeter (TLD) badge or an electronic dosimeter) is mandatory.
- Visitors or employees who have not attended radiation safety training are not permitted to enter these areas under any circumstances except in emergency situations.

6.5.3 Emergency planning

Emergency procedures will be developed to prepare for accidental spillage while transporting sources, fires and other relevant emergency situations.

6.5.4 Personal protective equipment

Respiratory protective devices would be permanently available in the workplace. Instruction, training, proper maintenance and efficient use of the respirators would be carried out on an ongoing basis throughout the year so as to ensure the coverage of all new employees.

6.5.5 Personal hygiene rules

All employees are made aware during site induction of the risk of radiation exposure. They are made aware of the increased risk to radiation exposure if personal hygiene is not followed before eating, drinking or smoking.

Ablutions facilities are made available on site to enable employees to follow good personal hygiene practices.

6.5.6 Job rotation

Designated employees dosage are monitored and calculated quarterly while pregnant employees dosage are calculated weekly. If an employee reaches 50 % of the annual exposure dose limitation, they would be removed to a non-designated area to ensure they are not being overexposed. Monitoring of these employees would continue to ensure no overexposure to radiation. If 75 % of the annual dose limitation is reached the employee would be sent on leave or moved to activities where there is low radiation exposure levels to ensure they are not over exposed. The levels by which jobs would be rotated are given in Table 6-2.

Table 6-2 Job rotation levels

Exposure level	Pregnant employee (mSv)	Designated employee (mSv)	Action
50% of dose limitation	0.5	10	Rotate employee to work in non-designated or lower radiation area
75% of dose limitation	0.75	15	Employee to be sent on leave to prevent over exposure

6.5.7 Management of pregnant employees dose

During general site induction, it would be made known to employees that they should report to the Human Resource Department or their supervisor, as soon as practical if they become pregnant during the course of their employment. Once an employee has reported her pregnancy, the employee is issued with a personal dosimeter (Canary), and is provided with an Excel spreadsheet to record her daily dose received. She would also be trained in filling out the spreadsheet.

The spreadsheet will calculate the dose above background received the accumulated dose to date and give a predicted dose based on the dose received and the pregnancy time remaining.

An employee's dose would be monitored throughout the pregnancy and she would be relocated to a less radioactive area if needed to ensure her dose received would not exceed 1 mSv over the pregnancy period.

7 COMPLIANCE WITH LIMITS

The majority of risks associated with radiation are known and have been quantified. The objective of radiation protection is to limit the exposure to radiation by the application of comprehensive programs of measurements of all significant radiation sources.

Where it is expected that a worker would be exposed to radiation as a result of their employment, they must not exceed certain prescribed dose limits. In Australia, these dose limits are prescribed in the *Recommendations for Limiting Exposure to Ionizing Radiation* (1995) and *National Standard for Limiting Occupational Exposure to Ionizing Radiation* (2002), Radiation Protection Series No. 1 which reflects international best practice in radiation protection.

A dose constraint is an upper value on the annual dose that members of the public or member of the workforce may receive from a planned operation or a single source. A dose constraint would allow for exposures from other sources without the annual limit being exceeded.

The dose limit for members of the public from all sources is an effective dose of 1 mSv in a year, and this or its risk equivalent should be considered as criteria not to be exceeded in the future. The ICRP and IAEA suggest that, for the control of public exposure, an appropriate value for the dose constraint is 0.3 mSv in a year (mSv/y) exclusive of natural background levels.

This dose constraint should take into account multiple pathways of exposure as members of the public could receive exposure from a number of sources. To comply with the above limit, a facility such as a radioactive waste disposal facility (which constitutes a single source) must be designed so that the estimated average dose to the relevant critical groups of members of the public, who may be exposed as a result of the facility and its operation, satisfies a dose constraint of not more than 0.3 mSv per year exclusive of background.

The current worker limit of radiation exposure is 20 millisieverts (mSv) per year averaged over 5 years, and not more than 50 mSv received in any one year. This dose limit only applies to radiation exposure received occupationally, and does not include exposures from natural background radiation or medical doses. To Ensure compliance to this level the facility would follow a dose constraint level 0f 5 mSv/y

To ensure compliance with these limits action levels are established and given in Table 7-1. If exceeded, formal investigation of the excursion is required.

Table 7-1 Investigation levels

Radiation parameter	Guideline level	Comment
Area Gamma dose rate		
Site boundary	More than 0.11 µGy/hr above background	
Supervised area	More than 0.50 µGy/hr above background	
Controlled area	More than 2.50 µGy/hr above background	
Restricted	More than 7.50 µGy/hr above background	
Personal external dose		
Designated worker	>2. mSv in a quarter	Assessed from TLD/ personal dosimeter
Non-designated worker	>0.5 mSv in a quarter	Assessed from TLD/ personal dosimeter
Personal internal dose		
Designated worker	>0.5 mSv in a quarter	Assessed from air sampling
Airborne radioactivity		
Total alpha activity on the personal air sample	>4 Bq/m^3 for shift sample	Four times derived air concentration limit 0.5 mSv.
Total alpha activity on the personal air sample	4 consecutive samples >1 Bq/m^3	Indicates potential for significant exposure.
Total alpha activity	>Mean + 3 std deviations	Work category mean.
Total Alpha activity on environmental air sample	>1 mBq/m^3 on high volume air sampler	100 µSv/year to a member of public continuously exposed. (>10 x background levels.
Airborne dust		
Inhalable dust on personal air sample	>10 mg/m^3 dust concentration	Statutory limit for inhalable (8 hour shifts).
Respirable dust on personal air sample	>3 mg/m^3	3 mg/m^3 (8 hour shifts).
Radon / Thoron in air		
Radon in air _ workplaces	>1000 Bq/m^3	Assessed from track etch -long term average.
Surface contamination		
Low toxicity alpha emitters (U238, Th232, Th228, Th230) on a surface	>0.4 Bq/cm^2	Averaged over 300 cm^2. Non-fixed - can be removed from surface during handling.
Other alpha emitters (Ra226, Ra224, Po210) on a surface	>0.04 Bq/cm2	Averaged over 300 cm2. Non-fixed - can be removed from surface during handling.

8 WORKER EXPOSURE AND CONTROLS

8.1 Transport

Workers involved in the transport of radioactive material to site could potentially be exposed to external gamma radiation from the waste package, inhalation of suspended dust (α- radiation) and inhalation of radon and decay products. Transport would be arranged by the customer and all exposure assessments should be addressed in the customers' transport management plan and emergency procedures. The Proponent requires that all packages that arrive on site must be transported in accordance with requirements of the Australian Code of Practice for the Safe Transport of Radioactive Material that adopts International Atomic Energy Agency (IAEA) Transport Safety Regulations.

8.2 Front gate

The truck transporting shipping containers would enter the facility and be weighed on the weighbridge and the driver would then proceed to the front gate office. The operator at the front gate would confirm:

- No visible damage to the shipping container(s).
- No evidence of material leaking from the shipping container(s).
- Radiation levels on the surface of the shipping container is in line with transport requirements.
- Various points of the truck would be inspected.

If the truck does not meet Tellus' required standards, it would be quarantined in a holding bay, away from areas in which people are working, and Tellus would liaise with the waste customer regarding the discrepancy. Once confirmed that the shipping container meets Tellus' transport standards, it would be moved to the hardstand.

Operators working at the front gate could potentially be exposed to external gamma radiation from the waste package, inhalation of suspended dust (α- radiation) and inhalation of radon and decay products.

Controls that would be implemented to ensure workers are not exposed to levels above the dose constraints include:

- Screening of waste packages on arrival to ensure the radiation levels (alpha beta and gamma) is within acceptable and safe levels.
- Wearing of electronic dosimeters to determine exposure levels.
- Ensuring packages are not damaged on arrival and adhere to the transport requirements.
- Dust controls if bulk material are handled.

- PPE if required.

8.3 Hardstand

Trucks would park temporarily on the hardstand whilst the shipping container is transferred to the hardstand. The shipping container remains closed. An external audit is conducted to ensure the container is not damaged or leaking. If it is found to be leaking Tellus would move it directly into the Waste Inspection Area to conduct an internal audit and remove the leaking/damaged waste packages. Clean-up of leaked material on the hardstand would be in accordance with SROP-06 Spill Clean-up Procedure.

Otherwise the shipping container would remain on the hardstand until the operators of the Waste Inspection Area are ready to receive it.

Workers involved in the inspection and clean up could potentially be exposed to external gamma radiation from the waste package, inhalation of suspended dust (α- radiation) and inhalation of radon and decay products.

Controls that can be implemented to ensure workers are not exposed to levels above the dose constraints include:

- Screening of waste packages to ensure correct time limits is placed on work (reducing exposure time by rotating workers etc.)
- Wearing of electronic dosimeters to determine exposure levels
- Limiting the time workers work near waste (determined by dose rate of waste package) to ensure they do not exceed dose constrains.
- Using remote controlled equipment if required.
- Ensuring packages are not damaged on arrival.
- Dust controls if bulk material are handled.
- Ensuring proper ventilation to prevent built up of radon gas
- PPE if required.

8.4 Waste inspection area

The shipping container would be lifted onto the Waste Inspection Area dock and one end of the container opened to allow access for the internal audit. The audit would be conducted in accordance with SROP-07 Internal Shipping Container Audit.

A number of waste packages would be removed from the shipping container and placed on the floor of the Waste Inspection Area. Radiation of the waste packages would be checked in accordance with SROP–04 Radiation Monitoring and would confirm if the emissions match those expected based on

the customer's waste preform. If the radioactivity recorded is higher than expected based on the information provided by the waste customer, the following actions would occur:

- The radiation meter would be re-calibrated in accordance with manufacturer's specifications.
- The radioactivity of the waste package(s) would be recorded again.
- If the recording is still higher than expected, but below the radiation levels are as per the transport code and labelling (no greater than: 5 µSv/h for a Category I-WHITE package; 500 µSv/h for a Category II-YELLOW package; or for a Category III-YELLOW package up to 2000 µSv/h (or 10 000 µSv/h if transported under exclusive use)and that non-fixed external contamination does not exceed 4 Bq/cm2.) the waste packages would be moved to the Radioactive Waste Warehouse. Tellus would liaise with the waste customer to confirm the reason for the discrepancy and if satisfactory, an Acceptance Certificate would be issued.
- If the recording is still higher than expected, and above the radiation levels are as per the transport code and labelling, further testing, options and cost involved would be discussed with the waste customer. If unable to treat and reduce the radioactivity to within acceptable levels, Tellus would be unable to place the waste package in the cell (as this would contravene approvals issued for the site) and the waste customer would be contacted to organise removal of the waste package from the site. The waste packages may be temporarily stored in the Radioactive Waste Warehouse until this is organised.

Following checking of the packages for radioactivity, sampling of these waste packages would occur in accordance with SROP-08 Sampling of Wastes, and each sample would undergo checks against the customer's documentation and laboratory testing.

The waste package would be audited against the customer's waste proforma to confirm the volume and type of waste delivered is as described in the customer's documentation. The outcome of the review of documentation would be:

- If the documentation is incomplete or does not match the waste that has arrived, the package is replaced into the shipping container, the container is closed, and is moved back to a section of the hardstand pending liaison with the waste customer.
- If documentation is complete, the waste packages would be inspected for damage and leaks. If the packaging is damaged significantly the pallet would be held in a safe and secure manner (in accordance with SROP–09 Damaged or Leaking Waste Package Procedure) whilst a solution is agreed to with the waste customer.

Tellus would make safe any damaged or leaking waste package as soon as possible to minimise worker exposure to the waste

Following internal audit of the shipping container, all waste packages examined would be repacked into the container. The shipping container would either be:

- Transferred directly to the cell for disposal.

- sent to the hardstand to await placement as per the Cell Schedule (described further below).
- Sent to the Radioactive Waste Warehouse for temporary storage.

Workers involved in the inspection of radioactive waste can be exposed to external gamma radiation from the waste package, Inhalation of suspended dust (α- radiation) and Inhalation of radon and decay products.

Controls that would be implemented to ensure workers are not exposed to levels above the dose constraints include screening of waste packages on arrival to ensure the radiation levels (alpha beta and gamma) is within acceptable (as specified in the transport code) and safe levels, wearing of electronic dosimeters to determine exposure levels, dust controls if bulk material are handled and PPE if required.

8.5 Lab

Composite and random samples of the newly arrived waste packages would be collected and tested in the onsite laboratory. Testing would ensure the chemicals sent are as per the waste customer's documentation.

The onsite laboratory would be accredited by the National Association of Testing Authorities (NATA) for the analysis to be performed. Chemical analysis would be performed in accordance with the laboratory methods accredited by NATA. The laboratory would produce sample results which would be stored in the Tellus Electronic Tracking System (TETS) alongside the waste customer's proforma and NEPM documentation.

Once the sample results match the customer's documentation, the remnants of the sample, the previously removed waste packages, equipment contaminated by the sample and the lab analyst's personal protective equipment (PPE) would be repacked into the shipping container and the container closed. The shipping container is transferred back to the hardstand. The shipping container remains on the hardstand until it is scheduled to be moved into the waste cell.

Controls that would be implemented to ensure workers are not exposed to levels above the dose constraints include screening of waste packages on arrival to ensure the radiation levels (alpha beta and gamma) is within acceptable (as specified in the transport code) and safe levels, wearing of electronic dosimeters to determine exposure levels and engineering designed controls I lab.

8.6 Radioactive waste warehouse

The Radioactive waste warehouse is designed to ensure that the dose rate outside of the building do not exceed 10µGy/hr. The warehouse would be demarcated as a designated area and access to the warehouse and time spend in it would be controlled.

8.7 Pre-treatment / packaging of wastes

Tellus may accept some wastes at the facility which are flammable, explosive, corrosive, biodegradable or reactive which would require pre-treatment or conditioning before being placed in

the disposal cell to ensure that they do not compromise cell integrity. Possible pre-treatment processes may include one or more of the following:

- Crushing and/or screening to ensure that the particle sizes of materials would not result in excessive voids being created (e.g. for pot liner materials).
- Solidification and stabilisation using pozzolanic cement, fly-ash or kaolinitic materials.
- Centrifugation or filtering to remove excess moisture.
- Evaporation and biological conditioning.

Workers involved in the packaging of radioactive waste for disposal (cementing and concreting) can be exposed to external gamma radiation from the waste package, Inhalation of suspended dust (α-radiation) and Inhalation of radon and decay products.

Controls include packaging within a well ventilated designated area, all workers coming into close proximity to the radioactive waste shall wear personal radiation monitors, limiting the time workers spend packaging, increasing the distance between workers packaging the waste and sources, and shielding.

8.8 Transfer of waste into cell

Workers involved in the unloading and burial of radioactive waste may be exposed to low levels of external gamma radiation from the waste package, Inhalation of suspended dust (α- radiation) and Inhalation of radon and decay products. The waste at this stage is packaged and would be lowered into the shafts by mobile equipment. Workers protection include shielding (provided by the waste packaging and mobile equipment), increase in distance from sources by using mobile equipment and scheduling of waste placement to ensure minimum time is spend near radioactive waste.

9 EMPLOYEE TRAINING

All personnel and contractors working on the site would undergo a standard induction that would include background and project specific information on radiological conditions and hazards.

The radiological induction would be provided through a power point presentation to be given by the RSO and an information booklet.

Relevant personnel would be trained in the use of all radiological monitoring equipment prior to commencement of the project.

This induction and training would be backed up by the on-site presence of the Radiation Safety Officer and off site access (via telephone and email) to radiological expertise through Hygiea Consulting.

10 RADIATION MONITORING PROGRAMMES

The radiation monitoring programs would follow a conventional format for each of the types of hazards described.

The aim of the monitoring programme is to:

- Demonstrate regulatory compliance.
- Assessment of the efficiency of work practices and engineering controls in preventing and limiting employee and public exposure to radiation.
- Provide data to enable knowledgeable radiation protection decision-making.

The general procedures are:

- To conduct area gamma and airborne activity surveys to define general baseline radiation levels before the project is started.
- To conduct area gamma and airborne activity surveys before finalising the preliminary earthworks phase to confirm that sufficient material has been removed and to confirm no spread of contamination to neighbouring areas
- To comprehensively monitor people who work in the areas by:
    - Individual gamma monitoring to determine external γ-radiation.
    - Random personal dust samling to determine airborne radioactivity.
- To conduct assessments of doses received by employees and the critical group.
- To ensure action levels are not exceeded.
- To investigate and correct any situation that results in an action level being exceeded.
- To adopt practical preventive measures at all times to limit the exposure of all persons.

The purpose of the Environmental program is to ensure that radiological impact to the local environment and to members of the public is minimal. This program is usually accomplished by area monitoring (dust and water monitoring, and area γ-surveys).

10.1 Environmental monitoring programme

The environmental monitoring program is adapted based on on-going interpretation of results and risk assessments before disposal and waste acceptance. The following environmental radiation monitoring programme (Table 10-1**Error! Reference source not found.**) would be followed as a minimum to ensure that the operations have no detrimental effect on the environment.

Table 10-1 Environmental monitoring schedule summary

Monitoring type	Type of monitoring	Type of radiation	Pre-operational	Baseline (operational)
Dust Monitoring	Environmental high volume dust samples	LLA	1/year from 6 representative locations.	2/year from representative locations.
Radon	Track etch	RnDP	1/ year from 3 locations.	2/year for first 3 years of operation – then as per determined risk.
Area γ-Monitoring	Pre disposal background gamma levels	γ-survey	Pre clearance survey before cell is mined.	Pre disposal (mined out pit), after disposal and after final capping.
	Boundary gamma surveys	γ-survey	Once off.	Annually.
	Equipment contamination clearance	α, β, γ-survey		As required before equipment that might be contaminated leave site.
Waste storage	Radiation store	γ-survey		Quarterly.
	Stockpiles	γ-survey		2/year.

10.1.1 Dust monitoring

Samples are deposited upon a pre-weighed (25.5 cm x 20.5 cm) glass-fibre filter paper with an effective sampling area of 382.5 cm^2 (22.5 cm x 17.0 cm). Upon completion of sampling, the filter paper is re-weighed to determine the mass of dust collected. The sub-samples are stored for a period of not less than seven days to allow short lived radioactive products to decay, and are then presented to the α-spectrometer to determine the long-lived α-emitting activity. The mean α-activity from the sub-samples is integrated over the total active area to determine total collected long-lived α-activity.

10.1.2 Environmental area γ- monitoring program

Environmental area γ- monitoring program would consist of:

- Site boundary monitoring surveys.
- γ- monitoring to determine Background levels.
- Clearance survey.

The environmental gamma survey would be done at a height of 1 metre from the ground. Keeping the monitor and audio indicator in the on position allow for the identification and monitoring of smaller areas with elevated gamma radiation levels. A grid of approximately 15 m x15 m is recommended.

- All monitoring locations are recorded using a Global Positioning System (GPS) receiver.
- Area γ- monitoring of the site boundary would be undertaken as part of the pre operational and operational baseline program. The monitoring locations would be recorded with the GPS coordinates and compared to the pre-project monitoring results.
- A survey would be undertaken once mining has been completed and before disposal to confirm the background levels in the pit. The survey results with the GPS coordinates would be record
- A clearance survey of each pit would be undertaken after completion of earthworks and capping to confirm area above pit is at background levels. Results and GPS coordinates would be recorded.

10.2 Occupational monitoring program

The purpose of the occupational monitoring program is to ensure that radiation exposures of the workforce remain below the statutory annual limit (20 mSv) and ALARA. Occupational radiation monitoring is carried out on a cross section of the employees. Results of area surveys and time and motion studies are also used to estimate potential doses for employees. The personal monitoring to be conducted would include:

- Personal dust samplers and analysis for gross α activity.

- Personal γ- monitoring with personal electronic dosimeters (Canary).
- Work Area γ- monitoring to demarcate areas based on exposure risk.

10.2.1 Personal dust monitoring

Personal dust sampling would be conducted in accordance to AS 3640:2004. Workplace atmospheres -Method for sampling and gravimetric determination of inhalable dust, 2004. Samples would be analysed for LLA. ICRP-66 recommends that a default AMAD of 5 µm is used for occupational exposures whilst for environmental exposures the default AMAD is taken to be 1 µm.

Sampling sizes for the baseline program would be in accordance with NIOSH Occupational exposure sampling strategy manual to ensure that there is a 90% confidence that at least one individual from the highest 10% exposure group is contained in the sample.

10.2.2 Personal γ-Radiation monitoring

Personal γ monitoring would be conducted to confirm the individual dose is kept below the action levels. This would be done with personal electronic dosimeters or Thermoluminescent Dosimeter (TLD) badges.

10.2.3 Area γ- Monitoring

Work areas would be classified based on the potential annual radiation exposure in excess of the natural background and would be demarcated accordingly.

The average level of natural background gamma radiation would be determined in the pre operational surveys.

11 PERIODIC ASSESSMENT AND REVIEW

This Radiation Management Plan would be reviewed on an annual basis. The review would be documented and involve stakeholders where appropriate. In addition to an annual review the frequency and scope of various monitoring programs would be periodically reviewed. This would ensure that the various monitoring programs are implemented in a way that would allow the timely identification and rectification of any potentially unforeseen circumstances or areas of concern.

12 SUMMARY AND CONCLUSION

Tellus Holdings Ltd (Tellus), an infrastructure project development company, is proposing to develop the Sandy Ridge Project located approximately 75 kilometres (km) North East of Koolyanobbing, in the Shire of Coolgardie, within the Goldfields Region of Western Australia.

The Sandy Ridge proposal is a kaolin open cut mine and use the mine voids for the secure storage and permanent isolation over geological time of hazardous, intractable and low to intermediate level radioactive waste in an arid environment, near surface, geological repository using best practice storage and isolation safety case. The location of the Sandy Ridge Project has been specifically chosen to meet the requirements of International and National codes relating to the siting of a near surface geological repository.

Intractable wastes do not have commercially viable recycling, reuse or disposal options; and include wastes that need time to breakdown; and chemical wastes that are not readily destroyed. These wastes need long-term management. The Facility provides a location where intractable wastes can be permanently isolated to protect the community and the environment. The type of industrial materials waste to be stored or permanently isolated are intractable and hazardous materials generated in the; mining, oil and gas, heavy industry, agricultural and government (emergency service) sectors.

Waste acceptance criteria (WAC) developed for this facility is described in the waste acceptance criteria (document reference: TCO-5-05). The radionuclide concentration limits is set taking into account the actual siting, design and planning of the facility (e.g. Natural geological barrier, arid climate, remoteness, engineered multi layered shielding and barriers, duration of institutional control, site specific management plans and operating procedures) and exposure dose constrains to ensure no person is exposed above the dose limit (as defined in Schedule I of the Radiation Safety (General) Regulations).

During the feasibility stage of the project, considerations were given to engineering best practice as well as socio economic factors to determine the most suitable design that would meet the safety requirements at an acceptable cost. The current proposal is open cut pit/cell with in-cell vertical shaft disposal of radioactive wastes.

All wastes would be securely isolated in the safety of the natural geological barriers formed by the extensive kaolin bed and the overlying geological units. Cells would be filled in layers with multiple sections in each layer containing wastes of similar characteristics. All space between waste packages would be backfilled and compacted to minimise air or void space that may result in settlement. Each layer would be compacted, until approximately 7m below the ground surface, where a thick capping layer of low permeability clay would be installed to prevent water ingress into the cell.

Following these steps, more compacted backfill and a clay domed cap would be situated on the top of the cell, to shed any landing rainfall. During the waste disposal process a roof canopy is positioned over the cell to exclude rainfall prior to the capping layer being installed. There may be instances (for

non-soluble waste types) where a cell may be filled with waste without a roof canopy. In addition, any potential stormwater surface flows would be diverted away from the cells by bund walls or levee banks.

The facility security design would be in accordance with ARPANSA RPS 11 in order to decrease the likelihood of the unauthorised access by persons with malicious intent.

It can be concluded on the basis of the characteristics described above and the initial dose assessments, that there is little credible risk to human health or the environment from suitably conditioned and packaged hazardous or intractable wastes that might be stored and isolated in appropriately designed disposal cell at Sandy Ridge.

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Radiation Assessments

TELLUS

RADIOLOGICAL RISK ASSESSMENT : FAUNA & FLORA
SANDY RIDGE FACILITY

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Appendix I ***ERICA Assessment Post Closure***

EXECUTIVE SUMMARY

Tellus proposes to construct and operate a dual Kaolin (Clay) mine and waste facility, accepting Class IV (Secure Landfill) and Class V (Intractable Landfill) waste.

The type of industrial materials to be accepted at the facility are intractable and hazardous materials generated in the mining, oil and gas, heavy industry, agricultural and government (emergency service) sectors.

As well as ensuring humans are adequately protected from exposure to radiation and radioactive material handled, stored and disposed at the Sandy Ridge near surface geological storage and isolation facility (the Facility), there is a need to ensure the environment, as a whole, is adequately protected.

An assessment has been undertaken, with the intention of estimating the radiological effects that waste materials could have on the environment. This includes all pathways of exposure, both during the period of operation and closure, with the view to demonstrate that potential radiological impacts are at an acceptable level of risk and manageable to safeguard fauna and flora.

This assessment was undertaken using the Environmental Risk from Ionising Contaminants Assessment (ERICA) software tool. In ERICA, the reference organisms are characterised by their dimensions, the concentration of radionuclides that they exhibit relative to the environmental media with which they are associated and the fraction of the time (occupancy) that they are present within, or at the surface of, the various environmental media. With this information, dose conversion factors can be used to convert concentrations in organisms into whole-body dose rates, which are then compared to threshold dose rates (dose constrains) (e.g. 10 µGy/h) for various broad categories of organisms to which there are not expected to be significant population effects.

Four exposure scenarios were modelled using ERICA Tier 2 assessments:

- Scenario 1 – exposure of fauna and flora present in the area surrounding the radioactive waste warehouse.
- Scenario 2 – exposure to windblown material originating from operational stockpiles e.g. plant tails; ore, sand, laterite and silcrete stockpiles.
- Scenario 3 – exposure to windblown material originating from adhoc stockpiles e.g. low level radioactive materials received as bulk or from emergency clean-up operations.
- Scenario 4 – exposure post closure, with capping material and rehabilitation of the GSIF established as well as for the duration of the institutional control period.

The conclusions of the assessment are as follows:

From the Scenario 3 modelling, it was indicated that exposure to waste materials at full-time occupancy (with no controls in place) could result in radiological impacts too high for adequate protection of flora and fauna, it is imperative to ensure that stockpiled radioactive bulk materials are sufficiently contained to prevent windblown (or other) dispersal to the surrounding environment. It is also recommended to establish control measures preventing fauna species access to stockpiled bulk materials during the operational phase of the project. The controls that will be implemented are discussed in section 9.2 of the radiation management plan and include a designated stockpile area with concrete slab and bunded walls, closing stockpile with tarp material, dust suppression agents and a monitoring program to confirm efficiency of controls implemented. With these controls in place and operating according to design the exposure risk should be sufficiently managed.

From the Scenario 1 modelling (exposure of fauna and flora present in the area surrounding the radioactive waste warehouse), and under the condition that the Sandy Ridge facility will be designed and constructed such that dose rates for all organisms present outside the warehouse are below the threshold dose rate of 10 μGy/h, no risk to any biota is foreseen from stored materials.

Upon closure, with a minimum capping of 7 meters, and for the duration of the institutional control period, no risk to non-human biota is foreseen, as modelled dose rates for all organisms are below the threshold dose rate of 10 μGy/h. External gamma dose rate on surface post closure (minimum cover of 7 m) would be negligible, even if all radioactive waste (2,500,000 tonnes) would be high activity concentration radium scales at an activity concentration of 17800 Bq/g radium (Ra-226 and Ra-228 combined).

1 SCOPE

Tellus proposes to construct and operate a dual kaolin (clay) mine and waste facility, accepting Class IV (Secure Landfill) and Class V (Intractable Landfill) wastes.

An assessment has been undertaken, with the intention of estimating the potential radiological effects that waste materials stored and disposed of at the Sandy Ridge facility could have on the flora and fauna. The assessment included all pathways of exposure during the periods of operation and closure, with the view to demonstrate that the radiological impacts are at an acceptable level of risk and manageable to safeguard fauna and flora.

2 INTRODUCTION

Tellus is planning to develop the Sandy Ridge Project (the Proposal). The Proposal is comprised of two main business components, mining of kaolin clay for export and storage and permanent isolation (disposal) of hazardous and intractable waste in mine voids.

The proposed commodity business involves mining kaolin mostly in an open cut methodology, processing on site and then exporting the kaolin via Fremantle Port to Asia where it will be used in various industrial sectors (e.g. paper, ceramics, fiberglass and paint). Kaolinite is a clay mineral also known as 'Kaolin clay', with the chemical composition $Al_2Si_2O_5(OH)_4$.

The waste aspect of the Proposal involves disposing of up to 100,000 tpa of intractable, hazardous and low level radioactive wastes in the mine voids (herein referred to as 'cells') over a 25 year period (i.e. 2,500,000 tonnes in total). Wastes would be accepted from across Australia.

Cells would be filled in layers with multiple sections in each layer. Each layer would be divided into sections containing wastes of similar characteristics. Each section will be backfilled, compacted and all air pockets/voids excluded. Each layer will be compacted, until approximately 7m below the ground surface, where a thick capping layer of low permeability clay will be installed to prevent water ingress into the cell. Following this, more backfilling and a clay domed cap would be situated on the top of the cell, to shed any landing rainfall. During the waste disposal process, a roof canopy is positioned over the cell to exclude rainfall prior to the thick capping layer being installed.

Waste acceptance criteria (WAC) developed for this facility is described in the waste acceptance criteria (document reference: TCO-5-05). The radionuclide concentration limits is set taking into account the actual siting, design and planning of the facility (e.g. Natural geological barrier, arid climate, remoteness, engineered multi layered shielding and barriers, duration of institutional control, site specific management plans and operating procedures) and exposure dose constrains to ensure no person is exposed above the dose limit (as defined in Schedule I of the

Radiation Safety (General) Regulations). These radioactive wastes are generally generated by medical research and industry, operation of research facilities (e.g. laboratory coats, overshoes, gloves), Naturally Occurring Radioactive Materials (NORMs), NORMs occurring on pipework and scale from industry, oil spills containing NORMs and orphan sources (i.e. gauges and instrumentation). Wastes which will not be disposed of into cells include: infectious materials, nuclear material, uncertified waste, putrescible waste and gases.

Tellus operations are underpinned by utilising a combination of engineered and natural barriers, known as a multi barrier system, which provides long term containment and isolation of the waste.

After the placement of waste in the cell has been completed, the following protection measures will be implemented:

- An all-weather cover will be maintained over the cell until it is backfilled and capped to allow for protection from all weather conditions, without the possibility of creating leachates or contaminated surface water.
- Any airspace surrounding the placed waste will be backfilled with kaolin processing plant waste product (low value kaolin and quartz sand) to fill all void space and provide stability.
- The cell will then be backfilled with compacted clay, silcrete, laterite and yellow sand.
- The surface of the cell will be covered with a domed clay cap to exclude rainfall.

After a period of subsidence monitoring to confirm the stability and integrity of the clay capping, topsoil will be placed over the cap and the area re-vegetated with species of local provenance. Local species would be selected based on their root system penetration (depth), ensuring that the capping design is not compromised.

Tellus will monitor and manage the site for an extended period following closure before returning ownership to State, a period termed institutional control. Further information on management of the Facility is provided in the Waste Facility Decommissioning and Closure Plan.

The institutional control period (ICP) will ensure the wastes stored and disposed of in the geological repository are undisturbed for a period of time until they no longer pose a risk to human health and the local environment.

3 THE ERICA TOOL

Plants and animals may be exposed to ionising radiation in the environment from different sources, and under different types of exposure situations. In all of these, the factors contributing to the doses received can vary enormously, and various assessment tools have been developed which are able to model these contributing factors appropriately and systematically. One of the readily available assessment tools is ERICA that predicts the risk to RAPs from ionising radiation.

A variety of approaches are available for assessing radiological impacts on non-human biota. Of these approaches, the ERICA Tool has the most developed concentration ratio-based transfer database for a wide range of Reference Organisms, arguably giving it the best basis for prospective assessments when site-specific data are not available. It also considered the largest number of radionuclides included within the ICRP Publication 38 [9].

3.1 TECHNICAL BASIS OF THE ERICA TOOL

The ERICA Tool is a software program that guides the user through the assessment process, keeps records and performs the necessary calculations to estimate dose rates to selected biota. The Tool interacts with a number of databases and other functions that help the assessor to estimate environmental media activity concentration, activity concentration in biota, and dose rates to biota. The ERICA Tool also interfaces with the FREDERICA radiation effects database, which is a compilation of the scientific literature on radiation effect experiments and field studies, organised around different wildlife groups and, for most data, broadly categorised according to four effect umbrella endpoints: morbidity, mortality, reproduction and mutation.

The database of the ERICA tool has been built around a number of reference organisms. Each Reference Organism has its own specified geometry (and default transfer data) and is representative of terrestrial, freshwater or marine ecosystems.

The assessment elements of the ERICA integrated approach is organised in three separate tiers (Figure 1). Satisfying certain criteria in Tiers 1 and 2 allows the user to exit the assessment process while being confident that the effects on biota are low or negligible, and that the situation requires no further action. Where the effects are not shown to be negligible, the assessment should continue to Tier 3.

In the evaluation reported in this report, all assessments were undertaken at Tier 2. This was because Tier 2 allows the user the be more interactive than is the case with Tier 1 assessment, to change the default parameters and to select specific Reference Organisms. The evaluation is performed directly against the screening dose rate of 10 µGy h^{-1}.

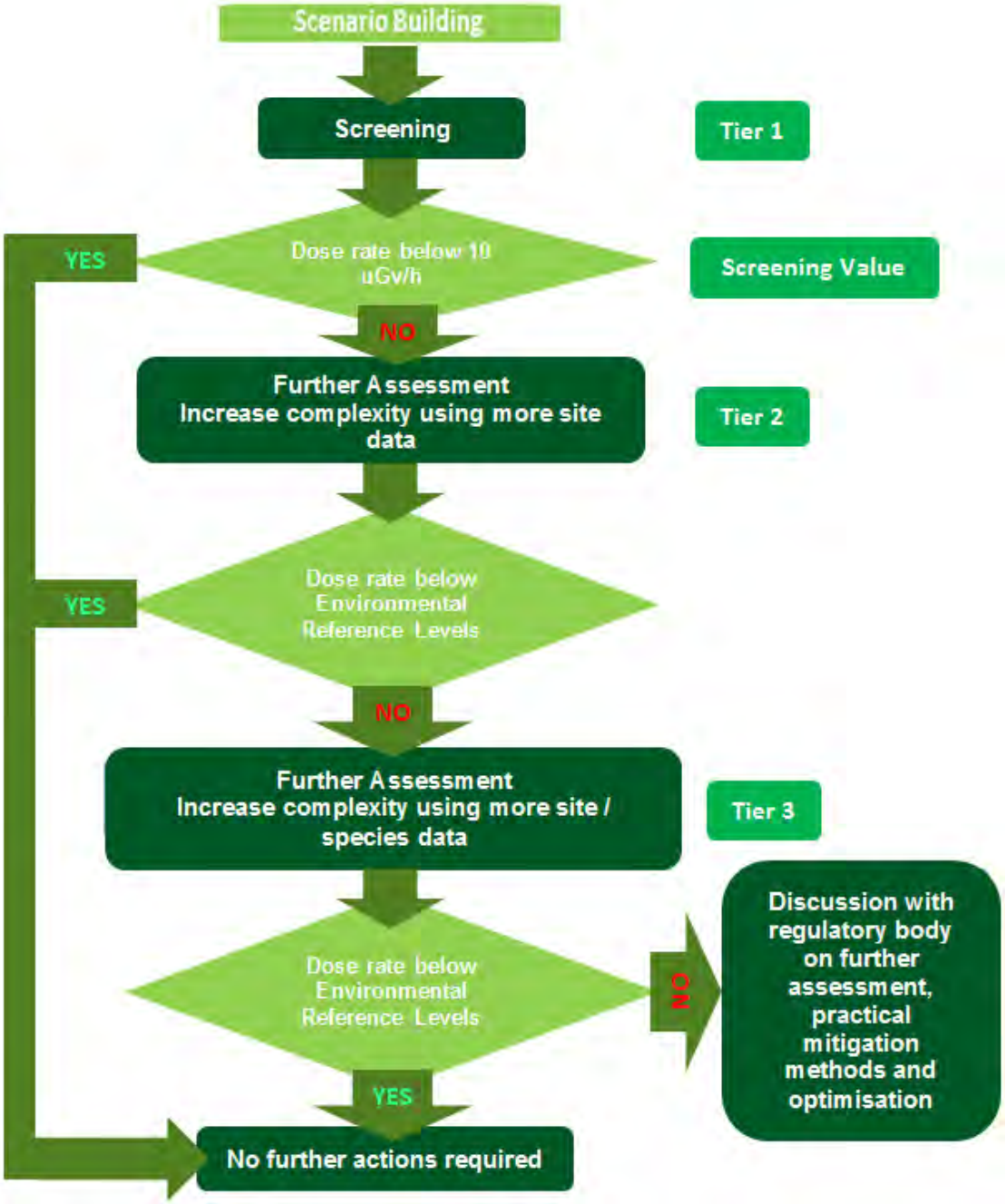

Figure 1: Tiered approach of ERICA Assessment using Screening Level Values

From ARPANSA (2015)

4 GEOGRAPHICAL AND ECOLOGICAL CONTEXT

4.1 GEOGRAPHICAL CONTEXT

The Proposal is located approximately 75 kilometres (km) north-east of Koolyanobbing, Western Australia. Access is via a 100 km road to the Intractable Waste Disposal Facility (IWDF) Mount Walton East (Crown Reserve No. 44102) that extends northward from the Boorabbin Siding on Great Eastern Highway; a 4.5 km westwards section along an existing road; and a 5.3 km northwards section of new site access road into the development envelope (See Figure 2)

There are no sensitive receptors within 5 km of the location of the Proposal. The nearest operation is the Class V IWDF Mount Walton East located approximately 6 km to the east, which operates on a campaign basis and does not have permanent residents. The nearest mining camp is the Carina Iron Ore Mine Accommodation Camp located approximately 52 km to the south east of Sandy Ridge.

The location of the Sandy Ridge Project has been specifically chosen to meet the requirements of International and National codes relating to the siting of a near surface geological repository. These site characteristics include:

- **Geologically stable** — the development envelope sits within the Archean Yilgarn Block and is geologically typical of areas overlying deeply weathered granite domes. It has very low seismicity (no earthquakes have been recorded at Sandy Ridge) and no volcanic or tectonic activity.
- **Natural geological barrier** — the clay bed is laterally extensive (80 km long and 40 km wide), has been stable for approximately 20 million years and is up to 36 m thick. This is capped by erosion resistant silcrete and laterite layers typically 4 to 6 metres thick in total.
- **Semi-arid desert Mediterranean climate** — averages just over 250 mm of rainfall per annum and evaporation is greater than 2,000 mm per annum. This means very little rainfall occurs across the site and generally water will evaporate before it infiltrates.
- **No surface water receptors** - there are no channels or creeks in the development envelope.
- **Very little (if any) surface water runoff** – Due to the low rainfall, high evaporation, permeable upper soil profile and gently sloping topography, significant rainfall events infiltrate quickly. There is a low likelihood of surface flows in the local catchments and any flows are short-lived and local in nature.
- **Lack of commercial mineral deposits** – there is no evidence to suggest that there is potential for economic mineral or hydrocarbon deposits beneath the kaolin deposit.
- **Topography** – the development envelope is flat to gently undulating and suitable for the construction of infrastructure and heavy vehicle movement.

- **Absence of Population** – located in an area with no population, the nearest population centre is a non-permanent camp approximately 52 km away.
- **Agricultural land use** – there is no potential for medium to high value agriculture.
- **Environmental values** – the environmental values of the development envelope are currently unknown and will be determined through investigation.
- **Heritage** – no special cultural or historical significance has been identified through a completed heritage study and consultation with stakeholders familiar with the area.
- **No flooding** – the development envelope is not subject to flooding, nor is it predicted to be in the future. The site is at very low risk of encountering cyclones.
- **Very low rates of erosion** – the development envelope is not subject to the erosive forces of high winds or rain due to the climate, soil types and topography and has been stable for thousands of years.

4.2 CURRENT ECOLOGICAL CONTEXT

The Public Environmental Review (PER) describes the potential impacts to fauna and flora species native to the area.

The following species potentially occur within the proposed development envelope due to the presence of suitable habitat, however, based on observations recorded during visits to the site, it was considered that there is little evidence to suggest the presence of these species. The list of species includes:

- Malleefowl (Leipoa ocellata).
- Rainbow Bee-eater (Merops ornatus).
- Cattle Egret (Ardea ibis).
- Great Egret, White Egret (Ardea alba).
- Fork-tailed Swift (Apus pacificus).
- Western Quoll (Dasyurus geoffroii).
- Ricinocarpos brevis (Shrub-like plant).
- Tetratheca paynterae / Paynter's Tetratheca (Shrub-like plant).
- Calytrix creswellii (Shrub-like plant).
- Lepidosperma lyonsii (Grass-like plant).

Australian species like the Kangaroo, Emu, Cockatoo and Echidna were also added for modelling purposes.

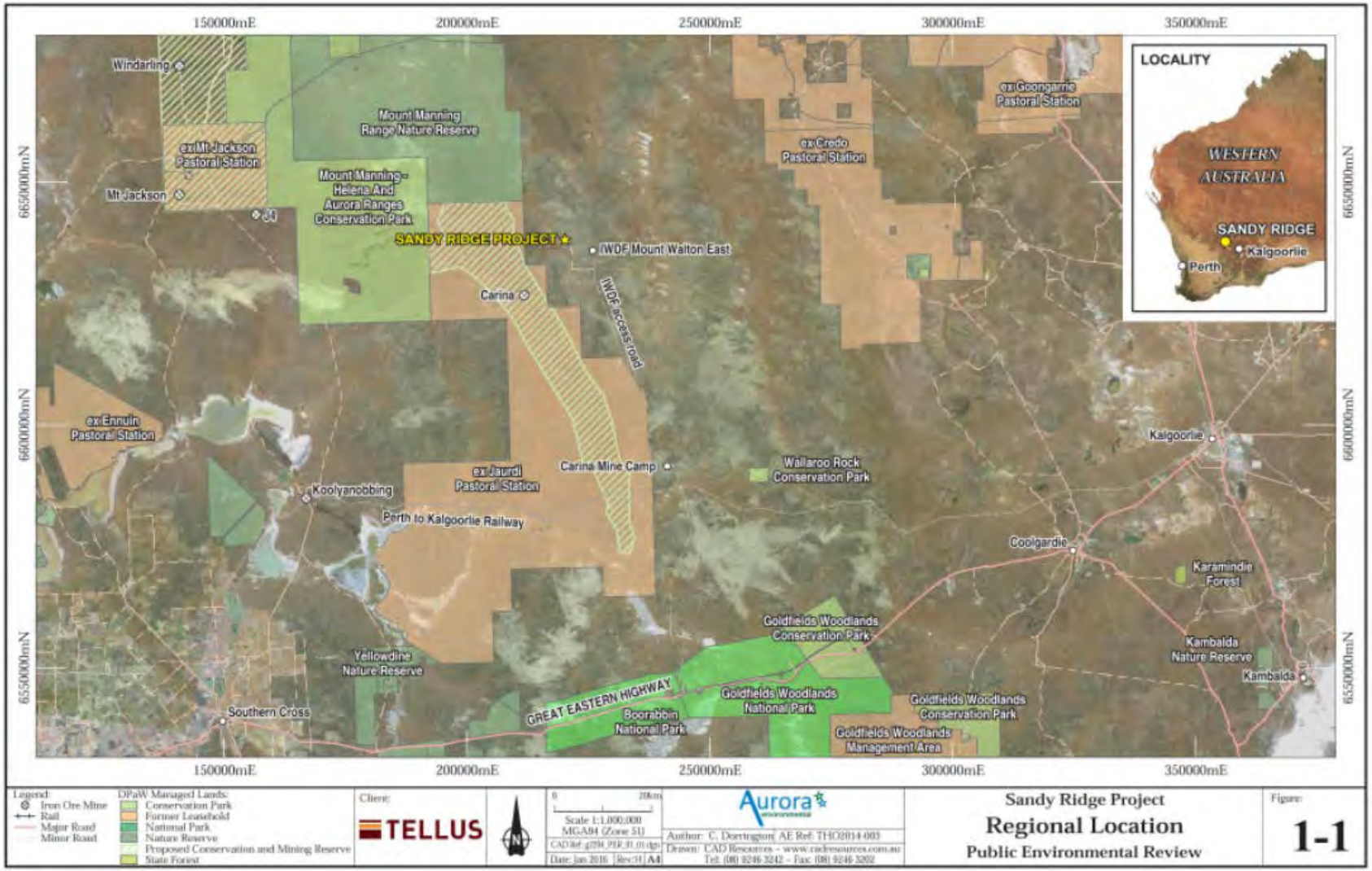

Figure 2 Location Map

5 OBJECTIVE

The framework for radiological protection of the environment is broadly consistent with that for radiation protection of people (Figure 3). The established framework, based on a concept developed by Pentreath (1998; 1999; 2002; 2004; 2005; 2009) uses Reference Plants and Animals (RAPs) as conceptual and numerical proxies to assess the relationships between exposure and dose (using simple dosimetric models), and between dose and effect (using Derived Consideration Reference Levels (DCRL) (also referred to as Environmental Reference Levels (ERL) in some literature) as numerical guides), for different taxa of flora and fauna (ARPANSA, 2010). It is applicable under all exposure situations, i.e. when activities and facilities that alter the radiation environment are planned and operating in a regulated manner (planned exposure situations), and in the case of dealing with existing exposure situations such as legacy sites.

As well as ensuring that humans are adequately protected from exposure to radiation and radioactive material stored and disposed of at the facility, there is a need to ensure that the environment as a whole is adequately protected.

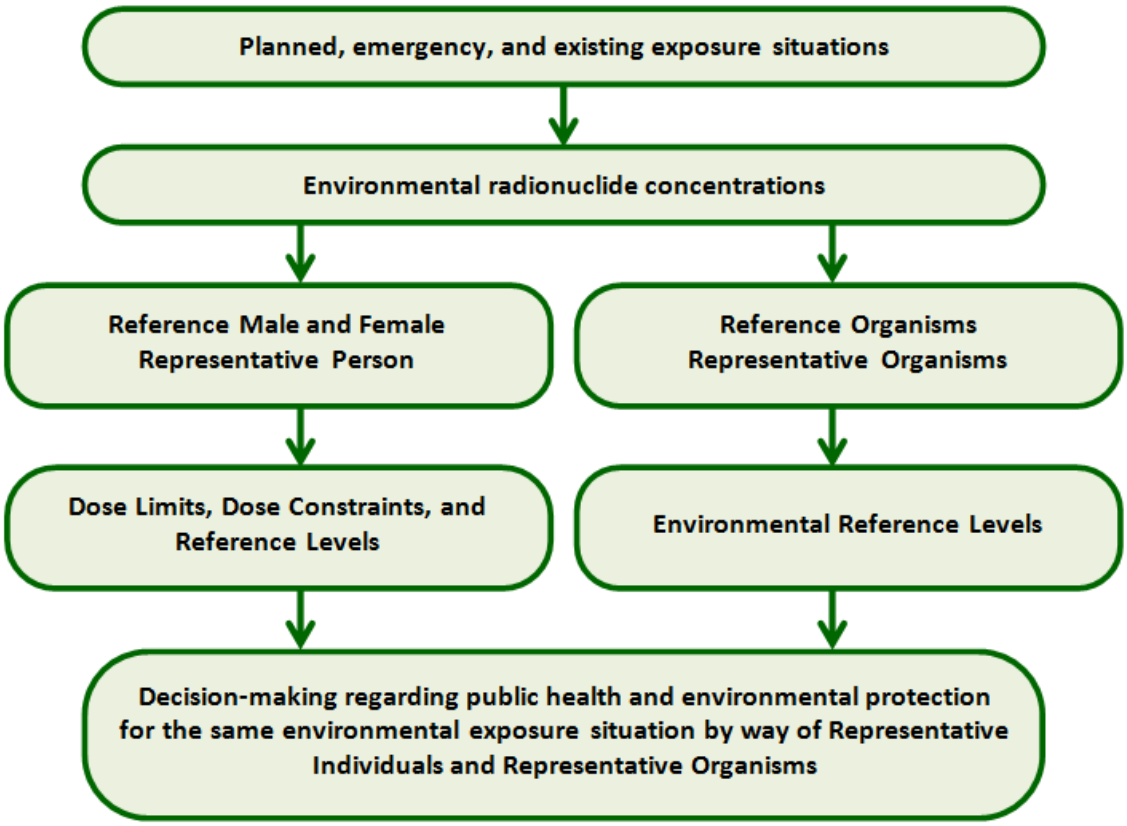

Figure 3: Framework for radiation protection of people (left) and wildlife (right)
(From ARPANSA (2015))

The objective of this assessment is to show that the radiological effects from the waste material stored and disposed of at the facility on the flora and fauna (all pathways of exposure), both during the periods of operation and closure, are at an acceptable level of risk and manageable to safeguard fauna and flora.

6 ASSESSMENT: BASIC CONCEPTS

This section outlines the basic concepts in assessment / decisions on protection of biota, namely: the dosimetric quantity; reference and representative organisms; and environmental reference levels.

6.1 DOSIMETRIC QUANTITY FOR PROTECTION OF NON-HUMAN SPECIES

The general approach to assessing potential or likely effects of ionising radiation on the health of fauna and flora involves estimations of the dose and/or the dose rate. The fundamental dosimetric quantity is the **absorbed dose**, i.e. the energy absorbed per unit mass of the material with which the radiation interacts. Absorbed dose is measured in the unit **gray** (Gy).

6.2 DEFINITION OF REFERENCE ORGANISMS

In the ERICA Tool, reference organisms are characterised by their dimensions, the concentrations of radionuclides that they exhibit relative to the environmental media with which they are associated and the fractions of the time that they are present within, or at the surface of, these various environmental media. The reference organisms selected for the ERICA Integrated Approach are listed in Table 1 below. They have been defined and used for the derivation of geometric relationships between radiation sources and organisms, as well as for considerations of the dosimetry of both external and internal exposure. The reference organisms can be grouped into three general ecosystem categories, namely terrestrial, freshwater and marine. In the current evaluation, only terrestrial organisms were considered.

Table 1: ERICA Reference Animals and Plants (RAPs)

Freshwater	Marine	Terrestrial
Amphibian *(frog)*	(Wading) bird *(duck)*	Amphibian *(frog)*
Benthic fish	Benthic fish *(flat fish)*	Bird *(duck)*
Bird *(duck)*	Bivalve mollusc	Bird egg *(duck egg)*
Bivalve mollusc	Crustacean *(crab)*	Detritivorous invertebrate
Crustacean	Macroalgae *(brown seaweed)*	Flying insects *(bee)*
Gastropod	Mammal	Gastropod
Insect larvae	Pelagic fish	Grasses and herbs *(wild grass)*
Mammal	Phytoplankton	Lichen and bryophytes

Freshwater	Marine	Terrestrial
Pelagic fish *(salmonid/trout)*	Polychaete worm	Mammal *(rat, deer)*
Phytoplankton	Reptile	Reptile
Vascular plant	Sea anemones/true coral	Shrub
Zooplankton	Vascular plant	Soil invertebrate (worm) *(earthworm)*
	Zooplankton	Tree *(pine tree)*

6.3 TERRESTRIAL REFERENCE ORGANISMS GEOMETRIES

One of the key practical purposes of reference organisms is to provide a means for the estimation of dose rates, where the ellipsoid can be used – by varying its axes – as a reasonable approximation for much of the existing wildlife on Earth (see Figure 4). Radiation damage arises from the ionisation that follows the path that radiation takes as it passes through tissues. Hence the dimensions of the organisms have relevance for the degree of radiation damage that may occur. These estimates, in turn, provide a basis for subsequent assessment of the likelihood and degree of radiation effects, using available effects information.

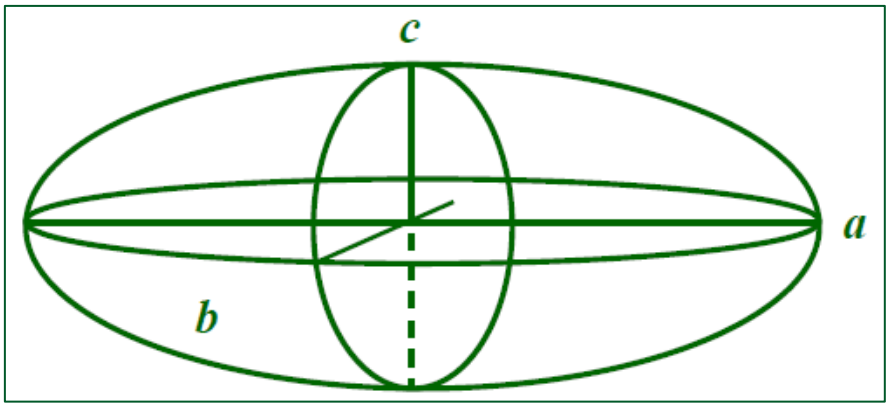

Figure 4: An ellipsoid, outlining the axes (a, b and c) that can be varied to accommodate for the different shapes of reference organism (image ARPANSA (2015)))

In summary, the simplifications introduced when using reference organisms include:

• the representation of different forms of fauna and flora by simple shapes (e.g. ellipsoids);

• an assumption of homogeneous radionuclide distribution in the tissues of the organism (internal dosimetry) and in environmental media (external dosimetry); and

• generic 'biology' in terms of habitat, occupancy, life cycle, reproduction and other factors.

Table 2: Geometries for some terrestrial fauna and flora species

Organism	Geometry defined by	Mass	Dimensions		
			Height	Width	Length
		kg	cm	cm	cm
Soil invertebrate (Worm)	ICRP - Earthworm	0.00524	1	1	10
Detritivorous invertebrate	FASSET - Woodlouse	0.00017	0.31	0.61	1.74
Flying insects	ICRP - Bee	0.000589	0.75	0.75	2.0
Gastropod	ERICA - Snail	0.0014	0.93	1.54	1.88
Lichen and bryophytes	ERICA - Bryophyte	0.00011	0.229	0.229	4.01
Grasses and herbs	ICRP – Wild Grass	0.00262	1.0	1.0	5.0
Shrub	ICRP – Wild Grass	0.00262	*1.0	*1.0	*5.0
Tree	ICRP – Pine Tree	471	30	30	1000
Mammal *(Rat)*	ICRP – Rat	0.314	5.0	6.0	20
Mammal *(Deer)*	ICRP – Deer	245	60	60	130
Bird	ICRP – Duck	1.26	8.02	10	30
Reptile	ERICA - Snake	0.744	3.49	3.49	116
Amphibian	ICRP - Frog	0.0314	2.5	3.0	7.99

**It was assumed that Shrubs has the same dimensions as grasses and herbs, since mass, ksi and chi are equal. Ksi (ξ) and chi (χ) are scaling parameters.*

from ARPANSA (2015)

In addition to these, representative fauna and flora species were included in the modelling to encompass species that may occur in the proposed development envelope (e.g. malleefowl) and are representative of the Australian landscape (e.g. emu).These are given in table 3.

Table 3:Geometries of Australian fauna and flora species

Organism	Geometry defined by	Mass	Dimensions		
			Height	Width	Length
		kg	cm	cm	cm
Malleefowl	Bird	2.5	11	13	33
Rainbow Bee-eater	Bird	0.027	3.252	3.252	4.878
Emu	Bird	50.0	38	36	70
Cockatoo	Bird	0.79	7.7	8.8	23.1
Cattle Egret	Bird	0.5	6.65	7.6	19.95
Great Egret	Bird	1	8.4	9.6	25.2
Fork-tailed Swift	Bird	0.035	3.54	3.54	5.31
Katydid Cricket	Insect	0.000589	0.75	0.75	2
Kangaroo	Mammal	54.0	36	36	76
Echidna	Mammal	4.5	13	18	37
Western Quoll	Mammal	1.1	9.12	7.6	30.4
Ricinocarpos brevis	Plant	0.00262	1	1	5
Paynter's Tetratheca	Plant	0.00262	1	1	5
Calytrix creswellii	Plant	0.00262	1	1	5
Lepidosperma lyonsii	Plant	0.00262	1	1	5

from ARPANSA (2015)

6.4 TERRESTRIAL REFERENCE ORGANISMS OCCUPANCIES

For the terrestrial ecosystem, the system becomes more complicated owing to the fact that for each reference organism only certain source-target configurations, i.e. presence of the reference organism at a specific place within its habitat, are permitted in the modelling. The permitted occupancies are provided in Table 4. Table 4 also summarises selected occupancies for additional species specific to the modelling

Table 4:Occupancy for selected terrestrial fauna and flora species

Reference Organism	In Soil	On Soil	In Air
Soil invertebrate (Worm) / Annelid	x		
Detritivorous invertebrate	x	x	
Flying insects		x	x[(a)]
Gastropod	x	x	
Lichen and bryophytes		x	
Grasses and herbs		x	
Shrub		x	
Tree		x	
Mammal *(Rat)*	x	x	
Mammal *(Deer)*		x	
Bird		x	x[(b)]
Reptile	x	x	
Amphibian	x	x	
Added Organism	**In Soil**	**On Soil**	**In Air**
Malleefowl		1	
Rainbow Bee-eater		1	
Emu		1	
Cockatoo		0.5	0.5
Cattle Egret		0.8	0.2
Great Egret		0.8	0.2
Fork-tailed Swift		0.5	0.5
Katydid Cricket	0.5	0.5	
Kangaroo		1	
Echidna	0.5	0.5	
Western Quoll	0.5	0.5	
Ricinocarpos brevis		1	
Paynter's Tetratheca		1	
Calytrix creswellii		1	
Lepidosperma lyonsii		1	

[(a)] DCC calculated for on soil
[(b)] DCC calculated for height of 3 m above ground level
For all in soil geometries, the DCC is derived using a 50-cm depth uniform volume source
For all on soil geometries and in air geometry for bird, the DCC is derived using a 10-cm depth uniform volume source

6.5 ENVIRONMENTAL SCREENING AND DERIVED CONSIDERATION REFERENCE LEVEL (DCRL'S)

DCRL's are dose rates to fauna and flora, excluding background levels, at which a more considered evaluation of the situation and the potential detriment to biota might be reasonable, and which should be considered in the over-all optimisation process (ARPANSA (2015).

DCRL can be considered as:

• A dose rate increment to fauna and flora above the natural and normal background level, which might result in detrimental health effects in the environment.

• A point of reference guiding optimisation, i.e. the level of effort expended on environmental protection, dependent on the overall management objectives and exposure situation.

As demonstrated in figure 5, the screening value of 10 µGy/h is the general default ERICA dose rate below which no effects at a population level to flora and fauna species are expected. (ARPANSA (2015))

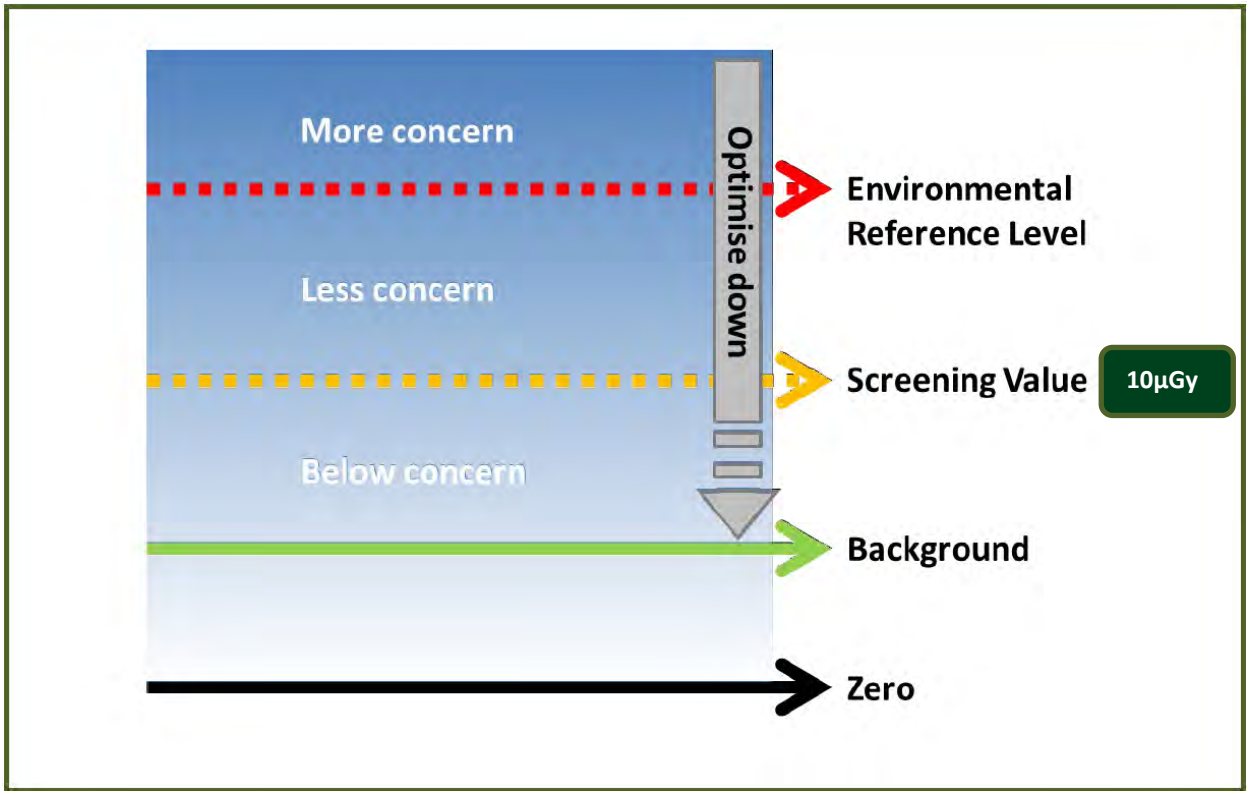

Figure 5: Use of environmental reference levels (or DCRL) and screening levels of dose rate for protection of the environment
(from ARPANSA (2015))

An international literature review has been conducted to derive exposure levels below which there is not expected to be significant population level effects for a range of organism types.

Different values have been derived for similar organisms due to the use of alternative data and/or application of differing levels of precaution. Note that (except where otherwise indicated) IAEA and UNSCEAR values refer to population effects, whereas ICRP give dose rate bands where effects may occur to individuals of that type of Reference Animals and Plants (RAPs).

Table 5: Summary of DCRL (µGy h-1) below which population level effects are not expected to occur

Organism	IAEA(1992)	UNSCEAR (1996,2011)	ICRP (2008)
Terrestrial Plants	400	100**	
Reference pine tree			4-40
Reference wild grass			40-400
Animals	40	40-100**	
Reference bee			400-4000
Reference earthworm			400-4000
Reference duck			4-40
Reference deer			4-40
Reference rat			4-40
Aquatic			
Freshwater organism	400	400	
Reference frog			40-400
Reference trout			40-400
Marine organism		400	
Reference crab			400-4000
Reference flatfish			40-400
Reference brown seaweed			40-400

*'Reference *organism type'* refers to the ICRP's Reference Animals and Plants (RAPs).

**Most highly exposed individuals.

7 ASSESSMENT OF RADIOLOGICAL IMPACTS ON FAUNA AND FLORA

In the current evaluation, four exposure scenarios were modelled using ERICA Tier 2 assessments:

- Scenario 1 – exposure of fauna and flora present in the area surrounding the radioactive waste warehouse.
- Scenario 2 – exposure to windblown material originating from operational stockpiles e.g. plant tails; ore, sand, laterite and silcrete stockpiles (during mining phase).
- Scenario 3 – exposure to windblown material originating from adhoc stockpiles e.g. radioactive materials received as bulk or from emergency clean-up operations.
- Scenario 4 – exposure post closure, with capping material and rehabilitation of the GSIF established as well as for the duration of the institutional control period.

Figure 6 is the conceptual infrastructure lay-out of the Proposal, overlain by areas relevant to modelled scenarios of exposure to fauna and flora during the operational phase (Scenarios 1 to 3) and post closure (Scenario 4).

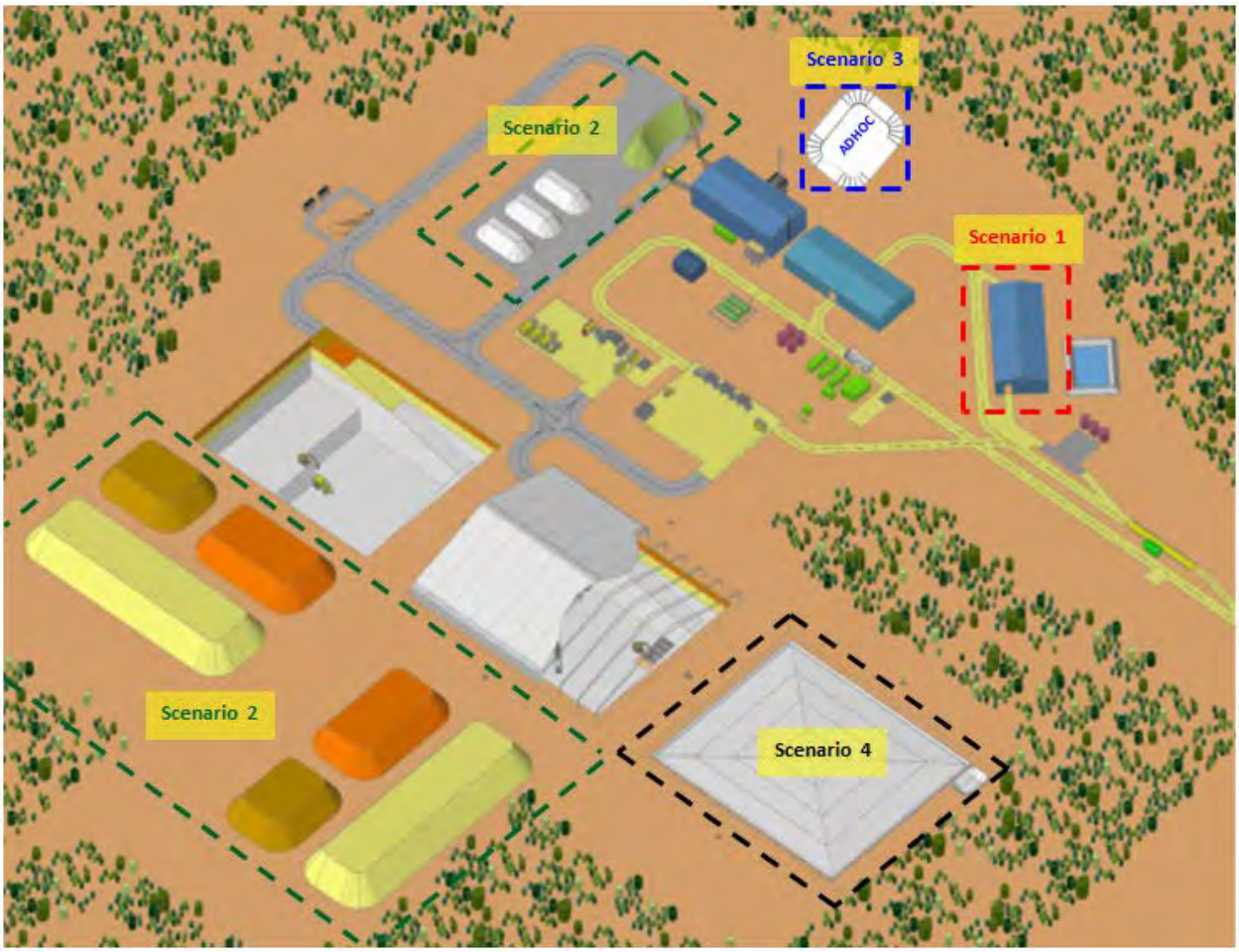

Figure 6: Conceptual Infrastructure Lay-out of the Sandy Ridge

Figure 7 shows the 7 m of capping material between the buried low level radioactive waste and the surface (Scenario 4).

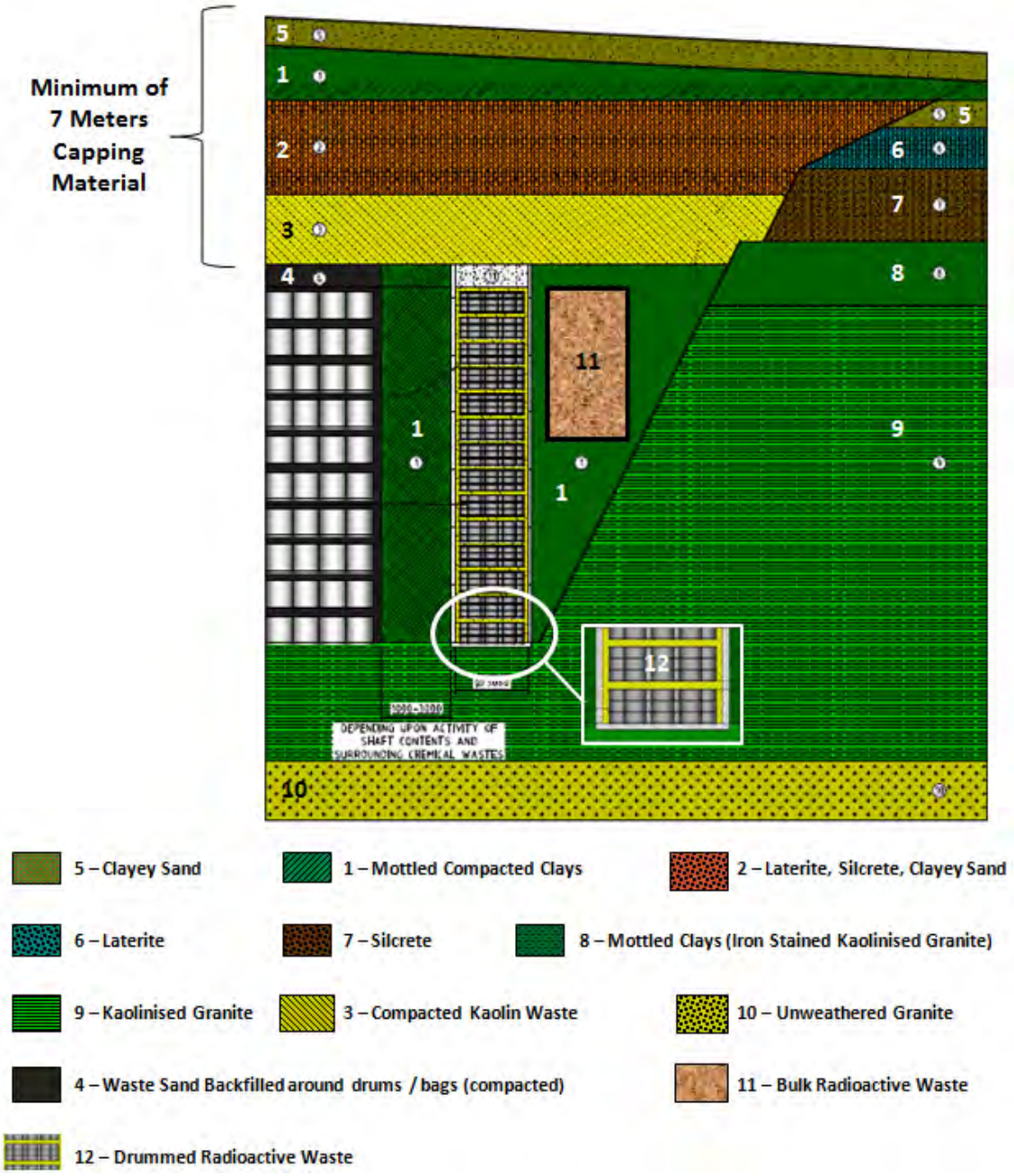

Figure 7 :Post Closure and Rehabilitation of the GSIF (Scenario 4)

7.1.1 ASSESSMENT OF RADIOLOGICAL IMPACTS TO FAUNA AND FLORA DURING THE OPERATIONAL PHASE OF THE PROJECT

Scenario 1 (exposure of fauna and flora present in the area surrounding the Radioactive Waste Warehouse)

As the facility will be accepting radioactive waste materials of various types, e.g. sealed sources, NORM containing pastes / sludges, contaminated solid material (e.g. plant equipment, laboratory PPE) and bulk contaminated soils or sands, an assessment was conducted to evaluate the potential radiological impact to fauna and flora surrounding the Radioactive Waste Warehouse used for storage of such materials.

According to RPS 5 [18], Section 5.1.2 (b), "a store for portable density / moisture gauges must be designed and constructed so that the radiation levels outside the store do not result in an ambient dose equivalent rate or directional dose equivalent rate, as appropriate, that exceeds 10 µSv/h". Assuming a conversion of 1 µGy to 1 µSv, the Radioactive Waste Warehouse will be designed and constructed such that dose rates for all organisms present outside the facility are below the threshold dose rate of 10 µGy/h. No risk to any biota is therefore foreseen from material stored within the facility.

Specific controls for the various materials potentially stored at the facility are summarised below.

Sealed sources will upon receipt be stored in the Radioactive Waste Warehouse, unpacked, inspected and verified. After verification, sources will be secured in a 60 L drum inside a 200 L drum. Cement slurry will be added to the 60 L drum to fill all the void spaces and to cover all the items. The cement filled 60 L drums will be placed in the centre of a 200 L drum, which is then filled with concrete. The 200 L drum will be marked with its identification number and labelled. These drums will be stored until the shaft is prepared for disposal. It is not foreseen that any contact with or dispersal of sources into the environment would be a likely scenario. No ERICA modelling has therefore been conducted using sealed sources as environmental media.

NORM containing pastes, sludges or liquids, will be stored in the Radioactive Waste Warehouse or in sea containers on hardstand (dependent upon activity). In campaigns waste will be unpacked, inspected and verified by laboratory testing. If required the waste will then be treated with absorbent and pozzolanic materials to form a slurry which will solidify and stabilise the waste. The slurry can be poured into drums, moulds, or contained sections of the cell where it will set. Again, it is not foreseen that any contact with or dispersal of these materials into the environment would be a likely scenario, given the controls intended. One scenario has however been modelled using radium sludge as environmental media, to simulate the unlikely event of

bulk storage of spadeable sludge on stockpiles with the potential to create pathways of distribution to the surrounding environment.

Contaminated solid material will be stored in Radiation Store building or in sea containers on hardstand (dependent upon activity) until suitable space is available in cell. Depending upon physical size and shape of materials, type and activity of radiation, these wastes can either be:

- Compacted in drums and filled with kaolin or cement grout prior to disposal.
- Crushed or cut to remove void space and fill remaining voids in with cement grout or kaolin solids.
- If necessary, place entire sea-container in cell, cut holes in top and fill all void space with cement grout.

It is not foreseen that any contact with or dispersal of the materials (as described for Scenario 1 above) into the environment would be a likely scenario, given the controls intended.

Scenario 2 (exposure to windblown material originating from operational stockpiles e.g. plant tails; ore, sand, laterite and silcrete stockpiles).

As plant tails, kaolin ores, and other bulk materials will be stockpiled during the operational phase of the project, the potential exist for these materials to be distributed into the surrounding environment through e.g. wind-, water- and material handlings actions, therefore potentially impacting on local fauna and flora. It is foreseen that such materials would be NORM-containing nuclides of the U-238, U-235 and Th-232 decay series.

A matrix of activity concentrations (per biota type) was therefore calculated which, when modelled, would give rise to dose levels (µGy h-1) below which species population level effects are not expected to occur. In creating this matrix, a Th-232 to U238 activity (Bq/g) ratio of 1 : 1 was assumed. Natural uranium was also assumed, i.e. the same isotopic ratio found in nature between U-235 and U-238, rendering an activity ratio of U-235 = 0.045 x U-238 with all chains being in Secular equilibrium.

Scenario 3 (exposure to windblown material originating from adhoc stockpiles e.g. radioactive materials received as bulk or from emergency clean-up operations)

Bulk contaminated soils or sands will be delivered to site in either bulka bags, shipping containers or as wetted down sand, depending on volume and physical characteristics of material. Practical transport will be arranged to coincide with a disposal campaign so it can be disposed of directly into pit, but if not viable, the material will be stored in the Radioactive Waste Warehouse. For large volumes of material, separate stockpile areas will be set up (adhoc stockpiles), and dust control measures introduced. These are discussed in section 9.2 of the radiation management plan and include a designated stockpile area with concrete slab and

bunded walls, closing stockpile with tarp material, dust suppression agents and a monitoring program to confirm efficiency of controls implemented.

ERICA Modelling was conducted on adhoc stockpiles with the potential to be released into the environment as result of e.g. windblown dispersal, thus potentially affecting local biota. It is foreseen that such materials would be NORM-containing nuclides of the U-238, U-235 and Th-232 decay series. No controls were considered in this assessment to demonstrate worst case scenario exposure conditions.

To form a baseline for potential radionuclide activity concentrations to be used as inputs into modelling scenarios, industry information on typical activity ranges of various type of potential bulk wastes, along with Category A and Category C waste (NHMRC, 1992) were collated as per Table 6.

Table 6: – Typical industry and waste-characterised activity ranges as per Australian regulation

Nuclide	Activity Concentration (Bq/g)							
	U & Th Sands*	Radium Scale#	Radium Sludge#	Oil & Gas+	Category A Waste@	Category C Waste@	VLLW^	LLW^
Pa-231	0.7						14.3	57.1
Pb-210	10	0.02-75	0.1-1300		≤ 5	5 - 500		
Po-210	4	0.02-1.5	0.004-160		≤ 5	5 - 500		
Ra-226	10	0.1-15000	0.05-800	1400	≤ 5	5 - 500	14.3	57.1
Ra-228	70	0.05[!]-2800	0.5-50	1587	≤ 10	5 - 500		
Th-227	0.5							
Th-228	70				≤ 10	5 - 500		
Th-230	11				≤ 5	5 - 500	14.3	57.1
Th-232	60	0.001-0.002	0.002-0.01		≤ 10	5 - 500	14.3	57.1
U-234							14.3	57.1
U-235	0.5						14.3	57.1
U-238	10	0.001-0.5	0.005-0.01		≤ 5	5 - 500	14.3	57.1
Total Activity concentration of Long-Lived alphas with T1/2 > 40 years:							1 - 100	100 - 400

* With reference to [1], Section 4.2.2
+ With reference to [1], Section 4.2.3
# Radium Scale & Sludge as per Table 19, Section 12.2.3 of [2]. For modelling purposes, the upper scale concentrations were used.
! Radium Scale as per Table 4, Section 1.8 of [3].
@ Category A and Category C Waste as per Secular Equilibrium Conditions [4], [5] and [6]. For modelling purposes, the upper scale concentrations were used.
Note that U-235 chain for Category A & C wastes, alpha and beta/gamma emitters' limits are very high and thus not included, since limiting nuclides are alphas of the Th-232 and U-238 chains
^ NORM with T1/2 > ~ 40 years as per [7] - long-lived alphas from the U-238, U-235 and Th-232 decay chains. The assumption was made that boundaries between VLLW, LLW and ILW refer to total activity (i.e. summation of long-lived alpha activity concentrations) and that decay chains are in secular equilibrium

7.1.2 ASSESSMENT OF RADIOLOGICAL IMPACTS TO FAUNA AND FLORA POST CLOSURE AND REHABILITATION

Scenario 4 (exposure post closure, with capping material and rehabilitation of the cell established as well as for the duration of the institutional control period).

To determine whether a minimum cover thickness of 7 meters (upon closure) would provide sufficient shielding from encapsulated waste material, an estimate of unshielded gamma dose rate is required combined with the half-value-layer of the material used for the cover (shielding material). The following mathematical equations are relevant and were used to determine whether cover shielding would be sufficient for each of the waste material types listed in Table 6.

Unshielded dose rate: $I_0 = \Gamma A / d^2 = \Gamma$ x Activity / (distance from waste source)^2

Where:
I_0= intensity (or dose rate) before shielding (µSv/h)
Γ= Dose conversion factor: Dose rate (µSv/h) at 1 m from a source per 1 GBq activity of the source
A = Activity of the source (GBq)
d = distance from the source (m)

Shielded dose rate: $I = I_0 / 2^n$

Where
I = intensity (or dose rate) after shielding (µSv/h)
I_0= intensity (or dose rate) before shielding (µSv/h)
n = number of half value layers (assumed that cover material would be Packed Soil[1] i.e. 7 m minimum cover material would relate to 77 halve value layers)

[1] As various materials are used for cover materials with various densities, a density (1.99 g/cm^3) of Packed Soil, with a Halve value layer of 9.1 cm (0.091 m) have been assumed

Table 7: Dose Rate (gamma) resulting from various waste material types before and after covering with 7 m of capping material

Description	Waste material Type								Criteria Activity
	U & Th Sands*	Radium Scale#	Radium Sludge#	Oil & Gas#	Cat A Waste@	Cat C Waste@	VLLW@	LLW@	
Ref Nuclide Selected	Th-232*	Ra-226#	Ra-226#	Ra-226#	Th-232	Th-232	Th-232@	Th-232@	Th-232
Activity Concentration of Source	70 Bq/g	17800 Bq/g	850 Bq/g	3000 Bq/g	15 Bq/g	1000 Bq/g	100 Bq/g	400 Bq/g	3700 Bq/g
Source Activity^	1.75E+05	4.45E+07	2.13E+06	7.50E+06	3.75E+04	2.50E+06	2.50E+05	1.00E+06	9.25E+06
I_0= intensity before shielding$ µSv/h	4.20E+08	9.92E+11	4.74E+10	1.67E+11	9.00E+07	6.00E+09	6.00E+08	2.40E+09	2.22E+10
I = intensity after shielding µSv/h	2.9E-15	6.9E-12	3.3E-13	1.2E-12	6.3E-16	4.2E-14	4.2E-15	1.7E-14	1.5E-13

*Th-232 is the dominant nuclide in Mineral Sands and the Head-of-Chain (U-238 + Th-232) activity concentration was assigned to Th-232 for calculation purposes

#Ra-226 selected as the dominant nuclide in the Oil & Gas, Radium Scale and Radium Sludge wastes and Ra-226 + Ra-228 activity concentration was assigned to Ra-226 for calculation purposes

@Th-232 selected as the dominant nuclide in Category A, Category C, VLLW and LLW and total chain activity concentration was assigned to Th-232 for calculation purposes

^Activity of Sources calculated based on a mass of 2,000,000 tonne (total waste after 25 years production) per material type

$ I_0 taken at a distance (d) from the source of 10 cm (0.1 m)

! As various materials are used for cover materials with various densities, a density (1.99 g/cm^3) of Packed Soil, with a Halve value layer (HVL) of 9.1 cm (0.091 m) have been assumed

As demonstrated from Table 7, external gamma dose rate on the surface post closure (minimum cover of 7 m) would be negligible (background radiation levels), even if all radioactive waste (2,500,000 tonnes) placed in the cell was high activity concentration radium scales at an activity concentration of 17800 Bq/g radium (Ra-226 and Ra-228 combined). Calculation demonstrates that the thickness of the cell capping layers will be a sufficient control measure to reduce radiation levels at the surface of the cell. Therefore no radiation impacts will occur to plants and animals that grow, use or traverse the cell caps during the institutional control period.

Radiation exposure to fauna and flora (post closure) would therefore be only as a result of any radiation present in the top layer of cover material. ERICA Modelling was therefore conducted assuming that the top layer of cover material would have similar radiological characteristics to background soils in the surrounding environment. A cover uranium content of 11 ppm [8] was therefore accepted (as representative of background soil) with the further assumption that thorium would also be present at 11 ppm. Assuming secular equilibrium and an activity ratio of U-235 = 0.045 x U-238, activity concentrations of individual nuclides were calculated as per Table 8.

If radionuclide levels in the cap material are at or below those given in Table 8 there will be no risk to Fauna and Flora residing on the cap.

Table 8:Activity concentrations (Bq/g) of the top layer of cover material upon closure

Nuclide	Activity Concentration (Bq/g)
	Closure Capping Material$
Pa-231	0.006
Pb-210	0.14
Po-210	0.14
Ra-226	0.14
Ra-228	0.04
Th-227	0.006
Th-228	0.04
Th-230	0.14
Th-232	0.04
U-235	0.006
U-238	0.14

$ Regional sampling of the granite shows the uranium content to be consistently at or below 11ppm [8]. The assumption was made that Th-232 ppm is equal to that of U-238, that U-235 to U-238 ratio is 0.045 (based on activity concentration) and that all three decay chains are in secular equilibrium.

8 FINDINGS AND CONCLUSIONS

8.1 FINDINGS

Appendix A to I summarises results of the various ERICA modelling assessments done per material type, detailing the following: activity concentration of source media (Bq/kg) to which biota are exposed; contributions of individual radionuclides to total, internal and external dose rate for each organism; and activity concentration or individual radionuclides transferred from source media into living organisms.

Scenario 1 (exposure of fauna and flora present in the area surrounding the radioactive waste warehouse)

The Radioactive Waste Warehouse will be designed and constructed such that dose rates for all organisms present outside the warehouse are below the threshold dose rate of 10 µGy/h. No risk to any biota is therefore foreseen from material stored within the Radioactive Waste Warehouse

Scenario 2 (exposure to windblown material originating from operational stockpiles e.g. plant tails; ore, sand, laterite and silcrete stockpiles).

A matrix of activity concentrations (per biota type) was calculated which, when modelled, would give rise to dose levels (µGy h-1) below which species population level effects (derived effect levels) are not expected to occur. This activity concentration matrix is summarised in Table 9.

Table 9: Matrix of calculated activity concentrations (per species type) giving rise to dose levels below which species population level effects are not expected to occur

Organism Group	ERICA Screening Level	Derived Effects Levels (µGy/h)	
	10 µGy/h$	40 µGy/h	400 µGy/h
Plants (Shrubs & Grasses)@	0.25*	1*	10* - 11*
Plants (Trees)#	3.5*	15*	160*
Birds#	3*	12* – 13*	120* - 130*
Mammals Large#	1.8*	8*	80*
Mammals Small#	1.5* – 1.8*	6* – 7*	60* - 75*
Insects - Flying@	1.5* - 2*	7* - 9*	90*
Insects – Ground dwelling@	1.5* - 2*	7* - 9*	68* -85*

*Head of Chain activity concentration (Bq/g), i.e. Bq/g Th-232 + Bq/g U-238
Assumed Th-232: U238 activity (Bq/g) ratio of 1: 1
U-235 and U-238 activity ratio of U-235 = 0.045 x U-238
All decay chains assumed to be in Secular equilibrium
@Organisms with DCRL levels at 400 µGy/h
#Organisms with DCRL levels at 40 µGy/h

[$]ERICA Environmental Screening level

Scenario 3 (exposure to windblown material originating from adhoc stockpiles e.g. radioactive materials received as bulk or from emergency clean-up operations)

Table 10 is a summary of modelled total dose rate (per species evaluated) as a result of exposure to typical industry waste and Australian waste categories. As a first approach, the extreme condition was modelled, assuming that all organisms are exposed 100 percent of the time to stockpiled material i.e. simulating a condition of living on top of waste stockpiles or burrowing within.

Table 10: Total dose rate per organism exposed to different waste materials at 100% occupancy of the site

Organism	Total Dose Rate (µGy/h)							
	U & Th Sands	Radium Scale	Radium Sludge	Oil & Gas	Category A Waste	Category C Waste	VLLW	LLW
Grasses & Herbs	2697.4	3.7E+05	2.1E+04	3.52E+04	542.6	3.7E+04	680.0	2719.8
Malleefowl	92.8	8.0E+04	4.3E+03	7.75E+03	33.8	3.1E+03	91.0	363.8
Rainbow Bee-eater	96.3	8.1E+04	4.4E+03	7.83E+03	34.4	3.2E+03	91.5	365.9
Shrub	1445.4	6.8E+05	3.8E+04	6.39E+04	425.9	3.6E+04	851.6	3406.2
Bird	97.8	8.3E+04	4.5E+03	8.05E+03	35.2	3.2E+03	93.8	375.0
Echidna	142.5	1.0E+05	5.8E+03	9.77E+03	55.1	5.1E+03	323.8	1295.2
Emu	84.7	7.9E+04	4.3E+03	7.59E+03	32.4	3.0E+03	89.8	359.2
Flying insects	177.8	9.4E+04	5.2E+03	9.07E+03	50.6	4.3E+03	146.0	583.9
Annelid	308.0	1.0E+05	5.7E+03	1.03E+04	73.5	5.7E+03	215.0	860.2
Amphibian	181.4	1.0E+05	6.1E+03	1.04E+04	64.7	5.8E+03	160.8	643.2
Cockatoo	93.9	8.1E+04	4.3E+03	7.77E+03	34.0	3.1E+03	91.1	364.4
Kangaroo	130.2	1.2E+05	6.3E+03	1.10E+04	49.3	4.7E+03	342.5	1370.0
Kytydid Cricket	210.6	1.0E+05	5.5E+03	9.85E+03	56.6	4.7E+03	151.6	606.5
Mammal - large	108. 8	9.6E+04	5.5E+03	9.08E+03	49.4	4.8E+03	319.1	1276.4
Mammal - small	179.5	1.0E+05	5.9E+03	1.03E+04	61.2	5.5E+03	326.9	1307.7
Reptile	210.7	1.0E+05	6.1E+03	1.03E+04	71.1	6.3E+03	327.5	1310.0
Tree	76.2	2.9E+04	1.9E+03	2.90E+03	28.5	2.5E+03	38.4	153.6
Cattle Egret	95.0	8.1E+04	4.4E+03	7.80E+03	34.2	3.1E+03	91.3	365.1
Great Egret	94.2	8.1E+04	4.4E+03	7.78E+03	34.0	3.1E+03	91.2	364.6
Fork-tailed Swift	95.1	8.1E+04	4.4E+03	7.80E+03	34.2	3.1E+03	91.3	365.1
Western Quoll	149.6	1.0E+05	5.8E+03	9.92E+03	56.3	5.2E+03	324.8	1299.1
Ricinocarpus brevis	1455.2	6.9E+05	3.9E+04	6.49E+04	429.3	3.6E+04	861.7	3446.7
Paynter's Tetratheca	1455.2	6.9E+05	3.9E+04	6.49E+04	429.3	3.6E+04	861.7	3446.7
Calytrix Creswellii	1455.2	6.9E+05	3.9E+04	6.49E+04	429.3	3.6E+04	861.7	3446.7
Lepidosperma Lyonsii	2709.2	3.8E+05	2.2E+04	3.58E+04	545.3	3.8E+04	684.7	2738.8

These results demonstrate that modelled dose rates for all organisms exposed to stockpiled waste material for 100 percent of the time are well above the threshold dose rate of 10 μGy/h.

Dose rate to all grass and shrub-like plant species are also above the DCRL of 400 μGy/h upon exposure to any of the waste materials evaluated. Dose to insect species exposed to U and Th Sands, Category A waste or VLLW materials are below the DCRL of 400 μGy/h, but full-time exposure to other waste materials predicted doses above DCRL.

Dose rate to all mammals (large and small) are above the DCRL of 40 μGy/h upon exposure to any of the waste materials evaluated. Dose to bird species and to trees exposed to Category A waste is below the DCRL of 40 μGy/h, but full-time exposure to other waste materials predicted doses above DCRL.

Scenario 4 (exposure post closure, with capping material and rehabilitation of the GSIF established as well as for the duration of the institutional control period).

As demonstrated in Section 6.2.2 of this report, external gamma dose rate on the surface of the cell caps post closure (minimum cover of 7 m) would be negligible, even if all radioactive waste (2,500,000 tonnes) would be high activity concentration radium scales at an activity concentration of 17800 Bq/g radium (Ra-226 and Ra-228 combined). This calculation demonstrates that the thickness of the cell capping layers will be a sufficient control measure to reduce radiation exposure at the surface of the cell. Therefore no radiation impacts will occur to plants and animals that grow, use or traverse the cell caps during the institutional control period

Table 11 summarises species' total dose rate upon closure (as result of exposure to the top layer of the capping material), i.e. after establishment of capping the waste with 7 meters of material.

Table 11: Total dose rate per organism post-closure

Organism	Total Dose Rate (μGy/h)
	Closure Capping Material
Grasses & Herbs	7.2
Malleefowl	0.8
Rainbow Bee-eater	0.8
Shrub	8.7
Bird	0.8
Echidna	1.4
Emu	0.8
Flying insects	1.1
Annelid	1.3
Amphibian	1.5
Cockatoo	0.8
Kangaroo	1.3

Organism	Total Dose Rate (µGy/h)
	Closure Capping Material
Kytydid Cricket	1.1
Mammal - large	1.4
Mammal - small	1.5
Reptile	1.7
Tree	0.6
Cattle Egret	0.8
Great Egret	0.8
Fork-tailed Swift	0.8
Western Quoll	1.4
Ricinocarpus brevis	8.8
Paynter's Tetratheca	8.8
Calytrix Creswellii	8.8
Lepidosperma Lyonsii	7.2

Upon closure and during the institutional control period, the modelling demonstrates that dose rates for all organisms are below the threshold dose rate of 10 µGy/h. No risk to any biota is therefore foreseen when wastes are sufficiently capped.

8.2 CONCLUSIONS & RECOMMENDATIONS

From the Scenario 3 modelling, it was indicated that exposure to stockpiled waste material at full-time occupancy could result in radiological impacts too high for adequate protection of non-human biota, it is imperative to ensure that stockpiled radioactive bulk materials are sufficiently contained to prevent windblown (or other) dispersal to the surrounding environment. It is also recommended to establish control measures preventing fauna species access to stockpiled bulk materials or pits during the operational phase of the project. The controls that will be implemented to ensure the risk is mitigated and are discussed in the waste management plan

From the Scenario 1 modelling (exposure of fauna and flora present in the area surrounding the radioactive waste warehouse), and under the condition that the storage warehouse will be designed and constructed such that dose rates for all organisms present outside the warehouse are below the threshold dose rate of 10 μGy/h, no risk to any biota is therefore foreseen from material stored within the radioactive waste warehouse.

Upon closure, with a minimum capping of 7 meters, and for the duration of the institutional control period, no risk to non-human biota is foreseen, as modelled dose rates for all organisms are below the threshold dose rate of 10 μGy/h.

9 DEFINITIONS & ACRONYMS

Absorbed Dose – The energy deposited within any material by the passage through it of ionising radiation (Grays: 1 Gy = 1 joule / kg)

Activity concentration – means the concentration of a radioactive substance in any particular material expressed in terms of the activity of the radionuclide in Becquerel per kilogram of the material.

Biosphere – that part of the environment that is normally inhabited by living organisms and is taken generally to include those elements of the environment, including groundwater, surface water and marine resources, that are used by people or accessible to people.

Contamination – Releases to the wider environment of chemicals, including radionuclides, from human activities.

Derived consideration reference level (DCRL) – a band of dose rate within which there is likely to be some chance of deleterious effects of ionising radiation occurring to individuals of that type of reference animal of plant (derived from a knowledge of defined expected biological effects for that type of organism) that, when considered together with other relevant information, can be used as a point of reference to optimise the level of effort expected on environmental protection, dependent upon the overall management objectives and the relevant exposure situation. DCRL is conceptually equivalent to environmental reference levels (ERL).

Dose Rate – the average level of dose that any material or biota is exposed to over time (typically measured in mGy/h).

Environmental Media- oil, water, air, biota (plants and animals), or any other parts of the environment that can contain contaminants.

Environmental Reference Levels (ERL) - see Derived Consideration Reference Level (DCRL)

ERICA – Environmental Risk from Ionising Contaminants Assessment

Existing Exposure Situation – a situation of exposure that already exists when a decision regarding the need for control is required, including prolonged exposure situations after emergencies.

Modelling – the estimation of environmental media concentrations and / or dose or dose rate using equations to emulate natural processes. As far as possible, extant data are used to parameterise the equations but assumptions need to be made where adequate data do not exist.

Reference organism – an entity that provides a basis for the estimation of radiation dose rate to any living organism that is typical, or representative, of an impacted environment.

RAPs (Reference Animals and Plants) – a hypothetical entity, with the assumed basic biological characteristics of a particular type of animal or plant, as described to the generality of the taxonomic level of family, with defined anatomical, physiological, and life history properties, that can be used for the purpose of relating exposure to dose, and dose to effect, for that type of living organism.

Screening level – the absorbed dose rate to an organism above which further considerations or investigations are warranted.

Sealed source – means controlled material permanently contained in a capsule, or closely bound in a solid form, that is strong enough to be leak-tight for (a) the intended use of the controlled material and (b) any foreseeable abnormal events likely to affect the controlled material.

Storage – means the emplacement of waste in a facility with the intent and in a manner such that it can be retrieved at a later time.

Taxonomy – the branch of science concerned with classification, especially of organisms.

Waste acceptance criteria – quantitative or qualitative criteria specified by the regulatory body, or specified by an operator and approved by the regulatory body, for radioactive waste to be accepted by the operator of a repository for disposal, or by the operator of a storage facility for storage. Waste acceptance requirement might include, for example, restrictions on the activity concentration or the total activity or particular radionuclides (or type of radionuclide) in the waste or requirements concerning the waste form or waste package.

Waste disposal – means the placement of radioactive waste in a structure and in a manner such that there is no intention of retrieval.

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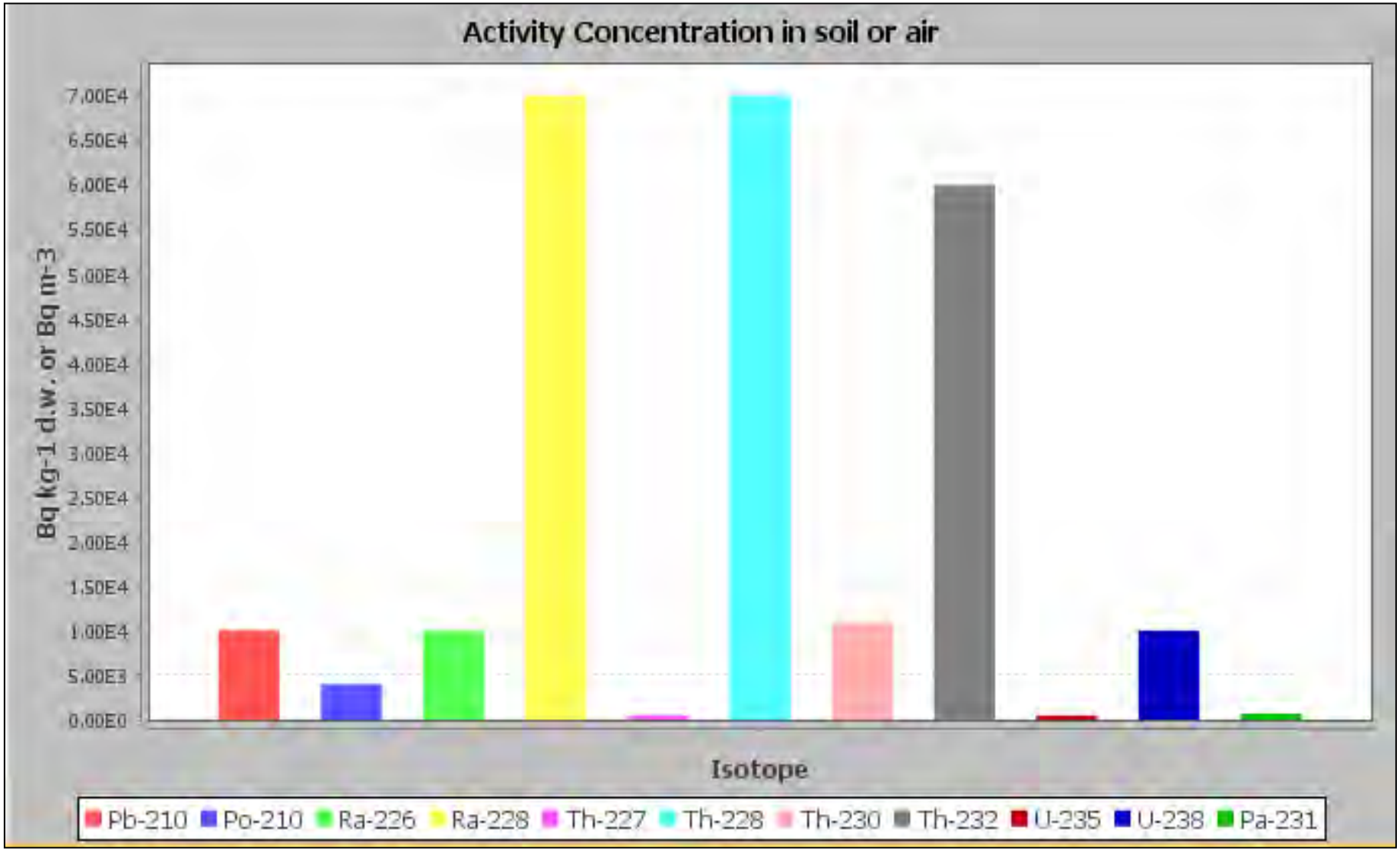
Appendix A

ERICA Assessment uranium and thorium sands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Bq kg-1 d.w. or Bq m-3
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6.00E4
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4.50E4
4.00E4
3.50E4
3.00E4
2.50E4
2.00E4
1.50E4
1.00E4
5.00E3
0.00E0
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Po-210
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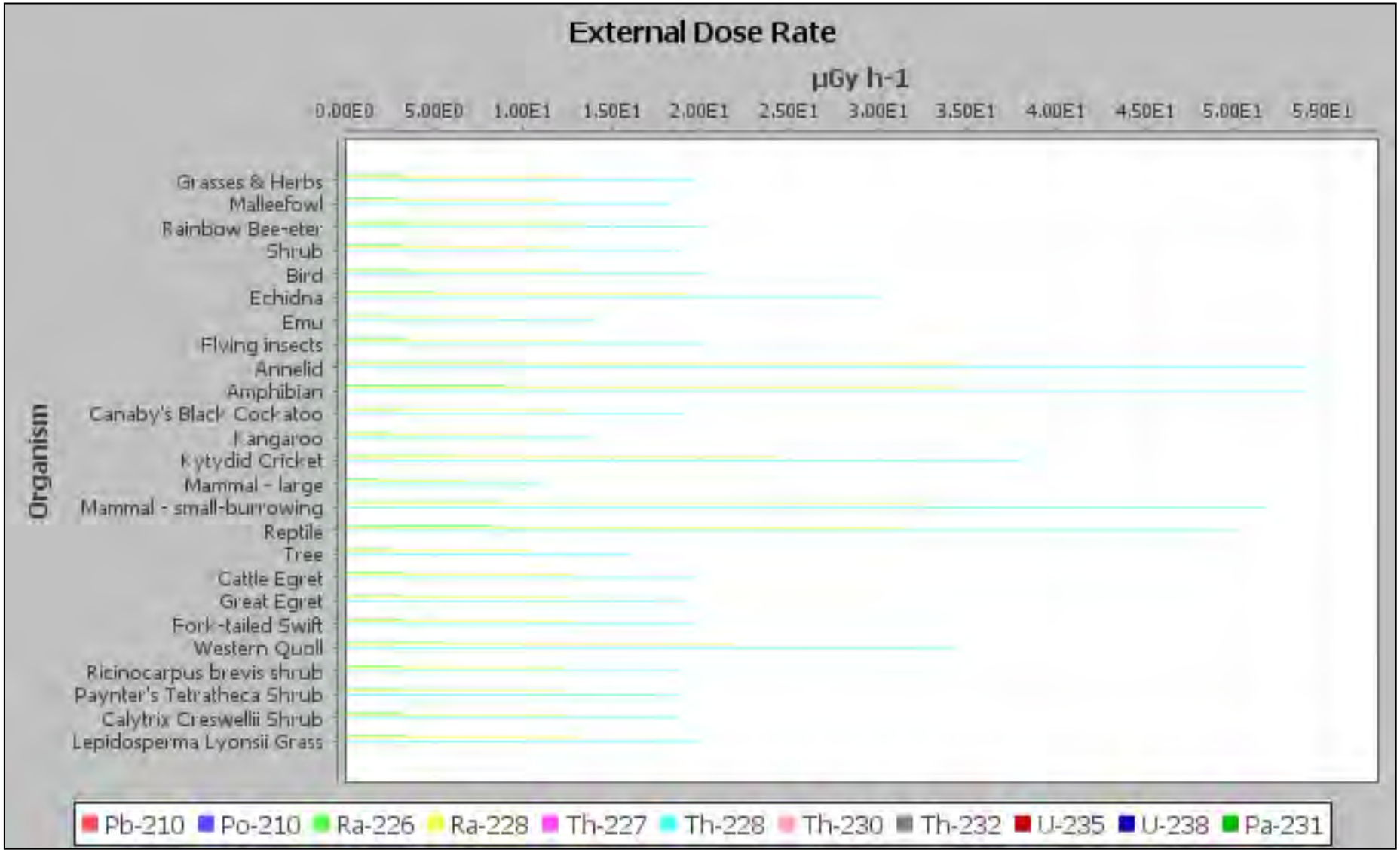
Ra-228
Th-227
Th-228
Th-230
Th-232
U-235
U-238
Pa-231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2.50E1
3.00E1
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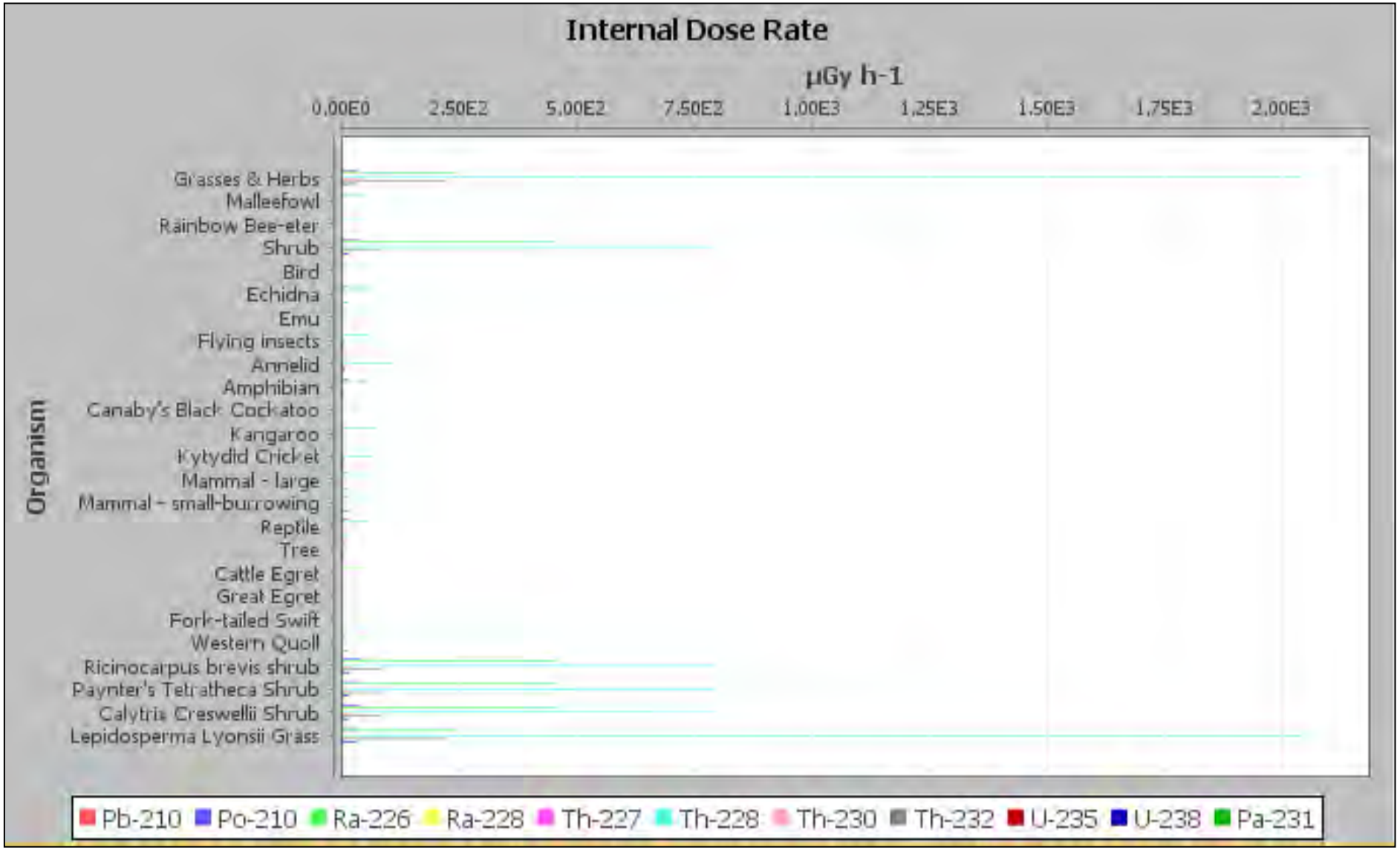
4.00E1
4.50E1
5.00E1
5.50E1
Organism
Grasses & Herbs
Malleefowl
Rainbow Bee-eter
Shrub
Bird
Echidna
Emu
Flying insects
Annelid
Amphibian
Canaby's Black Cockatoo
Kangaroo
Kytydid Cricket
Mammal - large
Mammal - small-burrowing
Reptile
Tree
Cattle Egret
Great Egret
Fork-tailed Swift
Western Quoll
Ricinocarpus brevis shrub
Paynter's Tetratheca Shrub
Calytrix Creswellii Shrub
Lepidosperma Lyonsii Grass
Pb-210
Po-210
Ra-226
Ra-228
Th-227
Th-228
Th-230
Th-232
U-235
U-238
Pa-231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5.00E2
7.50E2
1.00E3
1.25E3
1.50E3
1.75E3
2.00E3
Organism
Grasses & Herbs
Malleefowl
Rainbow Bee-eter
Shrub
Bird
Echidna
Emu
Flying insects
Annelid
Amphibian
Canaby's Black Cockatoo
Kangaroo
Kytydid Cricket
Mammal - large
Mammal - small-burrowing
Reptile
Tree
Cattle Egret
Great Egret
Fork-tailed Swift
Western Quoll
Ricinocarpus brevis shrub
Paynter's Tetratheca Shrub
Calytrix Creswellii Shrub
Lepidosperma Lyonsii Grass
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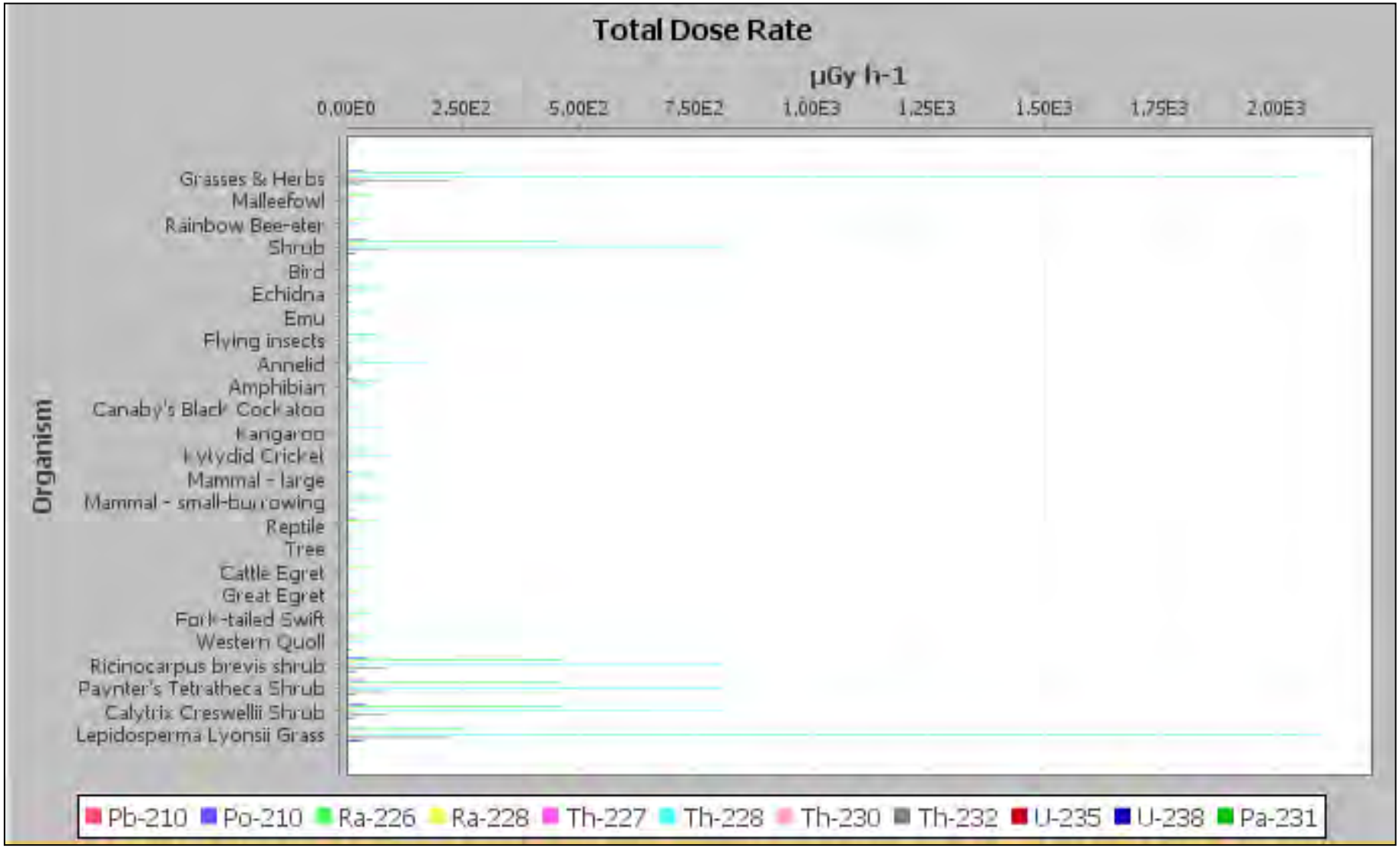
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2.00E3
Organism
Grasses & Herbs
Malleefowl
Rainbow Bee-eter
Shrub
Bird
Echidna
Emu
Flying insects
Annelid
Amphibian
Canaby's Black Cockatoo
Kangaroo
Kylydid Cricket
Mammal - large
Mammal - small-burrowing
Reptile
Tree
Cattle Egret
Great Egret
Fork-tailed Swift
Western Quoll
Ricinocarpus brevis shrub
Paynter's Tetratheca Shrub
Calytrix Creswellii Shrub
Lepidosperma Lyonsii Grass
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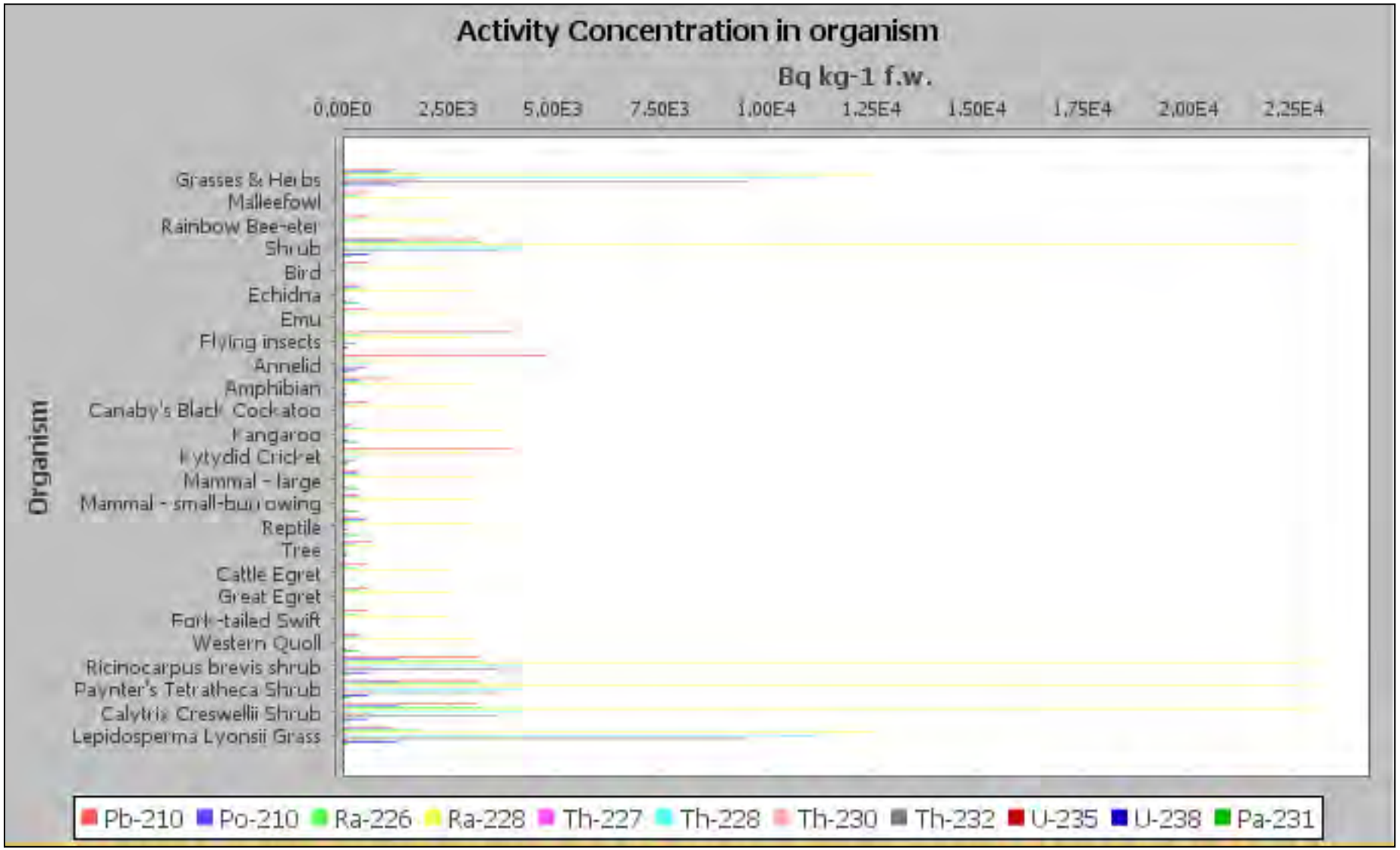
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7.50E3
1.00E4
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1.50E4
1.75E4
2.00E4
2.25E4
Organism
Grasses & Herbs
Malleefowl
Rainbow Bee-eter
Shrub
Bird
Echidna
Emu
Flying insects
Annelid
Amphibian
Canaby's Black Cockatoo
Kangaroo
Katydid Cricket
Mammal - large
Mammal - small-burrowing
Reptile
Tree
Cattle Egret
Great Egret
Fork-tailed Swift
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Ricinocarpus brevis shrub
Paynter's Tetratheca Shrub
Calytrix Creswellii Shrub
Lepidosperma Lyonsii Grass
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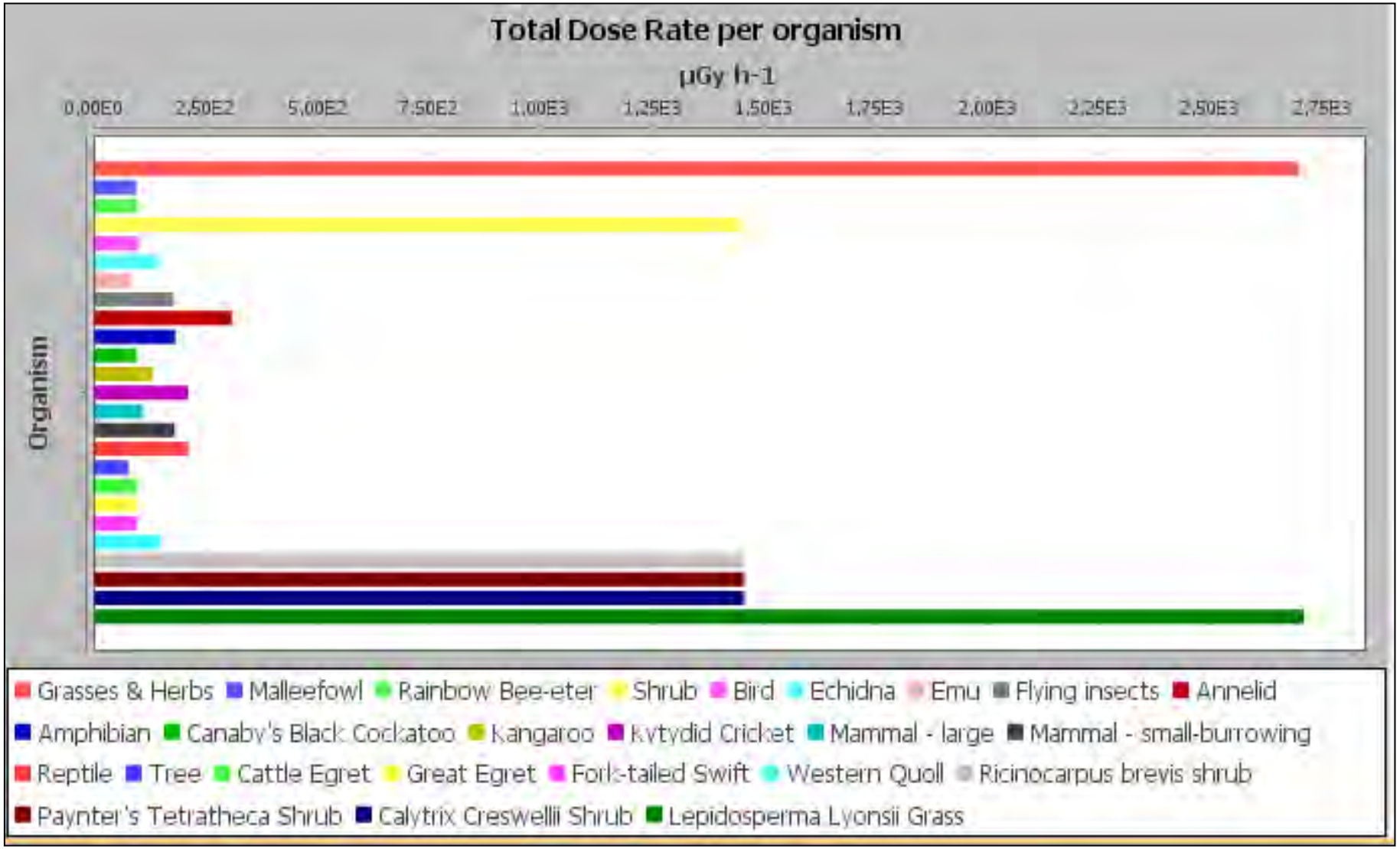
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7,50E2
1,00E3
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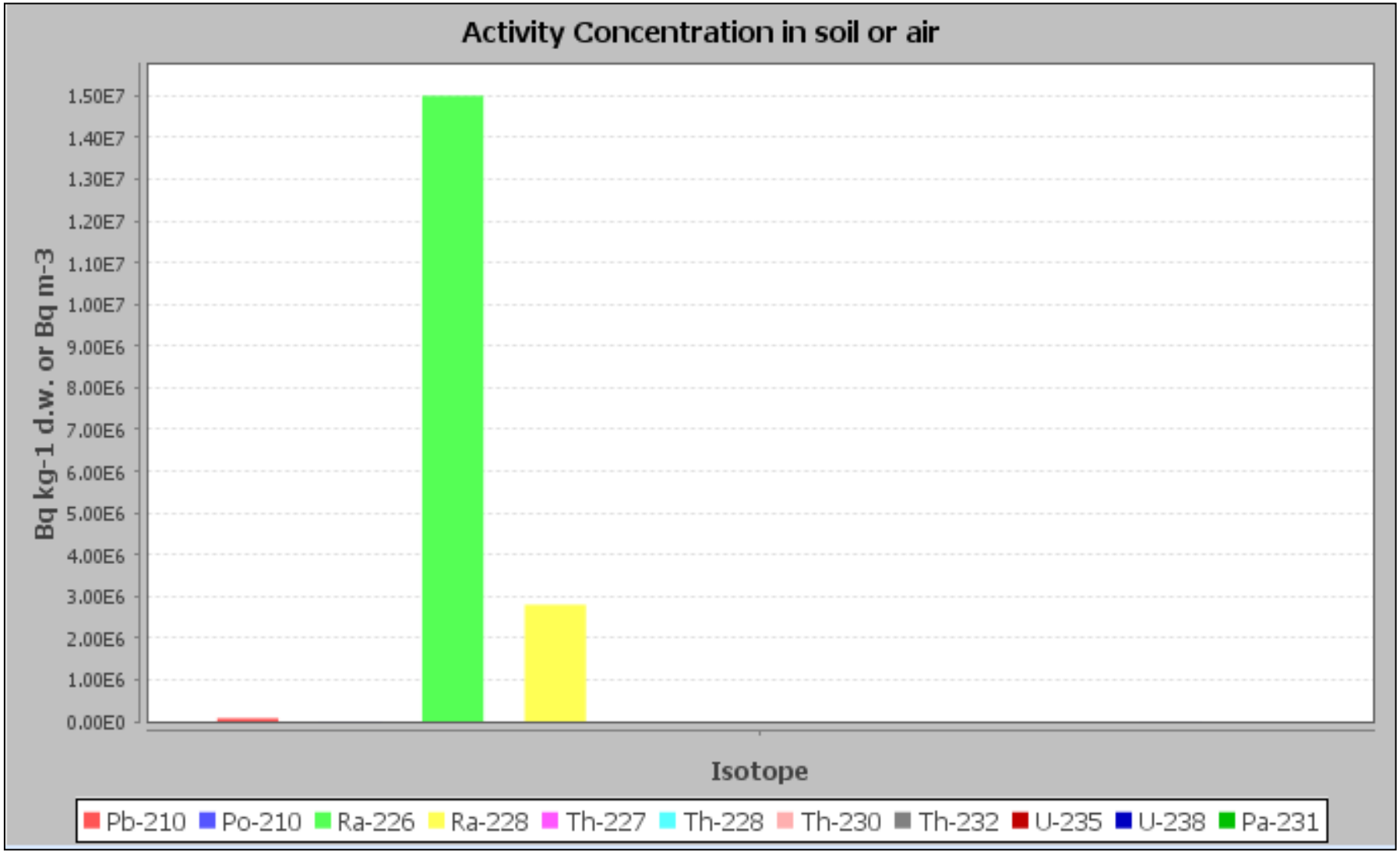
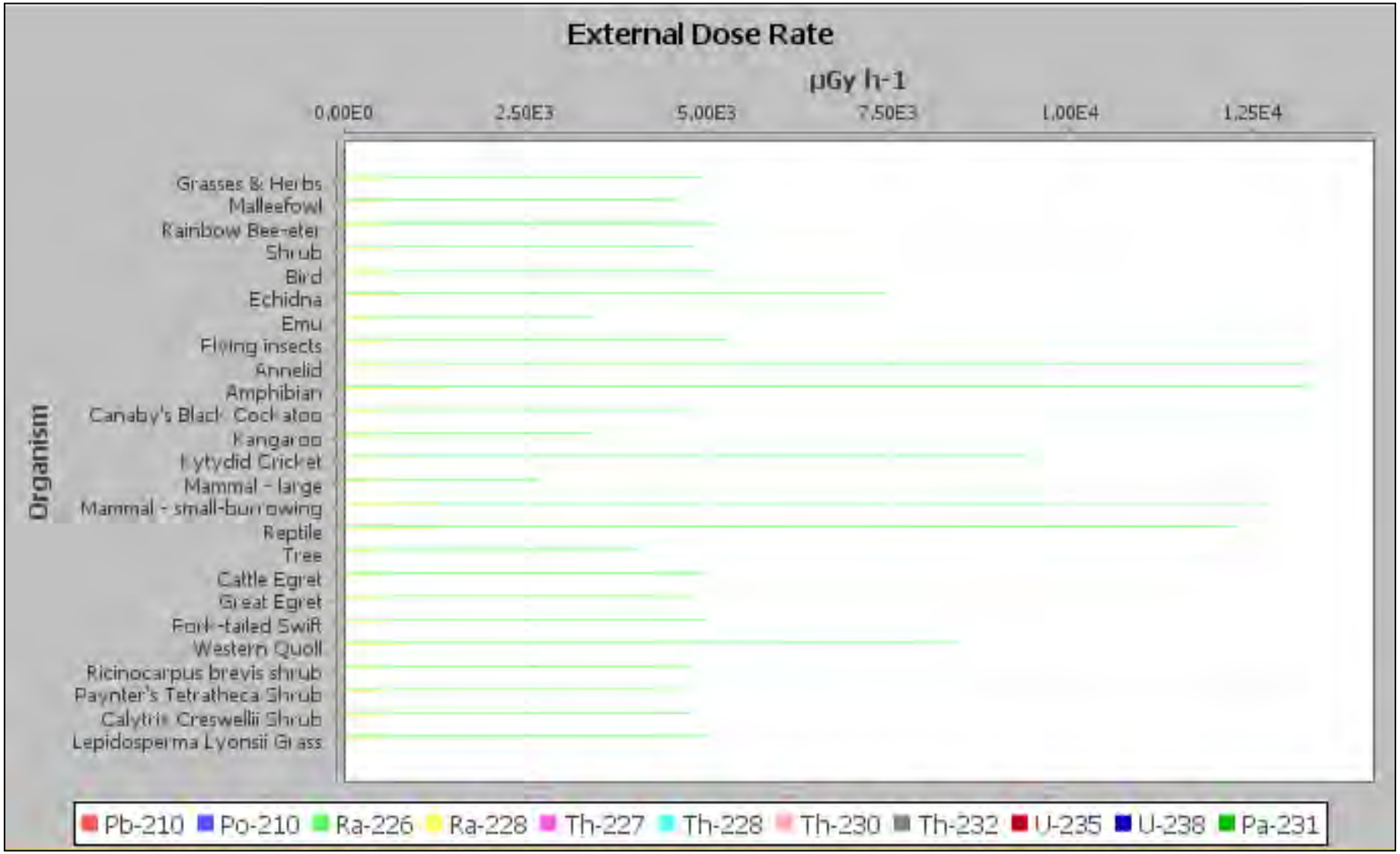
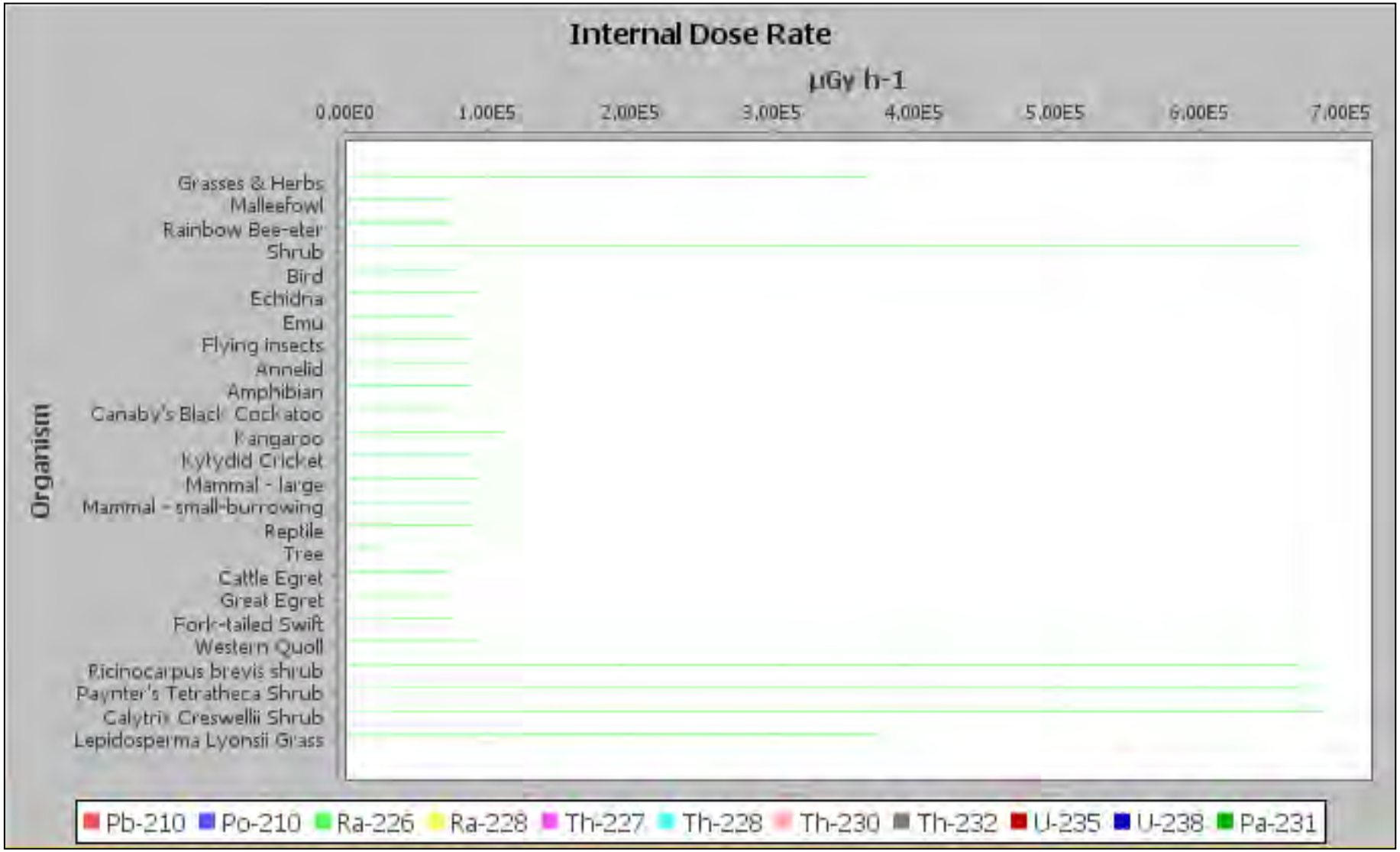
1,50E3
1,75E3
2,00E3
2,25E3
2,50E3
2,75E3
Organism
Grasses & Herbs
Malleefowl
Rainbow Bee-eter
Shrub
Bird
Echidna
Emu
Flying insects
Annelid
Amphibian
Canaby's Black Cockatoo
Kangaroo
Kytydid Cricket
Mammal - large
Mammal - small-burrowing
Reptile
Tree
Cattle Egret
Great Egret
Fork-tailed Swift
Western Quoll
Ricinocarpus brevis shrub
Paynter's Tetratheca Shrub
Calytrix Creswellii Shrub
Lepidosperma Lyonsii Grass

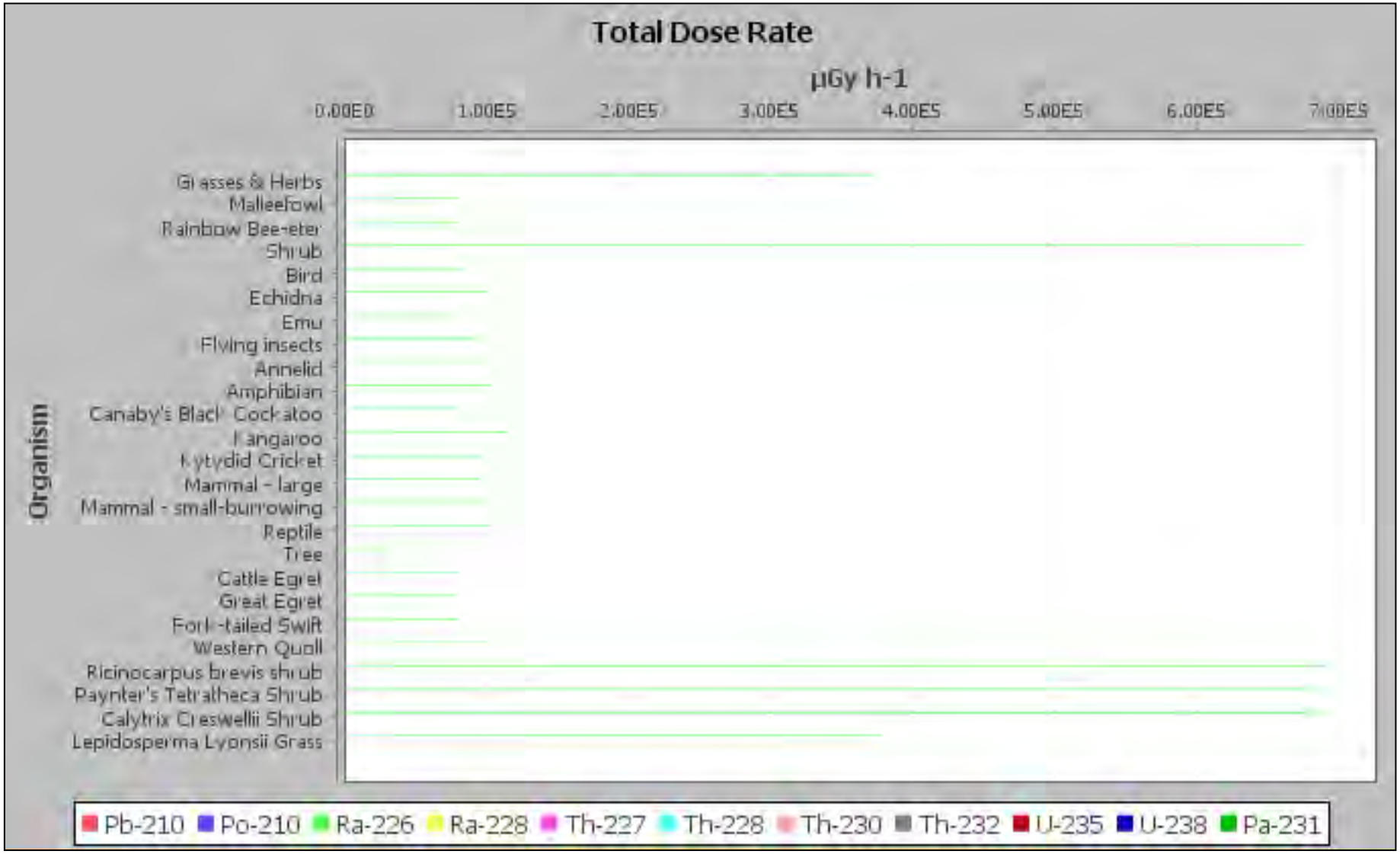
Appendix B

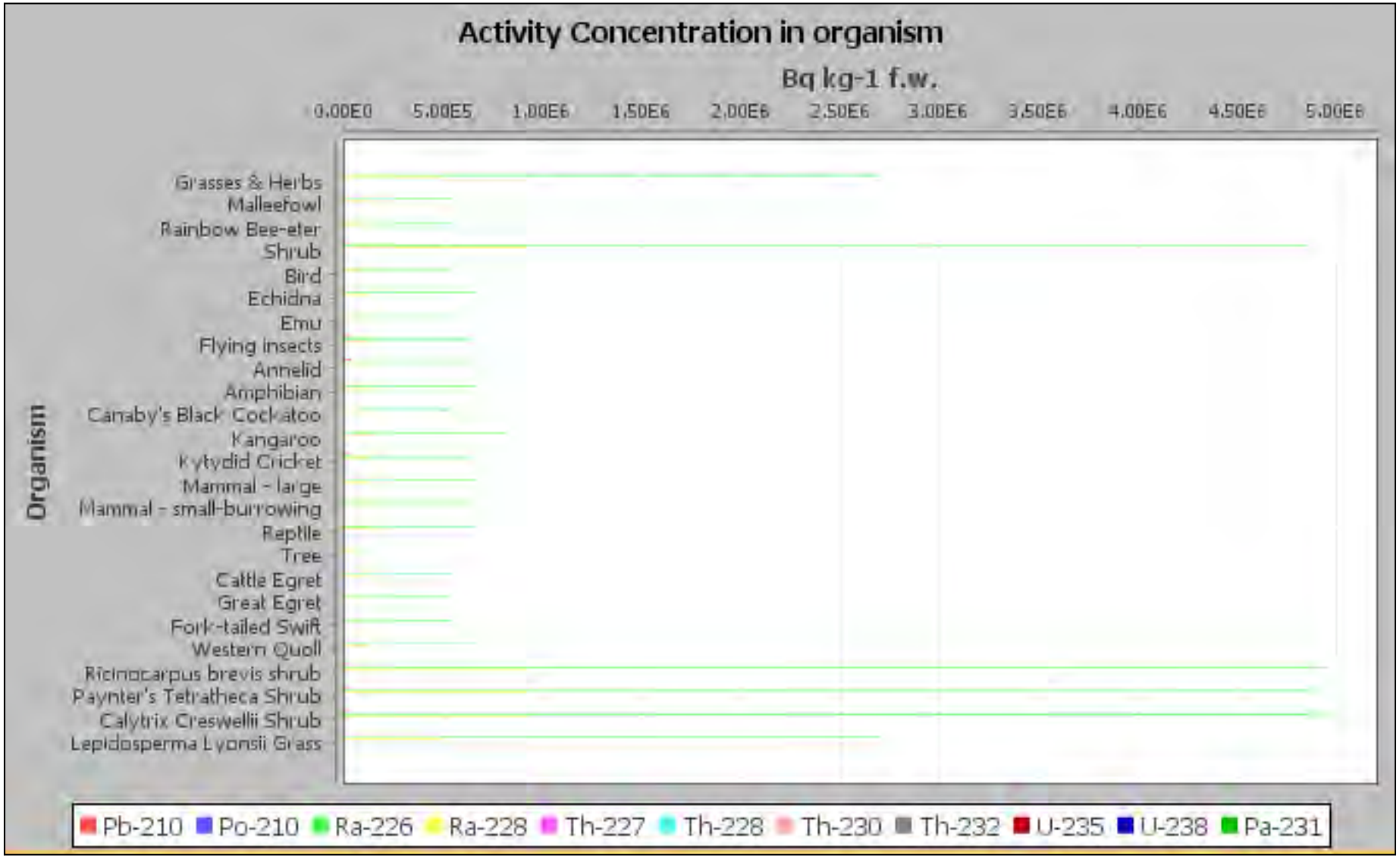
ERICA Assessment Radium Scales

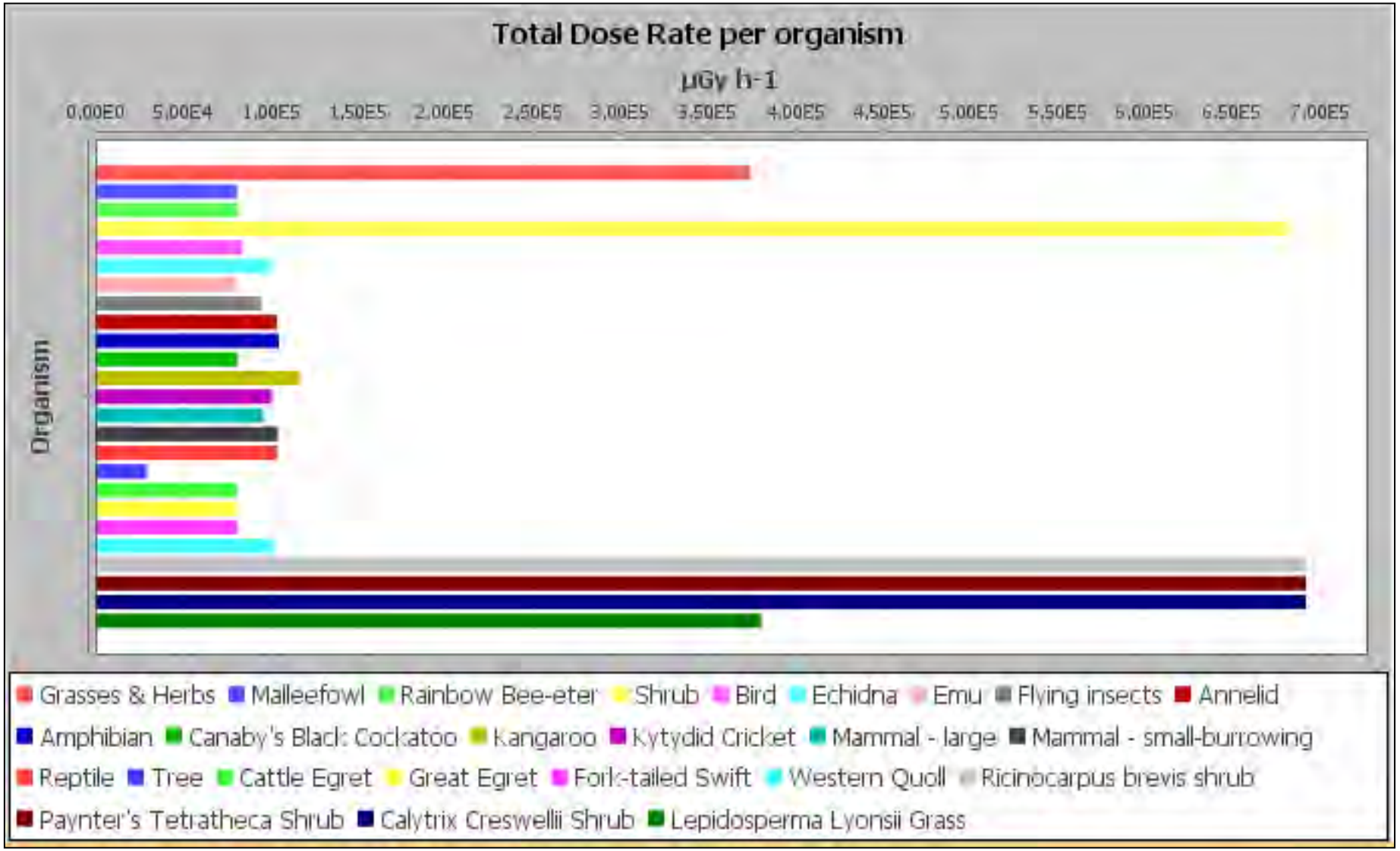

Activity Concentration in soil or air
Bq kg-1 d.w. or Bq m-3
1.50E7
1.40E7
1.30E7
1.20E7
1.10E7
1.00E7
9.00E6
8.00E6
7.00E6
6.00E6
5.00E6
4.00E6
3.00E6
2.00E6
1.00E6
0.00E0
Isotope
Pb-210
Po-210
Ra-226
Ra-228
Th-227
Th-228
Th-230
Th-232
U-235
U-238
Pa-231


External Dose Rate
µGy h-1
0.00E0
2.50E3
5.00E3
7.50E3
1.00E4
1.25E4
Organism
Grasses & Herbs
Malleefowl
Rainbow Bee-eter
Shrub
Bird
Echidna
Emu
Flying insects
Annelid
Amphibian
Carnaby's Black Cockatoo
Kangaroo
Katydid Cricket
Mammal - large
Mammal - small-burrowing
Reptile
Tree
Cattle Egret
Great Egret
Fork-tailed Swift
Western Quoll
Ricinocarpus brevis shrub
Paynter's Tetratheca Shrub
Calytrix Creswellii Shrub
Lepidosperma Lyonsii Grass
Pb-210
Po-210
Ra-226
Ra-228
Th-227
Th-228
Th-230
Th-232
U-235
U-238
Pa-231


Internal Dose Rate
µGy h-1
0.00E0
1.00E5
2.00E5
3.00E5
4.00E5
5.00E5
6.00E5
7.00E5
Organism
Grasses & Herbs
Malleefowl
Rainbow Bee-eter
Shrub
Bird
Echidna
Emu
Flying insects
Annelid
Amphibian
Canaby's Black Cockatoo
Kangaroo
Kytydid Cricket
Mammal - large
Mammal - small-burrowing
Reptile
Tree
Cattle Egret
Great Egret
Fork-tailed Swift
Western Quoll
Ricinocarpus brevis shrub
Paynter's Tetratheca Shrub
Calytrix Creswellii Shrub
Lepidosperma Lyonsii Grass
Pb-210
Po-210
Ra-226
Ra-228
Th-227
Th-228
Th-230
Th-232
U-235
U-238
Pa-231

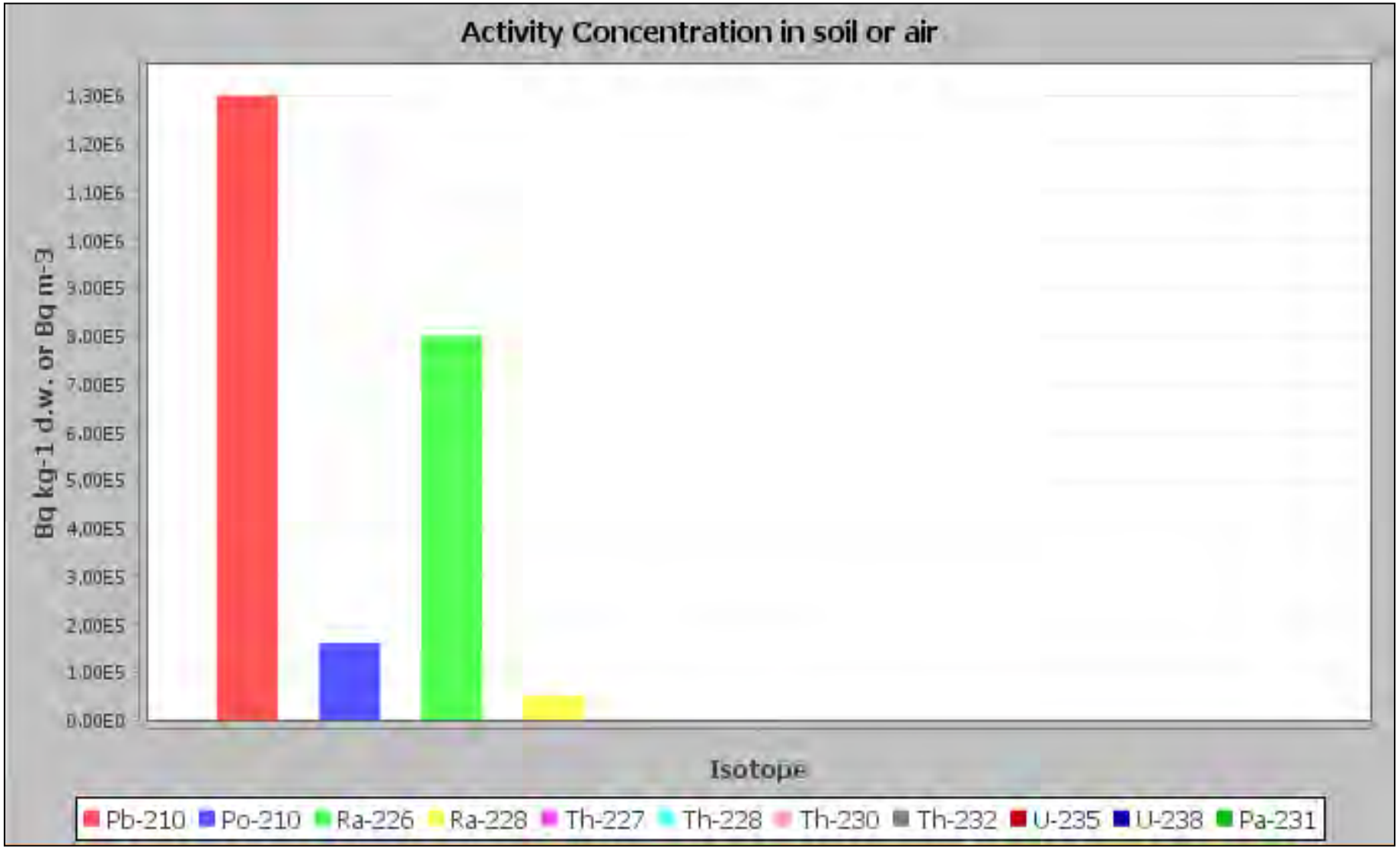

Total Dose Rate
µGy h-1
0.00E0
1.00E5
2.00E5
3.00E5
4.00E5
5.00E5
6.00E5
7.00E5
Organism
Grasses & Herbs
MalleeFowl
Rainbow Bee-eter
Shrub
Bird
Echidna
Emu
Flying insects
Annelid
Amphibian
Canaby's Black Cockatoo
Kangaroo
Katydid Cricket
Mammal - large
Mammal - small-burrowing
Reptile
Tree
Cattle Egret
Great Egret
Fork-tailed Swift
Western Quoll
Ricinocarpus brevis shrub
Paynter's Tetratheca Shrub
Calytrix Creswellii Shrub
Lepidosperma Lyonsii Grass
Pb-210
Po-210
Ra-226
Ra-228
Th-227
Th-228
Th-230
Th-232
U-235
U-238
Pa-231

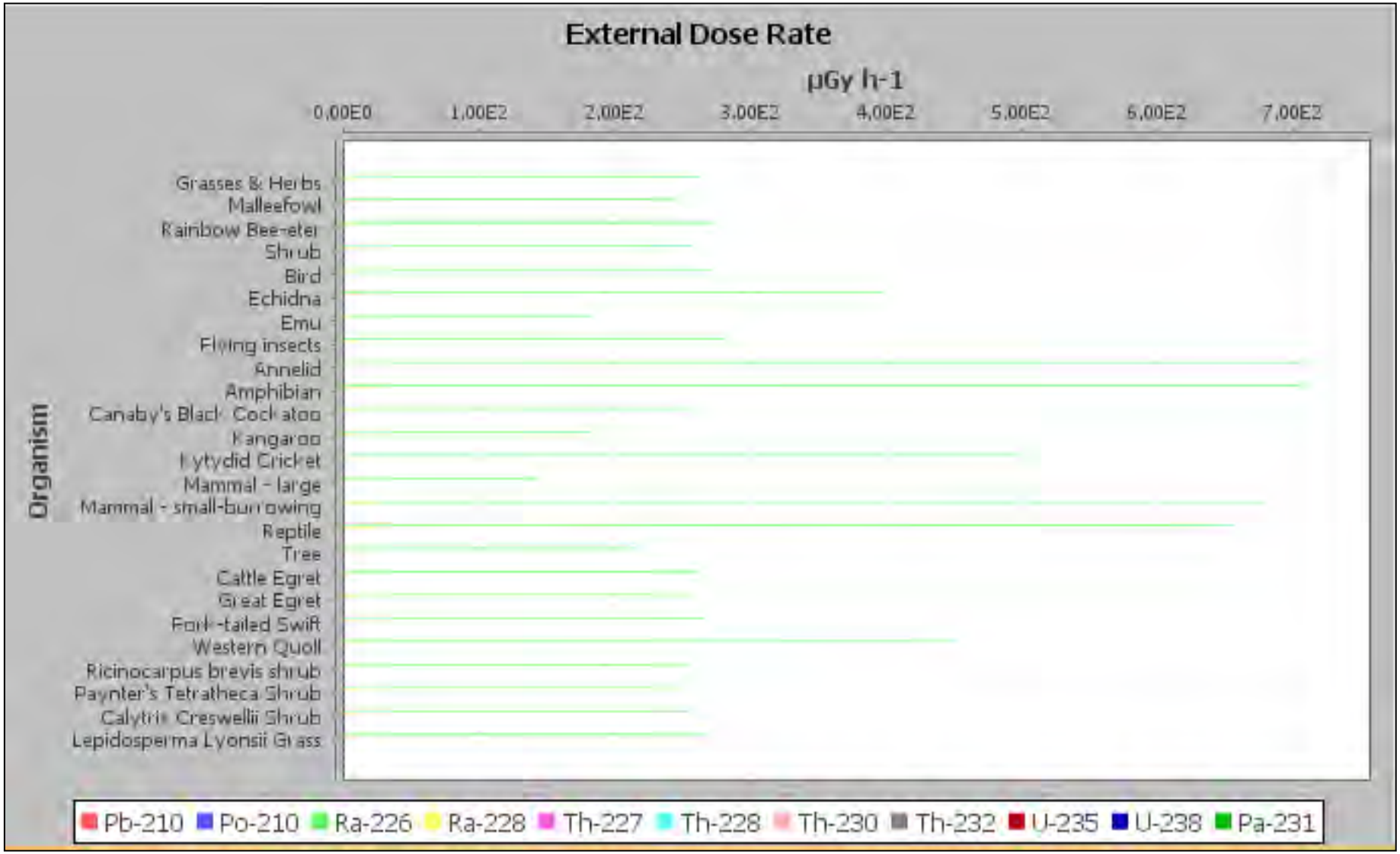

Activity Concentration in organism
Bq kg-1 f.w.
0.00E0
5.00E5
1.00E6
1.50E6
2.00E6
2.50E6
3.00E6
3.50E6
4.00E6
4.50E6
5.00E6
Organism
Grasses & Herbs
Malleefowl
Rainbow Bee-eter
Shrub
Bird
Echidna
Emu
Flying insects
Annelid
Amphibian
Canaby's Black Cockatoo
Kangaroo
Kytydid Cricket
Mammal - large
Mammal - small-burrowing
Reptile
Tree
Cattle Egret
Great Egret
Fork-tailed Swift
Western Quoll
Ricinocarpus brevis shrub
Paynter's Tetratheca Shrub
Calytrix Creswellii Shrub
Lepidosperma Lyonsii Grass
Pb-210
Po-210
Ra-226
Ra-228
Th-227
Th-228
Th-230
Th-232
U-235
U-238
Pa-231

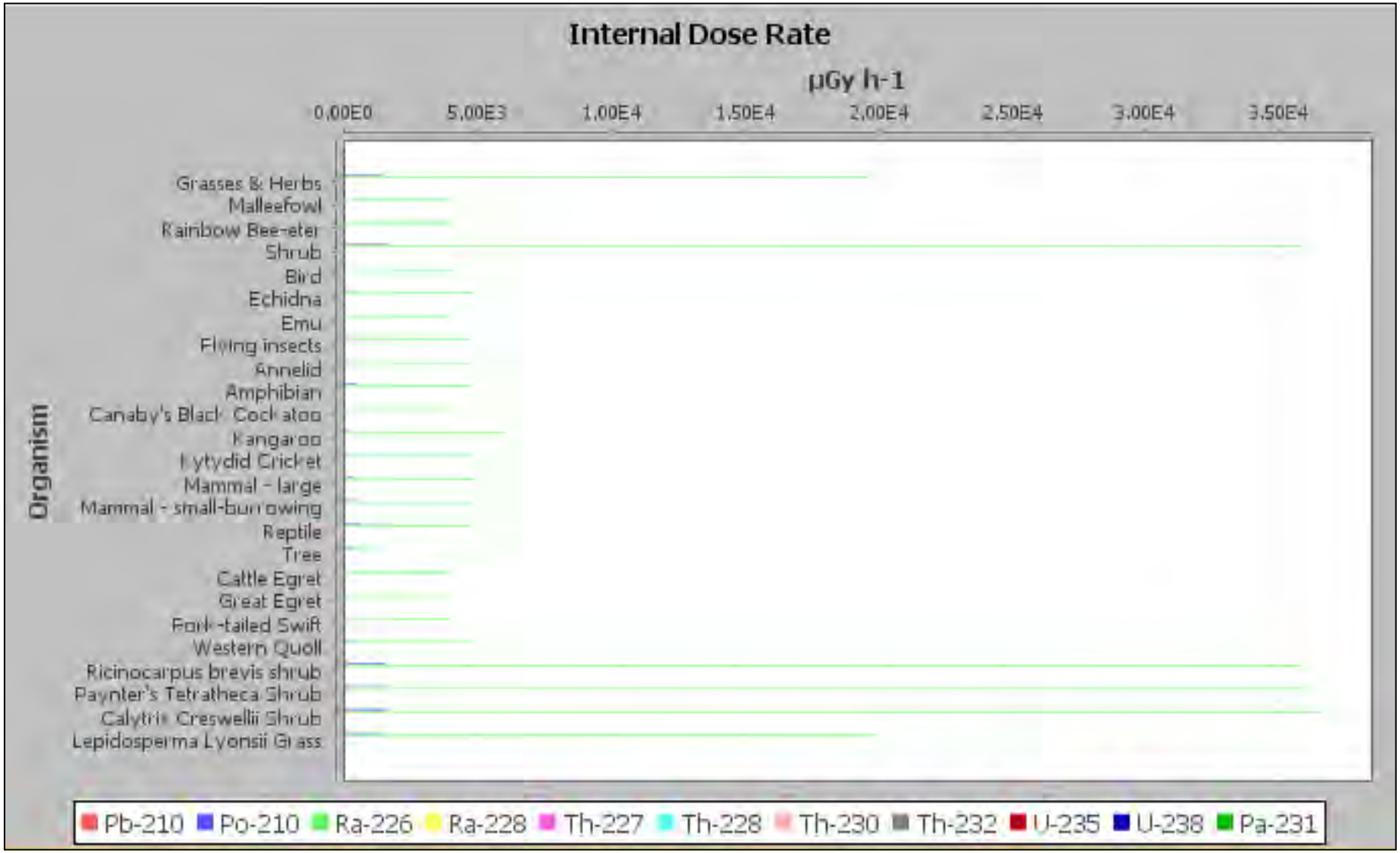

Total Dose Rate per organism
µGy h-1
0.00E0
5.00E4
1.00E5
1.50E5
2.00E5
2.50E5
3.00E5
3.50E5
4.00E5
4.50E5
5.00E5
5.50E5
6.00E5
6.50E5
7.00E5
Organism
Grasses & Herbs
Malleefowl
Rainbow Bee-eter
Shrub
Bird
Echidna
Emu
Flying insects
Annelid
Amphibian
Canaby's Black Cockatoo
Kangaroo
Kytydid Cricket
Mammal - large
Mammal - small-burrowing
Reptile
Tree
Cattle Egret
Great Egret
Fork-tailed Swift
Western Quoll
Ricinocarpus brevis shrub
Paynter's Tetratheca Shrub
Calytrix Creswellii Shrub
Lepidosperma Lyonsii Grass

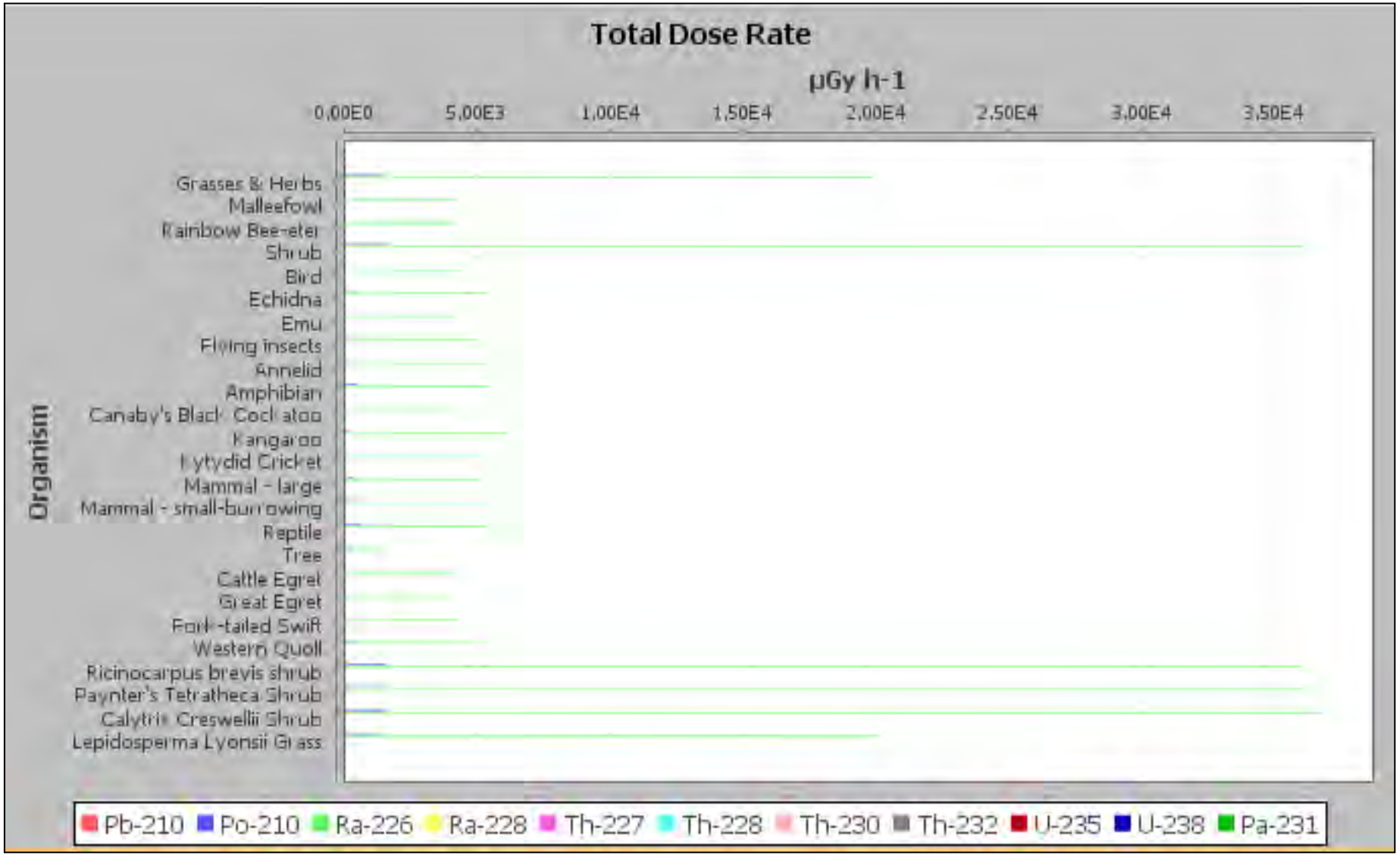
Appendix C

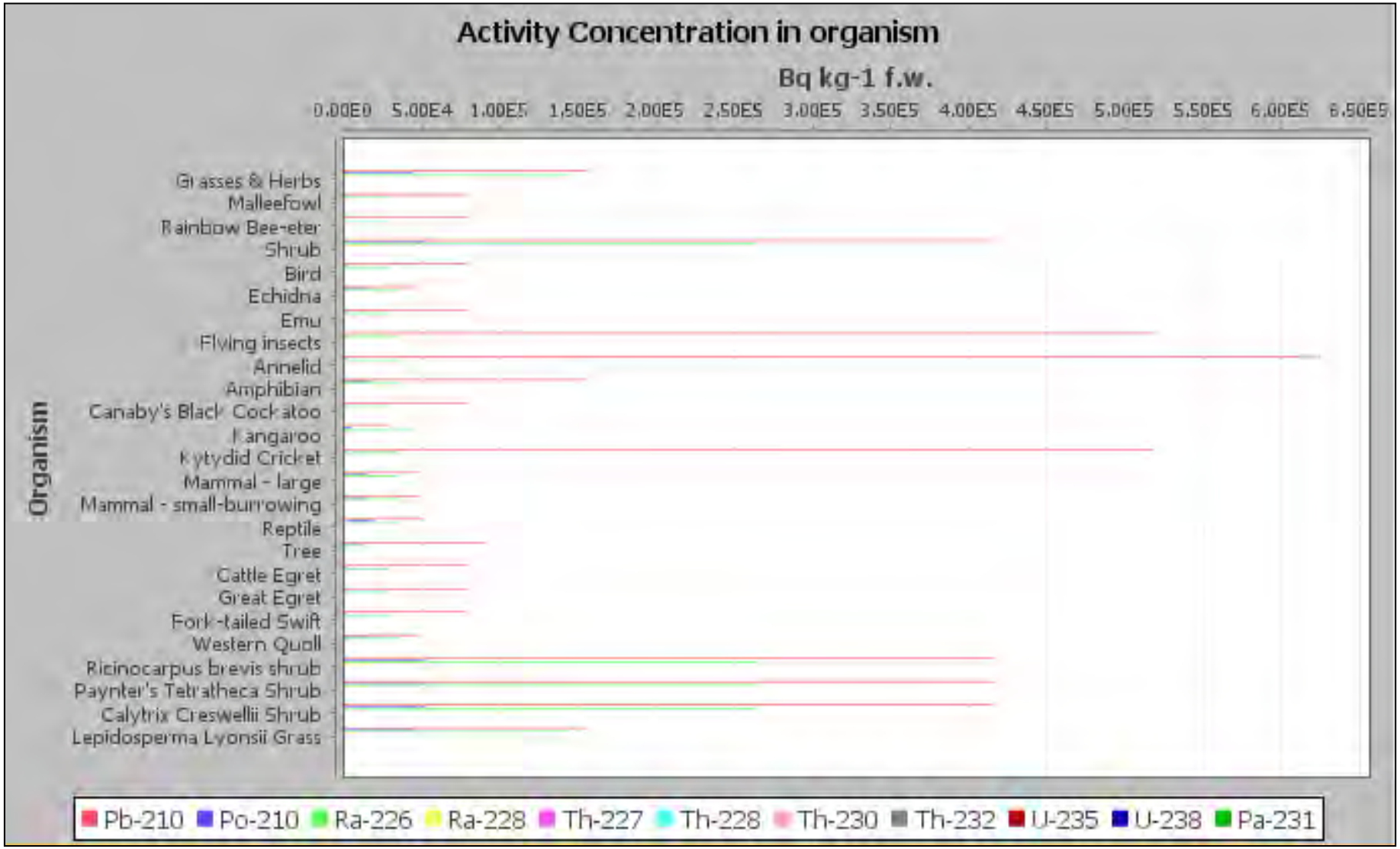
ERICA Assessment Radium Sludge

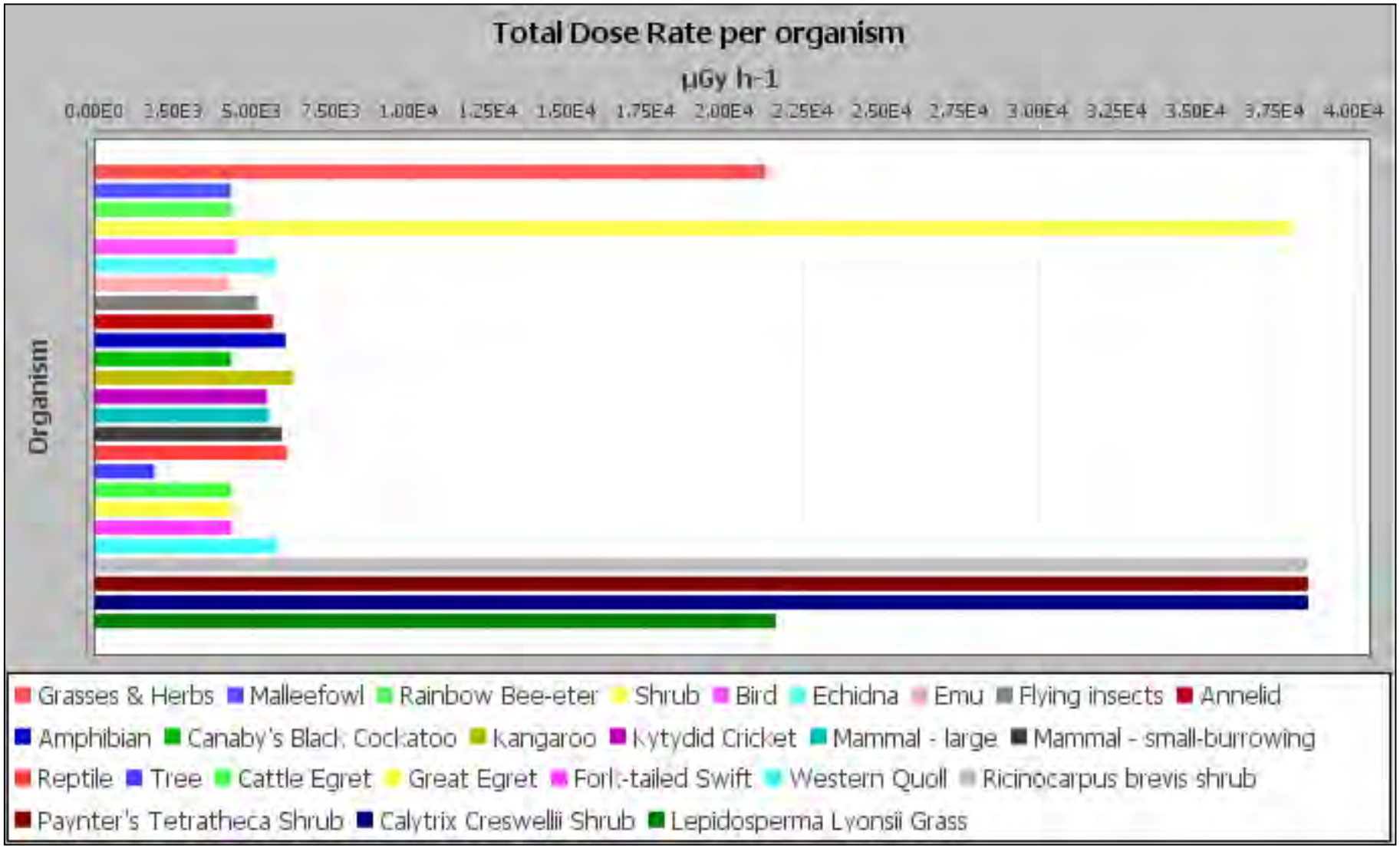

Activity Concentration in soil or air
Bq kg-1 d.w. or Bq m-3
1.30E6
1.20E6
1.10E6
1.00E6
9.00E5
8.00E5
7.00E5
6.00E5
5.00E5
4.00E5
3.00E5
2.00E5
1.00E5
0.00E0
Isotope
Pb-210
Po-210
Ra-226
Ra-228
Th-227
Th-228
Th-230
Th-232
U-235
U-238
Pa-231


External Dose Rate
µGy h-1
0.00E0
1.00E2
2.00E2
3.00E2
4.00E2
5.00E2
6.00E2
7.00E2
Organism
Grasses & Herbs
Malleefowl
Rainbow Bee-eter
Shrub
Bird
Echidna
Emu
Flying insects
Annelid
Amphibian
Canaby's Black Cockatoo
Kangaroo
Tytydid Cricket
Mammal - large
Mammal - small-burrowing
Reptile
Tree
Cattle Egret
Great Egret
Fork-tailed Swift
Western Quoll
Ricinocarpus brevis shrub
Paynter's Tetratheca Shrub
Calytrix Creswellii Shrub
Lepidosperma Lyonsii Grass
Pb-210
Po-210
Ra-226
Ra-228
Th-227
Th-228
Th-230
Th-232
U-235
U-238
Pa-231


Internal Dose Rate
µGy h-1
0.00E0
5.00E3
1.00E4
1.50E4
2.00E4
2.50E4
3.00E4
3.50E4
Organism
Grasses & Herbs
Malleefowl
Rainbow Bee-eter
Shrub
Bird
Echidna
Emu
Flying insects
Annelid
Amphibian
Canaby's Black Cockatoo
Kangaroo
Tytydid Cricket
Mammal - large
Mammal - small-burrowing
Reptile
Tree
Cattle Egret
Great Egret
Fork-tailed Swift
Western Quoll
Ricinocarpus brevis shrub
Paynter's Tetratheca Shrub
Calytrix Creswellii Shrub
Lepidosperma Lyonsii Grass
Pb-210
Po-210
Ra-226
Ra-228
Th-227
Th-228
Th-230
Th-232
U-235
U-238
Pa-231

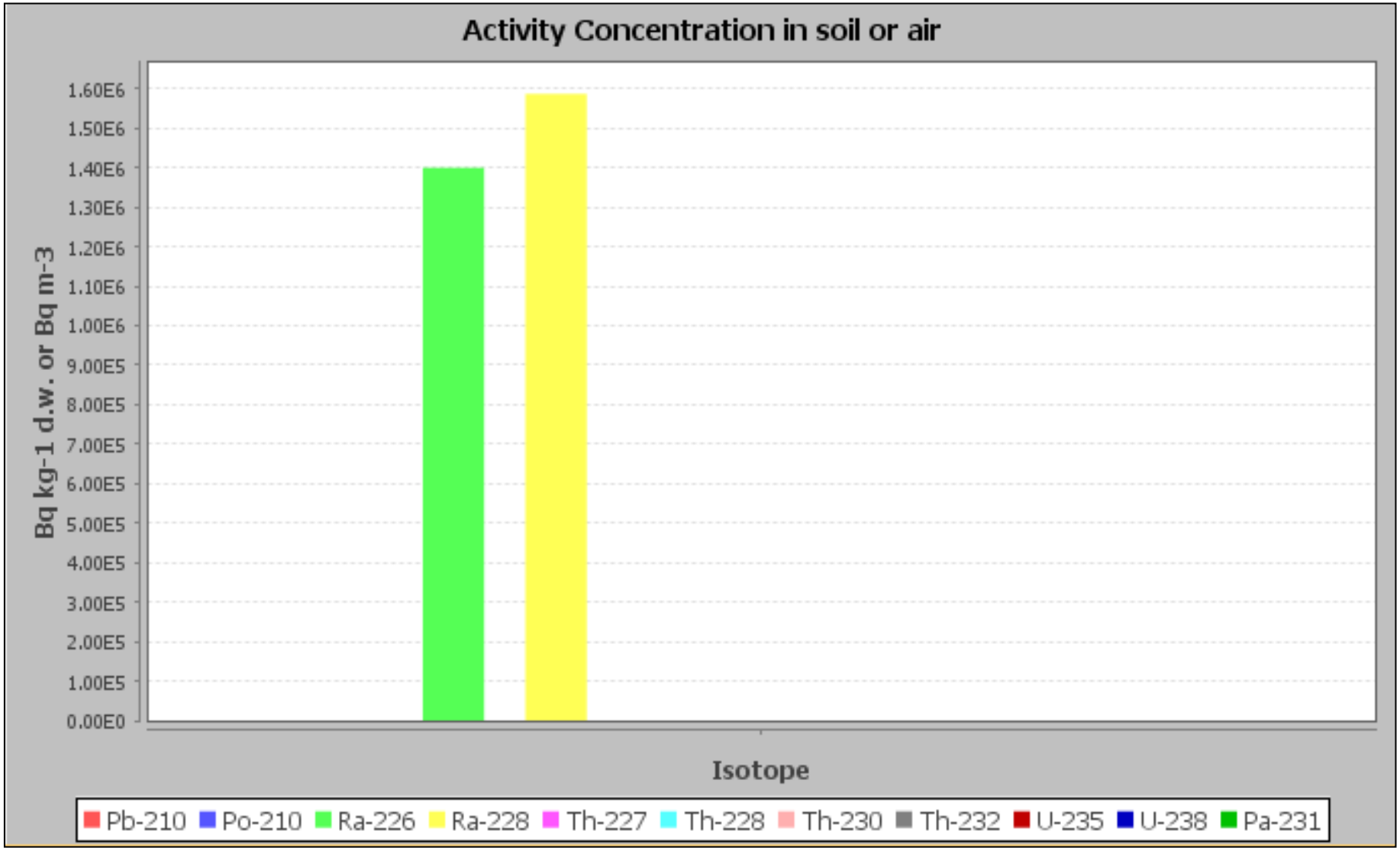

Total Dose Rate
µGy h-1
0.00E0
5.00E3
1.00E4
1.50E4
2.00E4
2.50E4
3.00E4
3.50E4
Organism
Grasses & Herbs
Malleefowl
Rainbow Bee-eter
Shrub
Bird
Echidna
Emu
Flying insects
Annelid
Amphibian
Canaby's Black Cockatoo
Kangaroo
Tytydid Cricket
Mammal - large
Mammal - small-burrowing
Reptile
Tree
Cattle Egret
Great Egret
Fork-tailed Swift
Western Quoll
Ricinocarpus brevis shrub
Paynter's Tetratheca Shrub
Calytrix Creswellii Shrub
Lepidosperma Lyonsii Grass
Pb-210
Po-210
Ra-226
Ra-228
Th-227
Th-228
Th-230
Th-232
U-235
U-238
Pa-231

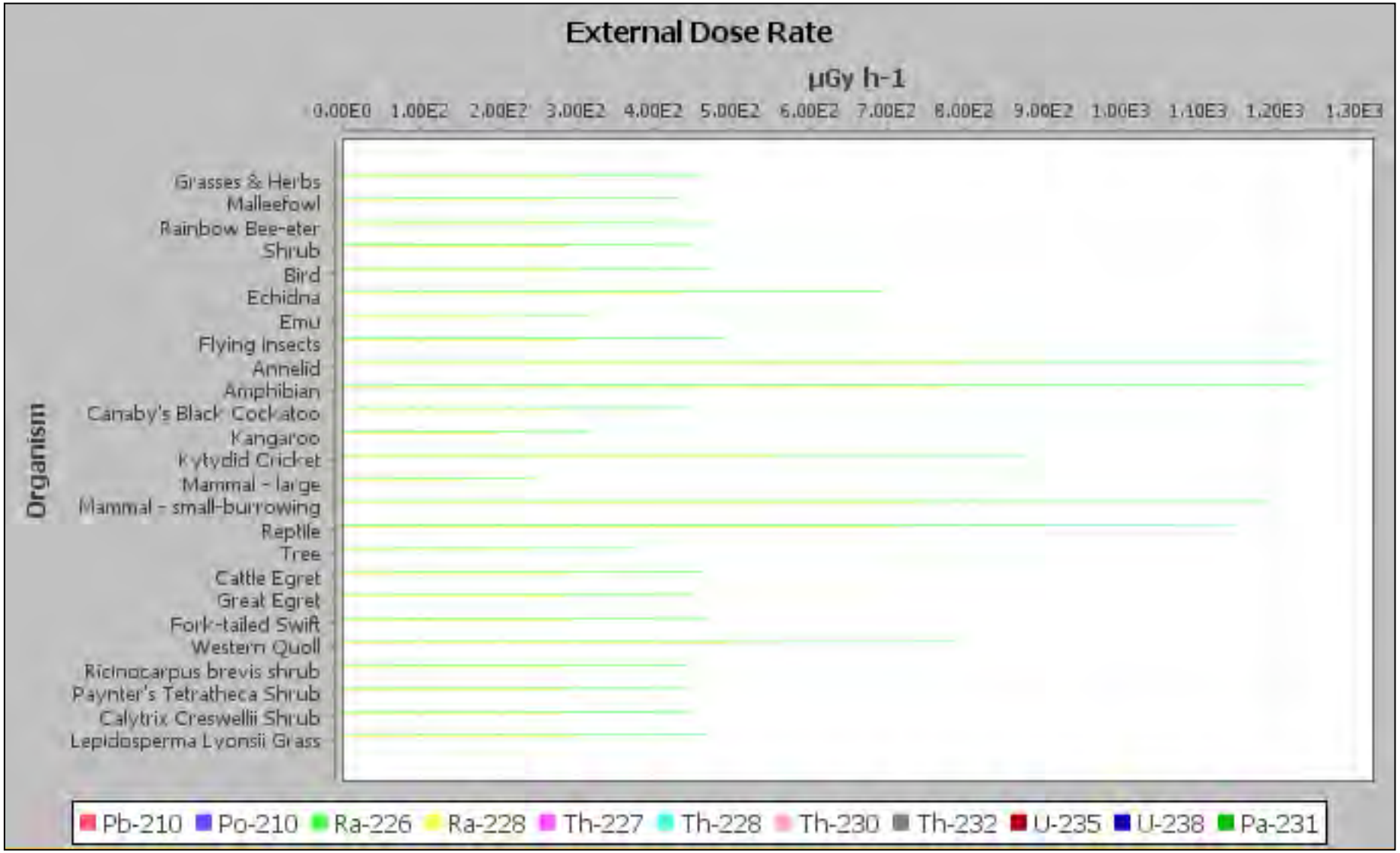

Activity Concentration in organism
Bq kg-1 f.w.
0.00E0
5.00E4
1.00E5
1.50E5
2.00E5
2.50E5
3.00E5
3.50E5
4.00E5
4.50E5
5.00E5
5.50E5
6.00E5
6.50E5
Organism
Grasses & Herbs
Malleefowl
Rainbow Bee-eter
Shrub
Bird
Echidna
Emu
Flying insects
Annelid
Amphibian
Canaby's Black Cockatoo
Kangaroo
Kytydid Cricket
Mammal - large
Mammal - small-burrowing
Reptile
Tree
Cattle Egret
Great Egret
Fork-tailed Swift
Western Quoll
Ricinocarpus brevis shrub
Paynter's Tetratheca Shrub
Calytrix Creswellii Shrub
Lepidosperma Lyonsii Grass
Pb-210
Po-210
Ra-226
Ra-228
Th-227
Th-228
Th-230
Th-232
U-235
U-238
Pa-231

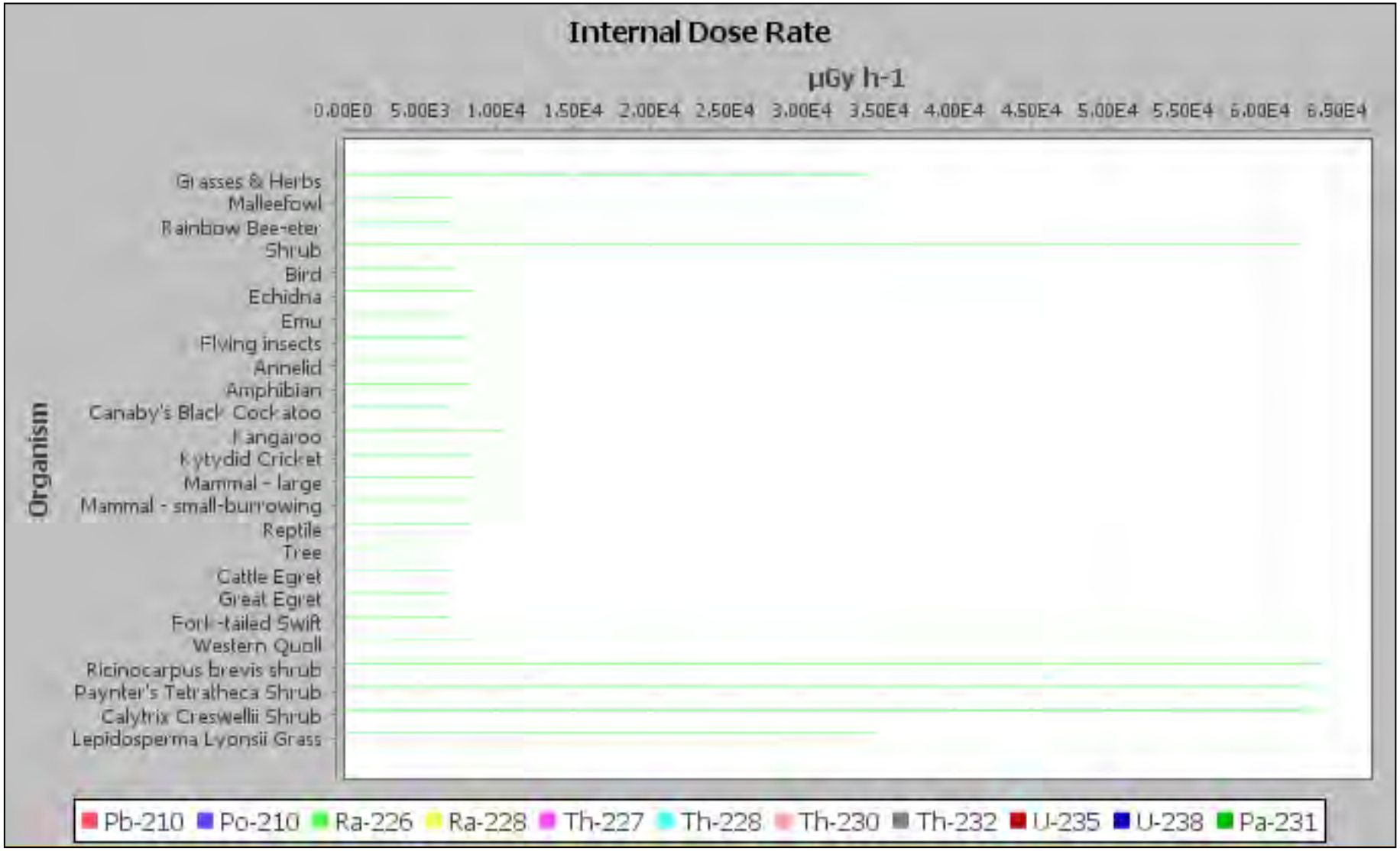

Total Dose Rate per organism
µGy h-1
0.00E0
2.50E3
5.00E3
7.50E3
1.00E4
1.25E4
1.50E4
1.75E4
2.00E4
2.25E4
2.50E4
2.75E4
3.00E4
3.25E4
3.50E4
3.75E4
4.00E4
Organism
Grasses & Herbs
Malleefowl
Rainbow Bee-eter
Shrub
Bird
Echidna
Emu
Flying insects
Annelid
Amphibian
Canaby's Black Cockatoo
Kangaroo
Kytydid Cricket
Mammal - large
Mammal - small-burrowing
Reptile
Tree
Cattle Egret
Great Egret
Forl:-tailed Swift
Western Quoll
Ricinocarpus brevis shrub
Paynter's Tetratheca Shrub
Calytrix Creswellii Shrub
Lepidosperma Lyonsii Grass

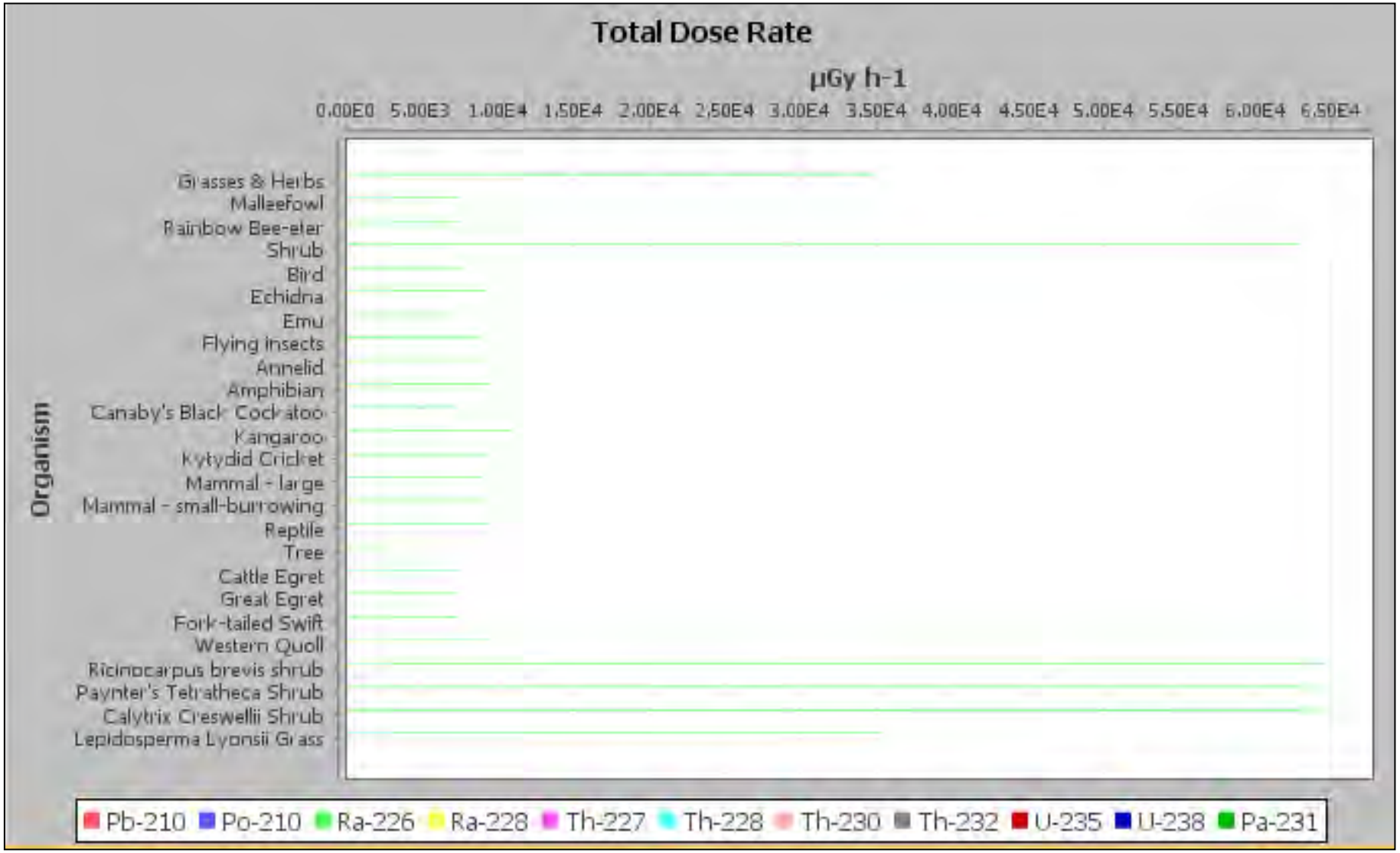
Appendix D

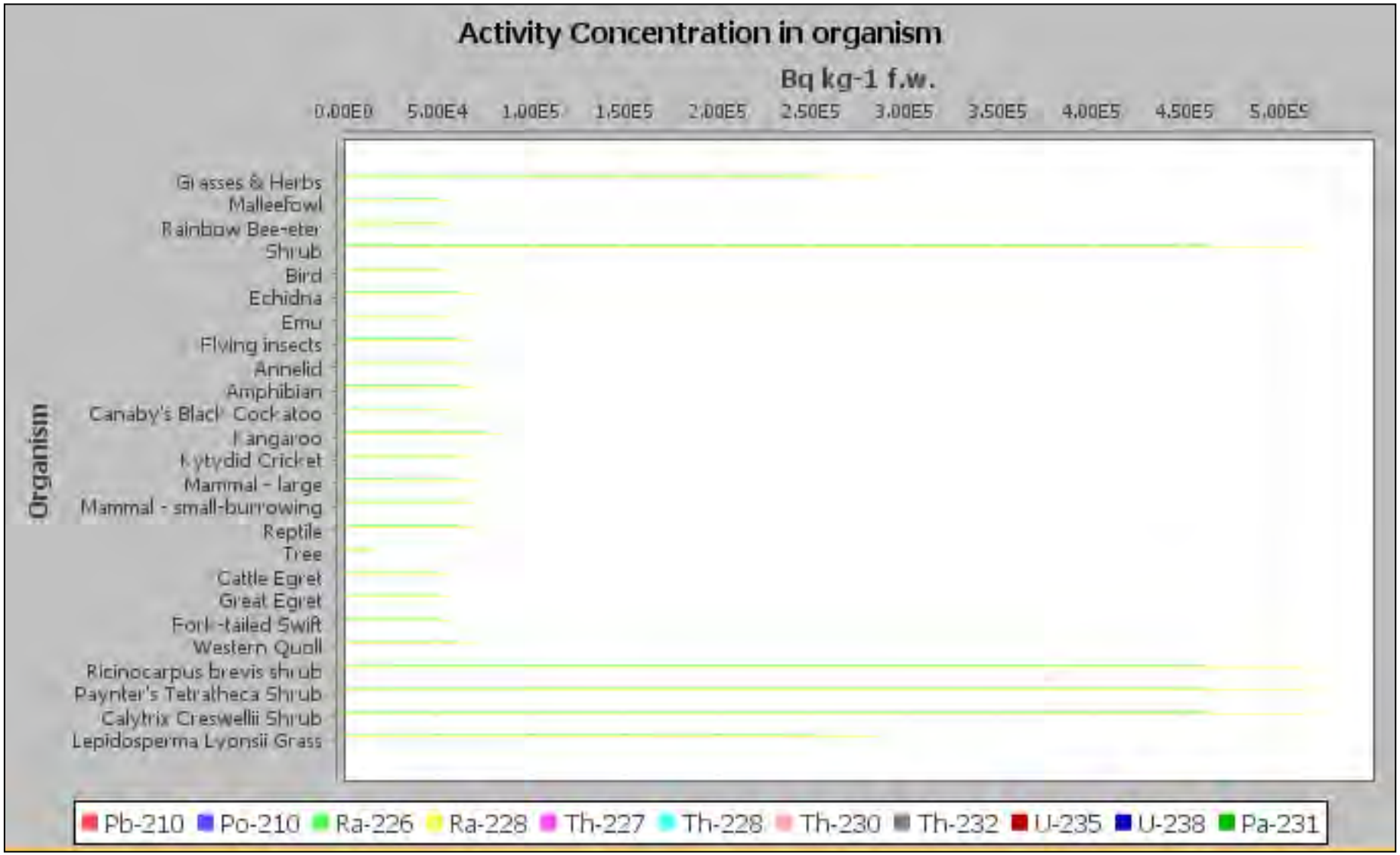
ERICA Assessment Oil and Gas Industry

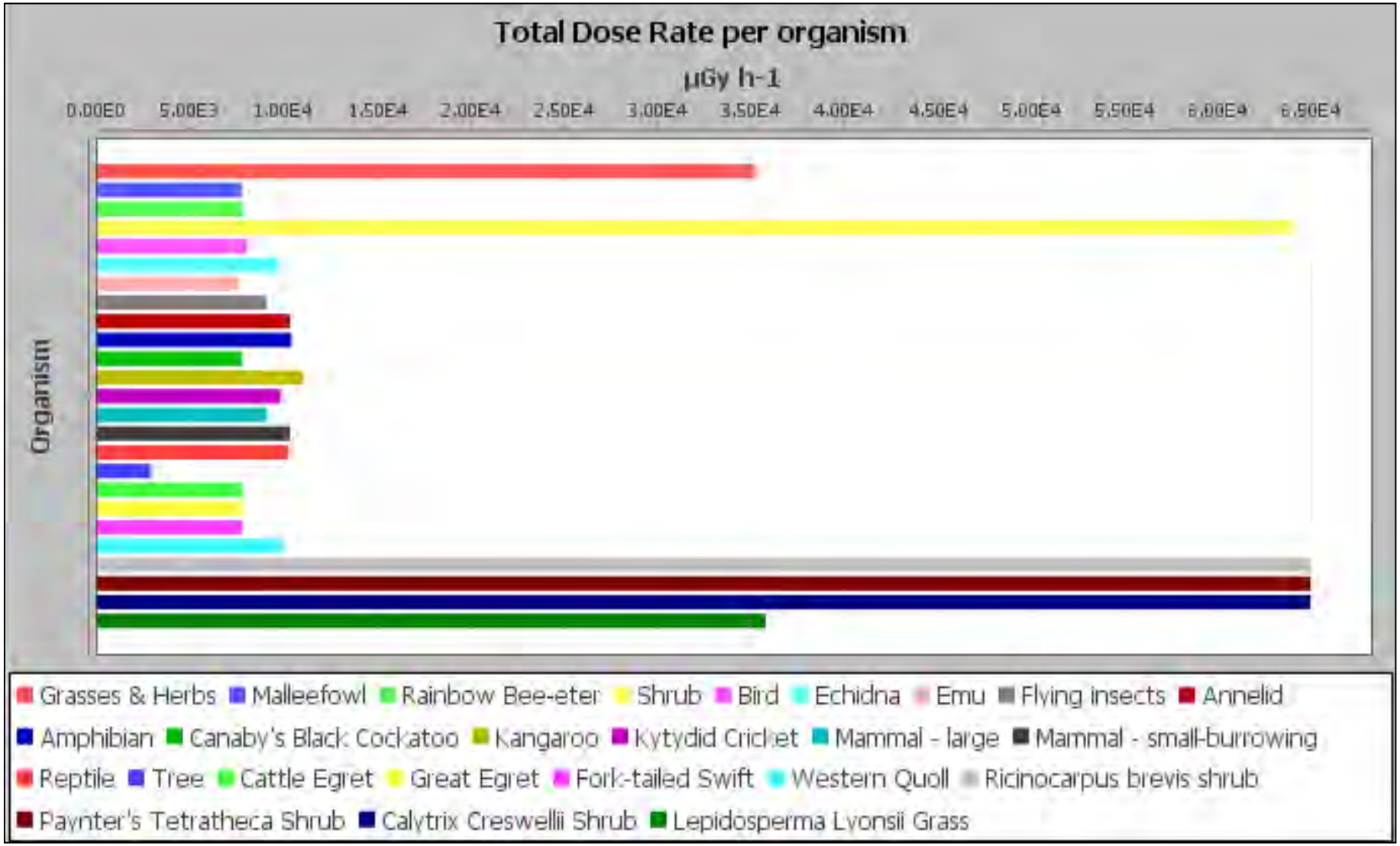

Activity Concentration in soil or air
Bq kg-1 d.w. or Bq m-3
1.60E6
1.50E6
1.40E6
1.30E6
1.20E6
1.10E6
1.00E6
9.00E5
8.00E5
7.00E5
6.00E5
5.00E5
4.00E5
3.00E5
2.00E5
1.00E5
0.00E0
Isotope
Pb-210
Po-210
Ra-226
Ra-228
Th-227
Th-228
Th-230
Th-232
U-235
U-238
Pa-231


External Dose Rate
µGy h-1
0.00E0
1.00E2
2.00E2
3.00E2
4.00E2
5.00E2
6.00E2
7.00E2
8.00E2
9.00E2
1.00E3
1.10E3
1.20E3
1.30E3
Organism
Grasses & Herbs
Malleefowl
Rainbow Bee-eter
Shrub
Bird
Echidna
Emu
Flying Insects
Annelid
Amphibian
Canaby's Black Cockatoo
Kangaroo
Kytydid Cricket
Mammal - large
Mammal - small-burrowing
Reptile
Tree
Cattle Egret
Great Egret
Fork-tailed Swift
Western Quoll
Ricinocarpus brevis shrub
Paynter's Tetratheca Shrub
Calytrix Creswellii Shrub
Lepidosperma Lyonsii Grass
Pb-210
Po-210
Ra-226
Ra-228
Th-227
Th-228
Th-230
Th-232
U-235
U-238
Pa-231


Internal Dose Rate
µGy h-1
0.00E0
5.00E3
1.00E4
1.50E4
2.00E4
2.50E4
3.00E4
3.50E4
4.00E4
4.50E4
5.00E4
5.50E4
6.00E4
6.50E4
Organism
Grasses & Herbs
Malleefowl
Rainbow Bee-eter
Shrub
Bird
Echidna
Emu
Flying insects
Annelid
Amphibian
Canaby's Black Cockatoo
Kangaroo
Kytydid Cricket
Mammal - large
Mammal - small-burrowing
Reptile
Tree
Cattle Egret
Great Egret
Fork-tailed Swift
Western Quoll
Ricinocarpus brevis shrub
Paynter's Tetratheca Shrub
Calytrix Creswellii Shrub
Lepidosperma Lyonsii Grass
Pb-210
Po-210
Ra-226
Ra-228
Th-227
Th-228
Th-230
Th-232
U-235
U-238
Pa-231

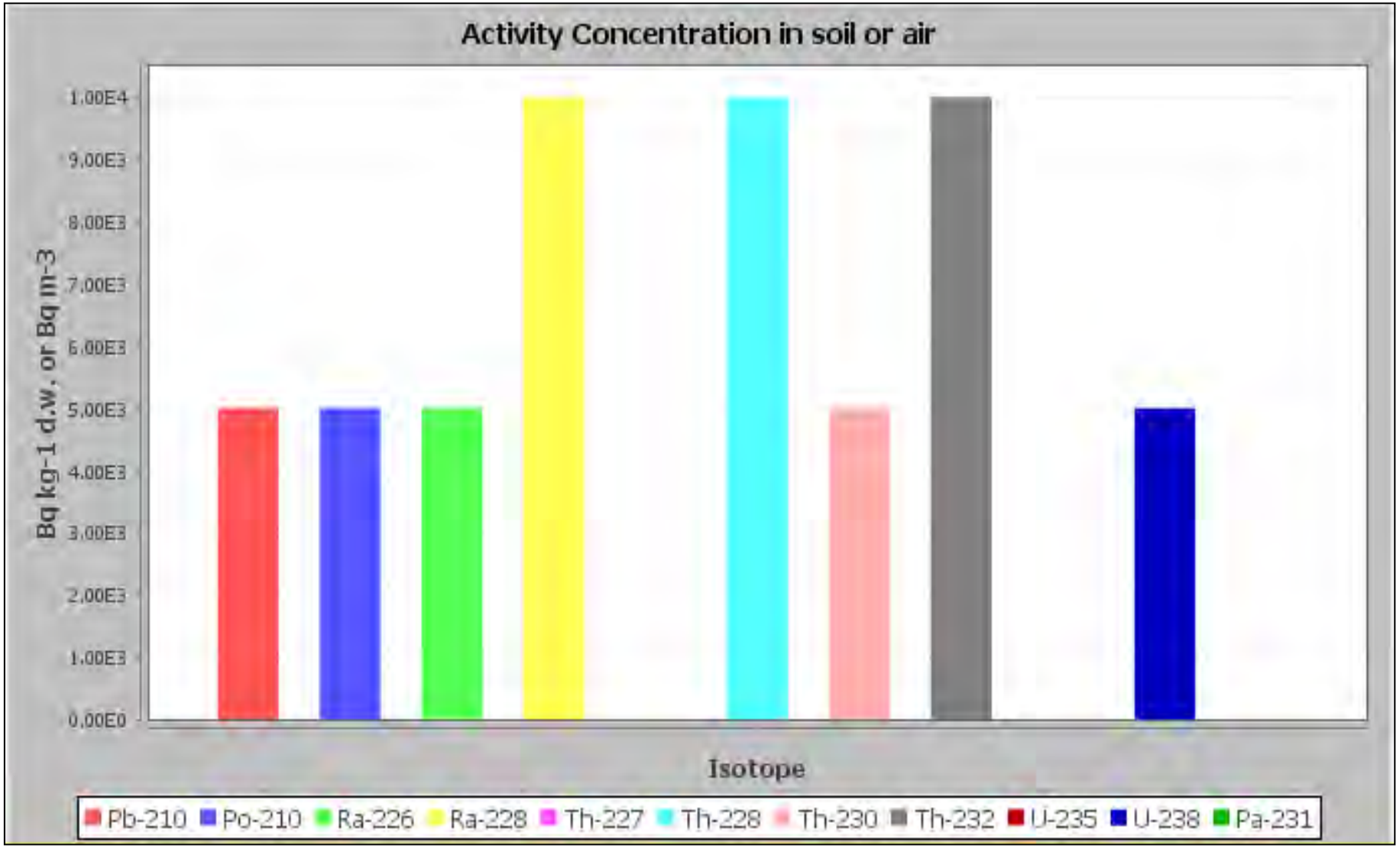

Total Dose Rate
µGy h-1
0.00E0 5.00E3 1.00E4 1.50E4 2.00E4 2.50E4 3.00E4 3.50E4 4.00E4 4.50E4 5.00E4 5.50E4 6.00E4 6.50E4
Organism
Grasses & Herbs
Malleefowl
Rainbow Bee-eter
Shrub
Bird
Echidna
Emu
Flying insects
Annelid
Amphibian
Canaby's Black Cockatoo
Kangaroo
Kytydid Cricket
Mammal - large
Mammal - small-burrowing
Reptile
Tree
Cattle Egret
Great Egret
Fork-tailed Swift
Western Quoll
Ricinocarpus brevis shrub
Paynter's Tetratheca Shrub
Calytrix Creswellii Shrub
Lepidosperma Lyonsii Grass
Pb-210 Po-210 Ra-226 Ra-228 Th-227 Th-228 Th-230 Th-232 U-235 U-238 Pa-231

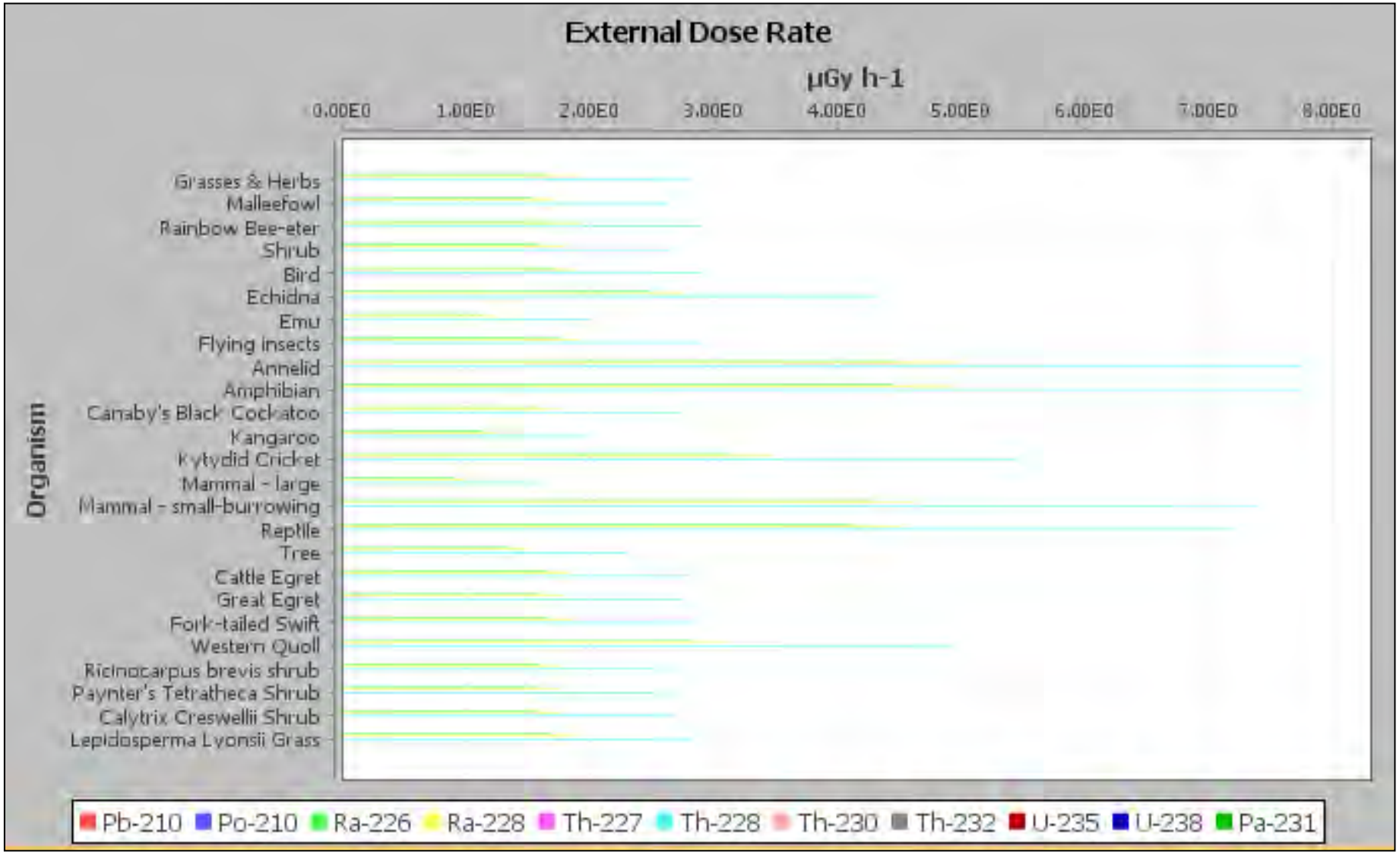

Activity Concentration in organism
Bq kg-1 f.w.
0.00E0
5.00E4
1.00E5
1.50E5
2.00E5
2.50E5
3.00E5
3.50E5
4.00E5
4.50E5
5.00E5
Organism
Grasses & Herbs
Malleefowl
Rainbow Bee-eter
Shrub
Bird
Echidna
Emu
Flying insects
Annelid
Amphibian
Canaby's Black Cockatoo
Kangaroo
Katydid Cricket
Mammal - large
Mammal - small-burrowing
Reptile
Tree
Cattle Egret
Great Egret
Fork-tailed Swift
Western Quoll
Ricinocarpus brevis shrub
Paynter's Tetratheca Shrub
Calytrix Creswellii Shrub
Lepidosperma Lyonsii Grass
Pb-210
Po-210
Ra-226
Ra-228
Th-227
Th-228
Th-230
Th-232
U-235
U-238
Pa-231

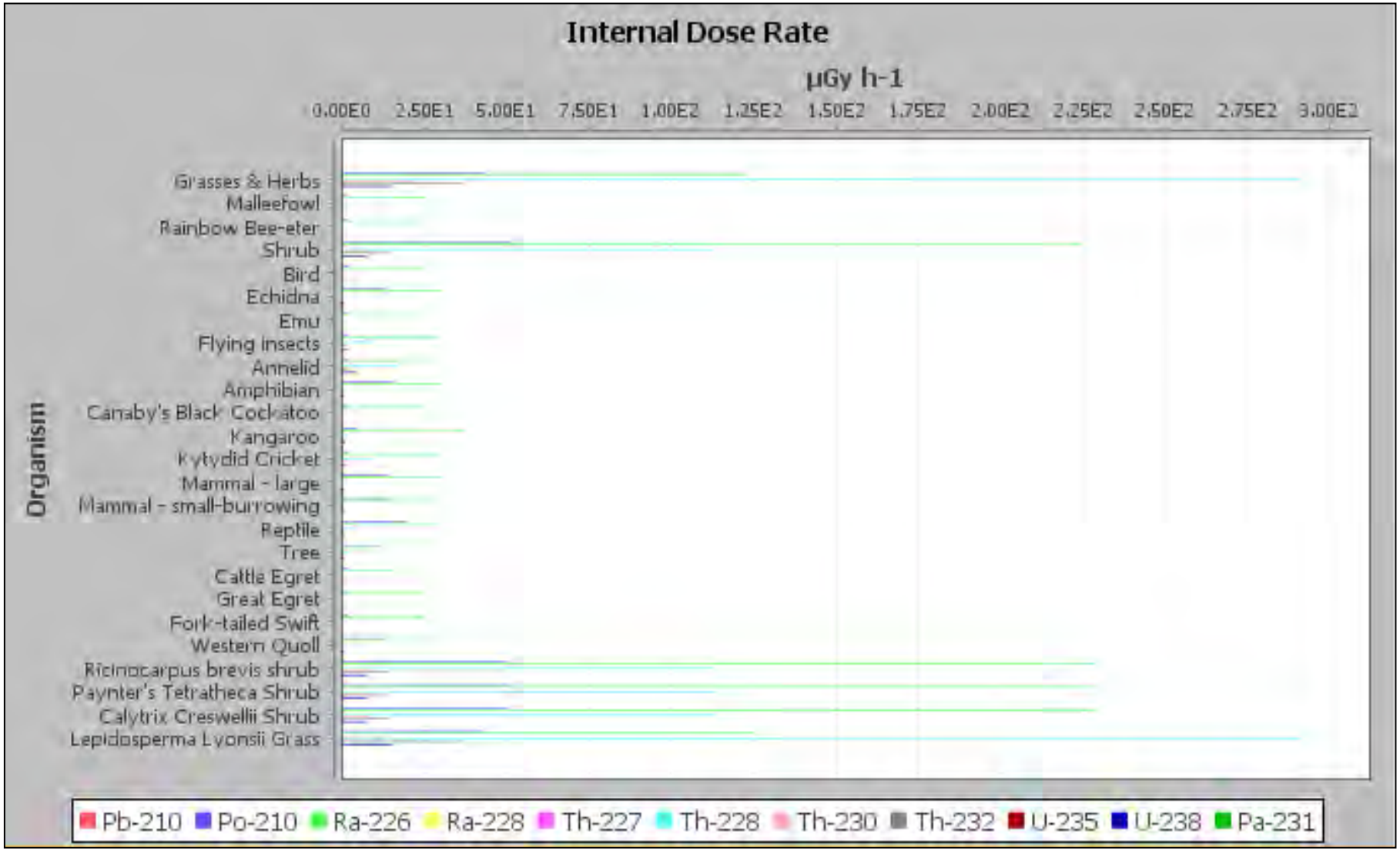

Total Dose Rate per organism
µGy h-1
0.00E0
5.00E3
1.00E4
1.50E4
2.00E4
2.50E4
3.00E4
3.50E4
4.00E4
4.50E4
5.00E4
5.50E4
6.00E4
6.50E4
Organism
Grasses & Herbs
Malleefowl
Rainbow Bee-eter
Shrub
Bird
Echidna
Emu
Flying insects
Annelid
Amphibian
Canaby's Black Cockatoo
Kangaroo
Kytydid Cricket
Mammal - large
Mammal - small-burrowing
Reptile
Tree
Cattle Egret
Great Egret
Fork-tailed Swift
Western Quoll
Ricinocarpus brevis shrub
Paynter's Tetratheca Shrub
Calytrix Creswellii Shrub
Lepidosperma Lyonsii Grass

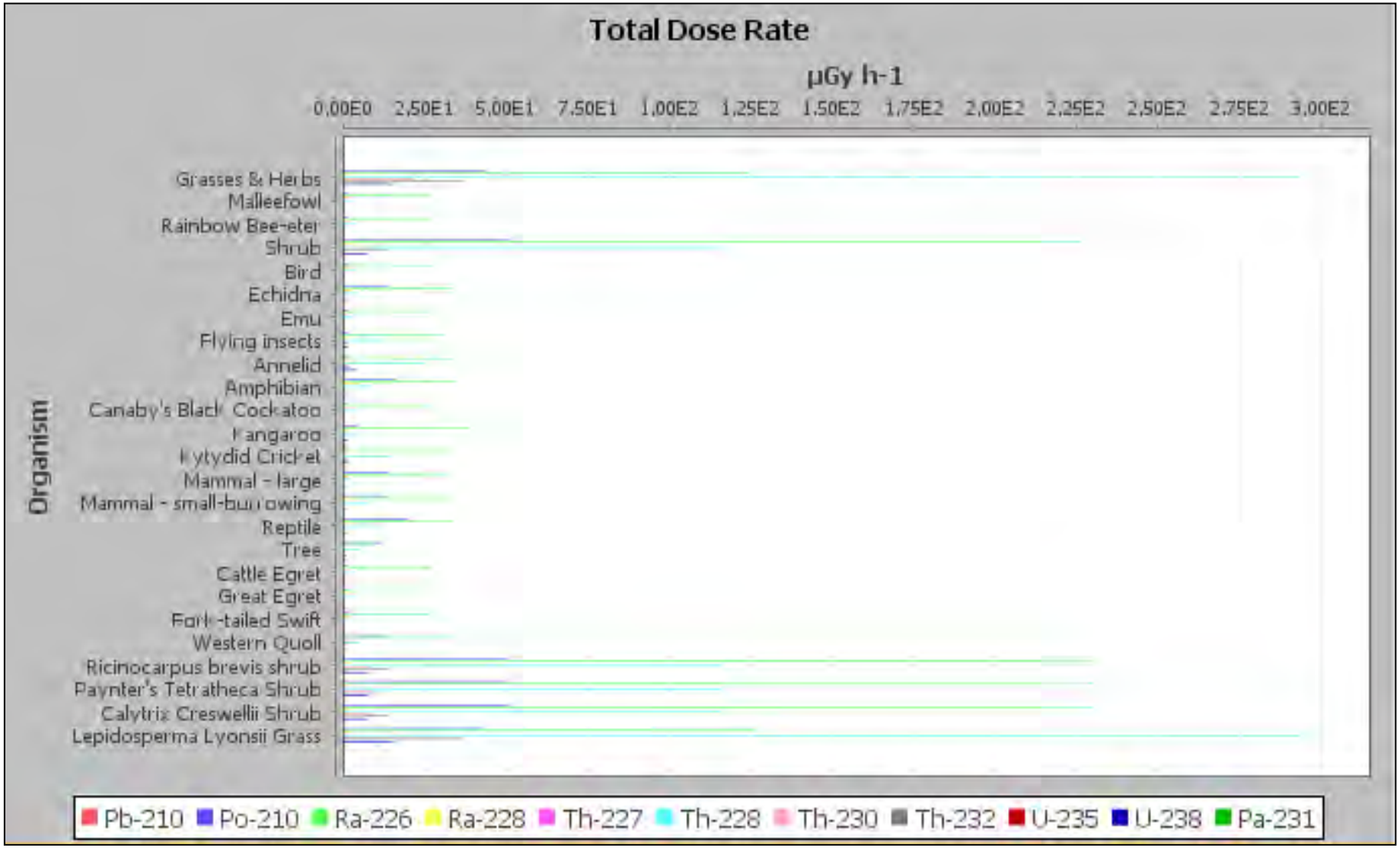
Appendix E

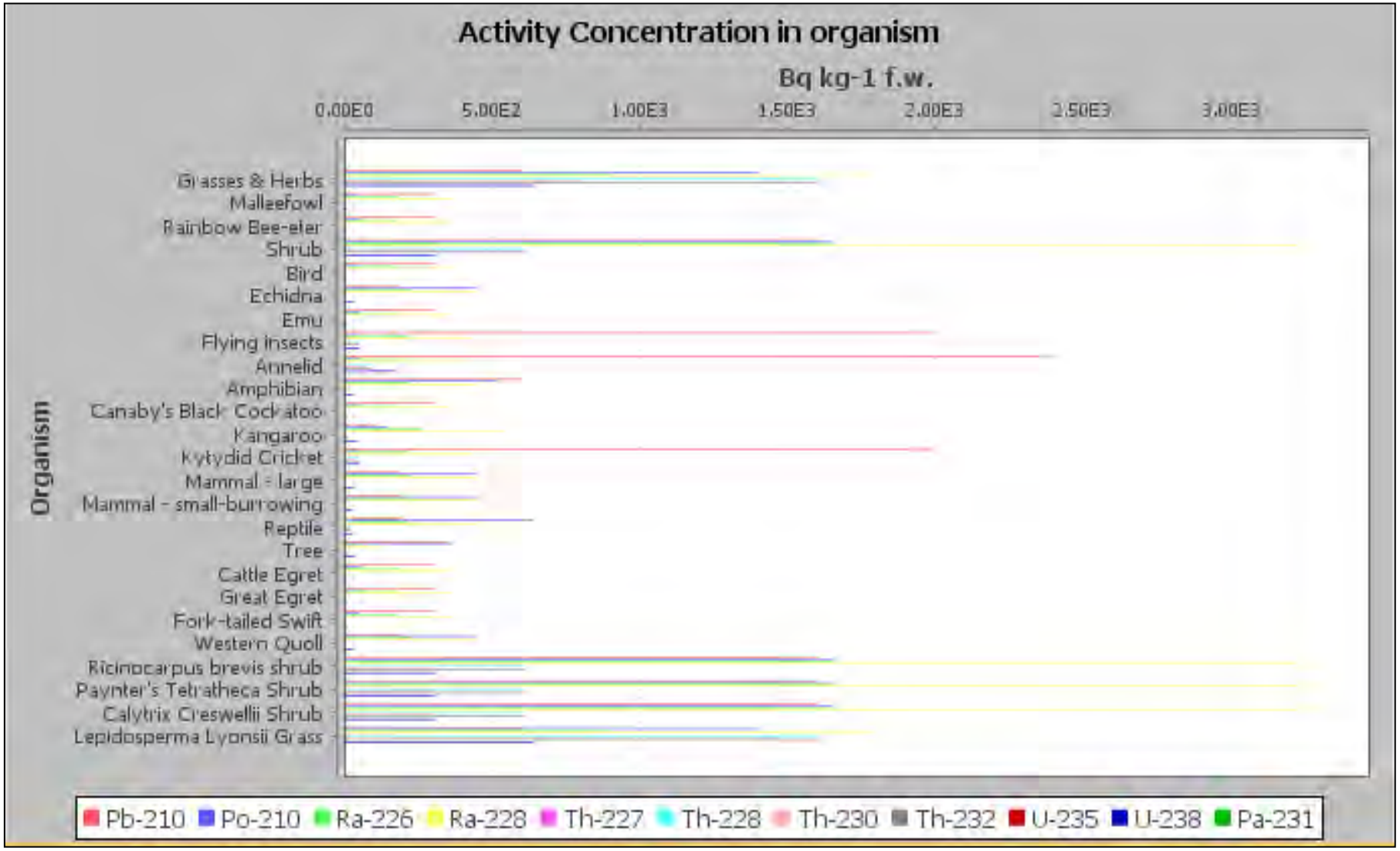
ERICA Assessment Category A Waste

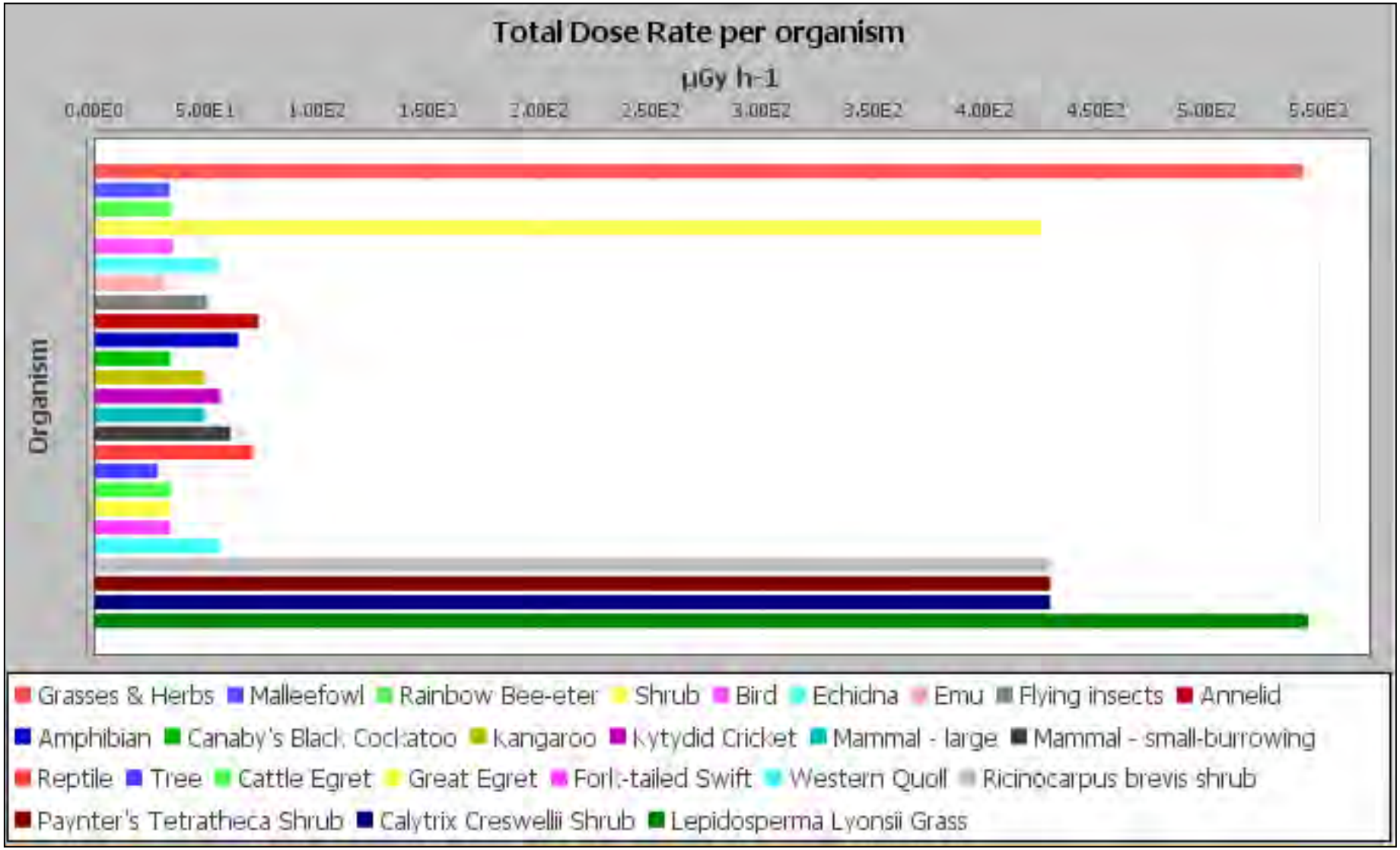

Activity Concentration in soil or air
Bq kg-1 d.w. or Bq m-3
1.00E4
9.00E3
8.00E3
7.00E3
6.00E3
5.00E3
4.00E3
3.00E3
2.00E3
1.00E3
0.00E0
Isotope
Pb-210
Po-210
Ra-226
Ra-228
Th-227
Th-228
Th-230
Th-232
U-235
U-238
Pa-231


External Dose Rate
µGy h-1
0.00E0
1.00E0
2.00E0
3.00E0
4.00E0
5.00E0
6.00E0
7.00E0
8.00E0
Organism
Grasses & Herbs
Malleefowl
Rainbow Bee-eter
Shrub
Bird
Echidna
Emu
Flying insects
Annelid
Amphibian
Canaby's Black Cockatoo
Kangaroo
Kytydid Cricket
Mammal - large
Mammal - small-burrowing
Reptile
Tree
Cattle Egret
Great Egret
Fork-tailed Swift
Western Quoll
Ricinocarpus brevis shrub
Paynter's Tetratheca Shrub
Calytrix Creswellii Shrub
Lepidosperma Lyonsii Grass
Pb-210
Po-210
Ra-226
Ra-228
Th-227
Th-228
Th-230
Th-232
U-235
U-238
Pa-231


Internal Dose Rate
µGy h-1
0.00E0
2.50E1
5.00E1
7.50E1
1.00E2
1.25E2
1.50E2
1.75E2
2.00E2
2.25E2
2.50E2
2.75E2
3.00E2
Organism
Grasses & Herbs
Malleefowl
Rainbow Bee-eter
Shrub
Bird
Echidna
Emu
Flying insects
Annelid
Amphibian
Canaby's Black Cockatoo
Kangaroo
Kytydid Cricket
Mammal - large
Mammal - small-burrowing
Reptile
Tree
Cattle Egret
Great Egret
Fork-tailed Swift
Western Quoll
Ricinocarpus brevis shrub
Paynter's Tetratheca Shrub
Calytrix Creswellii Shrub
Lepidosperma Lyonsii Grass
Pb-210
Po-210
Ra-226
Ra-228
Th-227
Th-228
Th-230
Th-232
U-235
U-238
Pa-231

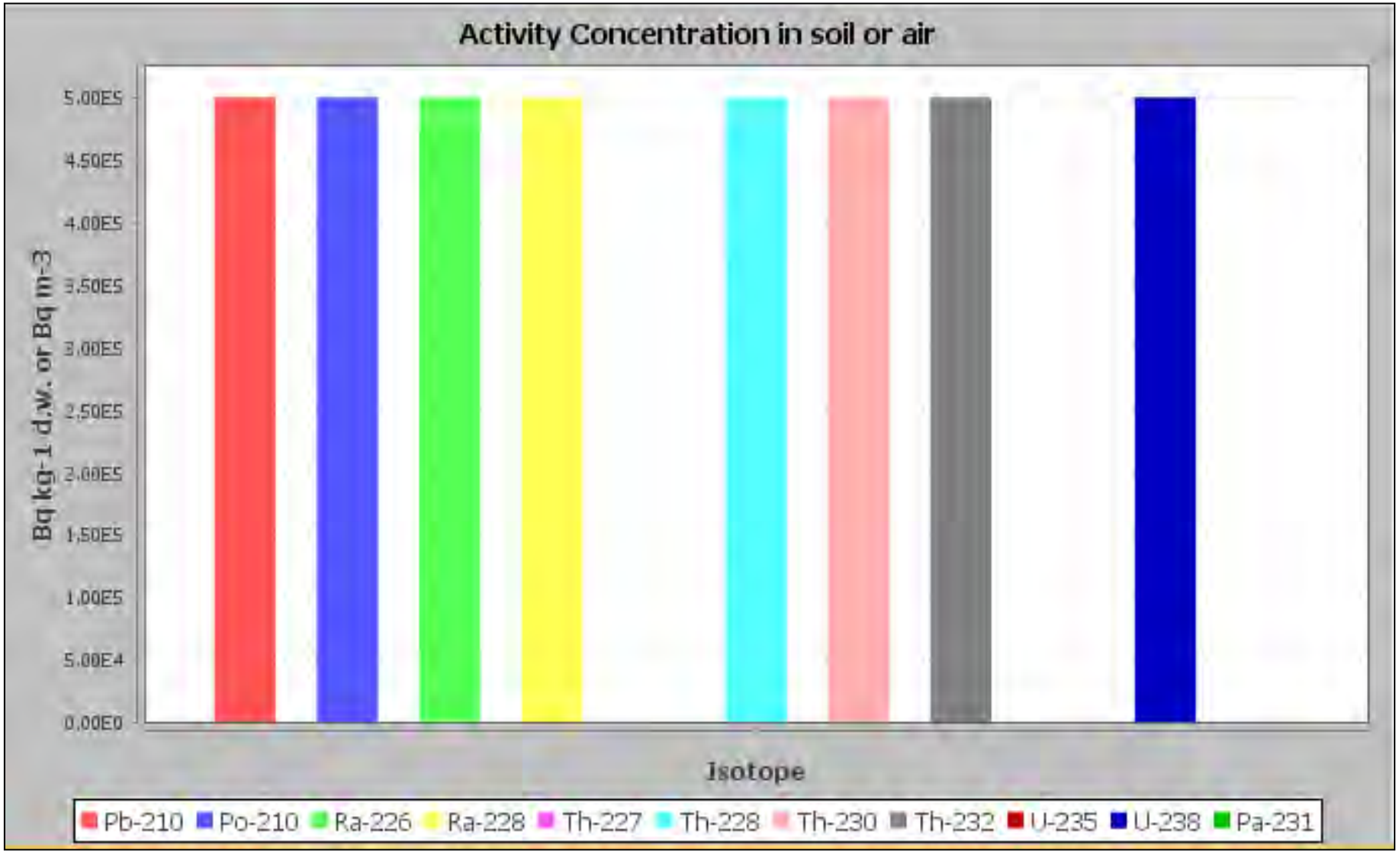

Total Dose Rate
µGy h-1
0,00E0
2,50E1
5,00E1
7,50E1
1,00E2
1,25E2
1,50E2
1,75E2
2,00E2
2,25E2
2,50E2
2,75E2
3,00E2
Organism
Grasses & Herbs
Malleefowl
Rainbow Bee-eter
Shrub
Bird
Echidna
Emu
Flying insects
Annelid
Amphibian
Canaby's Black Cockatoo
Kangaroo
Katydid Cricket
Mammal - large
Mammal - small-burrowing
Reptile
Tree
Cattle Egret
Great Egret
Fork-tailed Swift
Western Quoll
Ricinocarpus brevis shrub
Paynter's Tetratheca Shrub
Calytrix Creswellii Shrub
Lepidosperma Lyonsii Grass
Pb-210
Po-210
Ra-226
Ra-228
Th-227
Th-228
Th-230
Th-232
U-235
U-238
Pa-231

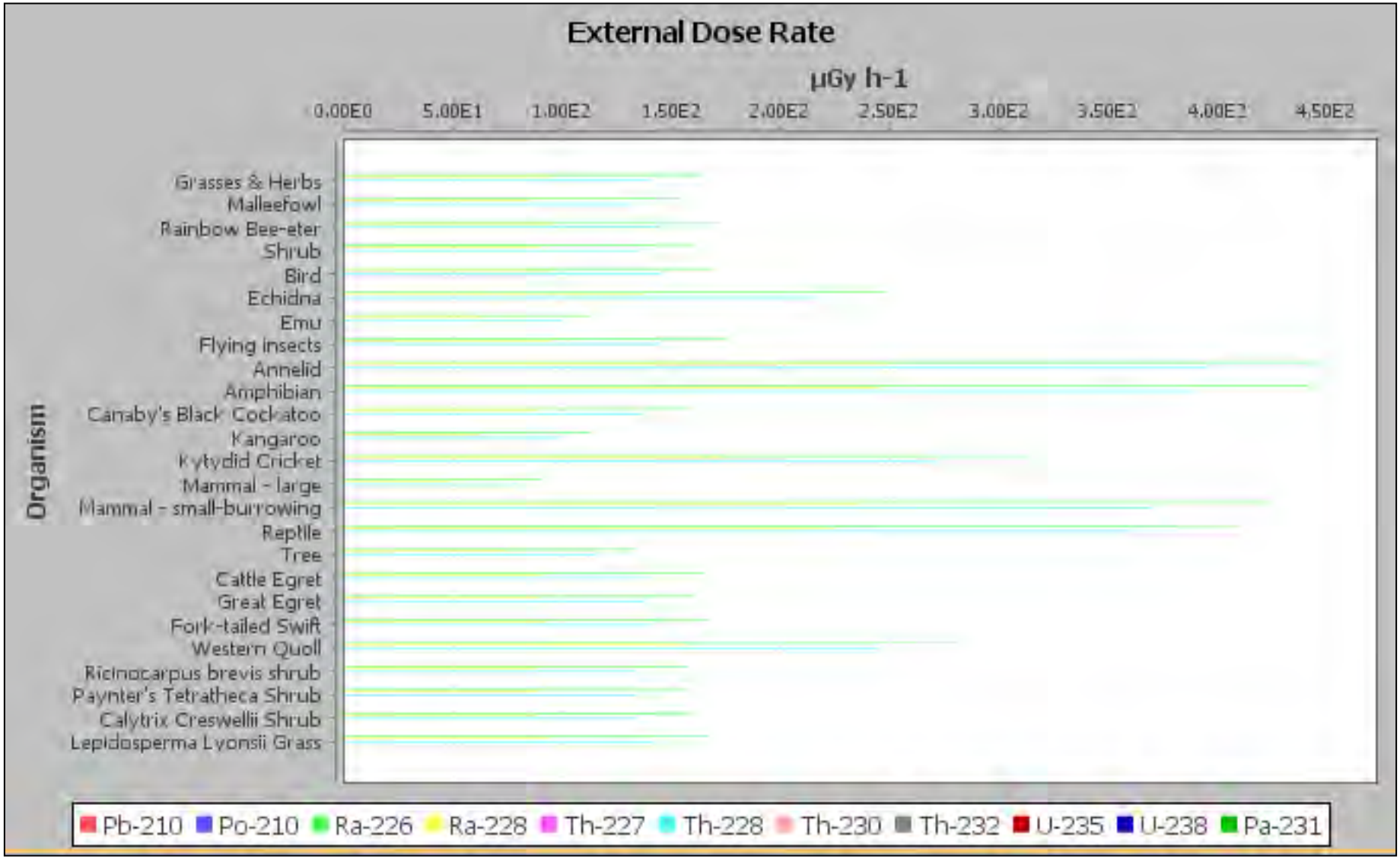

Activity Concentration in organism
Bq kg-1 f.w.
0.00E0
5.00E2
1.00E3
1.50E3
2.00E3
2.50E3
3.00E3
Organism
Grasses & Herbs
Malleefowl
Rainbow Bee-eter
Shrub
Bird
Echidna
Emu
Flying insects
Annelid
Amphibian
Canaby's Black Cockatoo
Kangaroo
Kytydid Cricket
Mammal - large
Mammal - small-burrowing
Reptile
Tree
Cattle Egret
Great Egret
Fork-tailed Swift
Western Quoll
Ricinocarpus brevis shrub
Paynter's Tetratheca Shrub
Calytrix Creswellii Shrub
Lepidosperma Lyonsii Grass
Pb-210
Po-210
Ra-226
Ra-228
Th-227
Th-228
Th-230
Th-232
U-235
U-238
Pa-231

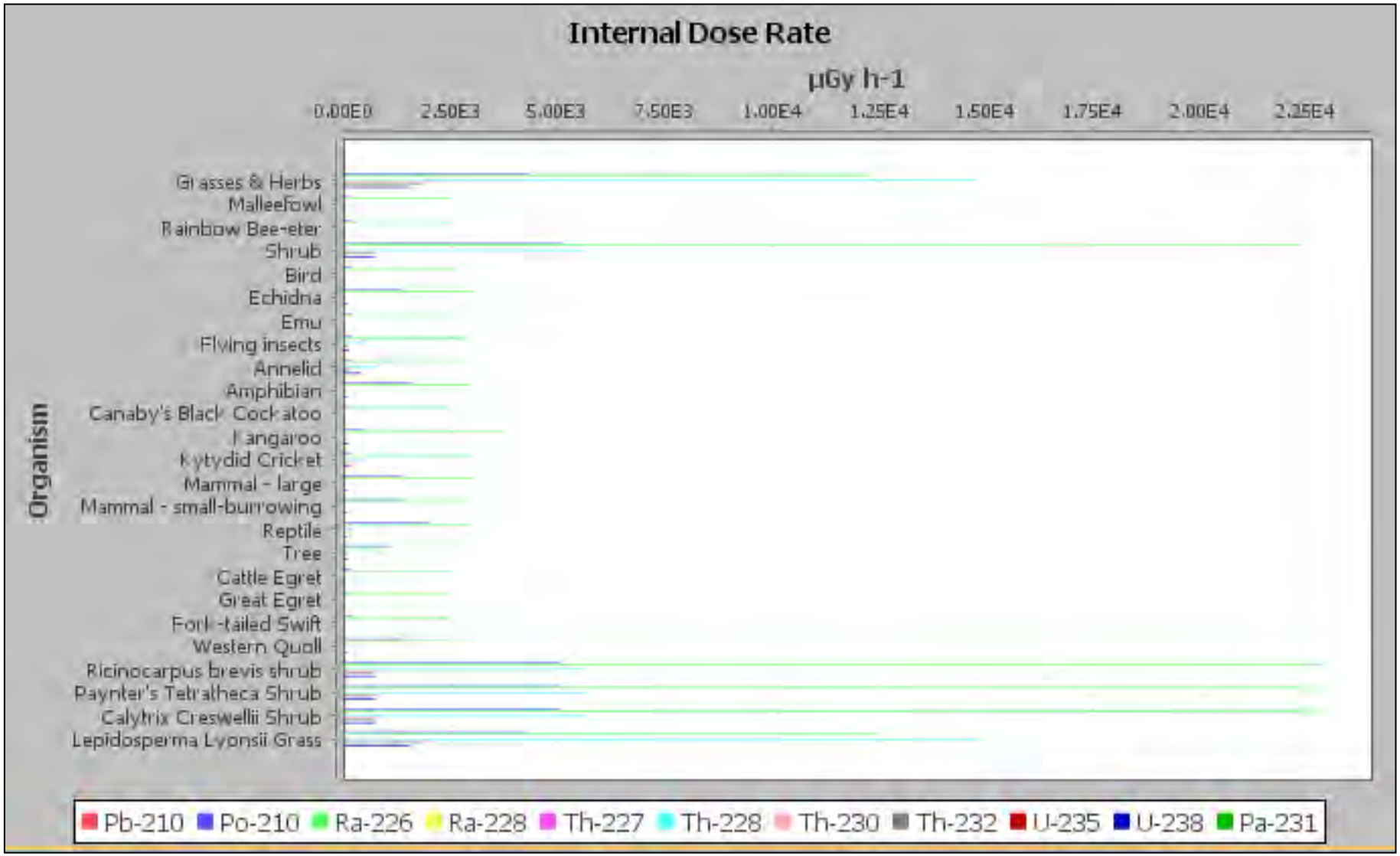

Total Dose Rate per organism
µGy h-1
0.00E0
5.00E1
1.00E2
1.50E2
2.00E2
2.50E2
3.00E2
3.50E2
4.00E2
4.50E2
5.00E2
5.50E2
Organism
Grasses & Herbs
Malleefowl
Rainbow Bee-eter
Shrub
Bird
Echidna
Emu
Flying insects
Annelid
Amphibian
Canaby's Black Cockatoo
Kangaroo
Kytydid Cricket
Mammal - large
Mammal - small-burrowing
Reptile
Tree
Cattle Egret
Great Egret
Fork-tailed Swift
Western Quoll
Ricinocarpus brevis shrub
Paynter's Tetratheca Shrub
Calytrix Creswellii Shrub
Lepidosperma Lyonsii Grass

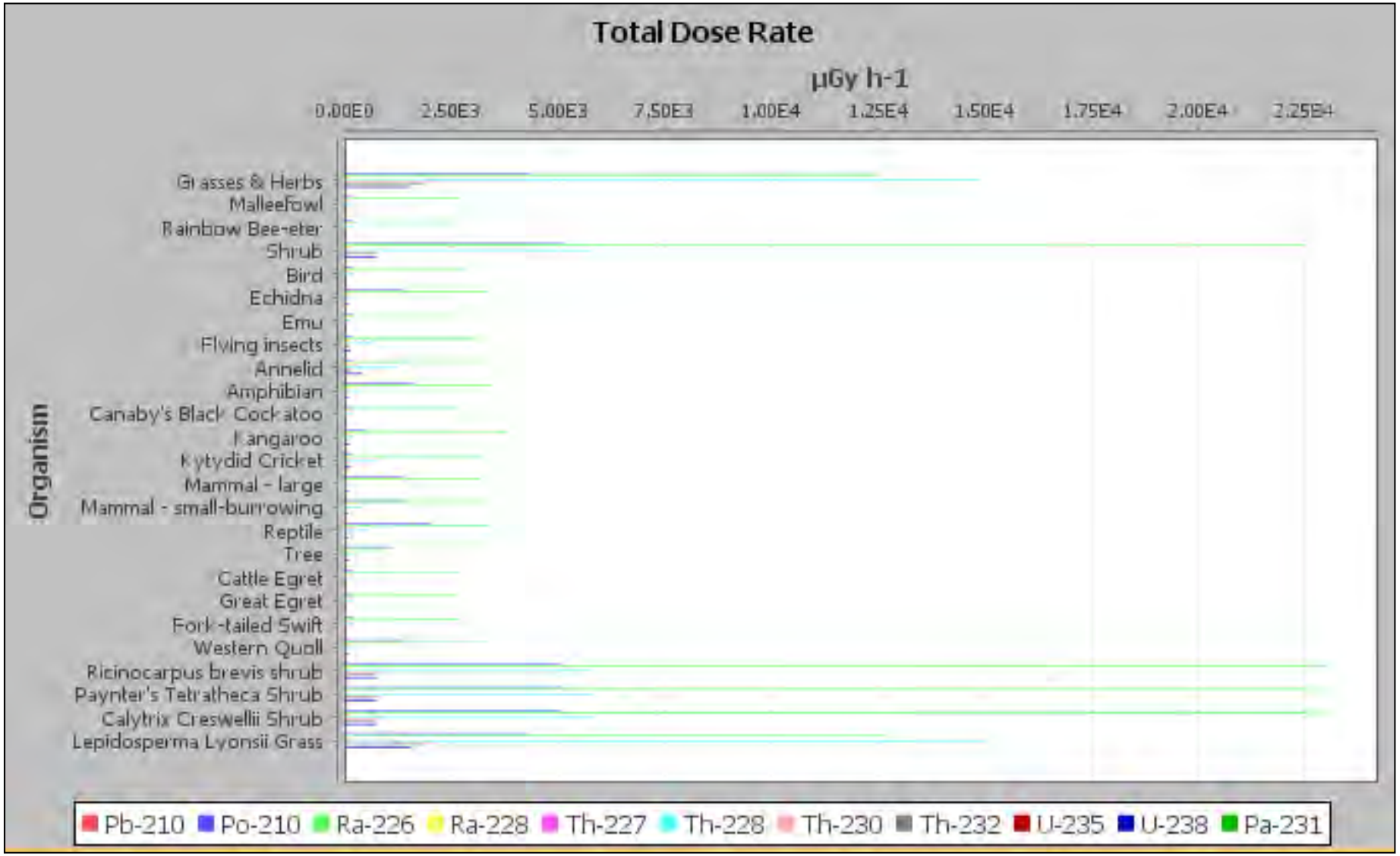
Appendix F

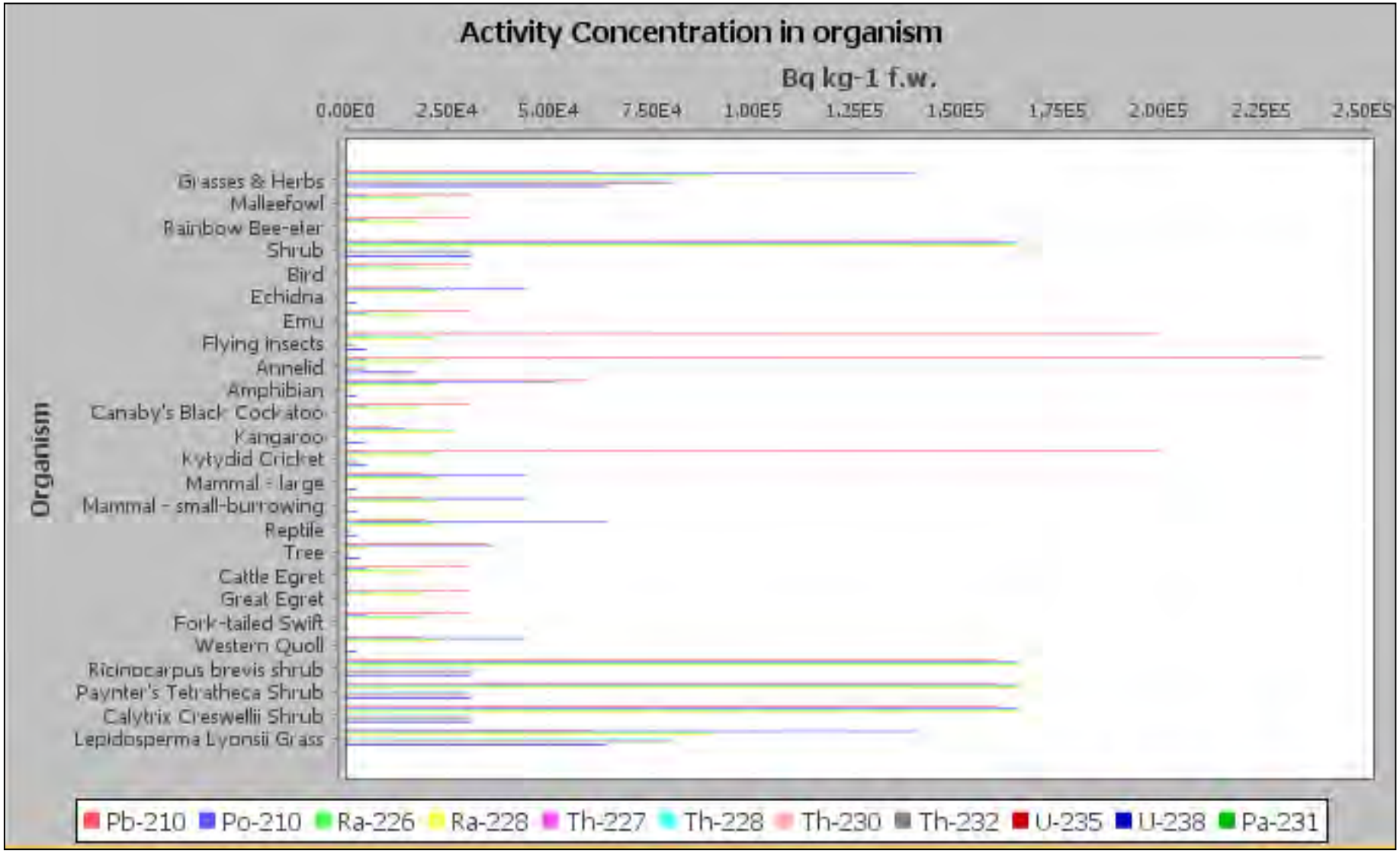
ERICA Assessment Category C Waste

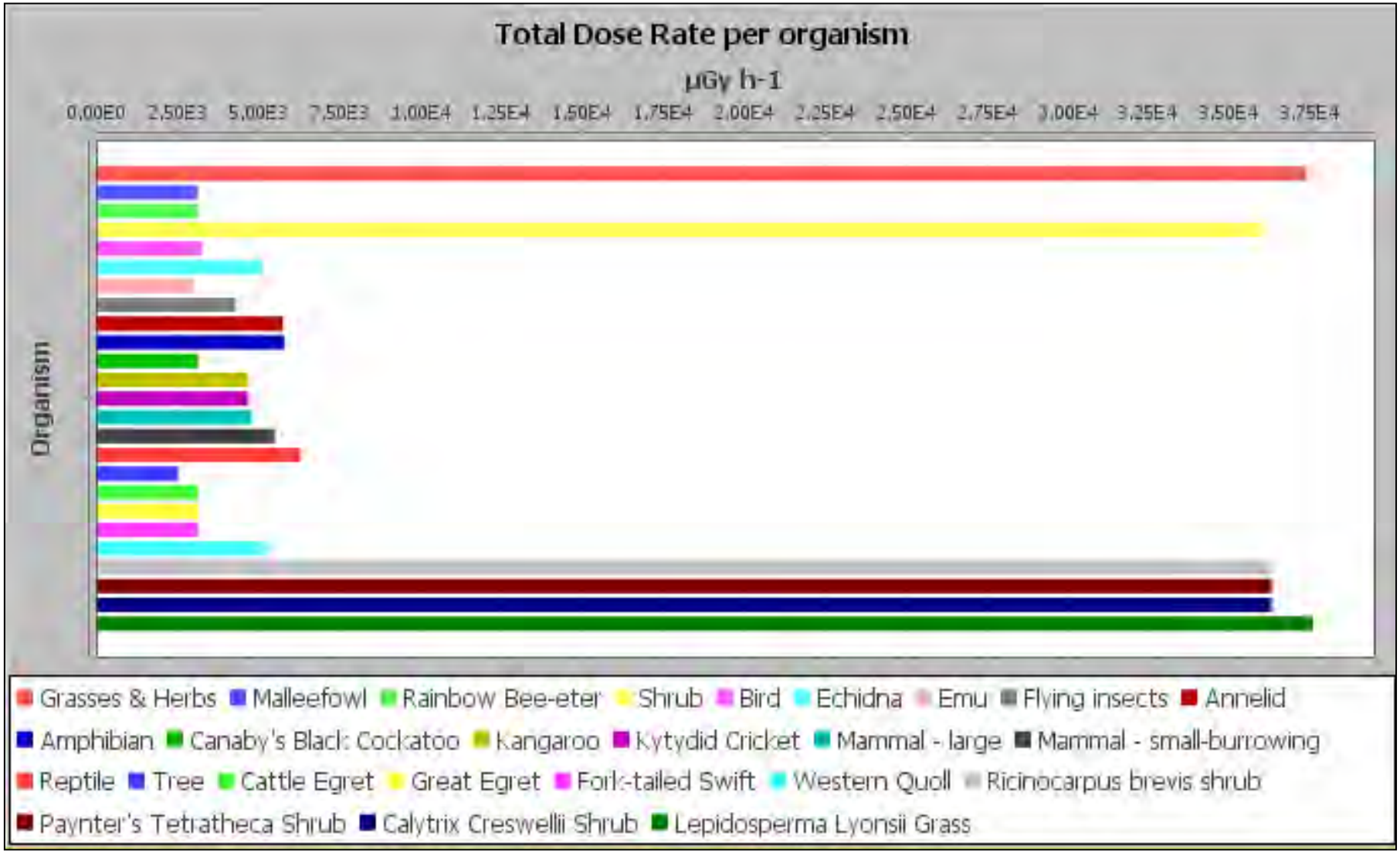

Activity Concentration in soil or air
Bq kg-1 d.w. or Bq m-3
5.00E5
4.50E5
4.00E5
3.50E5
3.00E5
2.50E5
2.00E5
1.50E5
1.00E5
5.00E4
0.00E0
Isotope
Pb-210
Po-210
Ra-226
Ra-228
Th-227
Th-228
Th-230
Th-232
U-235
U-238
Pa-231


External Dose Rate
µGy h-1
0.00E0
5.00E1
1.00E2
1.50E2
2.00E2
2.50E2
3.00E2
3.50E2
4.00E2
4.50E2
Organism
Grasses & Herbs
Malleefowl
Rainbow Bee-eter
Shrub
Bird
Echidna
Emu
Flying insects
Annelid
Amphibian
Canaby's Black Cockatoo
Kangaroo
Kytydid Cricket
Mammal - large
Mammal - small-burrowing
Reptile
Tree
Cattle Egret
Great Egret
Fork-tailed Swift
Western Quoll
Ricinocarpus brevis shrub
Paynter's Tetratheca Shrub
Calytrix Creswellii Shrub
Lepidosperma Lyonsii Grass
Pb-210
Po-210
Ra-226
Ra-228
Th-227
Th-228
Th-230
Th-232
U-235
U-238
Pa-231


Internal Dose Rate
µGy h-1
0.00E0
2.50E3
5.00E3
7.50E3
1.00E4
1.25E4
1.50E4
1.75E4
2.00E4
2.25E4
Organism
Grasses & Herbs
Malleefowl
Rainbow Bee-eter
Shrub
Bird
Echidna
Emu
Flying insects
Annelid
Amphibian
Canaby's Black Cockatoo
Kangaroo
Kytydid Cricket
Mammal - large
Mammal - small-burrowing
Reptile
Tree
Cattle Egret
Great Egret
Fork-tailed Swift
Western Quoll
Ricinocarpus brevis shrub
Paynter's Tetratheca Shrub
Calytrix Creswellii Shrub
Lepidosperma Lyonsii Grass
Pb-210
Po-210
Ra-226
Ra-228
Th-227
Th-228
Th-230
Th-232
U-235
U-238
Pa-231

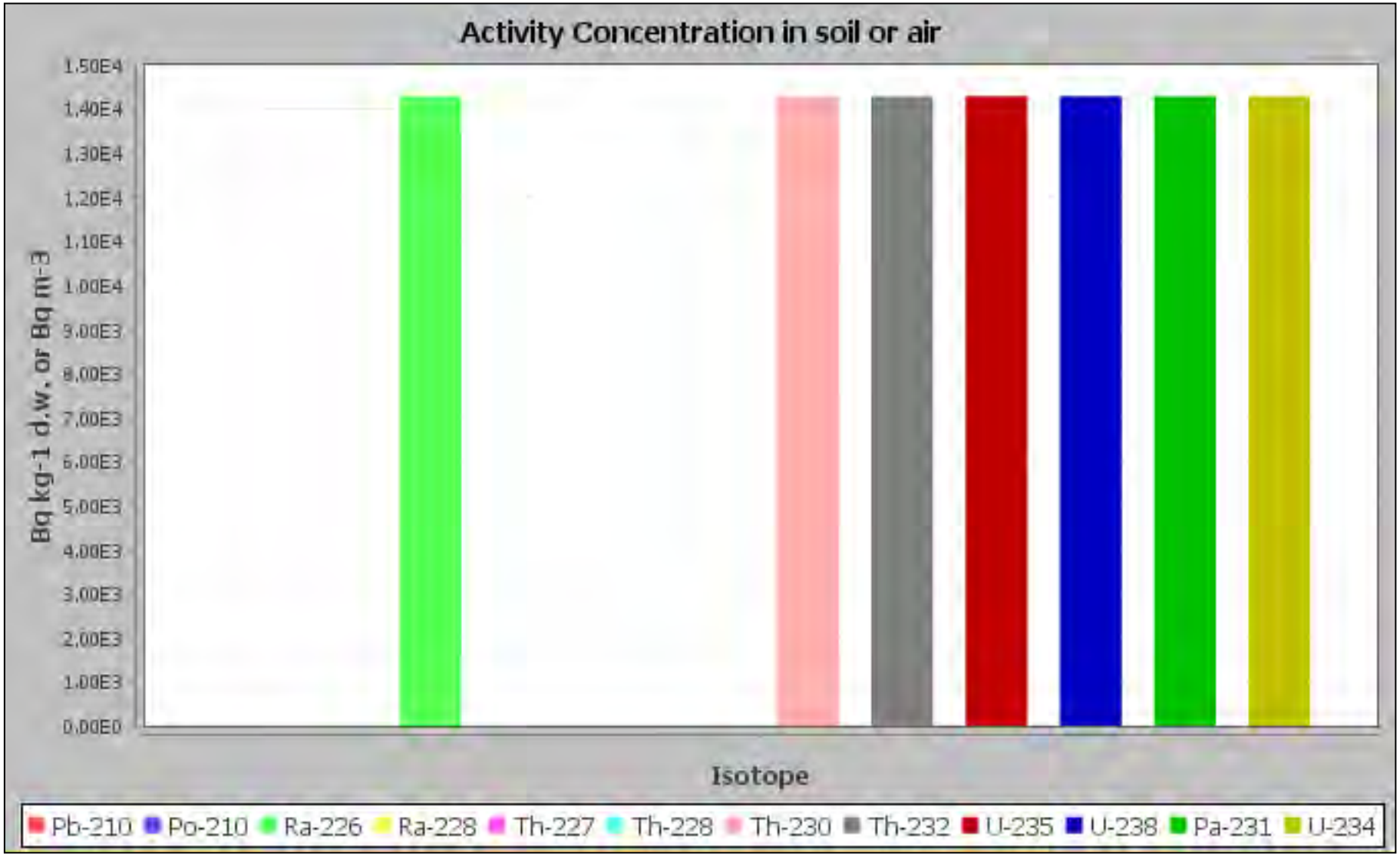

Total Dose Rate
µGy h-1
0.00E0
2.50E3
5.00E3
7.50E3
1.00E4
1.25E4
1.50E4
1.75E4
2.00E4
2.25E4
Organism
Grasses & Herbs
Malleefowl
Rainbow Bee-eter
Shrub
Bird
Echidna
Emu
Flying insects
Annelid
Amphibian
Canaby's Black Cockatoo
Kangaroo
Kytydid Cricket
Mammal - large
Mammal - small-burrowing
Reptile
Tree
Cattle Egret
Great Egret
Fork-tailed Swift
Western Quoll
Ricinocarpus brevis shrub
Paynter's Tetratheca Shrub
Calytrix Creswellii Shrub
Lepidosperma Lyonsii Grass
Pb-210
Po-210
Ra-226
Ra-228
Th-227
Th-228
Th-230
Th-232
U-235
U-238
Pa-231

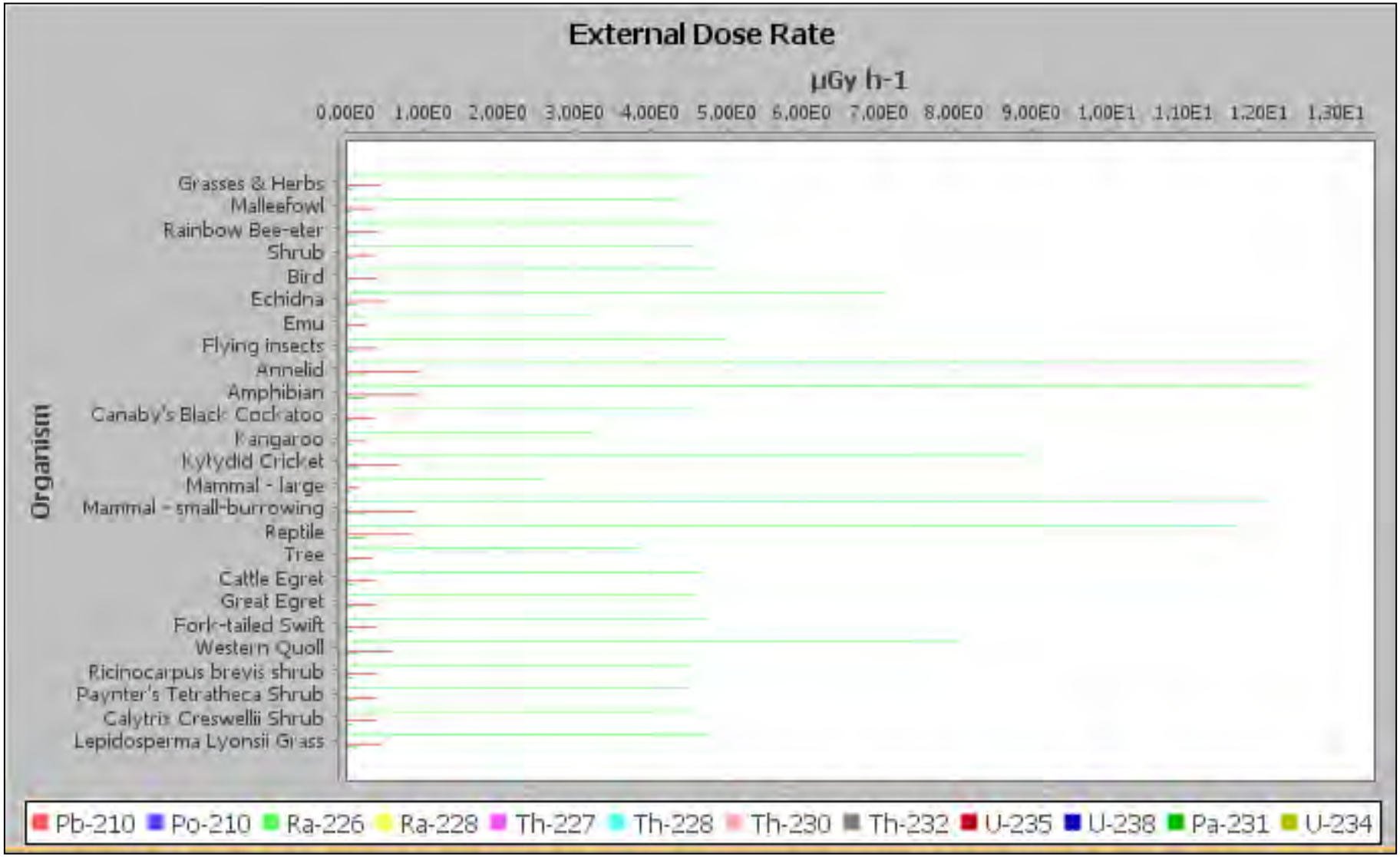

Activity Concentration in organism
Bq kg-1 f.w.
0.00E0
2.50E4
5.00E4
7.50E4
1.00E5
1.25E5
1.50E5
1.75E5
2.00E5
2.25E5
2.50E5
Organism
Grasses & Herbs
Malleefowl
Rainbow Bee-eter
Shrub
Bird
Echidna
Emu
Flying insects
Annelid
Amphibian
Canaby's Black Cockatoo
Kangaroo
Kytydid Cricket
Mammal - large
Mammal - small-burrowing
Reptile
Tree
Cattle Egret
Great Egret
Fork-tailed Swift
Western Quoll
Ricinocarpus brevis shrub
Paynter's Tetratheca Shrub
Calytrix Creswellii Shrub
Lepidosperma Lyonsii Grass
Pb-210
Po-210
Ra-226
Ra-228
Th-227
Th-228
Th-230
Th-232
U-235
U-238
Pa-231

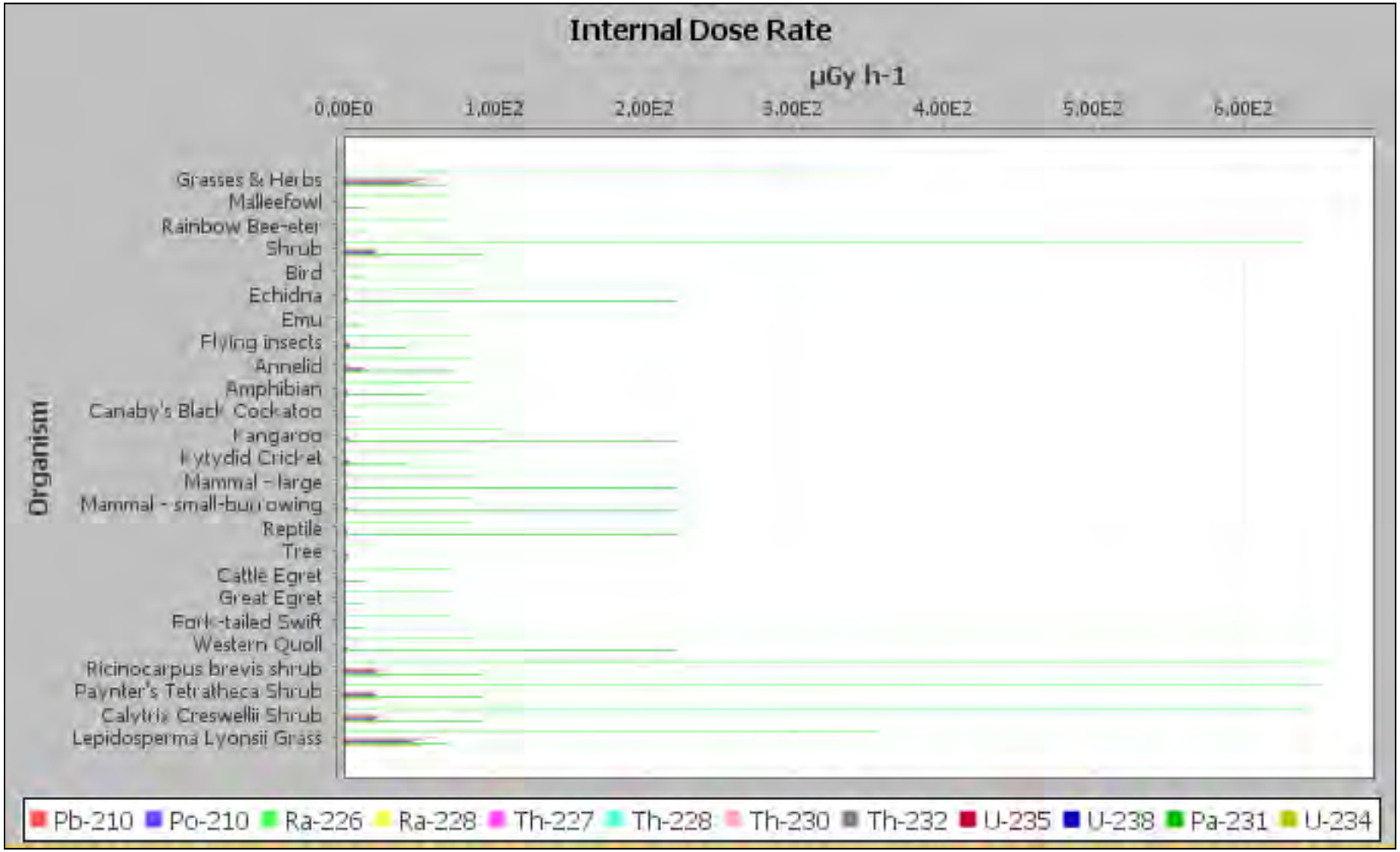

Total Dose Rate per organism
µGy h-1
0.00E0
2.50E3
5.00E3
7.50E3
1.00E4
1.25E4
1.50E4
1.75E4
2.00E4
2.25E4
2.50E4
2.75E4
3.00E4
3.25E4
3.50E4
3.75E4
Organism
Grasses & Herbs
Malleefowl
Rainbow Bee-eter
Shrub
Bird
Echidna
Emu
Flying insects
Annelid
Amphibian
Canaby's Black Cockatoo
Kangaroo
Kytydid Cricket
Mammal - large
Mammal - small-burrowing
Reptile
Tree
Cattle Egret
Great Egret
Fork-tailed Swift
Western Quoll
Ricinocarpus brevis shrub
Paynter's Tetratheca Shrub
Calytrix Creswellii Shrub
Lepidosperma Lyonsii Grass

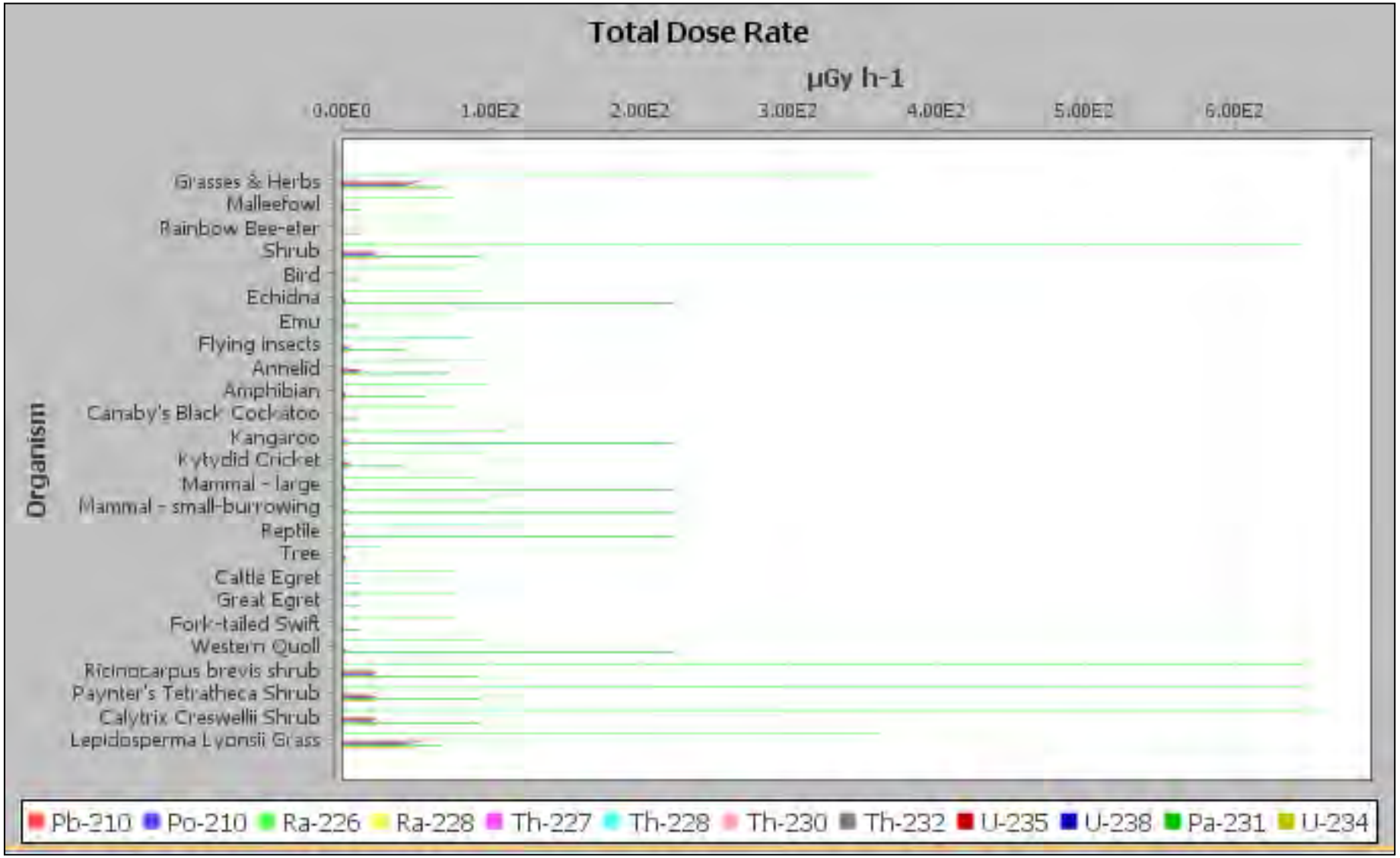
Appendix G

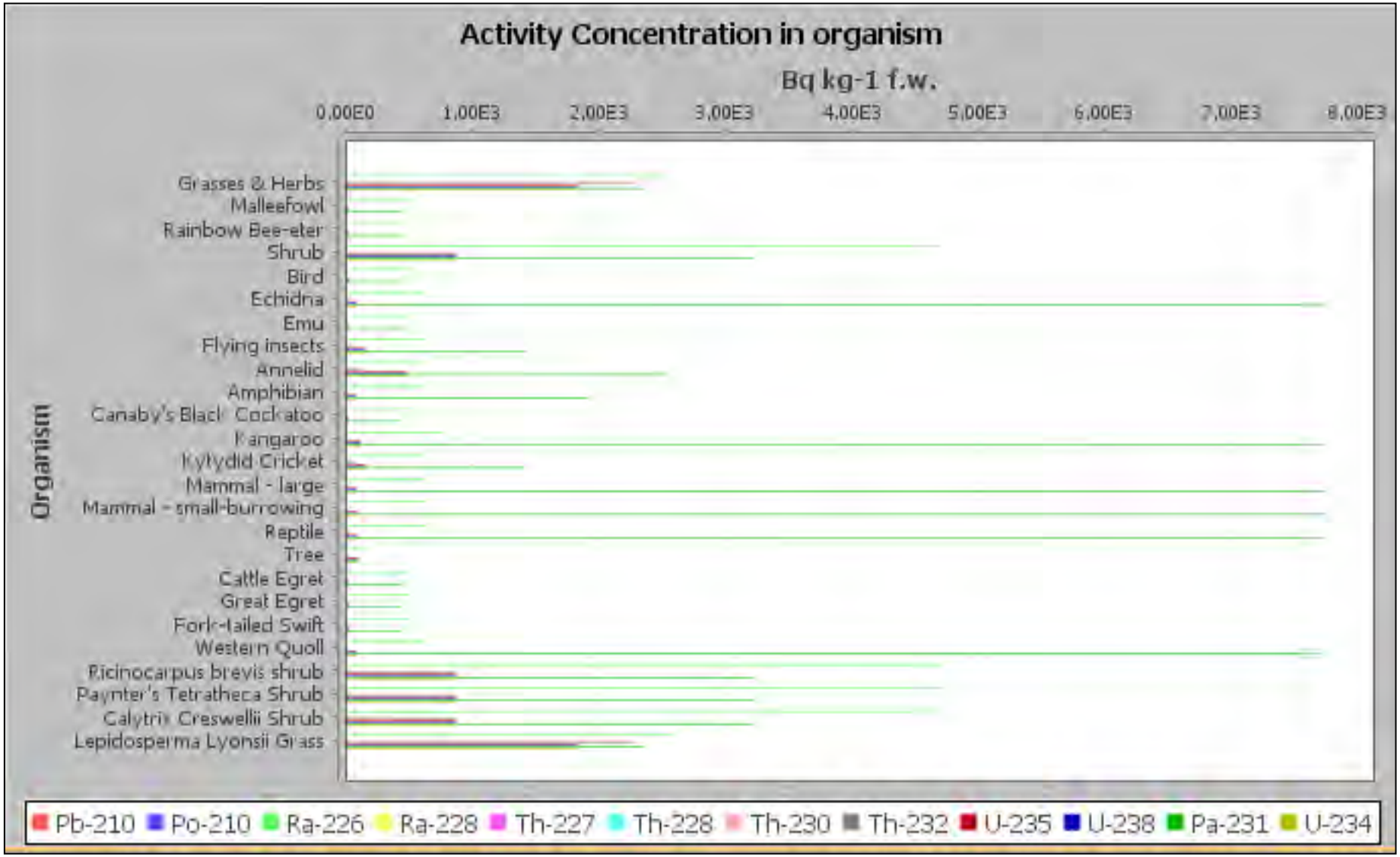
ERICA Assessment VLLW

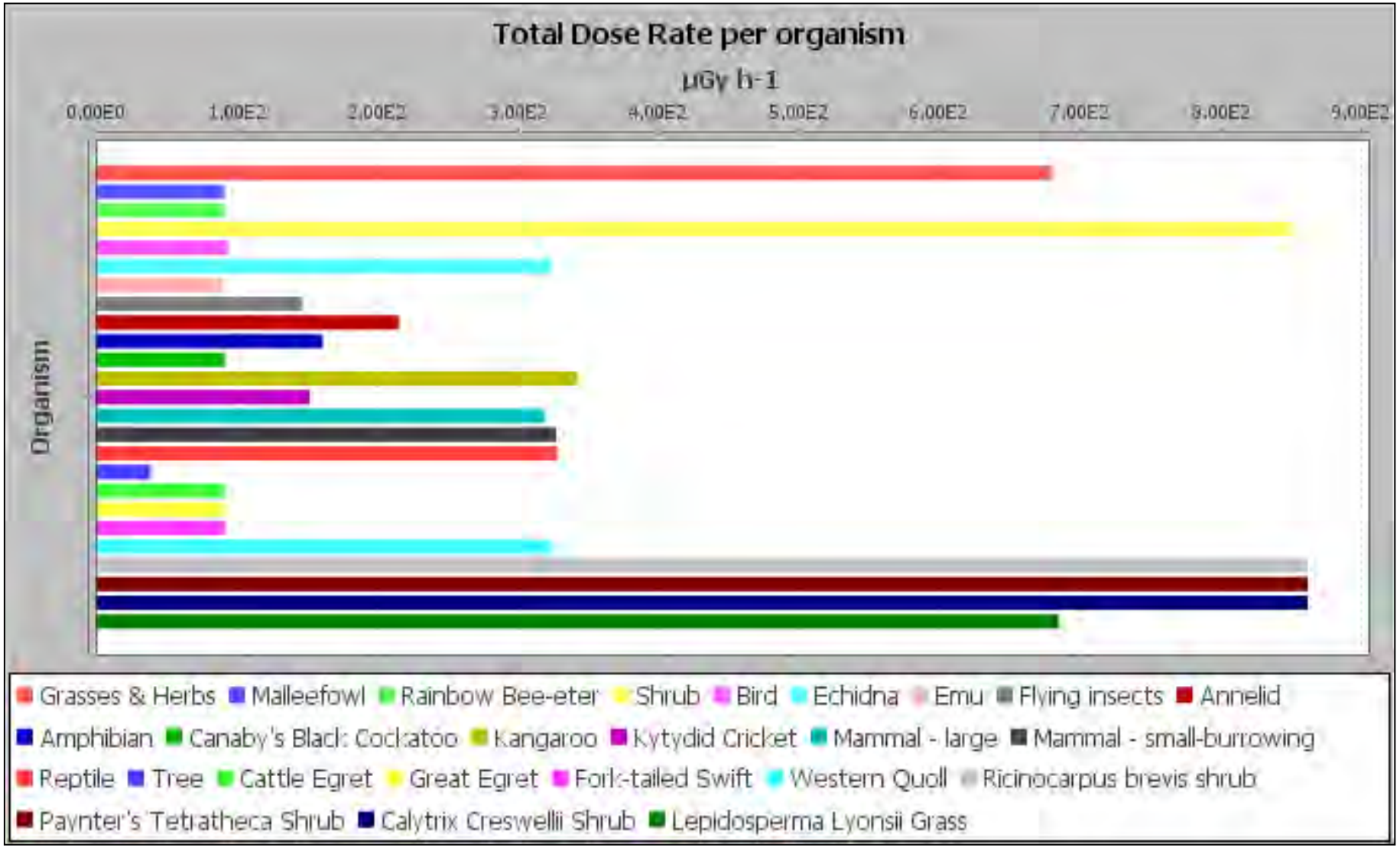

Activity Concentration in soil or air
Bq kg-1 d.w. or Bq m-3
1.50E4
1.40E4
1.30E4
1.20E4
1.10E4
1.00E4
9.00E3
8.00E3
7.00E3
6.00E3
5.00E3
4.00E3
3.00E3
2.00E3
1.00E3
0.00E0
Isotope
Pb-210
Po-210
Ra-226
Ra-228
Th-227
Th-228
Th-230
Th-232
U-235
U-238
Pa-231
U-234


External Dose Rate
µGy h-1
0.00E0
1.00E0
2.00E0
3.00E0
4.00E0
5.00E0
6.00E0
7.00E0
8.00E0
9.00E0
1.00E1
1.10E1
1.20E1
1.30E1
Organism
Grasses & Herbs
Malleefowl
Rainbow Bee-eter
Shrub
Bird
Echidna
Emu
Flying insects
Annelid
Amphibian
Canaby's Black Cockatoo
Kangaroo
Kytydid Cricket
Mammal - large
Mammal - small-burrowing
Reptile
Tree
Cattle Egret
Great Egret
Fork-tailed Swift
Western Quoll
Ricinocarpus brevis shrub
Paynter's Tetratheca Shrub
Calytrix Creswellii Shrub
Lepidosperma Lyonsii Grass
Pb-210
Po-210
Ra-226
Ra-228
Th-227
Th-228
Th-230
Th-232
U-235
U-238
Pa-231
U-234


Internal Dose Rate
µGy h-1
0.00E0
1.00E2
2.00E2
3.00E2
4.00E2
5.00E2
6.00E2
Organism
Grasses & Herbs
Malleefowl
Rainbow Bee-eter
Shrub
Bird
Echidna
Emu
Flying insects
Annelid
Amphibian
Canaby's Black Cockatoo
Kangaroo
Katydid Cricket
Mammal - large
Mammal - small-burrowing
Reptile
Tree
Cattle Egret
Great Egret
Fork-tailed Swift
Western Quoll
Ricinocarpus brevis shrub
Paynter's Tetratheca Shrub
Calytrix Creswellii Shrub
Lepidosperma Lyonsii Grass
Pb-210
Po-210
Ra-226
Ra-228
Th-227
Th-228
Th-230
Th-232
U-235
U-238
Pa-231
U-234

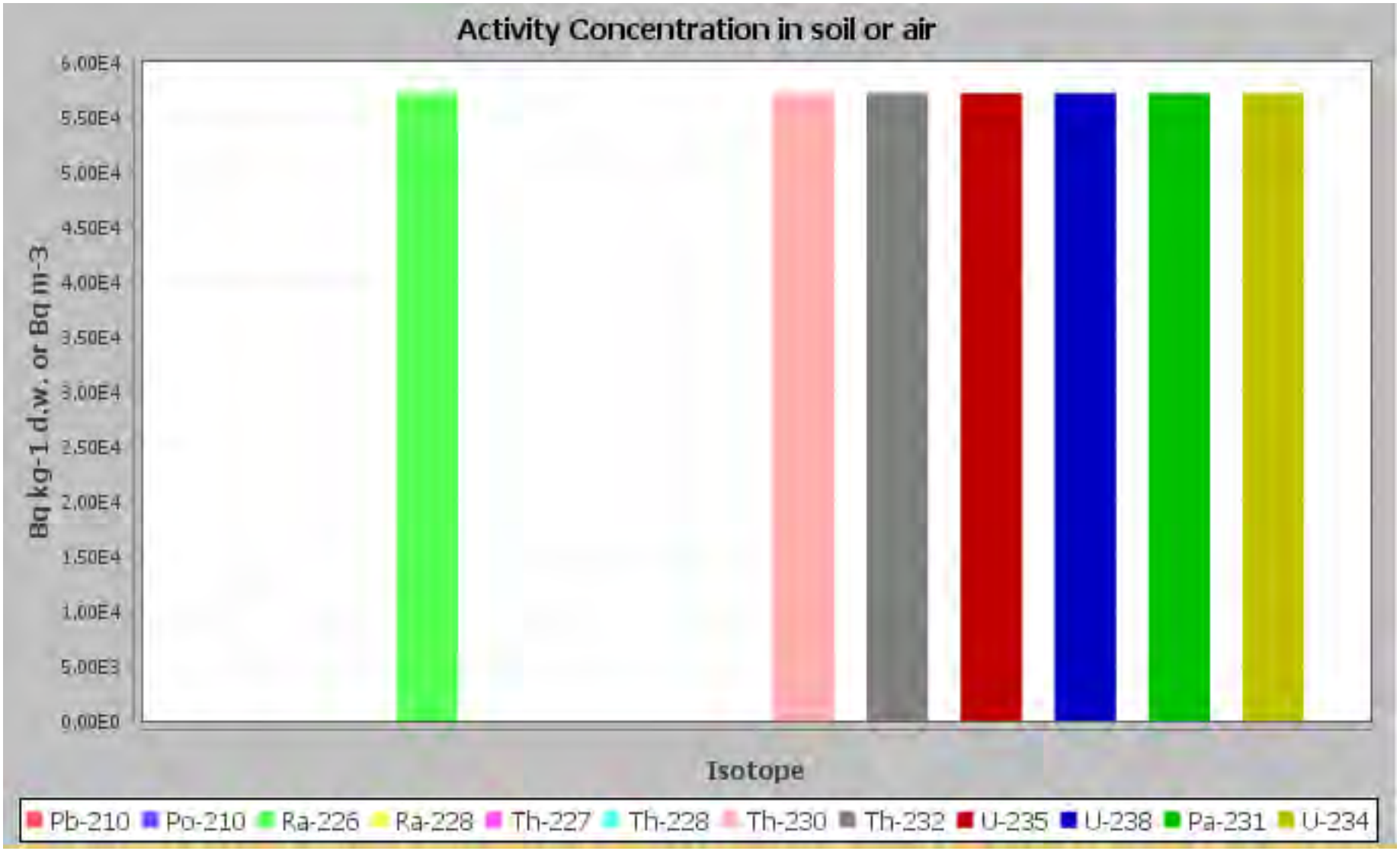

Total Dose Rate
µGy h-1
0.00E0
1.00E2
2.00E2
3.00E2
4.00E2
5.00E2
6.00E2
Organism
Grasses & Herbs
Malleefowl
Rainbow Bee-eter
Shrub
Bird
Echidna
Emu
Flying insects
Annelid
Amphibian
Canaby's Black Cockatoo
Kangaroo
Kytydid Cricket
Mammal - large
Mammal - small-burrowing
Reptile
Tree
Cattle Egret
Great Egret
Fork-tailed Swift
Western Quoll
Ricinocarpus brevis shrub
Paynter's Tetratheca Shrub
Calytrix Creswellii Shrub
Lepidosperma Lyonsii Grass
Pb-210
Po-210
Ra-226
Ra-228
Th-227
Th-228
Th-230
Th-232
U-235
U-238
Pa-231
U-234


Activity Concentration in organism
Bq kg-1 f.w.
0,00E0
1,00E3
2,00E3
3,00E3
4,00E3
5,00E3
6,00E3
7,00E3
8,00E3
Organism
Grasses & Herbs
Malleefowl
Rainbow Bee-eter
Shrub
Bird
Echidna
Emu
Flying insects
Annelid
Amphibian
Canaby's Black Cockatoo
Kangaroo
Kytydid Cricket
Mammal - large
Mammal - small-burrowing
Reptile
Tree
Cattle Egret
Great Egret
Fork-tailed Swift
Western Quoll
Ricinocarpus brevis shrub
Paynter's Tetratheca Shrub
Calytrix Creswellii Shrub
Lepidosperma Lyonsii Grass
Pb-210
Po-210
Ra-226
Ra-228
Th-227
Th-228
Th-230
Th-232
U-235
U-238
Pa-231
U-234

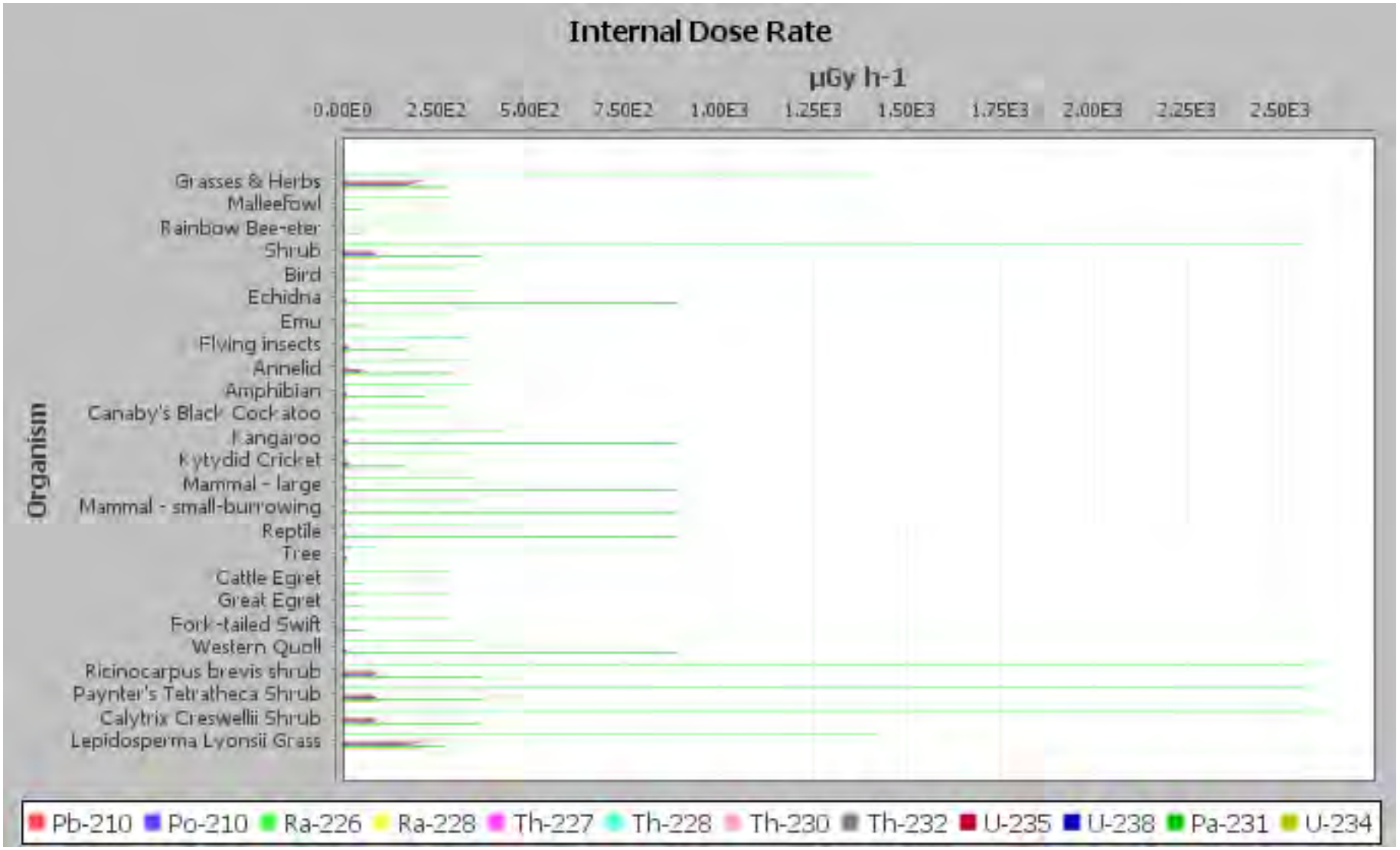

Total Dose Rate per organism
µGy h-1
0.00E0
1.00E2
2.00E2
3.00E2
4.00E2
5.00E2
6.00E2
7.00E2
8.00E2
9.00E2
Organism
Grasses & Herbs
Malleefowl
Rainbow Bee-eter
Shrub
Bird
Echidna
Emu
Flying insects
Annelid
Amphibian
Canaby's Black Cockatoo
Kangaroo
Kytydid Cricket
Mammal - large
Mammal - small-burrowing
Reptile
Tree
Cattle Egret
Great Egret
Fork-tailed Swift
Western Quoll
Ricinocarpus brevis shrub
Paynter's Tetratheca Shrub
Calytrix Creswellii Shrub
Lepidosperma Lyonsii Grass

Appendix H

ERICA Assessment LLW


Activity Concentration in soil or air
Bq kg-1 d.w. or Bq m-3
6.00E4
5.50E4
5.00E4
4.50E4
4.00E4
3.50E4
3.00E4
2.50E4
2.00E4
1.50E4
1.00E4
5.00E3
0.00E0
Isotope
Pb-210
Po-210
Ra-226
Ra-228
Th-227
Th-228
Th-230
Th-232
U-235
U-238
Pa-231
U-234

External Dose Rate
µGy h-1
0.00E0
5.00E0
1.00E1
1.50E1
2.00E1
2.50E1
3.00E1
3.50E1
4.00E1
4.50E1
5.00E1
Organism
Grasses & Herbs
Malleefowl
Rainbow Bee-eter
Shrub
Bird
Echidna
Emu
Flying insects
Annelid
Amphibian
Carnaby's Black Cockatoo
Kangaroo
Kytydid Cricket
Mammal - large
Mammal - small-burrowing
Reptile
Tree
Cattle Egret
Great Egret
Fork-tailed Swift
Western Quoll
Ricinocarpus brevis shrub
Paynter's Tetratheca Shrub
Calytrix Creswellii Shrub
Lepidosperma Lyonsii Grass
Pb-210
Po-210
Ra-226
Ra-228
Th-227
Th-228
Th-230
Th-232
U-235
U-238
Pa-231
U-234


Internal Dose Rate
µGy h-1
0.00E0
2.50E2
5.00E2
7.50E2
1.00E3
1.25E3
1.50E3
1.75E3
2.00E3
2.25E3
2.50E3
Organism
Grasses & Herbs
Malleefowl
Rainbow Bee-eter
Shrub
Bird
Echidna
Emu
Flying insects
Annelid
Amphibian
Canaby's Black Cockatoo
Kangaroo
Kytydid Cricket
Mammal - large
Mammal - small-burrowing
Reptile
Tree
Cattle Egret
Great Egret
Fork-tailed Swift
Western Quoll
Ricinocarpus brevis shrub
Paynter's Tetratheca Shrub
Calytrix Creswellii Shrub
Lepidosperma Lyonsii Grass
Pb-210
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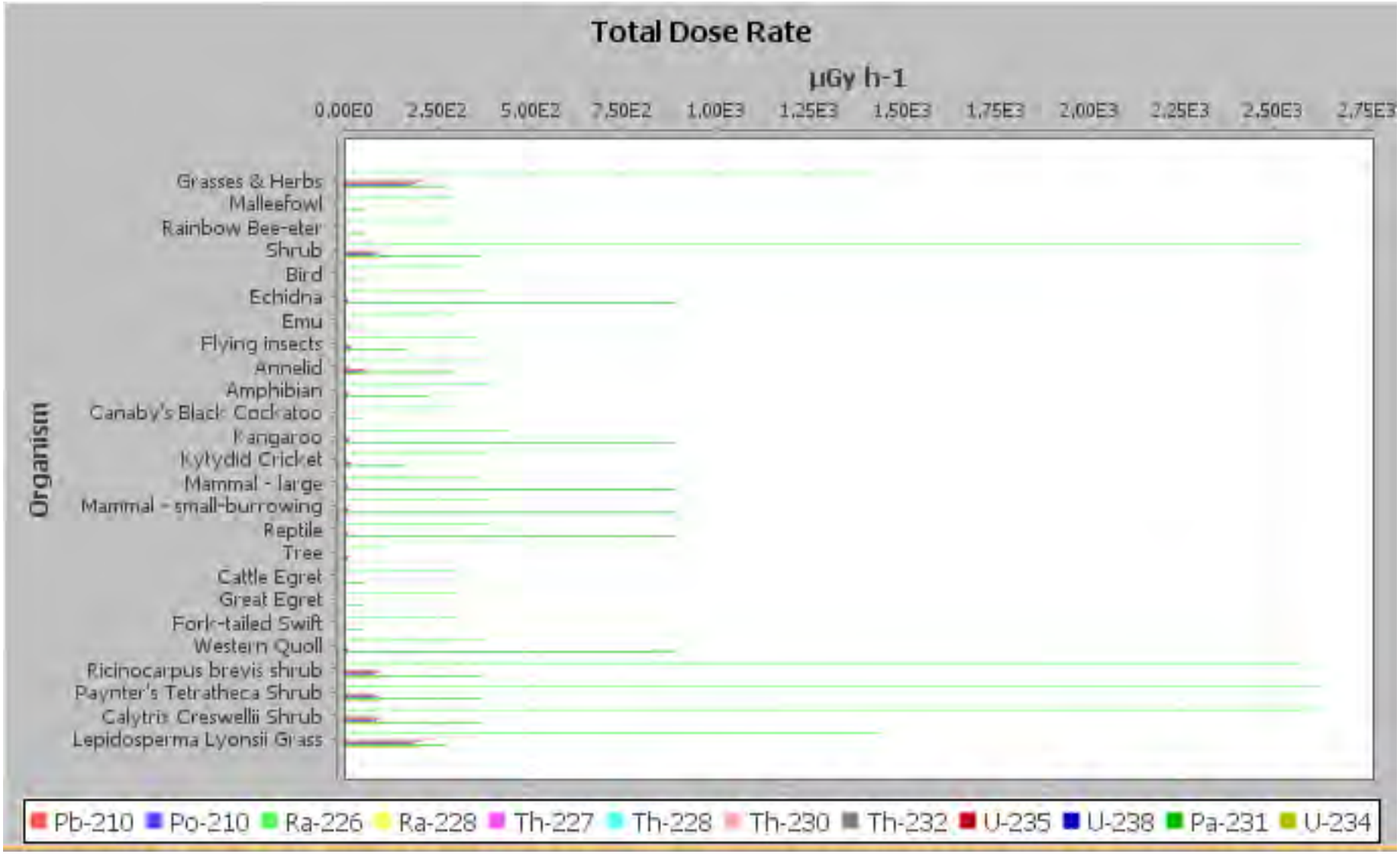
U-234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2.00E3
2.25E3
2.50E3
2.75E3
Organism
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Rainbow Bee-eter
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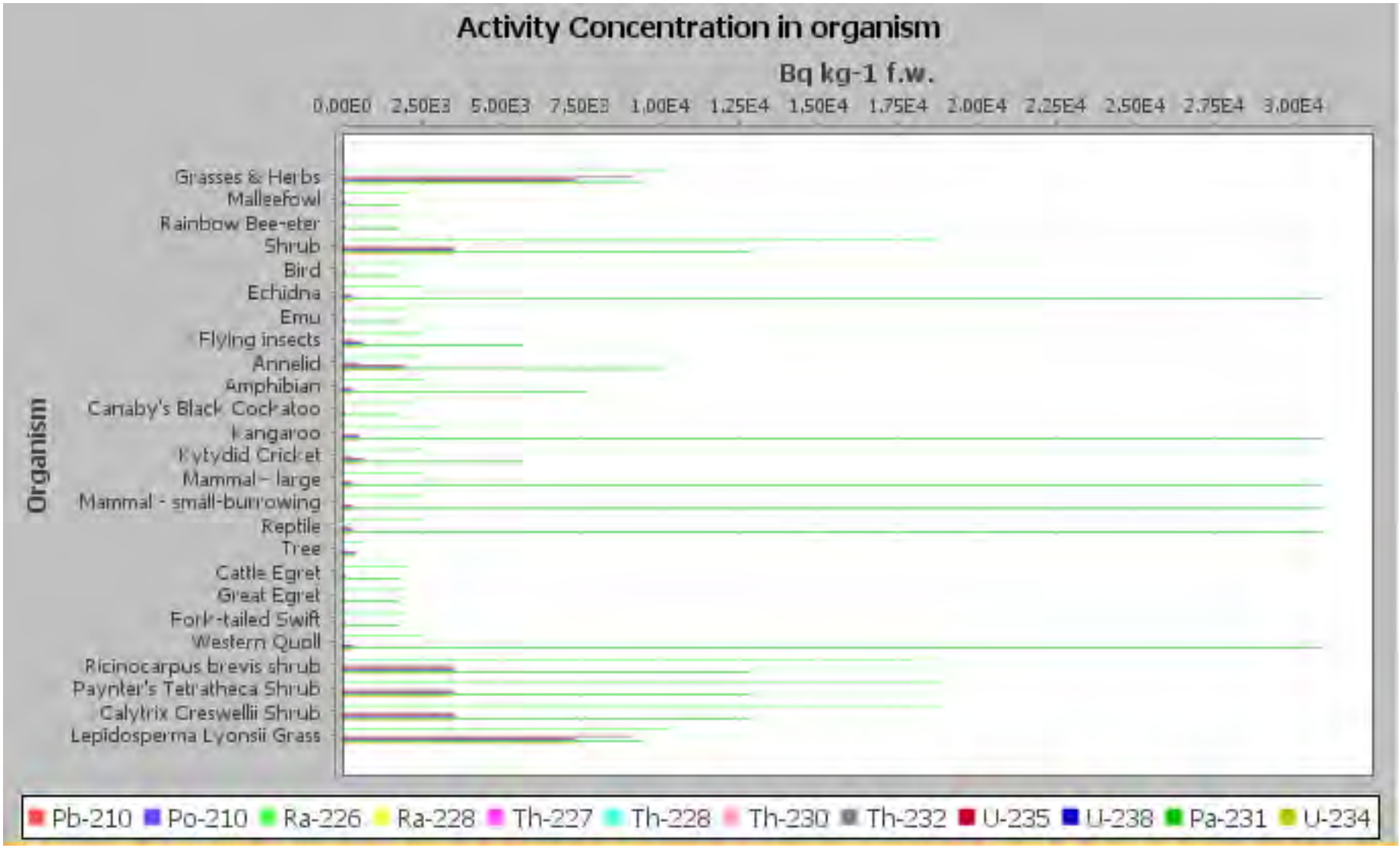
U-234


Activity Concentration in organism
Bq kg-1 f.w.
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2.50E3
5.00E3
7.50E3
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1.50E4
1.75E4
2.00E4
2.25E4
2.50E4
2.75E4
3.00E4
Organism
Grasses & Herbs
Malleefowl
Rainbow Bee-eter
Shrub
Bird
Echidna
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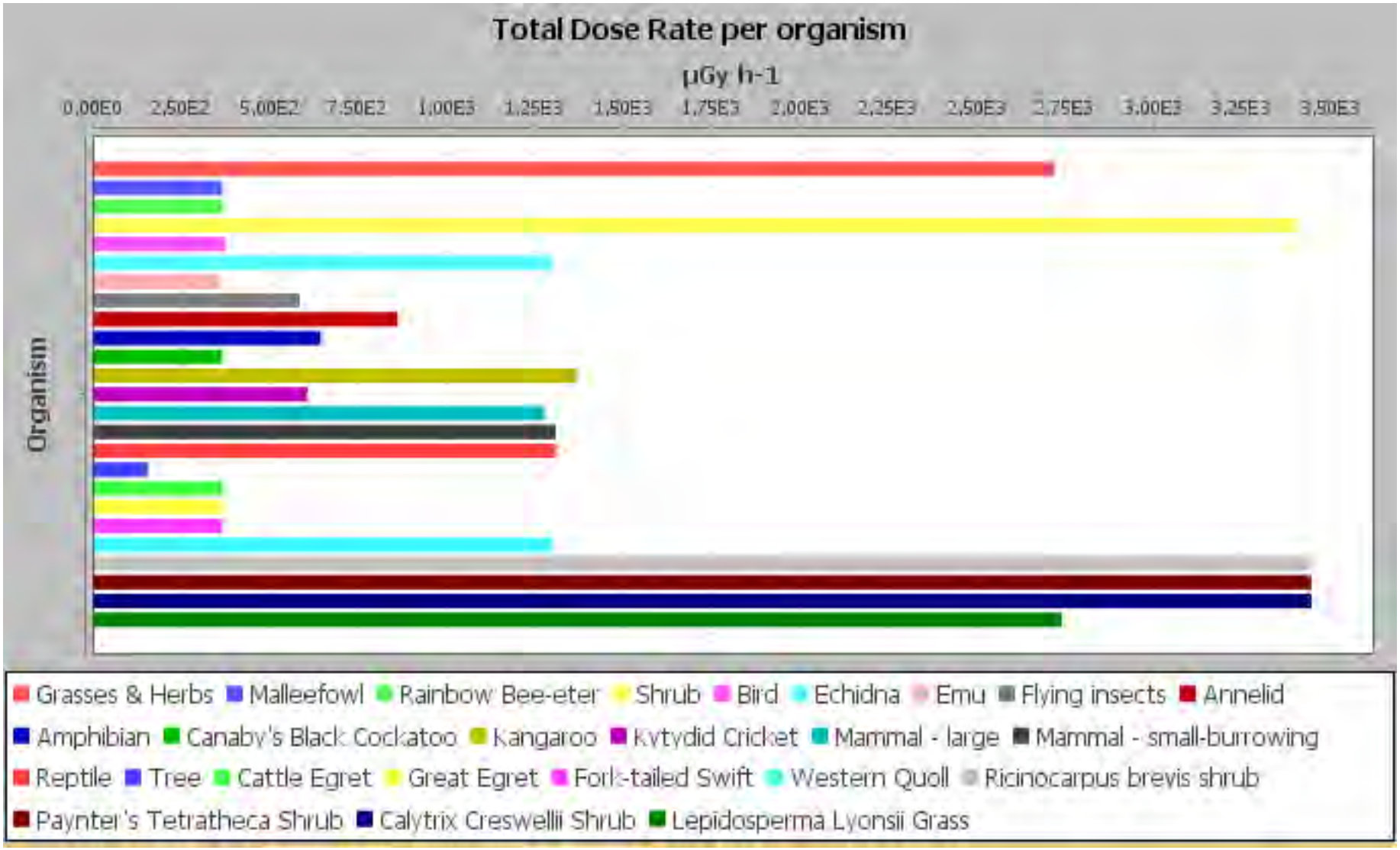
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µGy h-1
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2,50E2
5,00E2
7,50E2
1,00E3
1,25E3
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1,75E3
2,00E3
2,25E3
2,50E3
2,75E3
3,00E3
3,25E3
3,50E3
Organism
Grasses & Herbs
Malleefowl
Rainbow Bee-eter
Shrub
Bird
Echidna
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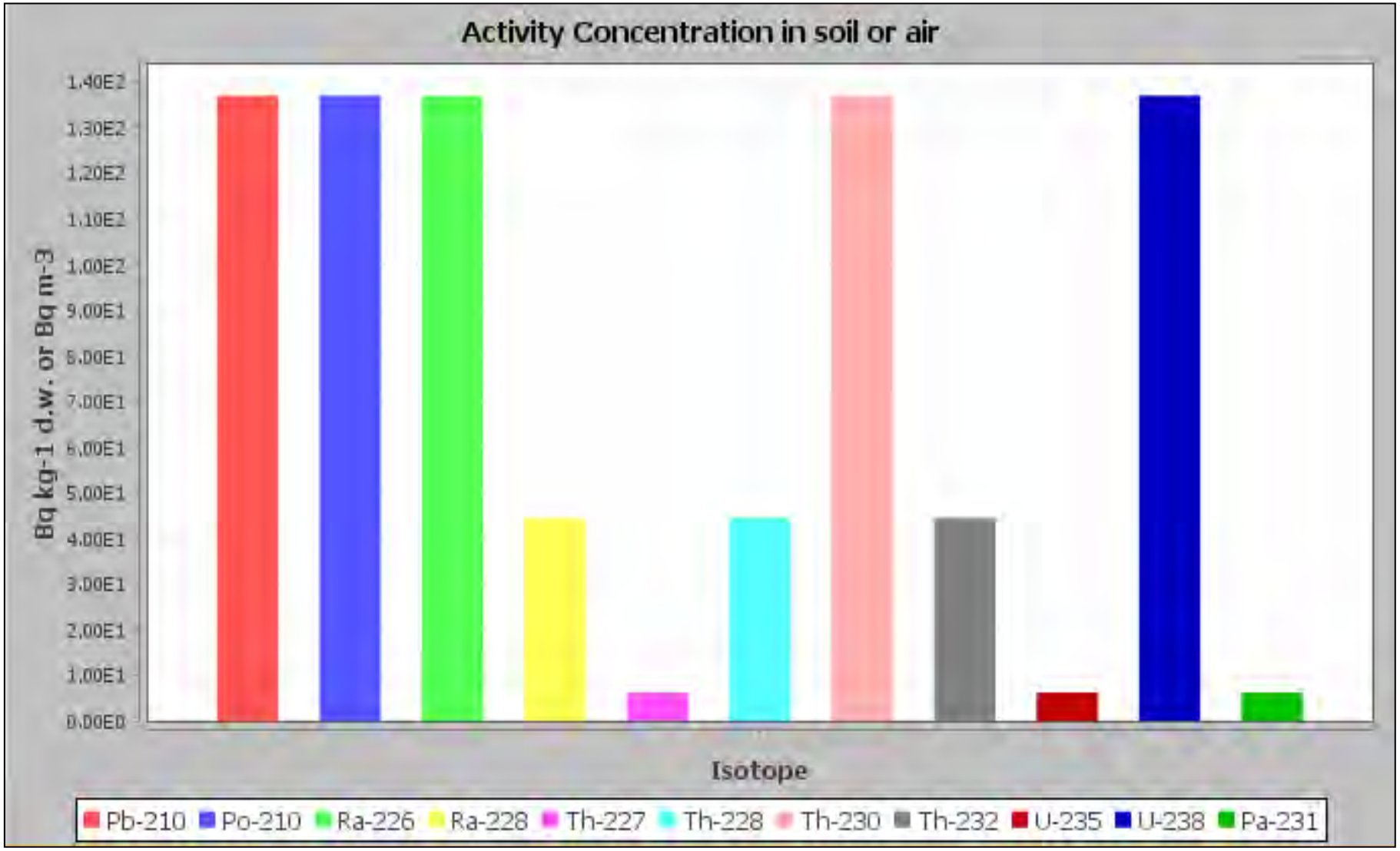
Paynter's Tetratheca Shrub
Calytrix Creswellii Shrub
Lepidosperma Lyonsii Grass

Appendix I

ERICA Assessment Post Closure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8.00E1
7.00E1
6.00E1
5.00E1
4.00E1
3.00E1
2.00E1
1.00E1
0.00E0
Isotope
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Po-210
Ra-226
Ra-228
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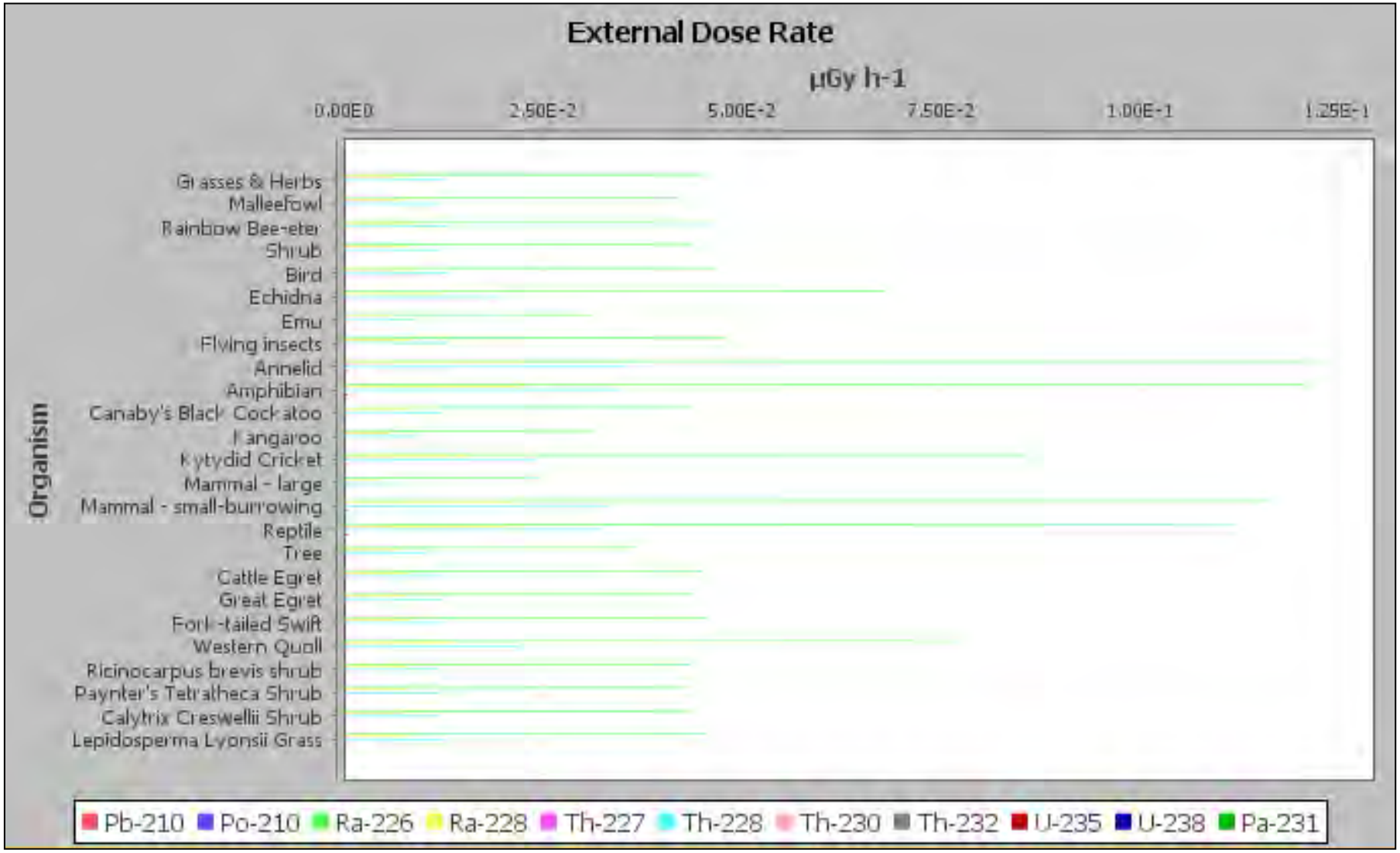
Pa-231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7.50E-2
1.00E-1
1.25E-1
Organism
Grasses & Herbs
Malleefowl
Rainbow Bee-eter
Shrub
Bird
Echidna
Emu
Flying insects
Annelid
Amphibian
Canaby's Black Cockatoo
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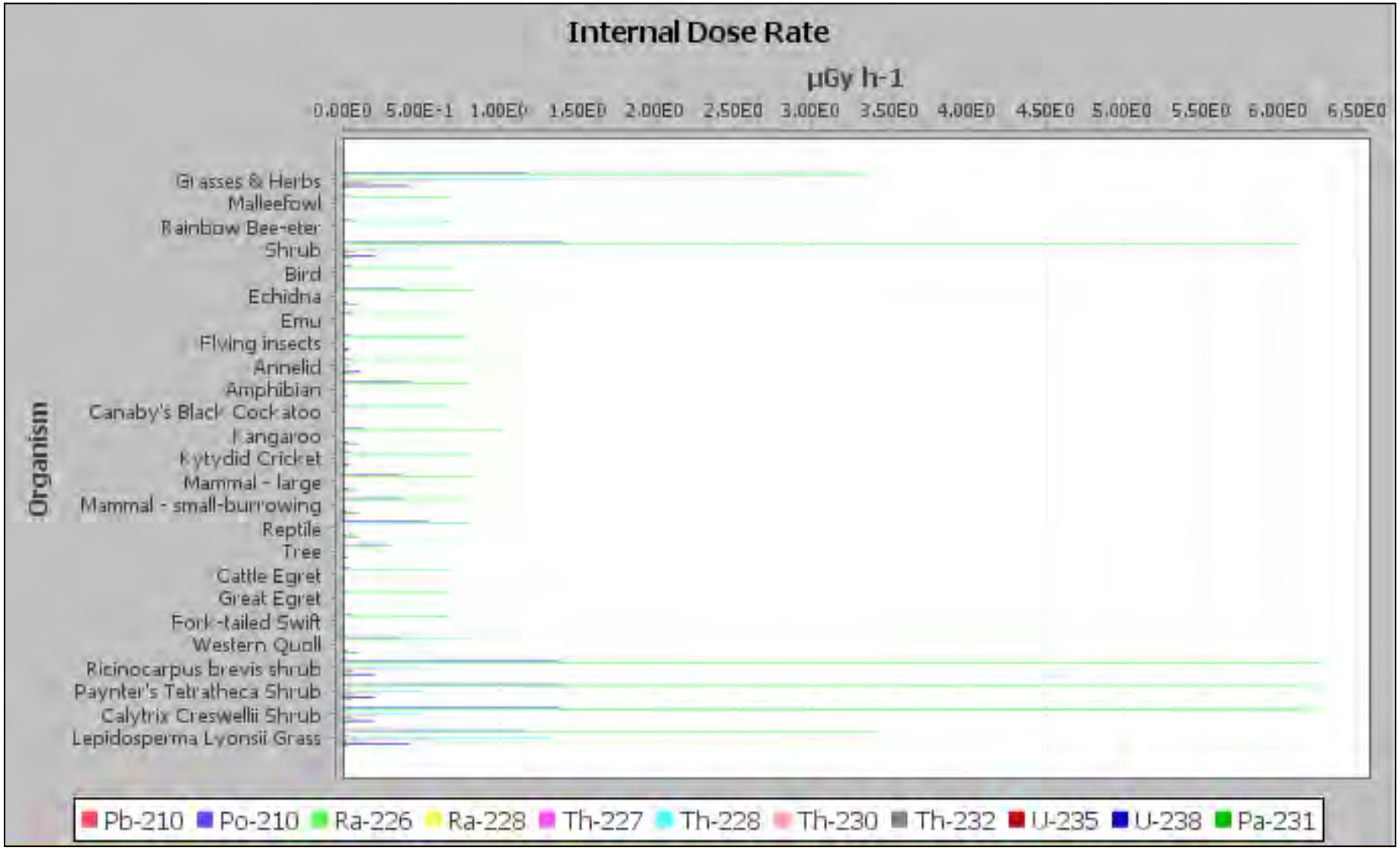
Pa-231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Organism
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Malleefowl
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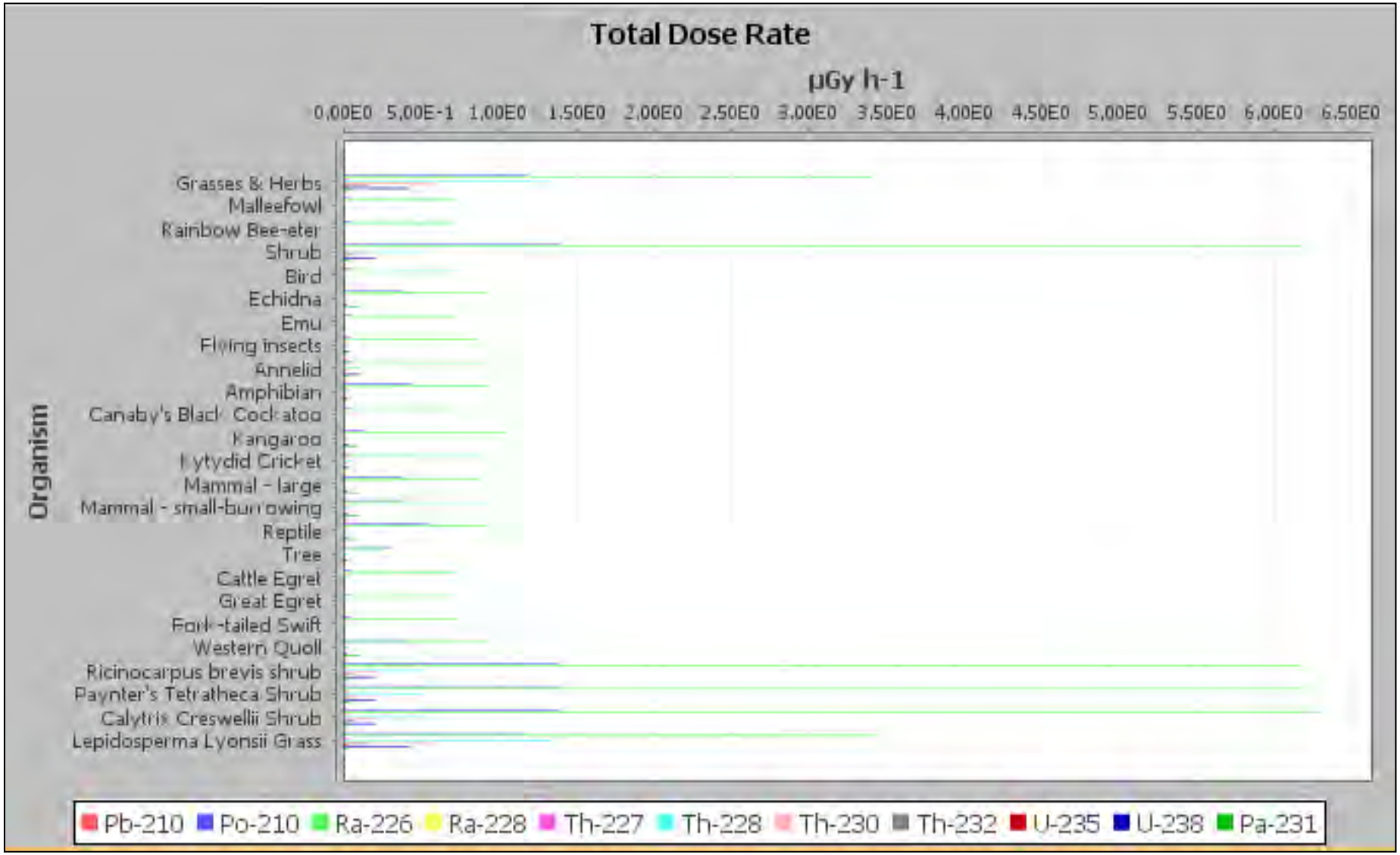
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3.50E0
4.00E0
4.50E0
5.00E0
5.50E0
6.00E0
6.50E0
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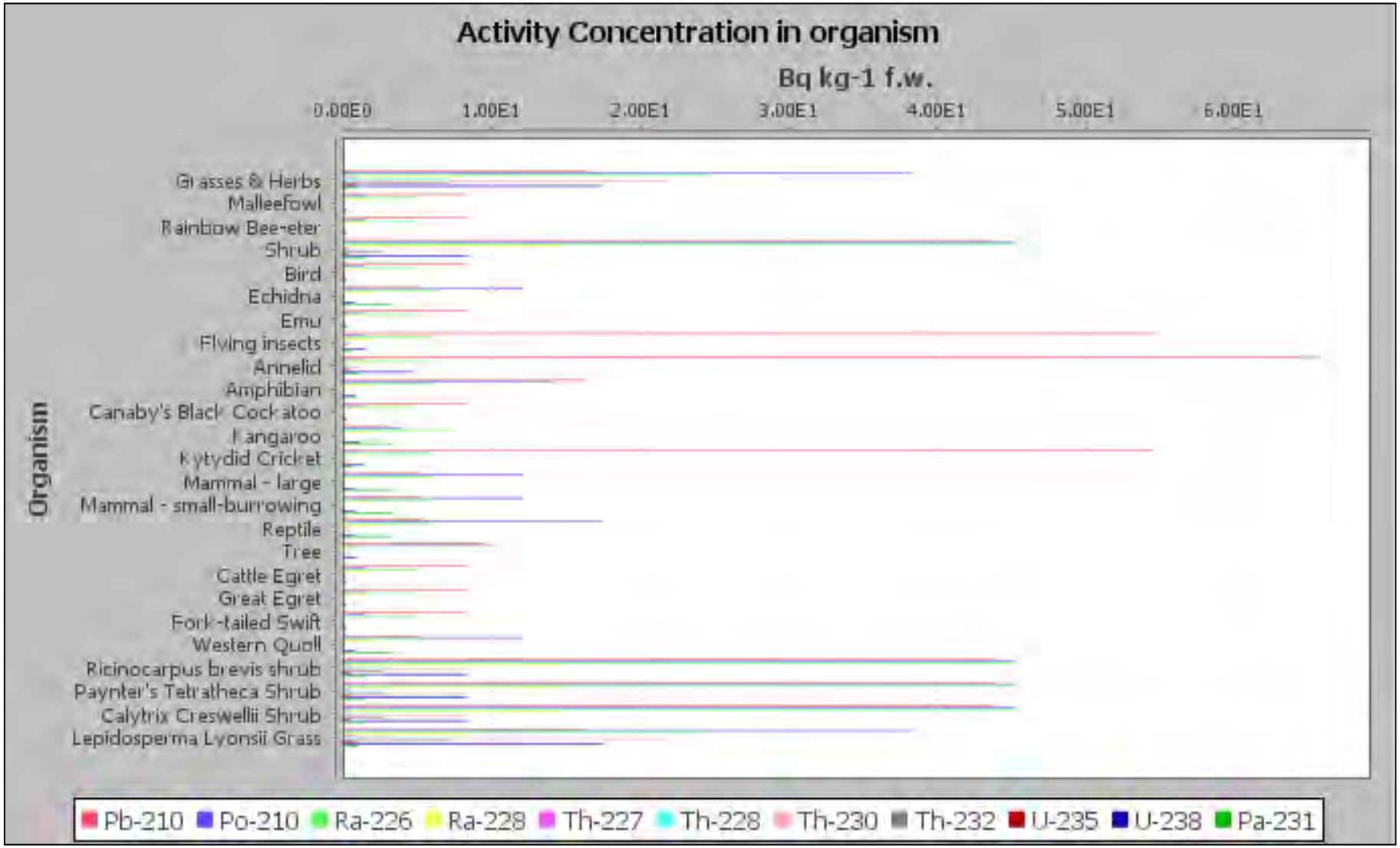
Activity Concentration in organism
Bq kg-1 f.w.
0.00E0
1.00E1
2.00E1
3.00E1
4.00E1
5.00E1
6.00E1
Organism
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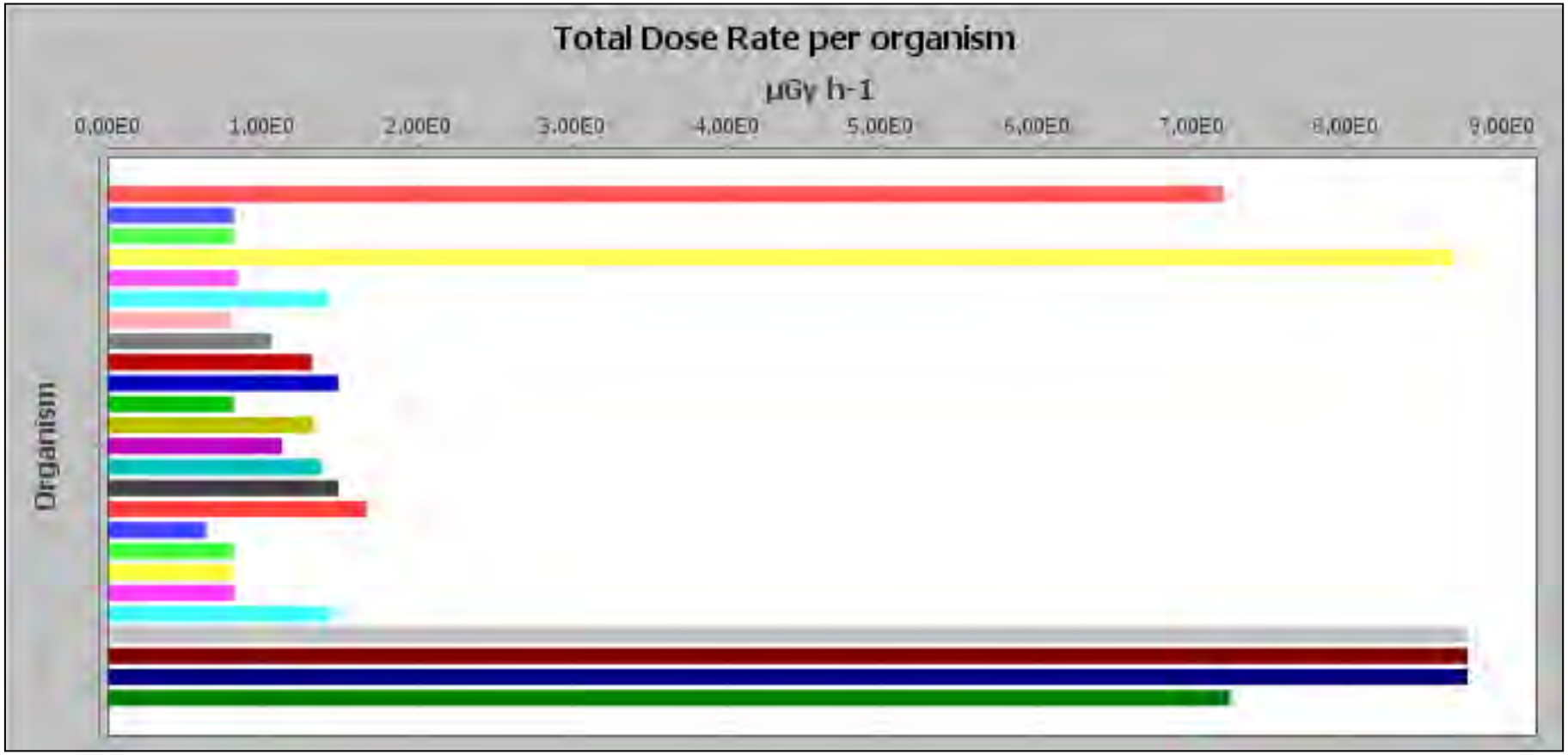
Total Dose Rate per organism
µGy h-1
0,00E0
1,00E0
2,00E0
3,00E0
4,00E0
5,00E0
6,00E0
7,00E0
8,00E0
9,00E0
Organism

Radiation Assessments

TELLUS

RADIOLOGICAL RISK ASSESSMENT: WORKER DOSE ASSESSMENT

Company Name: TELLUS HOLDING
Document No.:
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Prepared by:	Henriëtte Rossouw RSO Hygiea Consulting
Endorsed by:	

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1 INTRODUCTION

Hygiea Consulting was engaged by Tellus Holdings Ltd (the Proponent) to conduct a Human Health Risk Assessment (HHRA) on the workforce to assess the potential doses workers can receive as a result of their occupation at Sandy Ridge kaolin clay and waste storage facility (herein referred to as the 'Proposal' or the 'Facility').

The aim of the report is to provide a worker dose assessment . This report should be read in conjunction with the following reports

- *Sandy Ridge Project –Operating Strategy*
- *Radiological Risk Assessment- Fauna and Flora (ERICA)*
- *Radiological Risk Assessment- : Disposal of Radioactive Waste(RESRAD)*
- *Radiation Waste Management plan*
- *Waste acceptance criteria (WAC) developed for this facility is described in the waste acceptance criteria (document reference: TCO-5-05).*

1.1 BACKGROUND

The Proposal comprised of two main business components, mining of kaolin clay for export and storage and permanent isolation (disposal) of hazardous and intractable waste in mine voids.

The proposed commodity business involves mining kaolin mostly in an open cut methodology, processing on site and then exporting the kaolin via Fremantle Port to Asia where it will be used in various industrial sectors (e.g. paper, ceramics, fiberglass and paint). Kaolinite is a clay mineral also known as 'Kaolin clay', with the chemical composition $Al_2Si_2O_5(OH)_4$.

The waste aspect of the Proposal involves disposing of up to 100,000 tpa of intractable, hazardous and low level radioactive wastes in the mine voids (herein referred to as 'cells') over a 25 year period (i.e. 2,500,000 tonnes in total). Wastes would be accepted from across Australia.

Tellus will program the placement of waste into the disposal cell in based on the nature of the waste and planning of the cell layout to store waste of similar characteristics in designated areas of the cell. Radoioactive waste will be diposed of after chemical waste were placed in the cell.. To ensure optimisation of protection higher activity waste will be disposed of at the deeper end of the cell in a shaft and lower activity waste at the top. This further reduces the possibility of interactions between wastes of different types and ensure exposure to radioactive material is reduced

Cells would be filled in layers with multiple sections in each layer. Each layer would be divided into sections containing wastes of similar characteristics. Each section will be backfilled, compacted and all air pockets/voids excluded. Each layer will be compacted, until approximately 7m below the ground surface, where a thick capping layer of low permeability clay will be installed to prevent water ingress into the cell. Following this, more backfilling and a clay domed cap would be situated on the top of the cell, to shed any landing rainfall. During the waste disposal process, a roof canopy is positioned over the cell to exclude rainfall prior to the thick capping layer being installed.

Waste acceptance criteria (WAC) developed for this facility is described in the waste acceptance criteria (document reference: TCO-5-05). The radionuclide concentration limits is set taking into account the actual siting, design and planning of the facility (e.g. Natural geological barrier, arid climate, remoteness, engineered multi layered shielding and barriers, duration of institutional control, site specific management plans and operating procedures) and exposure dose constrains to ensure no person is exposed above the dose limit (as defined in Schedule I of the Radiation Safety (General) Regulations). These radioactive wastes are generally generated by medical research and industry, operation of research facilities (e.g. laboratory coats, overshoes, gloves), Naturally Occurring Radioactive Materials (NORMs), NORMs occurring on pipework and scale from industry, oil spills containing NORMs and orphan sources (i.e. gauges and instrumentation). Wastes which will not be disposed of into cells include: infectious materials, nuclear material, uncertified waste, putrescible waste and gases.

2 WORKER HEALTH RISK ASSESSMENT METHODOLOGY

The methodology followed the guidance given in the following documents:

- Environmental Health Risk Assessment-Guidelines for assessing human health risks from environmental Hazards. enHealth Council 2012
- Approved Procedure for Dose Assessment Guideline RSG05 Department of Industry and Resources.(DoIR)1997
- Managing naturally occurring radioactive material (NORM) in mining and mineral processing – Guideline, DMP (2010) NORM 5 Dose Assessment (UNDER REVIEW)
- Assessing Dose of the Representative Person for the Purpose of the Radiation Protection of the Public. ICRP Publication 101a. Ann. ICRP 36 (3). ICRP, 2006.

1.2 APPROACH

The risk assessment model was adopted in accordance with that specified in enHealth 2012. The key stages include:

- Issue identification.
- Hazard identification.
- Dose–response assessment.
- Exposure assessment.
- Risk characterisation.

Figure 1 display the relationship between the Human Health Risk Assessment (HHRA)process and Risk Management

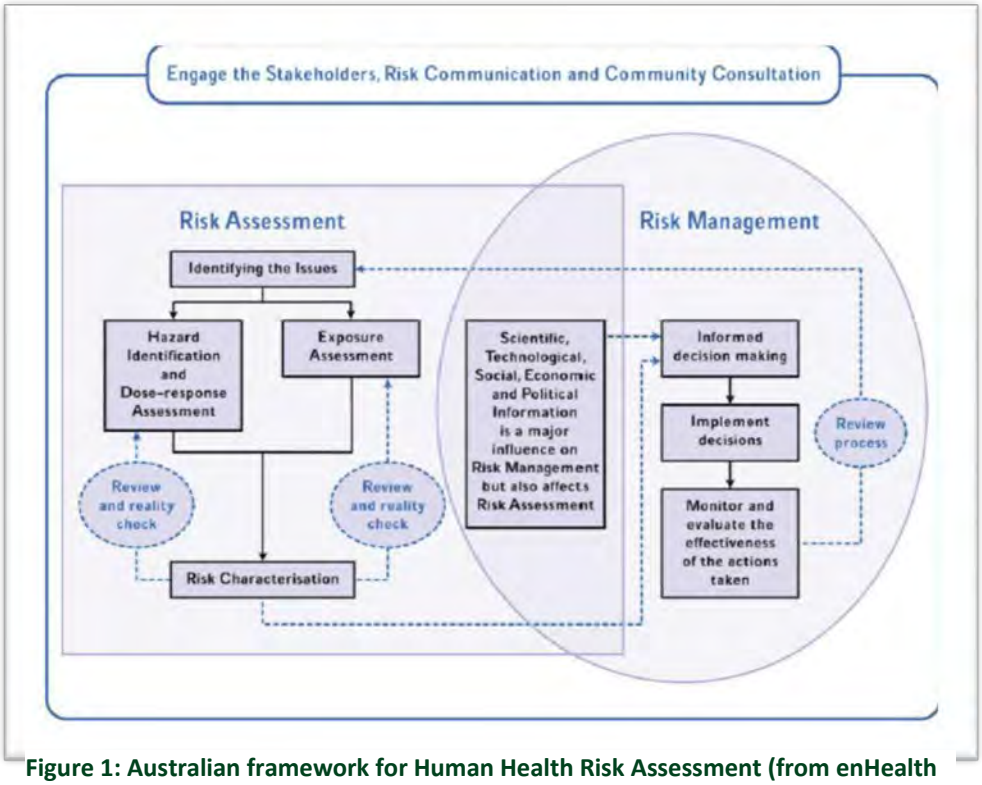

Figure 1: Australian framework for Human Health Risk Assessment (from enHealth 2004)

3 ISSUE IDENTIFICATION

Workers of the Proposal may be exposed to ionising radiation as a result of the handling and disposal of LLW . By assessing the potential exposure the proposal can identify the highest risk employment groups and tasks and ensure that correct controls are in place so that the

exposure is within dose constrain limits (>5 millisievert per annum (mSv/a)).Those controls are discussed in the waste management plan. It also serves to cofirm that the WAC is suitable to ensure no over exposure of the workforce will occure

1.3 IONIZING RADIATION AND HEALTH

The majority of risks associated with radiation are known and have been quantified. There have been many large scale studies worldwide of cancer risk in people arising from radiation exposure. While there is a possible increased risk of cancer and hereditary effects at low radiation doses or for radiation delivered over a long period of time, these effects are not always detectable in scientific studies. However, their likelihood increases as dose increases.(ICRP,2007)

The objective of radiation protection is to limit human exposure by the application of comprehensive programs that measure all significant radiation sources.
Where it is expected that a worker will be exposed to radiation as a result of their employment, they must not be exposed above prescribed dose limits. In Australia, these dose limits are prescribed in the *Recommendations for Limiting Exposure to Ionizing Radiation (1995)* and *National Standard for Limiting Occupational Exposure to Ionizing Radiation (2002), Radiation Protection Series No. 1* which reflects international best practice in radiation protection.

Harmful tissue reactions (acute or deterministic effects) occur when doses are high (greater than 500 mSv). These effects occur shortly after exposure (minutes to weeks) and can include sterility, skin burns and acute radiation syndrome. Death can occur at very high doses(10 000 mSv) (ARPANSA Fact Sheet – Ionising Radiation and Health)

The current limit of occupational radiation exposure is 20 mSv/a averaged over 5 years, and not more than 50 mSv received in any one year. This dose limit only applies to radiation exposure received occupationally, and does not include exposures from natural background radiation or medical doses. The dose limit for members of the public is 1 mSv/a.

The ARPANSA Regulatory Guide (ARPASA 2014) state that In the process of developing the safety case the applicant must propose a dose constraint for workers, below which protection will be optimised, in accordance with the national standard RPS No. 1 Recommendations for Limiting Exposure to Ionizing Radiation (1995) and National Standard for Limiting Occupational Exposure to Ionizing Radiation (republished 2002) and which would not exceed 5 mSv/a

1.4 RADIATION WASTE SOURCES

The types and form of radioactive waste that are likely to be managed at the facility would be generated from:

- Medical research and industry (use of radioisotopes and sealed radioactive sources which generate very low levels of activity concentrations).
- Mining and processing of mineral ores or other material containing NORMS such as phosphate minerals, mineral sands, coal, some gold bearing rocks and hydrocarbons. These generally contain long lived radionuclides at relatively low concentrations. However, NORMS such as scales arising in the oil and gas industry may have higher activity concentration levels but would still be categorised as low level wastes.
- Intervention actions, which are necessary after accidents or to remediate areas affected by past practices
- Disposal of disused sealed radioactive sources (including orphan sources).

Sandy Ridge is seeking approval to operate as a near surface geological repository. It will not operate as a deep geological repository and therefore, only Low Level Radioactive Waste (LLRW) can be accepted. Under no circumstances can the Facility accept High Level Radioactive Waste (HLRW) .

1.5 WASTE ACCEPTANCE LEVELS

Waste acceptance criteria (WAC) developed for this facility is described in the waste acceptance criteria (document reference: TCO-5-05). The radionuclide concentration limits is set taking into account the actual siting, design and planning of the facility (e.g. Natural geological barrier, arid climate, remoteness, engineered multi layered shielding and barriers, duration of institutional control, site specific management plans and operating procedures) and exposure dose constrains to ensure no person is exposed above the dose limit (as defined in Schedule I of the Radiation Safety (General) Regulations).

These radioactive wastes are generally generated by medical research and industry, operation of research facilities (e.g. laboratory coats, overshoes, gloves), Naturally Occurring Radioactive Materials (NORMs), NORMs occurring on pipework and scale from industry, oil spills containing NORMs and orphan sources (i.e. gauges and instrumentation). Wastes which will not be disposed of into cells include: infectious materials, nuclear material, uncertified waste, putrescible waste and gases.

4 EXPOSURE ASSESSMENT

1.6 POTENTIAL WORKER EXPOSURE PARAMETERS

Several possible pathways of radiation exposure were considered and assessed whether they are relevant to the exposure of the sensitive receptors as discussed in Table 1.

Table 1: Exposure pathways

Potential Worker Exposure Pathways	Relevant	Comment
External radiation exposure (γ-radiation)	Yes	Possibility due to nature of radioactive materials.
Inhalation of suspended dust (α-radiation)	Yes	Possible but unlikely due to control methods in place when handling NORM type waste
Ingestion of drinking water (α- and β-radiation)	No	All drinking water at operations and in surrounding areas is provided from separate water supplies. No reliant natural water source near facility. Therefore, any exposure due to the ingestion of drinking water could not be attributed to the site activities.
Incidental ingestion of dust and soil	No	Not considered applicable.
Surface contamination	No	Not considered applicable.
Inhalation of radon and decay products	Yes	Similar facilities indicate very low risk of inhalation of radon products due to nature of waste disposed, the proposed containment methods and the half-life of Radon. Included where relevant.
Ingestion of home grown produce or gathered bush food	No	Phase one and phase two flora studies indicate no local bush food consumption in area. Details are provided in the PER.
Ingestion of meat, milk or locally caught fish	No	Not considered because of the arid nature of location and the unlikelihood of these activities happening.

1.7 WORKFORCE SIMILAR EXPOSURE GROUPS

The following work categories and numbers of workers are planned (Table 2). Workers are placed in Similar Exposure Groups (SEG's) to ease assessment.

Table 2: Workforce information

Workforce SEG's	Description
Transport	Transport of workers is not part of the Tellus workforce and would be arranged by client.
Radiation waste receipt and storage	Workers involved in the unloading, inspection, and storage (warehouse) of radioactive waste.
Waste packaging	Workers involved in the packaging of radioactive waste for disposal (cementing and concreting).
Waste placement/burial	Unloading and burial of radioactive waste.
Chemical waste placement	Backfill of cell with chemical wastes and inert fill.
Earthmoving and contouring	Capping and closure of cell.
Administration and other staff	Supervisors, admin, security and other non-exposed workers.

1.8 ASSUMPTIONS

1.8.1 EXPOSURE HOURS

With uncertainty of how much radiation waste will be sent to the Facility for disposal the following exposure hours were assumed based on current market expectations (Table 3).

Table 3: Exposure hours

Workforce SEG's	Assumed hours per year	Logic of assumed hours
Radiation waste receipt and storage	1000	Unknown. Assume 1000 hours.
Waste Packaging	160	4 packing campaigns a year of 5 days each.
Waste placement/ burial	80	Actual radioactive waste handling component to take 20 hours max per campaign. Assuming 4 campaigns a year.
Chemical waste placement	1920	Full shift assumed.
Earthmoving and contouring	882	3 months.
Admin and other staff	2000	Assuming maximum.

1.8.2 GAMMA EXPOSURE

The following exposure levels were assumed based on similar facilities exposure records (Table 4).

Table 4: Exposure hours

Workforce SEG's	µSv/hr expected dose
Radiation waste receipt and storage	0.4
Waste Packaging	0.6
Waste placement/burial	0.05
Chemical waste placement	0.05
Earthmoving and contouring	0.05
Admin and other staff	0

1.8.3 INHALATION OF SUSPENDED DUST

There is a risk of exposure due to inhalation of dust during the packaging and handling of NORM waste. Drawing from experience and data from the mining and the oil and gas industry, the following values (Table 5) were assumed and are very conservative. The volume and the way waste would be packaged, as well as onsite procedural controls, would safeguard levels exceeding those shown in Table 5.

Table 5: Assumed dust ad concentration levels

Value	Average dust concentration mg/m^3	Average dust activity mBq/m^3
Ave	0.085	0.330

1.8.4 INHALATION OF RADON AND DECAY PRODUCTS

Similar facilities indicate very low risk of inhalation of Radon products due to the nature of waste disposed, the containment thereof and, the half-life of Radon. For the purpose of this assessment, it has been assumed the dose due to inhalation of Radon gas will be less than 0.004mSv/a.

1.9 INITIAL EXPOSURE ASSESSMENT

Based on the Approved Procedure for Dose Assessment (Guideline RSG05 Department of Industry and Resources. (DoIR)1997) the following doses were calculated for each workgroup (Table 6).

Table 6:Dose calculations for each workgroup per year

Workforce SEG's	Gamma dose (mSv/a)	Individual Internal Dose (mSv/a)	Inhalation of RnDP (mSv/a)	Total dose (mSv/a)
Rad waste receipt and storage	0.400	0.014	0.004	0.418
Waste packaging	0.096	0.002	0.004	0.102
Waste placement/burial	0.004	0.001	0.004	0.009
Chemical waste placement	0.096	0.000	0.000	0.096
Earthmoving and contouring	0.044	0.000	0.000	0.044
Admin and other staff	0.000	0.000	0.000	0.000

All of the workforce SEGS exposure is well below the occupational exposure limit of 10 mSv/a , the dose constrain level of 5mSv and are unlikely to be exposed above the public dose limit of 1msv/a.

Investigation into exposure levels from similar international facilities indicate that approximately 95% of the staff receive a dose less than 0.1 mSv/a, and 80 % less than 0.01 mSv/a. The exposure times at the international facility would be longer that those assumed as Sandy Ridge due to the amount of waste disposed. These levels are within similar range of those calculated above.

1.10 SENSITIVITY ANALYSIS ON ASSUMED VALUES

Sensitivity analysis (varying one-parameter-at-a-time) was conducted on the assumed variables within the dose assessment to determine how sensitive the modelled dose to a human receptor is to variations in the selected parameter. This analysis was carried out after the regular calculations were completed by taking each assumed parameter selected and repeating the calculation with the parameter under test set at a 50 % and a 100 % increase. Only a single test parameter is varied at a time.

The sensitivity of the parameters listed below was increased to determine the effect on the total dose calculated.

- *Assumed hours.*
- *Gamma Dose Rate.*
- *Dust Activity concentration.*

Figure 2 illustrated the effect of a 50 % and 100 % increase in the exposure time. Even with a 100 % increase in exposure time, the exposure levels will still be below the public exposure level of 1 mSv/a.

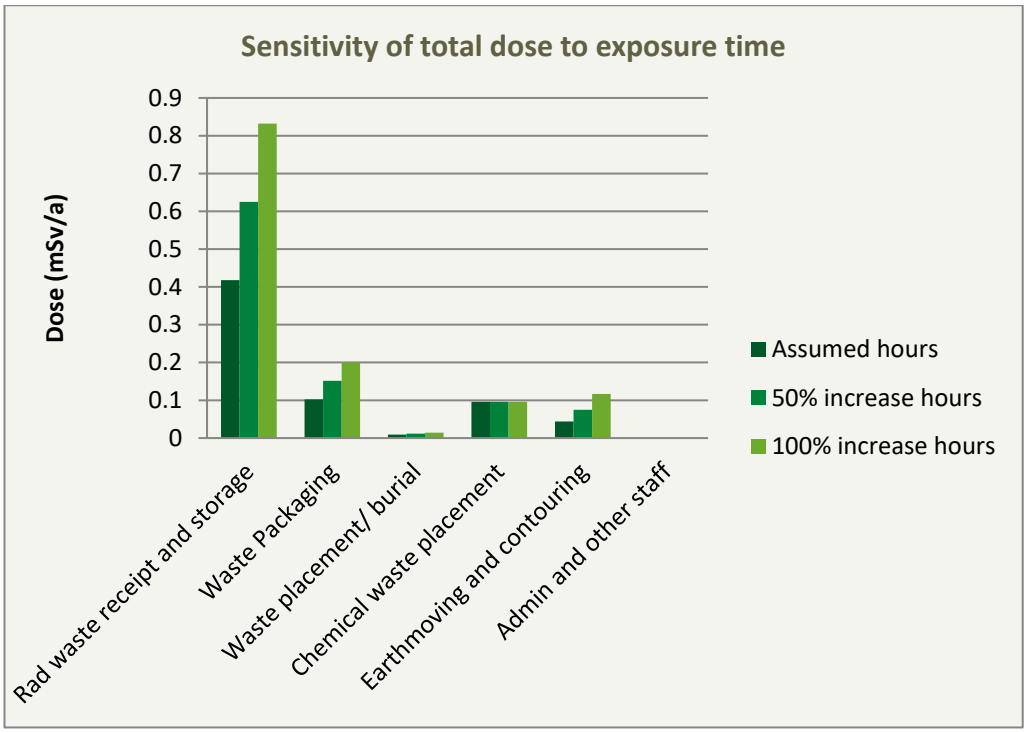

Figure 2: Sensitivity of dose to exposure time

The effect of dose rate being 50 % and 100 % greater than was assumed in the base calculations was also tested. Figure 3 shows that even with a 100 % increase in the dose rate no exposure calculated were above the public exposure limit of 1 mSv/a

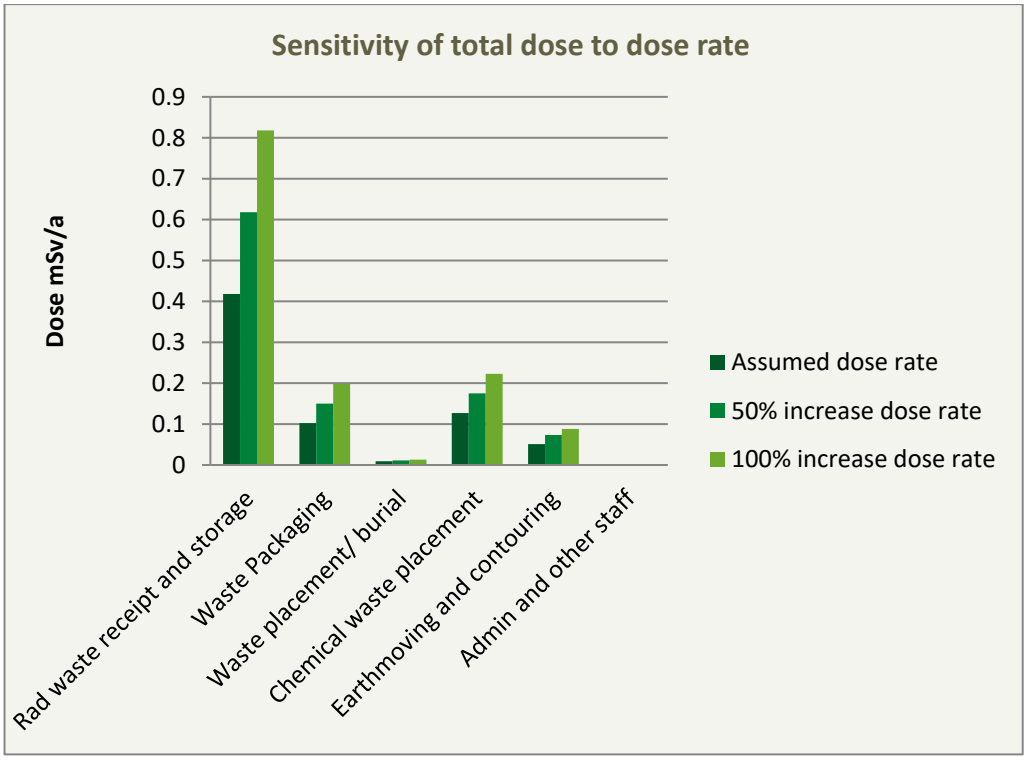

Figure 3: Sensitivity of dose to dose rate

Sensitivity analysis on the dose received if the activity concentration of the dust is 50 % and 100 % higher than was assumed in base calculation was conducted to test what effect it would have on the total dose. As indicated in Figure 4, all results were below the public exposure limit of 1 mSv/a.

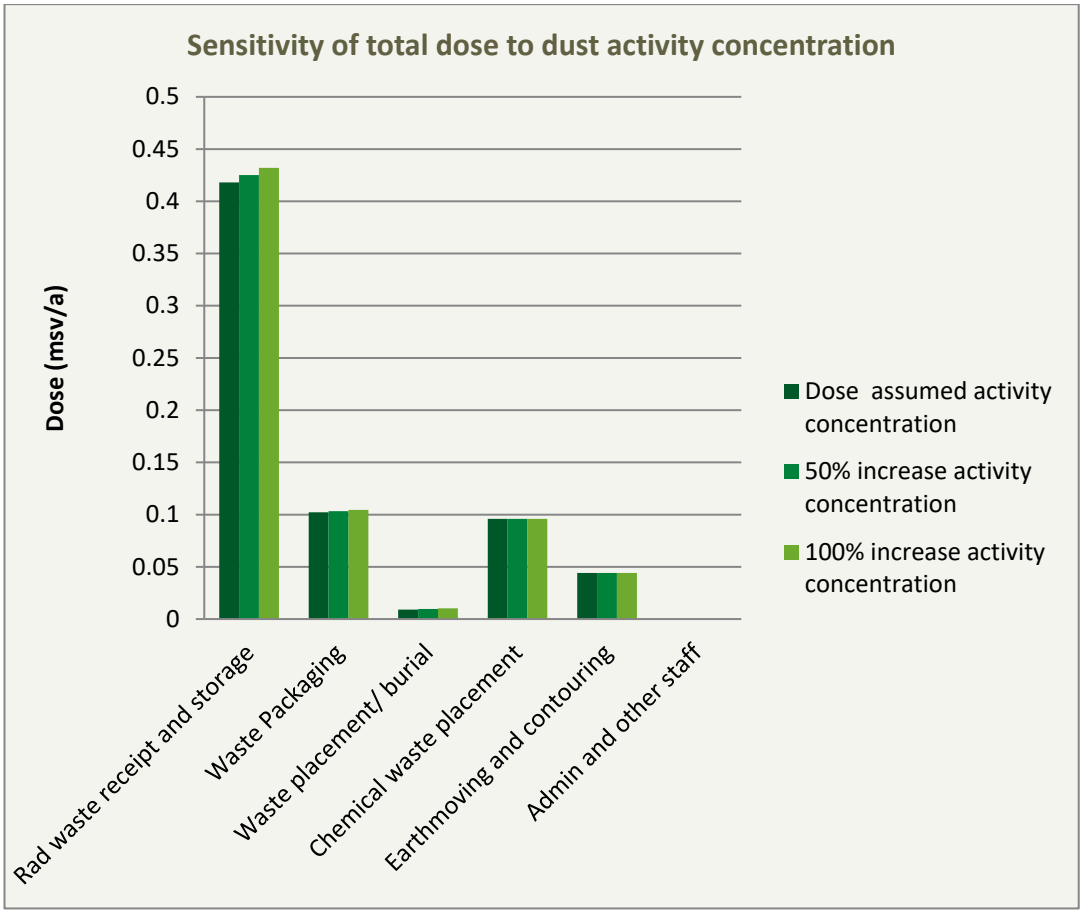

Figure 4: Sensitivity of total dose to dust activity concentration

5 RISK CHARACTERISATION AND RECOMMENDED CONTROLS

The Risk associated with each SEG exposure are summarised below and a brief description of controls that will be implemented to ensure the dose to workers is as low as reasonably practicable. These controls are discussed I ore details in the radiation management plan

1.11 TRANSPORT

Workers involved in the transport of radioactive material to site can be exposed to external gamma radiation from the waste package, Inhalation of suspended dust (α- radiation) And Inhalation of radon and decay products. (Calytrix Consulting (2013). Transport will be arranged by the client and all exposure assessments should be addressed in the clients transport management plan and emergency procedures. The Proponent requires that all packages that arrive on site must be transported in accordance with requirements of the Australian Code of Practice for the Safe Transport of Radioactive Material that adopts International Atomic Energy Agency (IAEA) Transport Safety Regulations.

1.12 RADIATION WASTE RECEIPT AND STORAGE

Workers involved in the unloading, inspection, and storage (warehouse) of radioactive waste can be exposed to external gamma radiation from the waste package, Inhalation of suspended dust (α- radiation) and Inhalation of radon and decay products. Dose assessment results indicate that exposure is very dependent on the duration of exposure. It was assessed that workers are unlikely to be exposed above 0.4 mSv/a Worst case scenario assessment (double the exposure time that is considered realistic) indicate that levels are unlikely to be above 1mSv/a.

Controls that will be implemented to ensure workers are not exposed to levels above the dose constraints include screening of waste packages on arrival to ensure the radiation levels (alpha beta and gamma) is within acceptable (as specified in the transport code) and safe levels, wearing of electronic dosimeters to determine exposure levels, Ensuring packages are not damaged on arrival, dust controls if bulk material are handled and PPE if required.

1.13 WASTE PACKAGING

Workers involved in the packaging of radioactive waste for disposal (cementing and concreting) can be exposed to external gamma radiation from the waste package, Inhalation of suspended dust (α- radiation) and Inhalation of radon and decay products. Dose assessment results indicate that exposure is very dependent on the duration of exposure. It was assessed that workers are unlikely to be exposed above 0.1 mSv/a. Worst case scenario

assessment (double the exposure time that is considered realistic) indicate that levels are unlikely to be above 0.2 mSv/a.

Controls include packaging within a well ventilated designated area, all workers coming into close proximity to the radioactive waste shall wear personal radiation monitors, limiting the time workers spend packaging, increasing the distance between workers packaging the waste and sources, and shielding.

1.14 WASTE PLACEMENT/BURIAL

Workers involved in the unloading and burial of radioactive waste may be exposed to low levels of external gamma radiation from the waste package, Inhalation of suspended dust (α-radiation) and Inhalation of radon and decay products. The waste at this stage is packaged and will be lowered into the shafts by mobile equipment. Workers protection include shielding (provided by the waste packaging and mobile equipment), increase in distance from sources by using mobile equipment and scheduling of waste placement to ensure minimum time is spend near radioactive waste.

Exposure from this SEG is expected to be below 0.01msv/a

1.15 CHEMICAL WASTE PLACEMENT

Workers involved in the unloading and burial of chemical waste may be exposed to low levels of external gamma radiation from the waste package, Workers protection include shielding (provided by the waste packaging, the radiation shaft and mobile equipment), increase in distance from sources by using mobile equipment and scheduling of waste placement to ensure minimum time is spend near radioactive waste.

Exposure from this SEG is expected to be below 0.1msv/a.

1.16 EARTHMOVING AND CONTOURING

Earthmoving and contouring SEG workers are tasked with the capping and closure of cell. They may be exposed to low levels of gamma radiation from the waste cell while cap is constructed. Dosage of this SEG is expected to be below 0.05mSv/a.

1.17 ADMINISTRATION AND OTHER STAFF

No Radiation dose above background is expected to occur in this SEG

6 CONCLUSION

All radiation exposure hazards identified during the baseline qualitative risk assessment were assessed against likelihood of exposure above the exposure limits (20 mSv/a) and above a dose constrain limit of 5mSv.

Even with an increase of 100 % higher than those assumed in the baseline calculations, no dose were above 1 mSv/a. Investigation into exposure levels from similar international facilities indicate that the most exposed worker was around 1.2 mSv/a (individual in charge of traveling crane operations above the disposal vaults). It is therefore unlikely that any person will be exposed to doses above 1.2 mSv/a

On the basis of the characteristics described above, the initial dose assessments and sensitivity analysis concludes that it is highly unlikely that workers will be exposed to levels above the dose constrain limit of 5 mSv/a . Risks from exposure would be further reduced by following standard guidelines and procedures for the transport and handling of dangerous and hazardous goods. In addition, the separation of low level radioactive wastes from other wastes, in appropriately designed pits, would further reduce the risks of exposure at the proposed Sandy Ridge Facility.

2 GLOSSARY OF TERMS

Absorbed dose	means the energy transferred from radiation to unit mass of the exposed matter. The unit used to describe absorbed dose is the gray (Gy);
Activity	the activity of a radioactive source is the number of atoms that are disintegrating per second, measured as Becquerels
ALARA	As low as reasonably achievable, taking into account social and economic factors
Alpha particle	Alpha particles are electrically charged helium atoms, ejected at very high speed (30 000 km/s) from the atom at the instant of breakdown. They are slowed and stopped by about the thickness of a sheet of paper or by about 3 cm of air. Alpha particles cannot get through the dead outer layer of the skin, but they make a dense ionization trail along their stopping track, so they can produce damage to biological tissue, if emitted inside the body following ingestion or inhalation. An alpha particle does not travel far in air before picking up free electrons and turning into an atom of inert helium.
Becquerel (bq)	One atom decaying (disintegrating) per second
Beta particle	Beta particles are electrons formed by the conversion of a neutron into a proton, and are emitted by the atom at nearly the speed of light (300 000 km/s). They can travel a few centimetres in solids and a few metres in air before stopping, but carry less energy, and give it up in track that is more spread-out and less dense than that of alpha particles (so the damage to human tissue is very much less).
Controlled area	means an area to which access is subject to control and in which workers are required to follow specific procedures aimed at controlling exposure to radiation
Contractor	means a person who under a contract performs work or supplies a service in connection with a mining activity on a mining site
Dose	means a measure of the radiation received or 'absorbed' by a target. For the purpose of this document reference to dose is a reference to effective dose

Effective dose	means the weighted sum of all the equivalent doses in all the tissues and organs of the body. The weighting ensures that the detriment is equal whether or not the whole body is irradiated uniformly. The units used to describe effective dose is the Sievert (Sv)
Equivalent dose	means a measure of the dose to a tissue or organ that expresses all radiation doses on a common biological scale. It is the product obtained by multiplying the average absorbed dose in the tissue or organ by a radiation weighting factor to account for the different potential for injury of different types of radiation
Emanation rate	The rate of release of radon from a solid surface area with units of $Bq/(m^2.s)$
Emanating power	The rate of release of radon from a broken material volume with units of $Bq/(m^3.s)$
Gamma ray or radiation	Gamma rays are electromagnetic energy, like x-rays, are very penetrating, and pass with some reduction in intensity through many centimetres of solids. Gamma exposure reduces with the inverse square of distance to the point source.
LLα or LLA	Long lived alpha emitters (dose from which is measured as mSv/a) means the presence in airborne dust of any of the alpha particle emitting radionuclides in the uranium decay series, except for those
mSv	Unit used to describe effective dose is the Sievert (Sv). Frequently used SI multiples are the millisievert (1 mSv = 10−3 Sv = 0.001 Sv) and microsievert (1 μSv = 10−6 Sv = 0.000001 Sv
Personal radiation dosimeters	Thermo-Luminescent Dosimeters, electronic dosimeters, Optical Stimulation Dosimeters, film badges, or quartz fibre electroscopes
Radiation	means ionizing radiation, that is electromagnetic or corpuscular radiation capable of producing ions directly or indirectly in its passage through matter
Radon (rn)	Radon (gas), the only decay product in the chain between uranium and lead which is a gas at standard temperature and pressure. It decays to lead via intermediaries called Radon daughters.
Reasonably practicable	Whether particular risk management measures are reasonably practicable (as defined by Section 5 of the Workplace Health and Safety Act 2007) is to be decided with regard to:

	(a) the likelihood that the risk could result in injury; and (b) the seriousness of any injury that could result from realisation of the risk; and (c) the availability, suitability, effectiveness and cost of the measures; and (d) any other relevant factors.
RnP	Unstable isotopes of polonium, bismuth and lead (Po218, Pb214, Bi214, Po214) produced during decay of radon gas (hence “radon daughters or progeny”). Their concentration is measured in terms of their PAEC. Radon progeny are charged particles and attach strongly to any nearby surface. The radon progeny of concern have short half-lives and therefore, if inhaled, attach to the walls of the lungs and decay rapidly before the normal lung clearance mechanisms can expel them. When radon progeny decay, they give off alpha, beta and/or gamma radiation.

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Radiation Assessments

TELLUS

Hygiea Consulting

RADIATION RISK ASSESSMENT-POST CLOSURE

SANDY RIDGE FACILITY

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1	RADIOLOGICAL RISK ASSESSMENT: POST CLOSURE	Draft	08/08/2016		HR

Prepared by:	Henriëtte Rossouw RSO Hygiea Consulting
Endorsed by:	

Executive summary

Tellus Holdings Ltd (Tellus) proposes to construct and operate a dual revenue Kaolin (clay) mine and waste facility, accepting Class IV (Secure Landfill) and Class V (Intractable Landfill) waste (the Proposal). The waste aspect of the Proposal involves storage or permanent isolation of up to 100,000 tonnes per annum (tpa) of intractable, hazardous and low level radioactive wastes in the mine voids (referred to as 'cells') over a 25 year period (i.e. up to 2,500,000 tonnes of wastes in total).

The properties of radioactive wastes vary, not only in terms of radioactive content and activity concentration but also in terms of their physical and chemical properties. A common characteristic of all radioactive waste is its potential to present a hazard to people and to the environment, and it must therefore, be managed so as to reduce any associated risk to acceptable levels. The preferred strategy for the management of all radioactive waste is to contain it (i.e. to confine the radionuclides to within the waste matrix, the packaging and the disposal facility) and to permanently isolate it from the environment. Materials would be stored in an arid environment, near surface, geological repository using a "best practice" storage and isolation approach underpinned by a safety case.

The primary design goal of a radioactive waste disposal facility is to provide for the protection of human health and the environment during the operation of the facility and in the longer term, after the facility is closed and until the time when the associated radiological hazard will reach an insignificant level through natural decay. This report deals specifically with the post-closure period of the facility and in particular the human intrusion scenarios during the period of passive safety

The dose limit for members of the public from all sources during operations is an effective dose of 1 mSv in a year. During the period of passive safety after closure a risk target approach is used and this should be considered as the target criteria not to be exceeded. To comply with the risk target during the passive safety period the waste disposal facility and management systems are designed so that the estimated average dose or risk to members of the public, who may be exposed as a result of the disposal facility in the future, shall not exceed a dose constraint of 0.3 mSv in year[1]. As well as considering passive safety where the disposal system evolves and performs as expected, consideration has been given to human intrusion, this report looks in particular at this. As human intrusion bypasses the designed barriers a dose constraint of 0.3mSv per year is not felt to be appropriate. ARPANSA[2] advise where it is calculated that human intrusion could result in doses of between 10 and 100 mSv for any human associated with the intrusion, there needs to be further evaluation of the scenario producing this result. Tellus has used a dose of 10mSv/yr. to asses a number of the human intrusion scenarios analysed.

An assessment has been undertaken, with the intention of estimating the post closure radiological effects that waste material could have on humans who may unknowingly be exposed to the radiation hazards on the site. The Assessment took into

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[1] IAEA-TECDOC-1380 Section 3.3.2

[2] Australian Radiation Protection and Nuclear Safety Agency – Licencing of Radioactive Waste Storage and Disposal facilities Section 3.3.5

consideration relevant pathways of exposure during the post closure period, to demonstrate that potential radiological impacts are at acceptable level of risk against set dose constrain levels to adequately safeguard humans.

This assessment was undertaken using both first principle calculations and RESRAD modelling software.

Five post-closure exposure scenarios were investigated:

1. Scenario 1 – First Principle evaluation of human intrusion next to the shaft containing (Category B) sealed radioactive sources that is in accordance to the waste acceptance criteria.

2. Scenario 2 – RESRAD evaluation of human intrusion - living on exposed bulk waste at activity concentration levels of Category A.

3. Scenario 3 – RESRAD evaluation of human intrusion - living on exposed bulk waste at activity concentration levels of Category C.

4. Scenario 4 – RESRAD evaluation of a recreational visitor to the site post closure.

5. Scenario 5 – A “reverse calculation” using RESRAD evaluation to determine radionuclide activity concentration levels in bulk NORM wastes which would give rise to tolerable exposure conditions for post closure and intrusion scenarios.

Scenario 1 results demonstrated the shielding provided is sufficient to shield the radiation from all sources assessed except high activity Caesium-137 sources. With an assumed 40 hours exposure the dose is 0.63mSv. Given the highly conservative nature of the assessment and the low probability of such an event occurring it can be concluded that the risk is sufficiently controlled.

The results from Scenarios 2 and 3, demonstrated in the unlikely case where humans would reside on top of exposed bulk waste of category A, an exposure of 587 hours / year could result in total maximum dose of 10 mSv/y. If the exposure were to occur on uncapped Category C waste, 6.5 hours occupancy would result in total maximum dose of 10 mSv/y. It is implausible that someone would spend this duration in the bulk waste due to site selection of the facility and the cap design. The long term (10,000 plus years) performance of the cap has been modelled using both near-surface hydrogeological and erosion modelling software. The modelling has confirmed that the cap design and site selection is robust from both water infiltration and erosion so the only way such an exposure could occur would be for example during an archaeological dig.

From the analysis of Scenario 4 it was shown that a maximum total dose of 6.2×10^{-7} mSv/y is incurred only at 100,000 years after closure, indicating that for the expected land-use post institutional control, no risk to human receptors are foreseen, given that the possibility of intrusion is mitigated through engineering controls.

In Scenario 5 the RESRAD (Onsite) code was also used, to determine radionuclide activity concentration levels in bulk NORM wastes which would give rise to conditions as specified above for post closure and intrusion scenarios. These values were adopted in the WAC for NORM waste.

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1 INTRODUCTION

1.1 BACKGROUND

Tellus is planning to develop the Sandy Ridge Project (the Proposal). The Proposal is comprised of two main business components, mining of kaolin clay for export and storage and permanent isolation (disposal) of hazardous and intractable waste in mine voids which will function as a near surface, arid area geological repository.

The waste aspect of the Proposal involves storage or permanent isolation of up to 100,000 tpa of intractable, hazardous and low level radioactive wastes in the mine voids (herein referred to as ‘cells’) over a 25 year period (i.e. up to 2,500,000 tonnes in total). Wastes would be accepted from across Australia.

Waste acceptance criteria (WAC) developed for this facility is described in the Tellus Waste Acceptance Criteria (document reference: TCO-5-05-002). The radionuclide concentration limits is set taking into account the actual siting, design and planning of the facility (e.g. natural geological barrier, arid climate, remoteness, engineered multi layered shielding and barriers, duration of institutional control, site specific management plans and operating procedures) and exposure dose constraints to ensure no person is exposed above the dose limit (as defined in Schedule I of the Radiation Safety (General) Regulations). These radioactive wastes are generally generated by medical research and industry, operation of research facilities (e.g. laboratory coats, overshoes, gloves), Naturally Occurring Radioactive Materials (NORM), NORM occurring on pipework and scale from industry, oil spills containing NORMs and orphan sources (i.e. gauges and instrumentation). Wastes which will not be disposed of into cells include: infectious materials, nuclear material, uncertified waste, putrescible waste and gases.

The properties of radioactive waste vary, not only in terms of radioactive content and activity concentration but also in terms of physical and chemical properties. A common characteristic of all radioactive waste is its potential to present a hazard to people and to the environment, and it must therefore be managed so as to reduce any associated risk to acceptable levels. The preferred strategy for the management of all radioactive waste is to contain it (i.e. to confine the radionuclides to within the waste matrix, the packaging and the disposal facility) and to permanently isolate it from the environment. Near-surface disposal of low level waste (LLW), at varying depths down to about 30 metres below ground surface, has been practiced internationally for over 20 years.

The radiological impact to humans and the environment from the disposal of radioactive waste are kept to acceptable levels by:

- Use of appropriate site selection criteria- an arid environment, near surface, geological repository.
- Appropriate design, construction and operation of the waste disposal facility.
- Establishment of limits upon radionuclide concentrations in the waste based on the approach that there is unrestricted access following a period of institutional control.
- Specification of qualitative criteria for the physical and chemical properties of waste and additional criteria on waste packaging and conditioning which ensures that the release of radionuclides from the site is minimised.
- Comprehensive safety assessment of the disposal site and disposal facility design.

Tellus operations are underpinned by utilising a combination of engineered and natural barriers, known as a multi barrier system, which provides long term containment and isolation of the waste.

Cells would be filled in layers with multiple sections in each layer. Each layer would be divided into sections containing wastes of similar characteristics.

After the placement of waste in the cell has been completed, the following protection measures will be implemented:

- An all-weather cover will be maintained over the cell until it is backfilled and capped to allow for protection from all weather conditions, without the possibility of creating leachates or contaminated surface water.
- Any airspace surrounding the placed waste will be backfilled with kaolin processing plant waste product (low value kaolin and quartz sand) or kaolinised granite overburden to fill all void space and provide stability.
- The cell will then be backfilled with compacted clay, silcrete, and laterite.
- The surface of the cell will be covered with a domed clay cap to exclude rainwater.

After a 10 year period of subsidence and environmental monitoring to confirm the stability and integrity of the cell, further kaolinised granite and soil will be placed over the cap and the area re-vegetated with species of local provenance. Local species would be selected based on their root system penetration (depth), ensuring that the capping design is not compromised.

Tellus will monitor and manage the site for an extended period following closure before returning ownership to the State, a period termed institutional control. The institutional control period (ICP) will ensure the wastes stored and disposed of in the geological repository are undisturbed for a period of time until they no longer pose a risk to human health and the local environment.

Further information on management of the Facility is provided in the Radiation Waste Management Plan.

1.2 SCOPE AND OBJECTIVES

The primary design goal of the Proposal is to provide for the protection of human health and the environment in the long term, after the facility is closed and until the time when the associated radiological hazard will reach an insignificant level.

The dose limit for members of the public from all sources is an effective dose of 1 mSv in a year, and this, or its risk equivalent, should be considered as criteria not to be exceeded in the future. To comply with this limit, the Proposal is designed so that the estimated average dose or risk to members of the public, who may be exposed as a result of the disposal facility in the future, shall not exceed a dose constraint level of 0.3 mSv in a year.

This assessment has been undertaken to estimating the radiological effects, post closure that disposed waste material could have on the environment and members of the public. This includes all relevant pathway of exposure and demonstrate that potential radiological impacts are within the dose constrain limits and manageable to adequately safeguard humans.

2 SITE GEOGRAPHICAL CONTEXT

The Proposal is located approximately 75 kilometres (km) north-east of Koolyanobbing, Western Australia. Access is via a 100 km road to the Mt Walton East Intractable Waste Disposal Facility (IWDF) that extends northward from the Boorabbin Siding on Great Eastern Highway; a new 4.5 km westwards section, and a 5.3 km northwards section of new site access road into the development envelope (Figure 1).

There are no sensitive receptors within 50 km of the location of the Proposal. The nearest operation is the Class V IWDF (Intractable Waste Disposal Facility) Mount Walton East located approximately 6 km to the East, which operates on a campaign basis and does not have permanent residents. The nearest mining camp is the Carina Iron Ore Mine Accommodation Camp located approximately 52 km to the South-East of Sandy Ridge.

The location of the Sandy Ridge Project has been specifically chosen to meet the requirements of International and National codes relating to the siting of a near surface geological repository. These site characteristics include:

- Geologically stable — the development envelope sits within the Archean Yilgarn Block and is geologically typical of areas overlying deeply weathered granite domes. It has very low seismicity (no earthquakes have been recorded at Sandy Ridge) and no volcanic or tectonic activity.
- Natural geological barrier — the kaolinised granite is laterally extensive (160 km long and 20 km wide), has been stable for at least 20 million years and is typically 30 to 50 m thick. This is capped by erosion resistant silcrete and laterite layers typically 4 to 6 metres thick in total, overlain by yellow clayey sand.
- Semi-arid desert Mediterranean climate — averages just over 250 mm of rainfall per annum and evaporation is greater than 2,000 mm per annum. This means very little rainfall occurs across the site and all water will evaporate before it infiltrates beyond 4 to 6 m depth.
- No surface water receptors - there are no channels or creeks in the development envelope.
- Very little (if any) surface water runoff – Due to the low rainfall, high evaporation, permeable upper soil profile and gently sloping topography, significant rainfall events infiltrate quickly to shallow depths before being evaporated. There is a low likelihood of surface flows in the local catchments and any flows are short-lived and local in nature.
- Lack of commercial mineral deposits – there is no evidence to suggest that there is potential for economic mineral or hydrocarbon deposits beneath the kaolin deposit.
- Topography – the development envelope is flat to gently undulating and suitable for the construction of infrastructure and heavy vehicle movement.
- Absence of Population – located in an area with no population, the nearest population centre is a non-permanent mining camp approximately 52 km away.
- Agricultural land use – there is no potential for medium to high value agriculture.
- Environmental values – there will not be any adverse impact to conservation significant flora or vegetation listed under the *Wildlife Conservation Act 1950* (WC Act) or the EPBC Act.
- Heritage – no special cultural or historical significance has been identified through a completed heritage study and consultation with stakeholders familiar with the area.

- No flooding – the development envelope is not subject to flooding, nor is it predicted to be in the future. The site is at very low risk of encountering cyclones.
- Very low rates of erosion – the development envelope has extremely low rates of erosion and there is no possibility of glacial activity in the future.

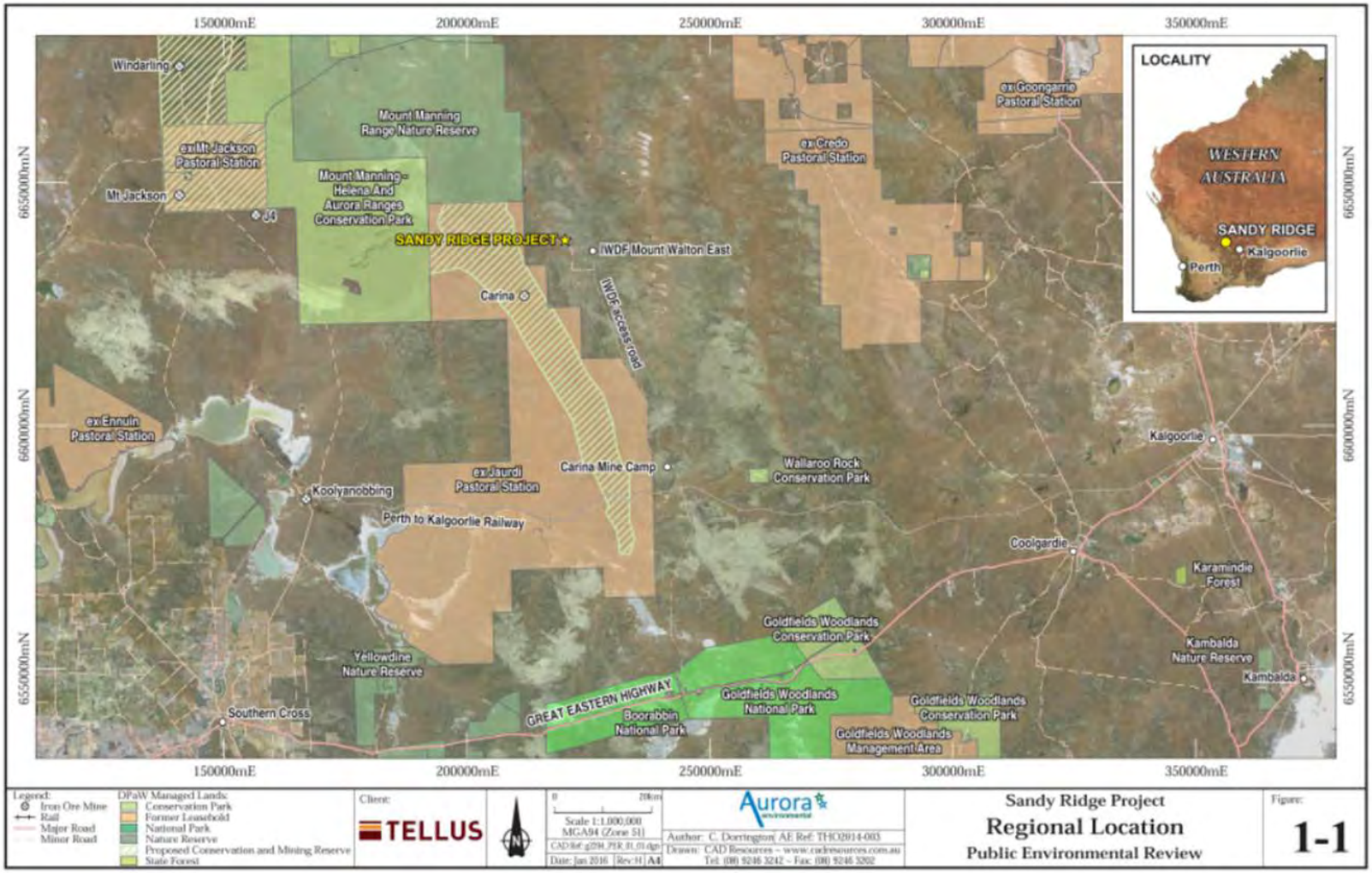


Figure 1: Location Map

3 RADIOACTIVE WASTE CLASSIFICATION

Radioactive waste is defined as ‘radioactive material in gaseous, liquid or solid form for which no further use is foreseen, and which is controlled as radioactive waste by a regulatory body’.

In Australia there are 2 main documents in relation to the classification of radioactive waste:

- The ARPANSA Safety Guide for Classification of Radioactive Waste (2010).
- NHMRC Code of practice for the near surface disposal of radioactive waste in Australia (1992) (RHS35) - currently under review.

In Australia, a system of categorising radioactive waste relating to near surface disposal is proposed in the NHMRC Code of practice for the near surface disposal of radioactive waste in Australia (1992) (RHS35). The classification was based on international recommendations for radioactive waste management adapted for the type of waste generated in Australia. Those categories suitable for near surface disposal are Category A, Category B and Category C. Category S is not suitable for near surface disposal. The classification is only used by regulatory authorities to classify waste destined for disposal, not as a general classification system.

The classification of radioactive waste has also been defined in the General Safety Guide Classification of Radioactive Waste (No. GSG-1) published by the IAEA in late 2009.

Under the current international guidance, there is not a precise boundary between each of the waste categories, as limits on the acceptable level of activity concentration will differ between individual radionuclides or groups of radionuclides.

The ARPANSA Safety Guide for Classification of Radioactive Waste (2010) largely reflects the international guidance referred to above. As such, it does not include quantitative values of allowable activity content for each significant radionuclide. Radioactive waste generated in Australia generally falls within the VSLW, VLLW, LLW or ILW classifications. Australia does not generate any electricity from nuclear power and therefore currently does not generate any used fuel that would be classified as HLW.

- Exempt waste – is excluded from regulatory control because radiological hazards are negligible.
- Low-level waste (LLW) - may include short lived radionuclides at higher levels of activity concentration and also long-lived radionuclides, but only at relatively low levels of activity concentration. LLW covers a very wide range of radioactive waste, from waste that does not require any shielding for handling or transportation, up to activity levels that require more robust containment and isolation periods of up to a few hundred years

- Intermediate-level waste (ILW) - contains increased quantities of long-lived radionuclides and needs an increase in the containment and isolation barriers compared to LLW. ILW needs no provision for heat dissipation during storage and disposal. Long-lived radionuclides such as alpha emitters will not decay to a level of activity during the time for which institutional controls can be relied upon.
- High-level waste (HLW) - is sufficiently radioactive to require both shielding and cooling, generates >2 kW/m³ of heat and has a high level of long-lived alpha-emitting isotopes.

The Disposal facility will only accept Low Level Waste (LLW). i.e., Low level waste and short lived intermediate level waste as per ARPANSA 2010 Correspond to Category A, B or C under the NHMRC 1992.

3.1 WASTE TYPES

The types and form of radioactive waste that are likely to be managed at the Facility would be generated from:

- Medical research and industry (use of radioisotopes and sealed radioactive sources which contains low activity concentrations).
- Industrial gauges and commercial sources.
- Mining and processing of mineral ores or other material containing naturally occurring radioactive material (NORM), such as phosphate minerals, mineral sands, coal, some gold bearing rocks and hydrocarbons. These generally contain long lived radionuclides at relatively low concentrations. NORM such as scales arising in the oil and gas industry may have higher activity concentration levels but would still be categorised as low level wastes. NORM wastes may include contaminated equipment and piping.
- Intervention actions, which are necessary after accidents or to remediate areas affected by past practices.
- Disposal of disused sealed radioactive sources (including orphan sources).

All wastes need to be ‘characterised’. This means that information is collected about the waste in order to build up a picture of its properties. Data is collected about the radiological, chemical and physical properties of the waste. This information helps to decide how the waste should be handled, packaged, stored and safely disposed of by the facility.

4 RADIOACTIVE WASTE MANAGEMENT

The effective management of low and intermediate level waste depends on knowledge of the waste characteristics and the contained radioactivity.

The property of radioactive waste varies, not only in terms of radioactive content and activity concentration but also in terms of physical and chemical properties. A common characteristic of all radioactive waste is its potential to present a hazard to people and to the environment, and it must, therefore, be managed so as to reduce any associated risk to acceptable levels.

The preferred strategy for the management of all radioactive waste is to contain it (i.e. to confine the radionuclides to within the waste matrix, the packaging and the disposal facility) and to isolate it from the environment.

This section provides a broad overview of the waste, predisposal practices and the proposed waste acceptance criteria. More detailed description of the management strategies that will be implemented is given in the Radiation Waste Management Plan (RWMP) and in the Waste Storage and Disposal Zoning Procedure (TCO-5-05-004).

4.1 PREDISPOSAL MANAGEMENT OF RADIOACTIVE WASTE

The overall objective of predisposal management of radioactive waste is to produce waste packages that can be handled, transported, stored and disposed securely and safely. In addition to compliance with individual dose limits, the practices that are adopted in waste conditioning, packaging and other containment shall be carried out to ensure that any potential exposure will be as low as reasonable achievable.

Below is a brief description as to how Tellus proposes to manage radioactive waste accepted at the Proposal. More detail on exposure control and waste management practices is given in the RWMP.

4.1.1 SEALED SOURCES

Sealed sources will upon receipt be stored in the Radioactive Waste Warehouse, unpacked, inspected and verified. After verification, sources will be secured in a 60 L drum inside a 200 L drum. As illustrated in Figure 2, high density cement grout will be added to the 60 L drum to fill all the void spaces and to cover all the items. The cement filled 60 L drums will be placed in the centre of a 200 L drum, which is then filled with high density cement grout. The 200 L drum will be marked with its identification number and labelled. These drums will be stored until the shaft is prepared for disposal. Drums will then be transferred to the cell, loaded into the shaft and covered and surrounded with kaolinised granite fill or other non-reactive wastes combined with pozzolanic material to form a cementitious mixture.

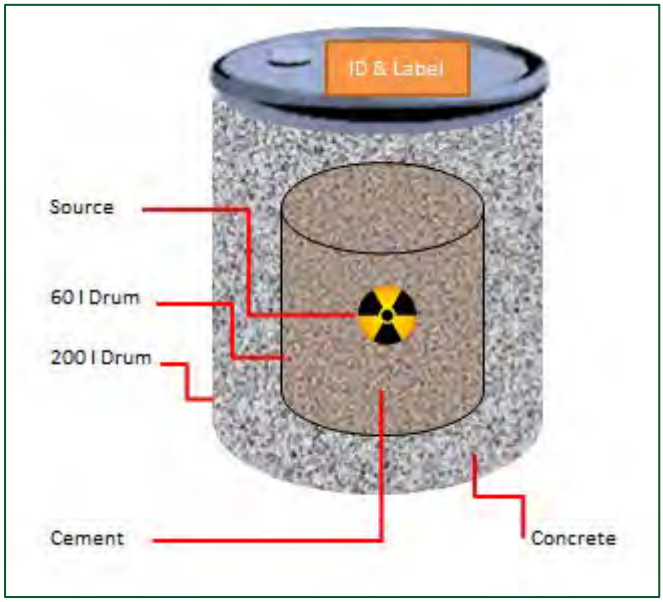


Figure 2: Packaging of sealed sources

4.1.2 NORM CONTAINING PASTES / SLUDGES / LIQUIDS

Once delivered to site NORM containing pastes, sludges or liquids, will be stored in the Radioactive Waste Warehouse or in sea containers on hardstand (dependent upon activity). In campaigns waste will be unpacked, inspected and verified by laboratory testing. If required the waste will then be treated with absorbent and pozzolanic materials to form a slurry which will solidify and stabilise the waste. The slurry can be placed into drums, moulds, or contained sections of the cell where it will set to form a stable solid.

4.1.3 CONTAMINATED SOLID MATERIALS

Contaminated solid material will be stored in Radiation Store building or in sea containers on hardstand (dependent upon activity) until suitable space is available in cell. Depending upon physical size and shape of materials, type and activity of radiation, these wastes can either be:

- Compacted in drums and filled with kaolin or cement grout prior to disposal.
- Crushed or cut to remove void space and fill remaining voids in with cement grout or kaolinised granite solids.
- If necessary, an entire sea-container or whole equipment into a cell, and all void spaces filled with cementitious grout material.

4.1.4 CONTAMINATED SOIL OR SANDS (BULK MATERIAL)

Bulk contaminated soils or sands will be delivered to site in either bulk bags, shipping containers or as wetted down sand, depending on volume and physical characteristics of material. Practical transport will be arranged to coincide with a disposal campaign so it can be disposed of directly into pit, but if not viable, the material will be stored in the Radioactive Waste Warehouse. For large volumes of material, separate stockpile areas will be set up (adhoc stockpiles), and dust control measures introduced. These are discussed in section 9.2 of the radiation management plan and include a designated stockpile area with concrete slab and bunded walls, closing stockpile with tarpaulin material, dust suppression agents and a monitoring program to confirm efficiency of controls implemented. The stockpile area and surrounding area will be screened after removal of the stockpile to ensure dose rate levels are back to background radiation levels. The bulk material can be disposed of directly in the cell, diluted or mixed with other material, or mixed with binders or pozzolanic materials if required.

5 DISPOSAL OF RADIOACTIVE WASTE

Disposal options are designed to contain the waste by means of passive engineered and natural features and to isolate it from the environment to the extent necessitated by the associated hazard. The term ‘disposal’ refers to the emplacement of radioactive waste into a facility or a location with no intention of retrieving the waste. The term disposal implies that retrieval is not intended; it does not mean that retrieval in not possible.

The specific aims of disposal are:

- To contain the waste.
- To isolate the waste from the environment and to reduce substantially the likelihood of, and all possible consequences of, inadvertent human intrusion into the waste.
- To inhibit, reduce and delay the migration of radionuclides at any time from the waste to the environment.
- To ensure that the amount of radionuclides reaching the environment due to any migration from the disposal facility are such that possible radiological consequences are acceptably low at all times.

5.1 NEAR SURFACE DISPOSAL

Near-surface disposal of low level waste (LLW), at varying depths down to about 30 metres below ground surface, has been practiced internationally for over 20 years. Near surface repositories provide adequate containment for short lived low and intermediate level waste and for some long lived low and intermediate level waste when greater confinement is provided.

The rationale of near surface disposal depends on the assumption that, by the end of the institutional control period, the activity of the waste will have decayed to harmless levels with respect to likely future uses of the site and consequent potential exposure pathways. For a geological repository, the site provides significantly longer isolation of the waste (for geological time).

5.2 FACILITY DESIGN

During the feasibility stage of the project consideration were given to engineering best practice as well as socio economic considerations to determine the most suitable design that will meet the safety requirements at acceptable cost. The current

proposal is open cut pit with in-cell vertical shaft disposal of sealed source radioactive wastes. During the waste disposal process a roof canopy is positioned over the cell to exclude rainwater prior to the capping layer being installed. There may be instances (for non-soluble waste types) where a cell may be filled with waste without a roof canopy. In addition, any potential stormwater surface flows would be diverted away from the cells by bund walls or levee banks.

A hybrid solution identified for the storage of sealed source radioactive wastes which cannot be placed in an open-cell with other chemical wastes is the construction of shafts within the planned open-cell storage. A number of shafts can be constructed within a cell using pre-formed cylindrical shaft segments. As the cell is progressively filled with other wastes, more segments are stacked upon each other to create a shaft. A buffer of compacted kaolinised granite is placed around each segment and bulk NORM wastes are also used to provide further isolation from chemical waste.

Sealed source waste can be placed into the shaft at any time, but it is expected that the shaft will progress to several metres of depth before a campaign of waste placement takes place, so as to provide a level of physical separation and a shield between the radioactive waste and workers on the active surface. Waste drums are lowered into the shaft and each layer is backfilled with kaolinised granite to fill void spaces. Higher activity wastes can be backfilled with cementitious slurry if required. A concrete lid is used on the shaft to prevent un-authorised human entry. Upon the shaft reaching and being filled with waste to the base of cap level, the lid is left in place and the structure is covered by the cell cap materials The cost per unit of waste placement in this manner is less than underground mining and blind shaft sinking methods considered, but is far less risky than either of the alternatives as it is not dependent upon ground conditions and shafts can be constructed on-demand. This method is also able to be constructed with no special skills.

The geological environments allow the post-closure safety requirements to be achieved without relying on the integrity of the waste packages. In these cases, the prime function of the containers is to provide operational and transport safety.

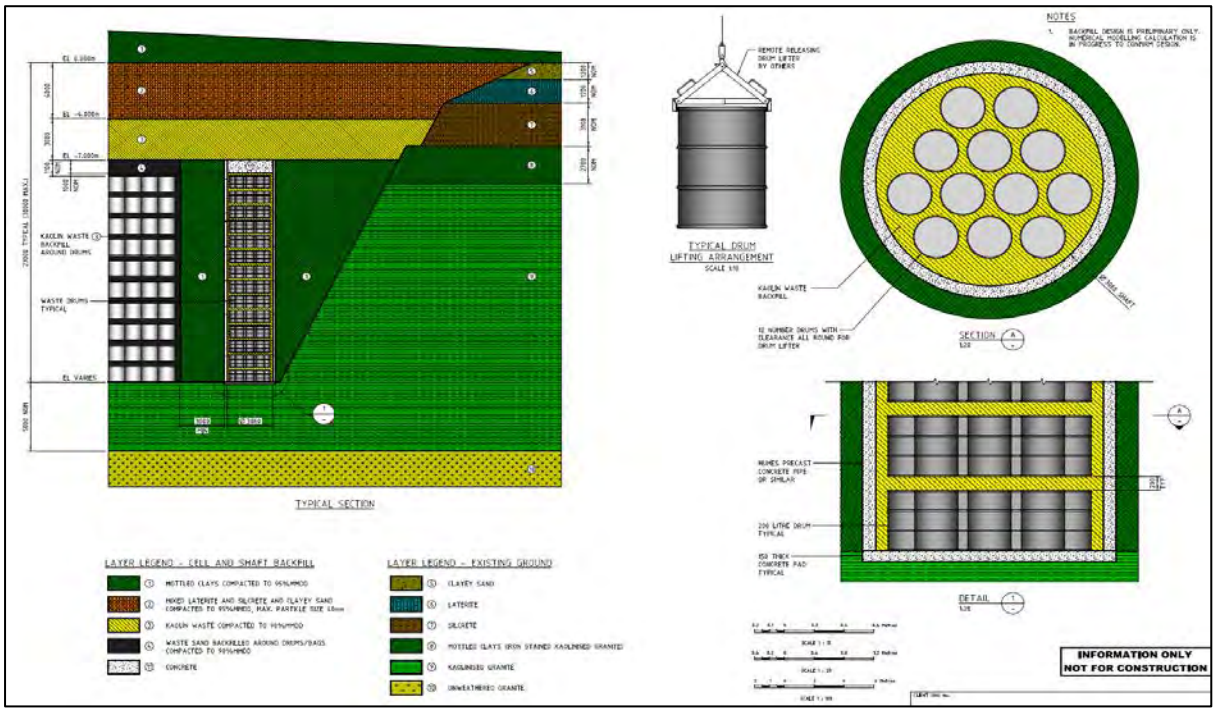


Figure 3: Shaft design

NORM wastes are placed in the open cell for disposal, in accordance with the Waste Storage and Disposal Zoning Procedure. Slurry or liquid form wastes will be mixed with kaolinised granite as an absorbent and pozzolanic materials prior to placement to create a cementitious mixture with at least 0.35MPa strength. A cover layer of compacted kaolinised granite or other un-reactive bulk waste is placed over layers of NORM waste if that layer is to be a working surface for people or machines in the placement of other wastes in subsequent layers.

5.3 CAPPING DESIGN

Once all wastes are placed in the cell and the area is ready for closure, an engineered cap consisting of compacted backfill materials is placed into the remaining void. This cap serves several purposes; preventing surface or meteoric water from entering the waste storage area and mobilising soluble waste chemicals, preventing erosion, acting as a barrier to un-authorised access of the isolated waste materials, and providing a barrier to radioactive emissions.

The engineered cap reduces the level of external exposure by covering the waste with a layer of “clean” material. This material absorbs gamma radiation emitted by the radionuclides in the waste, and also inhibits the exhalation of radon. The presence of the cover also removes the possibility of internal exposure via the dust inhalation pathway and of external exposure from material which settles on the skin.

The construction of the cap is completed by an earthmoving contractor whilst new waste placement activities occur in the next cell. After a monitoring period of 10

years, further overburden and soils are placed over the cap and progressive rehabilitation commences.

The long term (10,000 plus years) performance of the cap has been modelled using both near-surface hydrogeological and erosion modelling software. The modelling has confirmed that the cap design is robust from both water infiltration and erosion aspects.

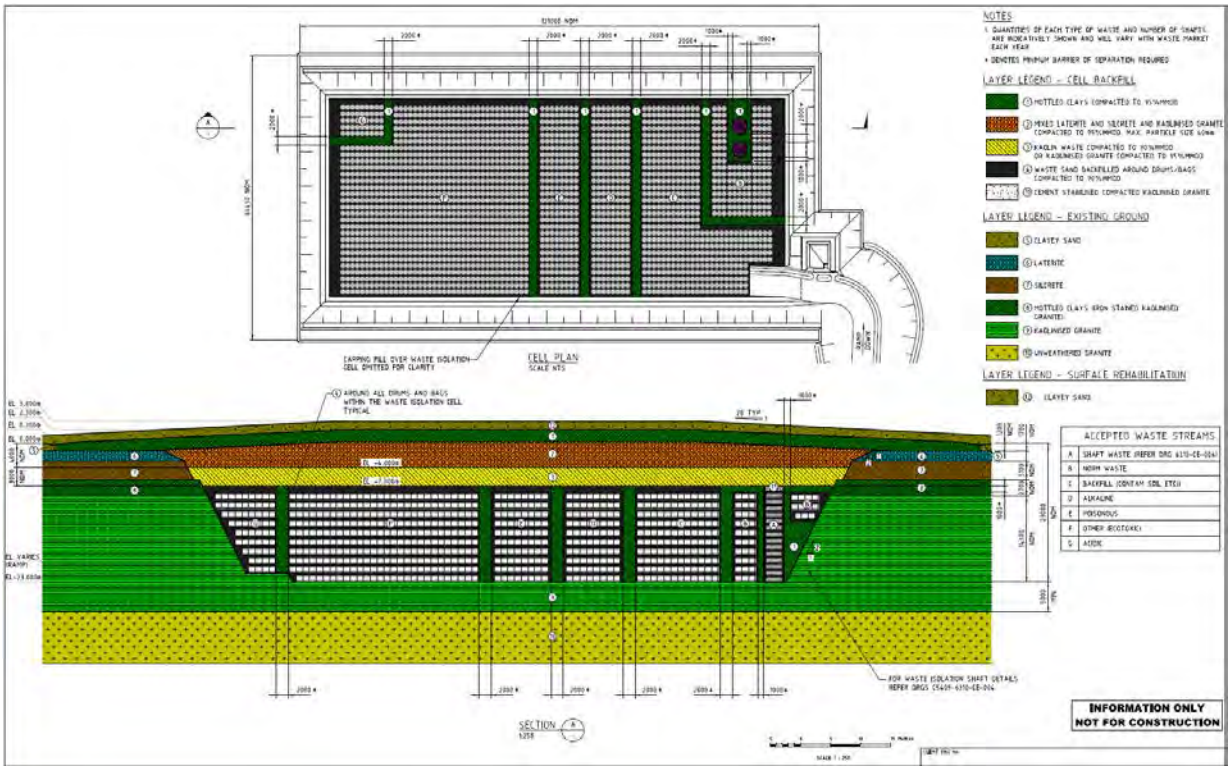


Figure 4: Cell backfill and cap design (section view)

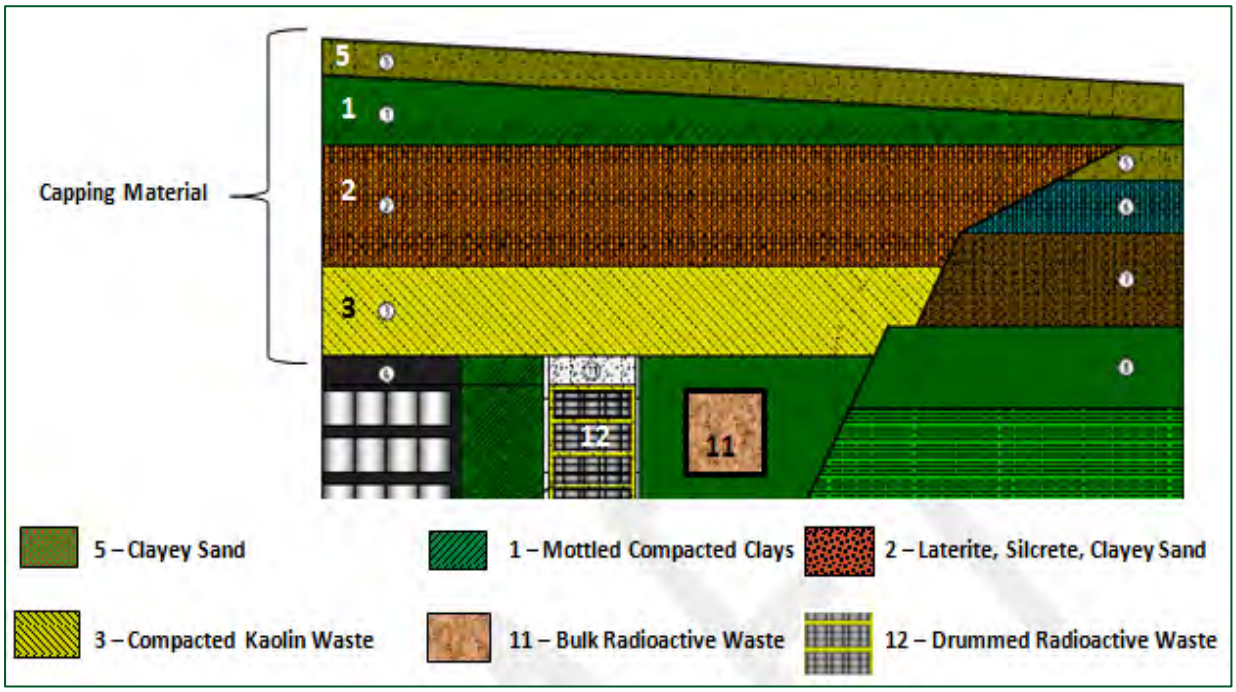


Figure 5: Post Closure and Rehabilitation of the Facility

5.4 MONITORING

Rehabilitation is progressive during the life of the facility. Monitoring of the clay caps over each cell takes place for 10 years before the final placement of surplus overburden, sub-soil and topsoil over the cap.

5.5 CLOSURE & REHABILITATION

After a period of monitoring to confirm the stability and integrity of the clay cap capping, topsoil will be placed over the cap and the area re-vegetated with species of local provenance. The root zone of these local flora species is such that the engineered cap would not be compromised and that direct uptake of radionuclides in not possible.

Tellus propose that a post-closure management plan over an agreed period of time is provided to ensure the integrity of the disposal cell caps and demonstrate that all waste is securely contained before responsibility for the site is transferred to the State Government.

5.6 FUTURE LAND USE

Any radiological assessment of the possible consequences of near surface disposal has to take into account the future use of the disposal site after the waste disposal phase has ended.

Upon demonstrating that all waste is securely contained and the site is suitable for commencement of the ICP, the responsibility for the site will be transferred to the State Government.

5.7 RADIOLOGICAL PROTECTION IN THE LONG TERM

The primary design goal of a radioactive waste disposal facility is to provide for the protection of human health and the environment in the long term, after the facility is closed and until the time when the associated radiological hazard will reach an insignificant level. In this period, the migration of radionuclides to the environment and consequent exposure of humans may occur due to slow degradation of barriers, slow natural processes and also following discreet events that may alter the disposal system barriers or lead to short term release of radionuclides [30]. Radiological protection criteria relevant to the post-closure phase of near surface disposal facilities are set out in the relevant IAEA Requirements [18] and in recent ICRP publications [29].

Radioactive waste disposal facilities shall be sited, designed, constructed, operated and closed so that protection in the long term is optimised, social and economic factors being taken into account, and a reasonable assurance provided that doses or risk in the long term will not exceed the dose or risk constraint for members of the public [30].

The dose limit for members of the public during operations from all sources is an effective dose of 1 mSv in a year, and this or its risk equivalent should be considered as criteria not to be exceeded. To comply with this limit, Tellus is designing the facility so that the estimated average dose or risk to members of the public, who may be exposed as a result of the disposal facility in the future, shall not exceed a dose constraint of 0.3 mSv in year.

The ICRP has given guidance on radiological criteria applied to human intrusion [29]. In circumstances where human intrusion could lead to doses to those living around the site sufficiently high that intervention on current criteria would almost always be justified, reasonable efforts should be made to reduce to probability of human intrusion or to limit its consequences. In this respect the ICRP has advised that an existing annual dose of around 10 mSv may be used as a generic reference level below which intervention is not likely to be justifiable and that an existing annual dose of around 100 mSv may be used as a generic reference level above which intervention should be considered always justifiable.

6 SAFETY ASSESSMENT

To determine whether a specific waste disposal practice will have unacceptable radiological effects, either direct or indirect, on humans, a ‘safety assessment’ must be carried out. The assessment aim to analysis of the system in order to predict its behaviour, comparison of the results with appropriate standards or criteria expressed the radiological impact in terms of dose or risk.

Safety assessments can also be utilised to assess and compare the feasibility of a range of disposal options in a generic manner and to develop quantitative and qualitative waste acceptance criteria. They can also be used to show which environmental exposure pathway are the most important for specific waste types, disposal facilities design and generic disposal sites.

An important part of the safety assessment for a near surface repository is estimation of the dose from inadvertent intrusion scenarios that hypothetically occur after the institutional control period. This dose is dependent on the specific activity of the waste in the repository at the time of intrusion and the engineering controls I place to safeguard humans.

There are many ways in which a disposal site could potentially present a radiation hazard and therefore a number of exposure scenarios can be postulated. Release of radionuclides into groundwater and their subsequent migration, together with human intrusion, intentional and unintentional, are two important means by which material buried in near surface sites can present a radiological hazard. Other scenarios relating to natural processes such as wind and water erosion may also need to be considered.

RESRAD is a computer model designed to estimate radiation doses and risks from residual radioactive materials. The model estimates direct exposure to external radiation from contaminated soil and internal dose from the inhalation of airborne radionuclides originating from contaminated soil or from radon emissions thereof.

The model also calculates internal doses from the ingestion of contaminated vegetables and leafy greens, meat, fish, milk, drinking water, and soil. The RESRAD code has become popular because of its adaptability to specific exposure situations, and its models being verified and validated as benchmarked against other codes in the environmental assessment and site clean-up arena (Faillance et al. 1994) [2].

The RESRAD (onsite) computer code evaluates the radiological dose and excess cancer risk to an individual who is exposed while residing in an area where the soil is contaminated with radionuclides Figure 6 illustrates all the potential exposure pathways that can be included in the RESRAD modelling. (Yu et al. 2001). Not all of

these pathways (as per Figure 6) are relevant to the Sandy Ridge site. Where a pathway is not relevant it was excluded from the assessment.

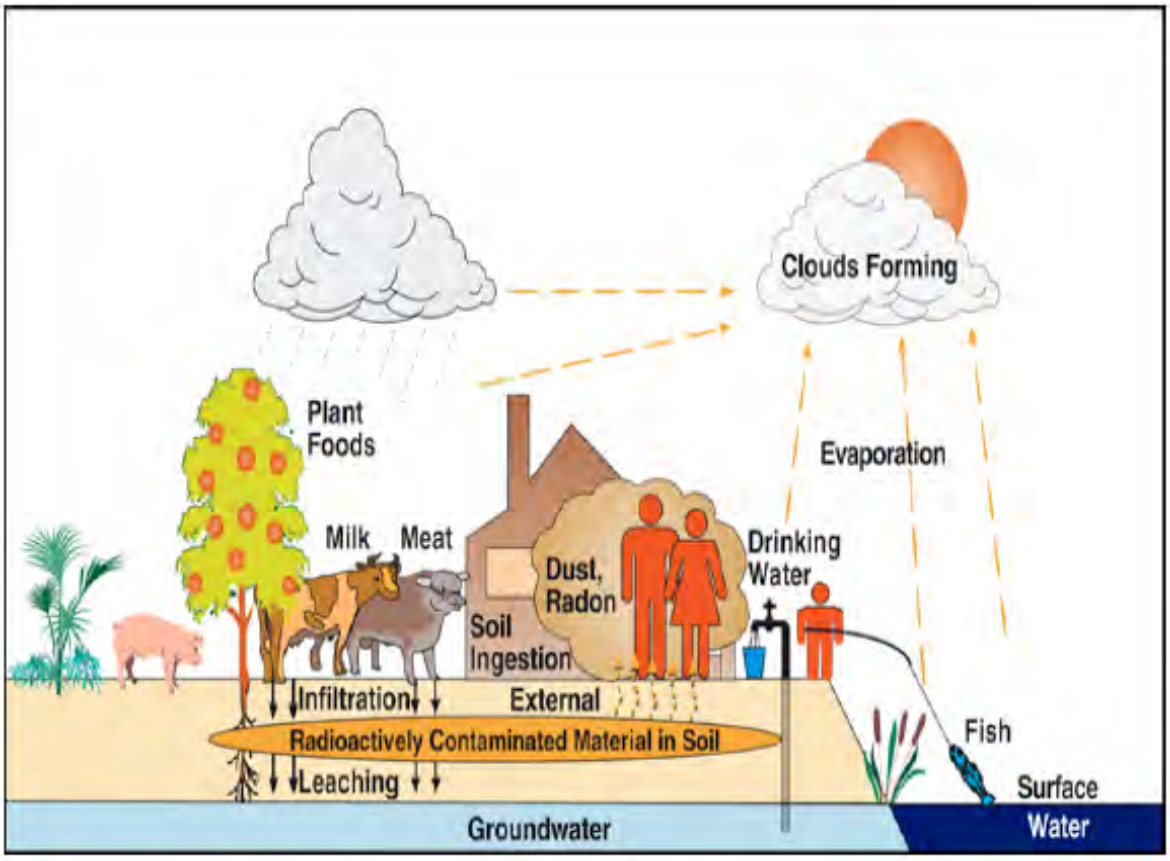


Figure 6: Potential pathways of exposure (RESRAD onsite)

7 EXPOSURE ASSESSMENT RATIONAL

It is necessary to consider the consequences of disturbance of the waste by human activities (human intrusion) at the end of the institutional control period. The likelihood of such an intrusion was reduced by choosing a site with low resource potential, low population, no agricultural or environmental value, engineered control and containments and ensuring that suitable government controls are established to manage future land uses at the site and records of what is contained within the site.

The RESRAD modelling tool (as well as first principle calculations) was used to assess the proposed waste disposal system in order to predict its behaviour, followed by comparison of the results with appropriate standards or criteria.

Four post-closure exposure scenarios were identified and are discussed below. The RESRAD tool was also used to determine the waste acceptance criteria for NORM waste and is also discussed in the report as scenario 5.

7.1 SCENARIO 1: HUMAN INTRUSION NEXT TO THE SHAFT CONTAINING CATEGORY B SEALED RADIOACTIVE SOURCES

For Scenario 1, a hypothetical scenario was assumed where a person excavates or digs next to the disposal shaft that contains sealed radioactive sources as illustrated in Figure 7.

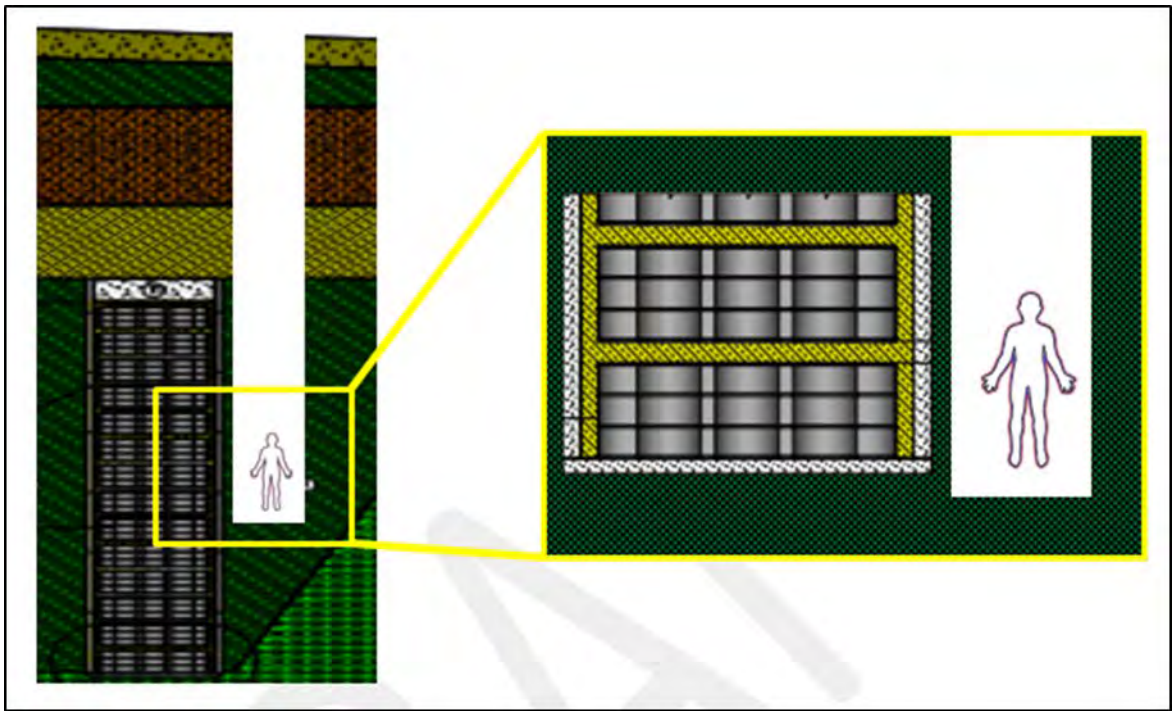


Figure 7: Scenario 1- Human intrusion next to radioactive sources shaft

The dose that will be received by a member of the public is dependent on the activity concentration of sources at the time exposure, the duration of exposure, distance from the shaft and shielding. Shielding will be provided by the double-isolated and concrete entombed packaging of sources (as discussed in section 4.1) and the shaft itself containing further shielding of either kaolinite material or concrete. High activity sources can also be packaged (and is likely to be so for transport) in lead casings. These will provide further shielding.

For the assessment it was assumed that the scenario occurs 100 years after disposal, that the maximum activity level (as per WAC) sources were disposed of and that the individual is directly next to the concrete shaft.

In the assessment the following shielding were assumed and is illustrated in Figure 8:

- 0.285 m concrete in drums
- 0.0013m steel around drums
- 0.2 m concrete from shaft.
- Lead casing of 0.0255m around high activity Cs137 sources.

- Shielding that will be provided from either waste kaolinite material or additional concrete inside the shaft was excluded from the assessment.

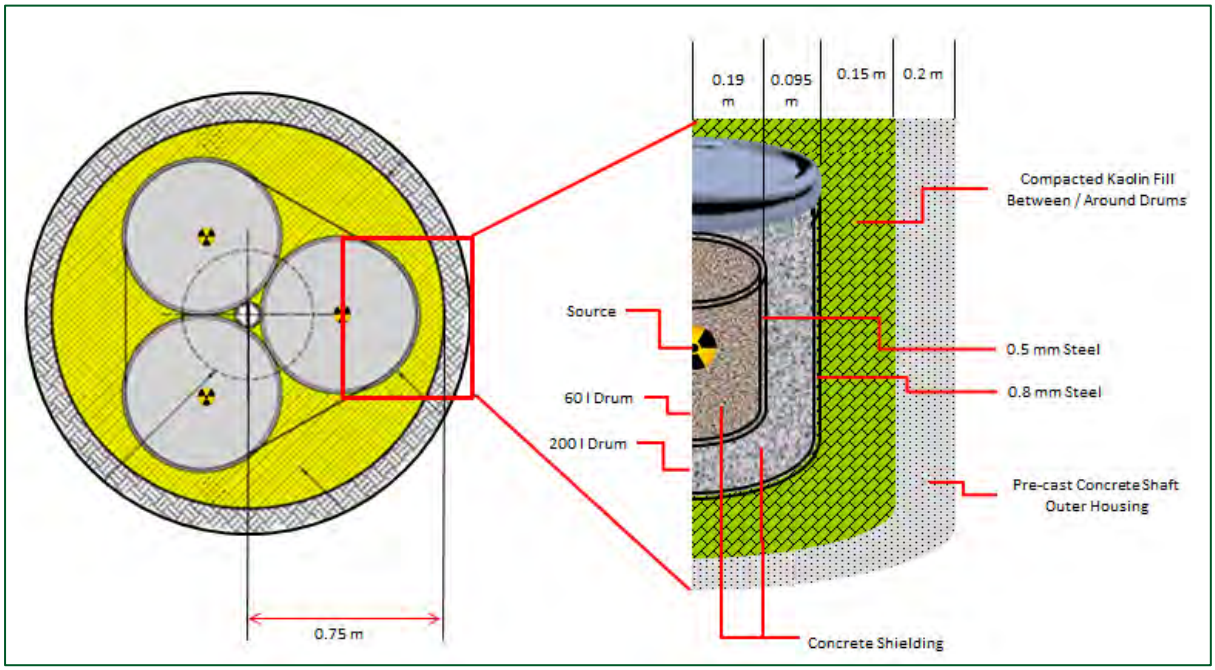


Figure 8: Source shielding prior to placement in shaft

Table 1 lists man-made radioisotopes (used in sealed sources) and assumed activity concentrations identified as the higher risk isotopes requiring shielding and control. The selection was based on half-life (preference to isotopes with half-lives 30 years and above); danger category (categories 2 & 3); and gamma energy, e.g. even though Pu-238 is a long lived nuclide with a half-life of 88 years, it is an alpha emitter with very little photon energy, therefore requiring almost no shielding, and was therefore not considered as higher risk due to its mode of decay. The activity concentration assumed is the upper limit for Category B waste as defined in NHMRC (1992)]. If “no limit” was given the activity assumed is the maximum activity disposed of at similar facilities.

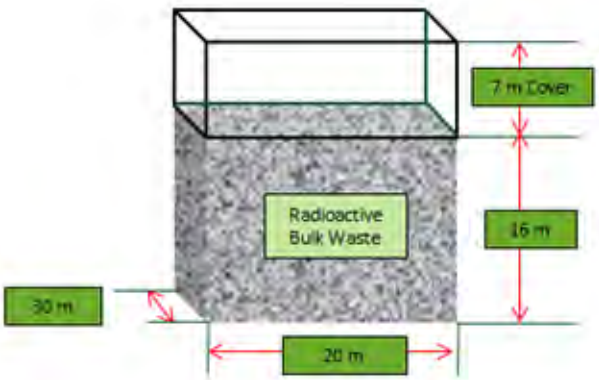
Table 1: Man-made isotopes and concentrations used in assessment.

Radioisotope	Symbol	Half-life	Initial Concentration Assumed (Bq)*
Americium-241	Am-241	432.17 y	2.00E+10
Caesium-137	Cs-137	30.07 years	2.00E+11
Californium-252	Cf-252	2.6 years	2.00E+10
Cobalt-60	Co-60	5.27 years	5.40E+07
Iridium-192	Ir-192	73.8 days	2.00E+10
Radium-226	Ra-226	1,600 years	1.00E+09
Selenium-75	Se-75	120 days	3.70E+08
Thulium-170	Tm-170	129 days	7.40E+12
Ytterbium-169	Yb-169	32 days	3.70E+11

7.2 SCENARIO 2 AND 3: HUMAN INTRUSION- LIVING ON EXPOSED BULK WASTE AT ACTIVITY CONCENTRATION LEVELS OF CATEGORY A AND C

Scenario 2 and 3 is representative of a case where the cell cap is completely removed and humans are living (unaware) on top of the bulk waste, this is also a surrogate for an archaeological dig taking place. The RESRAD modelling software to evaluate “human intrusion” into bulk radioactive waste at activity concentration levels of Category A (Scenario 2) and Category C (Scenario 3) wastes as per NHMRC (1992).

The assumed area and depth of waste assumed is shown in Figure 9.



Waste Surface Area:	600	m^2
Waste Depth:	16	m^2
Waste Volume:	9600	m^3
Waste Density:	1.5	t/m^3
Waste Tonnage:	14400	t
Radius of circle with equivalent surface area	13.82	m

Figure 9: Assumed area and depth of bulk NORM waste within the cell

To enable worst case modelling and comparison to the ICRP guidance on radiological criteria applied to human intrusion [29] occupancy of 50% (4,380 h/y) indoors and 25% (2,190 h/y) outdoors {as per default RESRAD occupancy for a resident scenario} was assumed. The event was modelled to occur at the end of the ICP (maximum dose). RESRAD input values used is given in Table 2.

Table 2: RESRAD input values for Scenario 2 and 3

Input Parameter	Scenario 2	Scenario 3
Description	Human Intrusion into Category A Waste	Human Intrusion into Category C Waste
Pathways	External Dust Radon Soil Ingestion	External Dust Radon Soil Ingestion
Capping thickness	0	0
Thickness of unsaturated zone	5 m	5 m
Erosion rate	0.00005 m/y (waste erosion)	0.00005 m/y (waste erosion)
Cover porosity	N/A	N/A
Cover radon diffusion coefficient	N/A	N/A
Contaminated fraction of household water	0	0
Groundwater fractional usage – household	0	0
Wind speed	5 m/s	5 m/s
Rainfall / precipitation	0.3 m/y	0.3 m/y
Occupancy	50% Indoors 25% Outdoors	50% Indoors 25% Outdoors
Density of contaminated zone	Site specific 1.5 t/m^3	Site specific 1.5 t/m^3

Input Parameter	Scenario 2	Scenario 3
Density unsaturated zone	Site specific 1.6 t/m^3	Site specific 1.6 t/m^3
Cover density	N/A	N/A
Area of contamination	600 m^2	600 m^2
Depth of contamination	16 m$^{\pi}$	16 m
Length parallel to aquifer flow	13.82 m	13.82 m
Catchment Area	100 km^2 (1x10^{10} m^2)	100 km^2 (1x10^{10} m^2)

Occupancy hours that will result in 100mSv/year and 10mSv/year (are per ICRP guidance on radiological criteria applied to human intrusion [29]) were determined to demonstrate the dependence of dose on exposure time and that with the multiple levels of controls in place the risk is manageable. In reality, the human intrusion scenario (where cap has been removed/eroded and waste is on surface as per Scenario 2 and 3) at Sandy Ridge is considered to be highly unlikely and the risk is mitigated through engineering controls, site selection, cap design including a cover of 7 m minimum upon closure.

7.3 SCENARIO 4: RECREATIONAL VISITOR TO THE SITE POST CLOSURE

Scenario 4 used the RESRAD modelling software to evaluate exposure of a recreational visitor to the facility (post closure with a minimum of 7 meters capping material) where bulk radioactive waste at activity concentration levels of Category C were disposed of. It was assumed that exposure will occur for 3.5 days per year.

Table 3: RESRAD input values for Scenario 4

Input Parameter	Scenario 4
Description	Recreational Visitor
Pathways	External Dust Radon
Capping thickness	7 m
Thickness of unsaturated zone	5 m
Erosion rate	0.00005 m/y
Cover porosity	0.1
Cover radon diffusion coefficient	0.000001 m^2/s
Contaminated fraction of household water	0

Input Parameter	Scenario 4
Groundwater fractional usage – household	0
Wind speed	5 m/s
Rainfall / precipitation	0.3 m/y
Occupancy	3.5 days/year
Density of contaminated zone	Site specific 1.5 t/m^3
Density unsaturated zone	Site specific 1.6 t/m^3
Cover density	Site specific 1.86 t/m^3
Area of contamination	600 m^2
Depth of contamination	16 m$^{\pi}$
Length parallel to aquifer flow	13.82 m
Catchment Area	100 km^2 (1x10^{10} m^2)

General assumptions for modelling:

- For most scenarios a basic radiation dose constraint of 0.3 mSv/y was adopted in line with best practice and the Radiological Council of WA Industry Guideline 'Reporting of Radiologically Contaminated Site NORM (2009)'. The RESRAD default is 0.25 mSv/y;
- 1.86 t/m3 cover density as calculated from the weighted average of different layers of cover material (3 m of compacted kaolin at 1.7 t/m^3 + 4 m of compacted laterite, silcrete, clayey sand mix at 2.1 t/m^3 + 0.8 m of compacted clay at 1.9 t/m^3 + 1.2 m of clayey sand at 1.4 t/m^3)

7.4 SCENARIO 5: WASTE ACCEPTANCE CRITERIA - CONCENTRATIONS LIMITS FOR NORM

In order to derive activity concentrations limits for individual radionuclides in NORM bulk wastes, two criteria were followed:

- Dose rate to a human receptor post closure (with capping material in place) to not exceed a dose constraint of 0.3 mSv in a year. Occupancy of 3.5 days a year was assumed as per ARPANSA TRS No. 141 [15] for an arid and remote site.
- Dose rate to a human receptor upon intrusion (no capping) corresponding to 10mSv/y.as per ICRP guidance on radiological criteria applied to human intrusion [29].

The RESRAD (Onsite) code was used, with conditions as specified in Table 4, to determine radionuclide activity concentration levels in bulk NORM wastes which would give rise to conditions as specified above for post closure and intrusion scenarios. Table 4 also includes dose rates which would result from exposure to waste containing individual nuclide concentrations as per Category C of the Near Surface Code [17] (NHMRC), both for post closure and intrusion. Modelling on Category C waste was conducted on a hypothetical scenario as per ARPANSA TRS No. 141 [15] for an arid and remote site as well as for Sandy Ridge specific conditions to determine if dose rates would adhere to conditions specified above.

These activity concentrations are intended to be used in the development of the radionuclide limits for NORM waste to be included in the site WAC.

Table 4: Scenario 5 specific RESRAD input values for determination of individual NORM Radionuclide limits for WAC

Input Parameter	Category C of the Near Surface Code [17] (NHMRC)				Determination of Individual Radionuclide Activity Concentration of Bulk NORM Waste		
Description	Conceptual Model for an Arid and Remote site (TRS No 141 [15]) on Category C waste, nuclides with $T_{1/2} \geq 30$ y.		Site Specific Conditions on Category C waste, nuclides with $T_{1/2} \geq 30$ y.		Waste giving rise to 10 mSv/y upon Intrusion	Waste giving rise to 50 mSv/y upon Intrusion	Waste giving rise to 100 mSv/y upon Intrusion
	Post Closure	Human intrusion	Post Closure	Human intrusion	Human intrusion	Human intrusion	Human intrusion
Institutional Control Period	100 years	100 years	100 years	100 years	100 years	100 years	100 years
Individual Radionuclide Concentrations (Bq/g)*					To be determined by RESRAD modelling		
Uranium-238	10000 (Bq/g)						
Uranium-234	10000 (Bq/g)						
Thorium-230	10000 (Bq/g)						
Uranium-235	10000 (Bq/g)						
Protractinium-231	10000 (Bq/g)						
Radium-226	500 (Bq/g)						
Thorium-232	500 (Bq/g)						
Pathways	External Dust Radon Ingestion: Plant Water Meat Milk	External Dust Radon Ingestion: Plant Water Meat Milk	External Dust Radon	External Dust Radon Soil Ingestion	External Dust Radon Soil Ingestion	External Dust Radon Soil Ingestion	External Dust Radon Soil Ingestion
Capping thickness	5 m#	0	7 m@	0	0	0	0
Thickness of unsaturated zone	5 m#	5 m#	N/A	N/A	N/A	N/A	N/A

Input Parameter	Category C of the Near Surface Code [17] (NHMRC)				Determination of Individual Radionuclide Activity Concentration of Bulk NORM Waste		
Erosion rate	0.0003 m/y#	0.0003 m/y# (waste)	0.00005 m/y@ (Sandy Ridge)	N/A	N/A	N/A	N/A
Cover porosity	default	N/A	0.1^	N/A	N/A	N/A	N/A
Cover radon diffusion coefficient	default	N/A	0.000001 m^2/s^	N/A	N/A	N/A	N/A
Contaminated fraction of household water			0[a]	0[a]	0[a]	0[a]	0[a]
Contaminated fractions for all pathways of ingestion	0.01#	0.01#					
Groundwater fractional usage – household			0[a]	0 [a]	0 [a]	0 [a]	0 [a %]
Groundwater fractional usage (all)	0.01#	0.01#					
Wind speed	default	default	5 m/s@	5 m/s@	5 m/s@	5 m/s@	5 m/s@
Rainfall / precipitation	0.3 m/y#	0.3 m/y#	0.3 m/y@	0.3 m/y@	0.3 m/y@	0.3 m/y@	0.3 m/y@
Occupancy	3.5 days/year# (0.0096 Fraction)	1 day/year (0.0027 Fraction)	3.5 days/year[5] (0.0096)	1 day/year (0.0027)	1 day/year (0.0027)	1 day/year (0.0027)	1 day/year (0.0027)
Density of contaminated zone	1.5# t/m^3	1.5# t/m^3	Site specific@ 1.5 t/m^3	Site specific@ 1.5 t/m^3	Site specific@ 1.5 t/m^3	Site specific@ 1.5 t/m^3	Site specific@ 1.5 t/m^3
Density unsaturated zone	Default 1.5 t/m^3	Default 1.5 t/m^3	Site specific@ 1.6 t/m^3	Site specific@ 1.6 t/m^3	Site specific@ 1.6 t/m^3	Site specific@ 1.6 t/m^3	Site specific@ 1.6 t/m^3
Cover density	Default 1.5 t/m^3	N/A	Site specific@ 1.86 - t/m^3	N/A	N/A	N/A	N/A
Waste Tonnage	3 Million Tonnes#	3 Million Tonnes#	14400@ Tonnes	14400@ Tonnes	14400@ Tonnes	14400@ Tonnes	14400@ Tonnes
Area of contamination	1000000# m^2	1000000# m^2	600@ m^2	600@ m^2	600@ m^2	600@ m^2	600@ m^2
Depth of contamination	2 m#	2 m#	16@ m[π]	16@ m[π]	16@ m[π]	16@ m[π]	16@ m[π]

Input Parameter	Category C of the Near Surface Code [17] (NHMRC)				Determination of Individual Radionuclide Activity Concentration of Bulk NORM Waste		

* Individual radionuclide Activity Concentration Limits for Category C Waste as per the Near Surface Code [16] but calculated for an Institutional Control Period (ICP) of 300 years
# Conditions of an Arid and Remote site as per TRS No 141 [15]
@ Sandy Ridge Site Specific Conditions
^ Assumption on cover material to be less penetrable by radon
a All pathways related to contaminated water usage removed, also for radon from water

8 ASSESSMENT RESULTS AND DISCUSSION

The following section discusses the results obtained through first principal calculations and RESRAD modelling for each of the Scenarios described in Section 7.

8.1 SCENARIO 1: HUMAN INTRUSION NEXT TO THE SHAFT CONTAINING CATEGORY B SEALED RADIOACTIVE SOURCES

The Activity Concentration at the end of the ICP was calculated using the following formula

$$(A) = A_o e^{-\lambda t}$$

Where:
A = Activity remaining in the radioactive material after time (t) from when the initial activity was measured (at time of disposal) (GBq)
A_o= Initial Activity of the radioactive material (time of disposal) (GBq)
e = Base of the natural logarithm
λ = Decay constant (ln2/T½) and ln2 is equal to the constant 0.693
t = Time since the initial activity was measured (days)

The Unshielded dose rate was calculated by using the following formula.

Unshielded dose rate: $I_0 = \Gamma A / d^2 = \Gamma$ x Activity / (distance from waste source)^2

Where:
I_0= intensity (or dose rate) before shielding (mSv/h)
Γ= Specific Gamma Ray Constant (mSv/h) at 1 m from a source per 1 GBq activity of the source
A = Activity of the source (GBq)
d = distance from the source (m) {assumed as 0.1 m / 10 cm}

The Shielded dose rate was then calculated as follows:

Shielded dose rate: $I = I_0 / 2^n$

Where:
I = intensity (or dose rate) after shielding (mSv/h)
I_0= intensity (or dose rate) before shielding (mSv/h)
n = number of HVL in shielding material

Dose received on the outside of the shaft with shielding in place was calculated by multiplying the shielded dose rate (I) calculated with the assumed exposure time (40 hours).

The results are summarised in the table below and given in full in Appendix 1 of this report.

As can be seen from results given in Table 5, the shielding provided from concrete in drum, steel around drums and concrete in shafts is sufficient to shield the radiation from all sources assessed except high activity Caesium-137 sources. By adding 0.0255m lead shielding (as found in standard source casings) the dose rate is further reduced from 0.16 mSv/hr to 0.02mSv/hr. With the assumed 40 hours exposure the dose is 0.63mSV. This is well below the public dose limit of 10 mSv/year considered as the threshold for human intrusion scenarios. Given the conservative nature of the assessment and the low probability of event occurring it can be concluded that the risk is sufficiently controlled.

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Table 5: Scenario 1 exposure assessment results summary

Isotope	Half Life y (years) d (days)	Specific Gamma Ray Constant	Source Activity (GBq)		I_0 Unshielded Dose Rate (mSv/h)#	I shielded Dose Rate (0.485 m concrete and 0.0013 steel) (mSv/h)	I shielded Dose Rate (concrete steel and lead casing of 0.0255 m) (mSv/h)	Dose 40 Hours exposure time
		mSv/hr/GBq at 1 meter	Initial *	After 100 y	After 100 y	After 100 y	After 100 y	(mSv)
Americium-241	432.17 y	8.48E-02	2.00E+01	1.70E+01	1.44E+02	0	0	0
Caesium-137	30.07 y	1.03E-01	2.00E+02	2.00E+01	2.06E+02	0.18	0.02	0.63
Californium-252	2.6 y	1.13E-02	20	5.31E-11	6.01E-11	0	0	0
Cobalt-60	5.27 y	3.70E-01	5.40E-02	1.05E-07	3.89E-06	0	0	0
Iridium-192	73.8 d	1.60E-01	2.00E+01	2.81E-148	4.50E-147	0	0	0
Radium-226	1,600 y	3.27E-04	1.00E+00	9.58E-01	3.14E-02	0	0	0
Selenium-75	120 d	2.32E-01	3.70E-01	1.06E-92	2.46E-91	0	0	0
Thulium-170	129 d	1.67E-03	7.40E+03	5.15E-82	8.62E-83	0	0	0
Ytterbium-169	32 d	8.84E-02	3.70E+02	0.00E+00	0.00E+00	0	0	0

8.2 SCENARIO 2 AND 3: HUMAN INTRUSION- LIVING ON EXPOSED BULK WASTE AT ACTIVITY CONCENTRATION LEVELS OF CATEGORY A AND C

Table 6 Summarises the RESRAD modelling results for Scenarios 2 and 3, In the unlikely case where humans would reside on top of exposed bulk waste of category A, a total dose of 112 mSv/y is incurred from occupancies considered being residential (RESRAD default). The dose received is directly proportional to the duration of exposure. Occupancy of 5,870 hours/year would reduce the total maximum dose to 100 mSv/y and 587 hours/year would reduce total maximum dose to 10 mSv/y.

From Scenario 3 it was shown that a maximum total dose of 10,170 mSv/y is incurred at 0.6 years after intrusion at occupancies considered being residential (RESRAD default). Occupancy of 65 hours/year would reduce the total maximum dose to 100 mSv/y and 6.5 hours / year would reduce total maximum dose to 10 mSv/y.

External gamma exposure was shown to be the highest contributor to total dose, followed by radon.

Table 6: RESRAD Results Scenario 2 and 3

Model Output	Scenario 2	Scenario 3
Maximum Dose (mSv/y)	111.9	10170
Time of Maximum Dose (years after ICP)	0.589	0.602
Gamma at Max Dose	71.09	6100
Dust at Max Dose	0.8173	80.15
Radon at Max Dose	38.06	3801
Soil ingestion at Max Dose	1.956	186.8
Total Dose at Time 0	108.7	9848
Gamma at Time 0	67.92	5782
Dust at Time 0	0.8141	79.83
Radon at Time 0	38.06	3801
Soil ingestion at Time 0	1.936	184.8

In reality, the risk is mitigated by site selection of the facility and the cap design. The long term (10,000 plus years) performance of the cap has been modelled using both near-surface hydrogeological and erosion modelling software. The modelling has confirmed that the cap design is robust from both water infiltration and erosion aspects ad therefore it is concluded that it is implausible for the exposure to occur.

8.3 SCENARIO 4: RECREATIONAL VISITOR TO THE SITE POST CLOSURE

From Scenario 4 it was shown that a maximum total dose of 6.2 x 10^{-7} mSv/y is incurred only at 100,000 years after closure, indicating that for the expected land-use post institutional control, no risk to human receptors are foreseen, given that the possibility of intrusion is mitigated through engineering controls. This exposure rate is determined by the RESRAD calculation using the assumption that 5 m of erosion has occurred at the site. Given the geological properties and climate at the site, this calculation scenario is extremely unlikely.

Table 7: RESRAD Results for Scenario 4

Model Output	Scenario 4
Maximum Dose (mSv/y)	6.20E-07
Time of Maximum Dose (years after ICP)	1.00E+05
Gamma at Max Dose	3.59E-09
Dust at Max Dose	0
Radon at Max Dose	6.16E-07
Total Dose at Time 0	0
Gamma at Time 0	0
Dust at Time 0	0
Radon at Time 0	0

8.4 SCENARIO 5: WASTE ACCEPTANCE CRITERIA - CONCENTRATIONS LIMITS FOR NORM

The RESRAD (Onsite) code was used, to determine radionuclide activity concentration levels in bulk NORM wastes which would give rise to conditions as specified above for post closure and intrusion scenarios. Table 8 summarizes the radionuclide restrictions that should be applied in the Waste Acceptance Criteria (WAC) for the Facility for the disposal of NORM bulk wastes.

For bulk NORM wastes having mixtures of radionuclides, an additional constraint should be adhered to so that the total dose from all the radionuclides should not exceed relevant dose limits or constraints. This is referred to as the summation rule and requires the following constraint:

$$\sum_i Q_i / Q_{i,l} <= 1$$

Where Qi (Bq) is the actual activity of radionuclide to be disposed and Qi, l (Bq) is the activity limit for radionuclide if it were the only radionuclide to be disposed of.

Table 8 Waste Acceptance Criteria (WAC) for the Facility for bulk NORM waste

Radionuclides	Half Life	Individual Radionuclide Activity Concentration of Bulk NORM Waste) (Bq/g)
U-238	4.468 billion years	1.0E+05
U-234	246,000 years	2.0E+06
Th-230	75,380 years	1.2E+04
U-235	703.8 million years	2.2E+04
Pa-231	32,760 years	7.1E+03
Ra-226	1,600 years	1.8E+03
Th-232	14.05 billion years	1.1E+03

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9 CONCLUSIONS

As can be seen from Scenario 1 results, the shielding provided from concrete in drum, steel around drums and concrete in shafts, is sufficient to shield the radiation from all sources assessed except high activity Caesium-137 sources. By adding 0.0255m lead shielding (as found in standard source casings) the dose rate is further reduced from 0.16 mSv/hr to 0.02mSv/hr. With the assumed 40 hours exposure the dose is 0.63mSV. This is well below the public dose limit of 1mSv/year. Given the conservative nature of the assessment and the low probability of event occurring it can be concluded that the risk is sufficiently controlled.

In the unlikely case where humans would reside on top of exposed bulk waste of category A, a total dose of 112 mSv/y is incurred from occupancies considered being residential (RESRAD default). The dose received is directly proportional to the duration of exposure. Occupancy of 5,870 hours/year would reduce the total maximum dose to 100 mSv/y and 5, 87 hours / year would reduce total maximum dose to 10 mSv/y.

From Scenario 3 it was shown that a maximum total dose of 10,170 mSv/y is incurred at 0.6 years after intrusion at occupancies considered being residential (RESRAD default). Occupancy of 65 hours/year would reduce the total maximum dose to 100 mSv/y and 6.5 hours/year would reduce total maximum dose to 10 mSv/y.

External gamma exposure was shown to be the highest contributor to total dose, followed by radon.

From Scenario 4 it was shown that a maximum total dose of 6.2×10^{-7} mSv/y is incurred only at 100,000 years after closure, indicating that for the expected land-use post institutional control, no risk to human receptors are foreseen, given that the possibility of intrusion is mitigated through engineering controls.

The RESRAD (Onsite) code was used, to determine radionuclide activity concentration levels in bulk NORM wastes which would give rise to conditions as specified above for post closure and intrusion scenarios. These values were adopted In the WAC for NORM waste.

10 DEFINITIONS & ACRONYMS

Activity concentration – means the concentration of a radioactive substance in any particular material expressed in terms of the activity of the radionuclide in Becquerel per kilogram of the material.

Biosphere – that part of the environment that is normally inhabited by living organism and is taken generally to include those elements of the environment, including groundwater, surface water and marine resources, that are used by people or accessible to people.

Category A waste – as defined in the near surface code (ARPANSA 1992). Category A waste covers solid waste with radioactive constituents, mainly beta or gamma emitting radionuclides, whose half-lives are considerably shorter than the institutional control period. The radioactivity will decay substantially during this period. Long-lived alpha-emitting radionuclides should only be present at very low concentrations. This category of waste will comprise, predominantly, lightly contaminated or activated items such as paper, cardboard, plastics, rags, protective clothing, glassware, laboratory trash or equipment, certain consumer products and industrial tools or equipment. It may also comprise lightly contaminated bulk waste from mineral processing or lightly contaminated soils.

Category B wastes - as defined in the near surface code (ARPANSA 1992) includes solid waste and shielded sources with considerably higher activities of beta- or gamma-emitting radionuclides than Category A waste. Long-lived alpha-emitting radionuclides should be at relatively low levels. This category of waste will comprise, typically, gauges and sealed sources used in industry, medical diagnostic and therapeutic sources or devices, and small items of contaminated equipment.

Category C waste – as defined in the near surface code (ARPANSA 1992). includes solid waste containing alpha-, beta- or gamma-emitting radionuclides with activity concentrations similar to those for Category B. However, this waste typically will comprise bulk materials, such as those arising from downstream processing of radioactive minerals, significantly contaminated soils, or large individual items of contaminated plant or equipment for which conditioning would prove to be impractical.

Characterisation of waste – determination of the physical, chemical and radiological properties of the waste to establish the need for further adjustment, treatment, conditioning, or its suitability for further handling, processing, storage or disposal.

Dose Rate – the average level of dose that any material or biota is exposed to over time (typically measured in mSv/h).

Engineered barrier – means a feature made or altered by humans which delays or prevents radionuclide migration from the waste or the disposal structure into its surroundings; it may be part of the waste package or part of the disposal structure.

Half-life ($t^{1/2}$) – is the time taken for the activity of a radionuclide to decrease to 50% of its initial value.

Half-value layers (HVL) - One half-value layer is defined as the amount of shielding material required to reduce the radiation intensity to one-half of the unshielded value.

Institutional control period (ICP) – control of a waste site by an authority or institution designated under the law of a country. This control may be active (monitoring, surveillance and remedial work) or passive (land use control) and may be a factor in the design of a nuclear facility (e.g. a near surface repository).

Intrusion – inadvertent or intentional, means the process by which living organism, including humans, may come in contact with disposed or stored waste.

Member of the public – means a person who is exposed only incidentally to radiation as a consequence of the disposal of radioactive waste at a site or the operation of a disposal facility. Public exposure may occur through inadvertent intrusion or from dispersal of radioactive contaminants from the site.

Near surface disposal – or shallow ground burial means the disposal of radioactive waste in structures located below and/or above the natural ground surface (within approximately 30 metres of it) and covered by layer(s) of natural and/or manufactured materials.

NORM – means Naturally Occurring Radioactive Material – all the radionuclides contained in NORM occur in the natural environment.

Pathway – means a process, or series of processes, by which radionuclides are transferred through the environment.

Scenario – means a possible series of events or conditions which describe means of human intrusion or other contact with disposed waste after the closure of the site and following the institutional control period.

Sealed source – means controlled material permanently contained in a capsule, or closely bound in a solid form, that is strong enough to be leak-tight for (a) the intended use of the controlled material and (b) any foreseeable abnormal events likely to affect the controlled material.

Storage – means the emplacement of waste in a facility with the intent and in a manner such that it can be retrieved at a later time.

Waste acceptance criteria (WAC) – quantitative or qualitative criteria specified by the regulatory body, or specified by an operator and approved by the regulatory body, for radioactive waste to be accepted by the operator of a repository for disposal, or by the operator of a storage facility for storage. Waste acceptance requirement might include, for example, restrictions on the activity concentration or the total activity or particular radionuclides (or type of radionuclide) in the waste or requirements concerning the waste form or waste package.

Waste disposal – means the placement of radioactive waste in a structure and in a manner such that there is no intention of retrieval.

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38. Australian Nuclear Science and Technology Organisation (ANSTO) 2011. Management of Radioactive Waste in Australia

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Appendix A

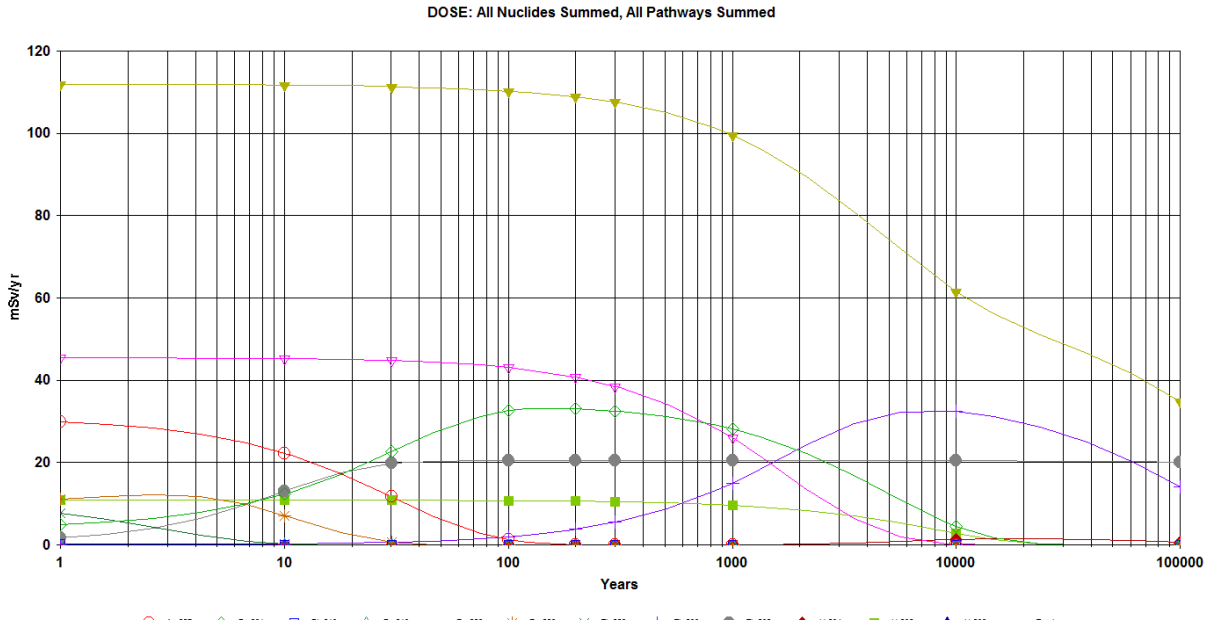
Scenario **1**

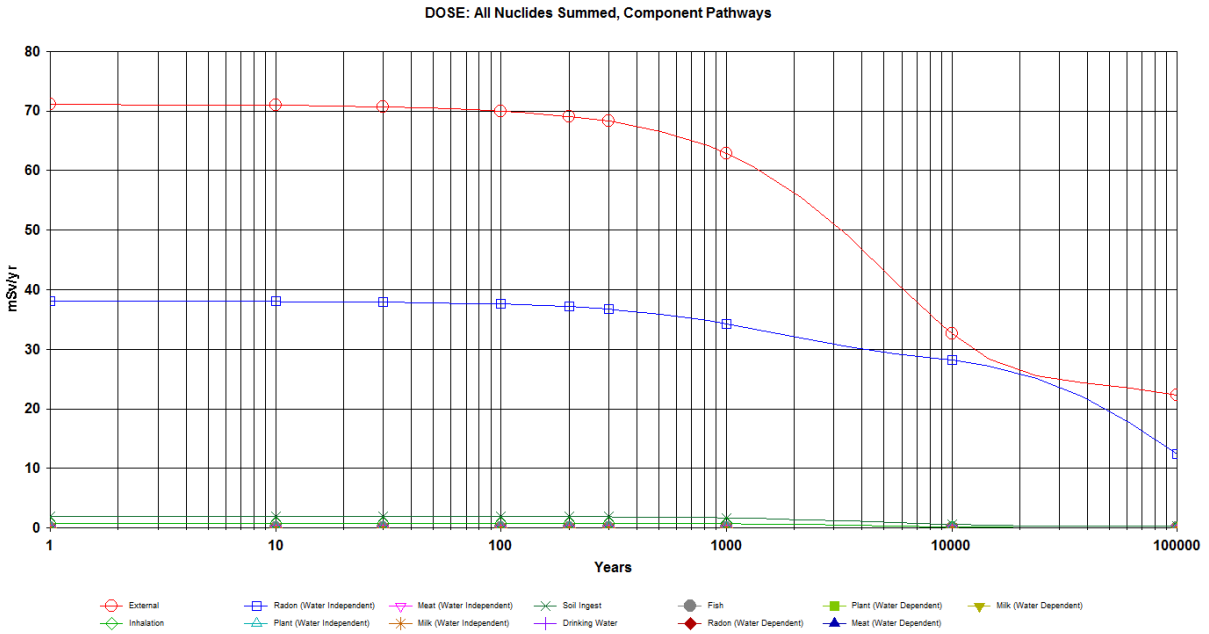
data

Table 9: Scenario 1 assessment data

Half Life Y (years) D (days)	Source Activity (GBq)		Γ	I_0 Unshielded Dose Rate (mSv/h)#		shielding concrete In drums	shielding steel from drums	shielding from lead casig	I shielded Dose Rate concrete (mSv/h)		I shielded Dose Rate steel (mSv/h)		I shielded Dose Rate lead casing 0.0255 m (mSv/h)	
	Initial *	100 y	mSv/hr/GBq at 1 meter	Initial *	After 100 y	0.285 m concrete in drums(n)	0.0013m steel around drums	lead casing 0.0255m	Initial *	After 100 y	Initial *	After 100 y	Initial *	After 100 y
432.17 y	2.00E+01	1.70E+01	8.48E-02	1.70E+02	1.44E+02	73.08	1.18	127.50	0.00	0.00	0.00	0.00		
30.07 y	2.00E+02	2.00E+01	1.03E-01	2.06E+03	2.06E+02	5.94	0.06	3.52	33.68	3.36	32.36	3.23	2.83	0.28
2.6 y	20	5.31E-11	1.13E-02	2.26E+01	6.01E-11	203.57	3.25	255.00	0.00	0.00	0.00	0.00		
5.27 ye	5.40E-02	1.05E-07	3.70E-01	2.00E+00	3.89E-06	4.71	0.06	2.08	0.08	0.00	0.07	0.00	0.02	0.00
73.8 d	2.00E+01	2.81E-148	1.60E-01	3.20E+02	4.50E-147	6.40	0.10	5.31	3.78	0.00	3.52	0.00		
1,600 y	1.00E+00	9.58E-01	3.27E-04	3.27E-02	3.14E-02	4.13	0.06	1.67	0.00	0.00	0.00	0.00		
120 d	3.70E-01	1.06E-92	2.32E-01	8.60E+00	2.46E-91	15.92	0.21	21.25	0.00	0.00	0.00	0.00		
129 d	7.40E+03	5.15E-82	1.67E-03	1.24E+03	8.62E-83	6.24	0.09	3.36	16.42	0.00	15.48	0.00	1.51	0.00
32 da	3.70E+02	0.00E+00	8.84E-02	3.27E+03	0.00E+00	6.24	0.09	3.36	43.37	0.00	40.87	0.00	3.99	0.00

Appendix B
Scenario 2 data


DOSE: All Nuclides Summed, All Pathways Summed
mSv/yr
120
100
80
60
40
20
0
1
10
100
1000
10000
100000
Years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mSv/yr
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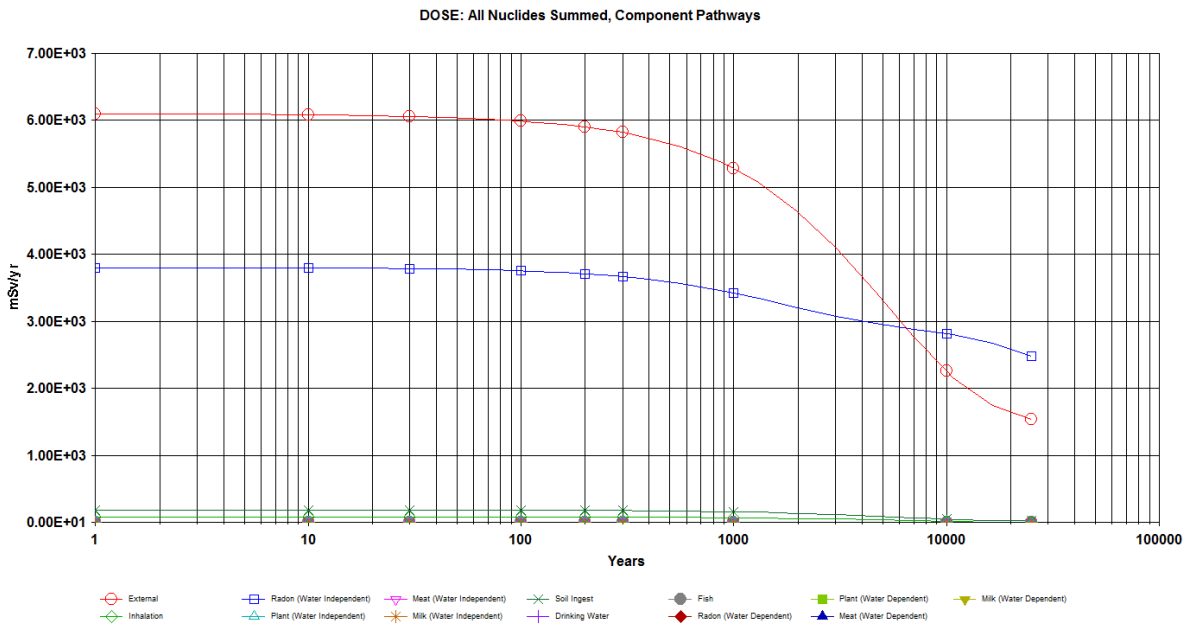
70
60
50
40
30
20
10
0
1
10
100
1000
10000
100000
Years
External
Inhalation
Radon (Water Independent)
Plant (Water Independent)
Meat (Water Independent)
Milk (Water Independent)
Soil Ingest
Drinking Water
Fish
Radon (Water Dependent)
Plant (Water Dependent)
Meat (Water Dependent)
Milk (Water Dependent)

Appendix C - Scenario 3 data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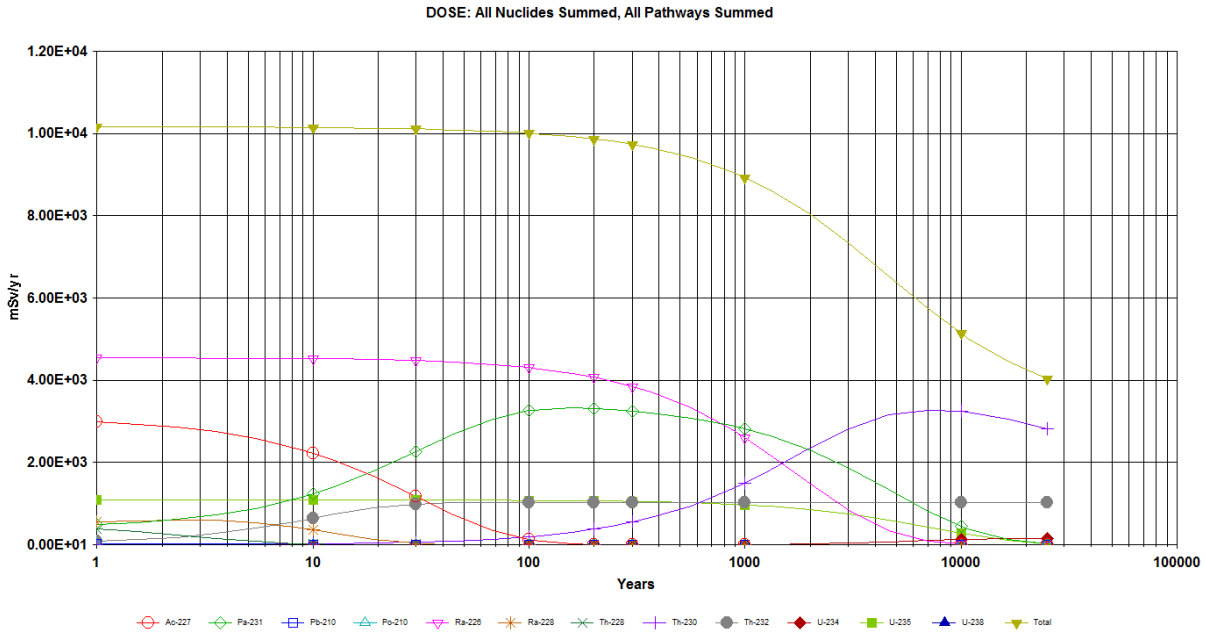
5.00E+03
4.00E+03
3.00E+03
2.00E+03
1.00E+03
0.00E+01
mSv/yr
1
10
100
1000
10000
100000
Years
External
Inhalation
Radon (Water Independent)
Plant (Water Independent)
Meat (Water Independent)
Milk (Water Independent)
Soil Ingest
Drinking Water
Fish
Radon (Water Dependent)
Plant (Water Dependent)
Meat (Water Dependent)
Milk (Water Dependent)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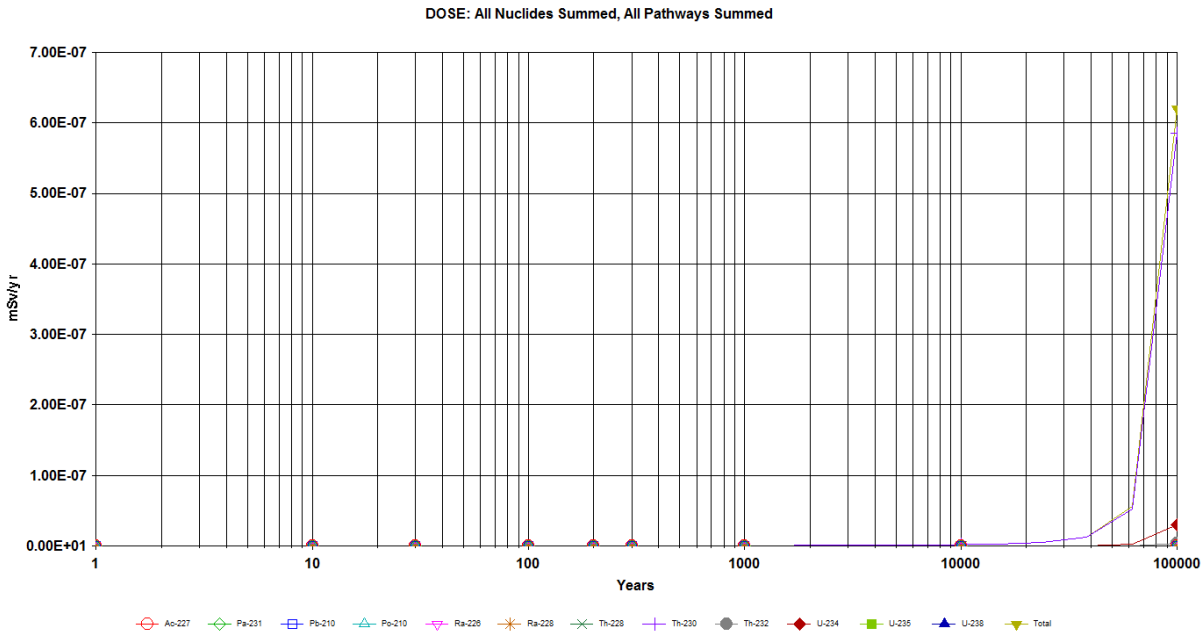
8.00E+03
6.00E+03
4.00E+03
2.00E+03
0.00E+01
mSv/yr
1
10
100
1000
10000
100000
Years
Ac-227
Pa-231
Pb-210
Po-210
Ra-226
Ra-228
Th-228
Th-230
Th-232
U-234
U-235
U-238
Total

Appendix D
Scenario 4
data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mSv/yr
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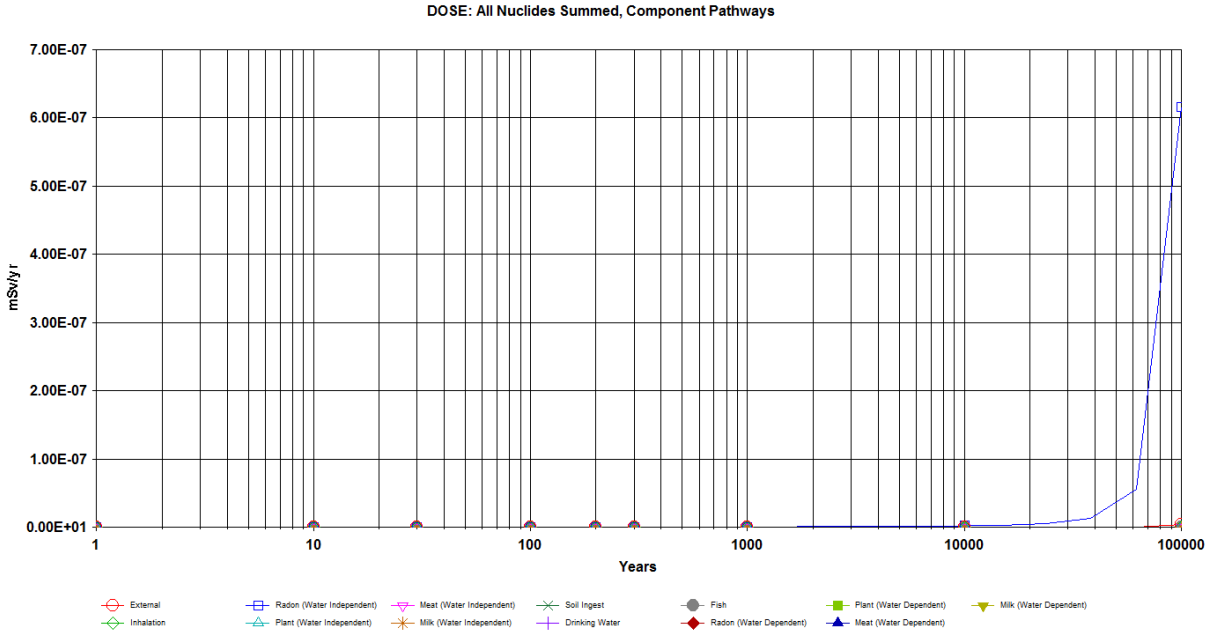
6.00E-07
5.00E-07
4.00E-07
3.00E-07
2.00E-07
1.00E-07
0.00E+01
1
10
100
1000
10000
100000
Years
Ac-227
Pa-231
Pb-210
Po-210
Ra-226
Ra-228
Th-228
Th-230
Th-232
U-234
U-235
U-238
Total


DOSE: All Nuclides Summed, Component Pathways
mSv/yr
7.00E-07
6.00E-07
5.00E-07
4.00E-07
3.00E-07
2.00E-07
1.00E-07
0.00E+01
1
10
100
1000
10000
100000
Years
External
Inhalation
Radon (Water Independent)
Plant (Water Independent)
Meat (Water Independent)
Milk (Water Independent)
Soil Ingest
Drinking Water
Fish
Radon (Water Dependent)
Plant (Water Dependent)
Meat (Water Dependent)
Milk (Water Dependent)

Appendix E
WAC data

Table 10:Determination of Individual Radionuclide Activity Concentration of Bulk NORM Waste

Nuclide	Category C Waste (Near Surface Code) – Activity Concentration Limit (Bq/g) for an institutional control period of 100 years					Waste Acceptance Criteria for the Sandy Ridge Facility (Determination of Individual Radionuclide Activity Concentration of Bulk NORM Waste)					
	Conceptual RESRAD Model; all pathways of exposure included; Conditions as per TRS No 141 for an Arid and Remote Site			RESRAD Sandy Ridge Conditions		RESRAD with Site Specific Conditions at Sandy Ridge: All pathways related to water Excluded, Intrusion, 1 day/year Occupancy					
	Category C Concentration Limit (Bq/g)	Post Closure 3.5 days/y (84 h/y), 5 m Cap	1 days/y (24 h/y), Intrusion	Post Closure 3.5 days/y (84 h/y), 7 m Cap	1 days/y (24 h/y), Intrusion	(Bq/g) to result in 10 mSv/y upon Intrusion	Modelled Dose Rate	(Bq/g) to result in 50 mSv/y upon Intrusion	Modelled Dose Rate	(Bq/g) to result in 100 mSv/y upon Intrusion	Modelled Dose Rate
		mSv/y @ 100y	mSv/y @ 100y	mSv/y @ 100y	mSv/y @ 100y		mSv/y @ 100y		mSv/y @ 100y		mSv/y @ 100y
U-238	10000	3.05E-25	3.05	0	1.06	1.00E+05	10.64	5.00E+05	53.2	1.00E+06	106.4
U-234	10000	1.02E-24	2.18	0	0.04	2.00E+06	8.62	1.00E+07	43.1	2.00E+07	86.2
Th-230	10000	2.26E-21	21.50	0	3.13	3.60E+04	11.28	1.80E+05	56.41	3.60E+05	112.8
U-235	10000	0	6.95	0	4.84	2.20E+04	10.65	1.10E+05	53.25	2.20E+05	106.5
Pa-231	10000	0	141.90	0	14.66	7.08E+03	10.38	3.54E+04	51.89	7.08E+04	103.8
Ra-226	500	2.41E-21	20.53	0	3.24	1.80E+03	11.66	8.00E+03	51.81	1.60E+04	103.6
Th-232	500	1.41E-18	31.62	0	4.58	1.10E+03	10.07	5.60E+03	51.27	1.12E+04	102.5

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Outline Safety Case

TELLUS

SANDY RIDGE FACILITY OUTLINE SAFETY CASE

Final Report | November 2016

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Document control

Rev	Issue date	Description	Originator	Checked	Approved
1	08/11/2016	Radiation Management Plan	S Reece	R Phillips	

Disclaimer

This Outline Safety Case which has been prepared as part of the Sandy Ridge Public Environmental Review (PER), has been prepared for submission to the Western Australian Environmental Protection Authority for the purpose of the Minister for Environment making a determination regarding whether to approve Tellus Holding Limited's Proposal under the Western Australian Environmental Protection Act 1986. This PER has been developed for this purpose only, and no one other than the Environmental Protection Authority or the Minister should rely on the information contained in this PER to make any decision.

In preparing the draft Public Environmental Review (PER) Tellus has relied on information provided by specialists' consultants, government agencies and other third parties available during the preparation period. Tellus has not fully verified the accuracy or completeness except where expressly acknowledged in the draft PER.

The PER has been prepared for information purposes only; and, to the full extent permitted by law, Tellus, in respect of all persons other than the Environmental Protection Authority or the Minister, makes no representation and gives no warranty or undertaking, expressed or implied, in respect of the information contained in the PER and does not accept responsibility and is not liable for any loss or liability whatsoever arising as a result of any person acting or refraining from acting on any information contained in the PER.

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EXECUTIVE SUMMARY

What is the facility?

Tellus is seeking environmental planning approval to construct and operate a dual revenue business.

The first aspect of the dual revenue model relates to the mining and export of kaolin clay. The second aspect relates to the emplacement and permanent isolation of Class IV and Class V intractable wastes in void spaces left behind from kaolin clay mining.

The placement of these wastes in a near surface repository, based on international best practice techniques, would isolate the wastes from the biosphere over geological time. Therefore, the Proposal seeks environmental approval.

If approved, the Proposal would be located in remote Western Australia (the Sandy Ridge facility (the 'Proposal')), (Figure 1–2 and 1–3).

What are the main safety related issues?

The delivery of waste at the Sandy Ridge Facility is an activity that could be the cause of a major incident and is therefore considered a key risk. The specific hazard is the release of waste that is a dangerous good in sufficient volume to cause serious harm to people, property or the environment. Releases could be caused by insecure waste stowage, vehicle accident or uncontrolled unloading.

Why is site low risk

The following international and national codes outline the major site selection factors for near surface geological repositories:

- *Classification and Disposal of Radioactive Waste in Australia – Consideration for Near Surface Burial in an Arid Area* (ARPANSA, 2010).
- *Code of Practice for the near-surface disposal of radioactive waste in Australia* (NHMRC, 1992).
- *Design, Construction, Operation and Surveillance of Repositories for Solid Radioactive Wastes in Shallow – Ground* (International Atomic Energy Agency, 1984).

Near surface disposal means the disposal of radioactive waste in structures located below and/or above the natural ground surface (within approximately 30 m of it) and covered by a layer(s) of natural and/or manufactured materials (NHMRC, 1992).

The list below provides reasons why the Sandy Ridge site meets the above listed codes and criteria for near surface geological repositories.

- It is geologically stable.
- The geology is a natural geological barrier.
- The site lies within a semi-arid desert.
- The site lacks a groundwater table and a regional aquifer system.
- The site lacks surface water systems such as rivers, creeks or major drainage lines.
- The site is very flat and therefore, there is little to no surface water run-off.
- The site does not flood.
- The site is not expected to be adversely affected by future climate change modelled scenarios.
- The site has very low erosion rates.
- The site receives very low average rainfall.
- The site experiences very high evaporation rates which are up to eight times higher than average rainfall rates.
- Soils across the site have a very low permeability which help prevent water seep through the soil profile.
- There are no major sensitive receptors, including human populations, within 75 km of the site.
- The site is not constrained by highly valued, significant items of cultural heritage significance.
- The site is not constrained by rare, vulnerable, threatened, endangered or migratory species under Commonwealth or State law.
- The site does not offer any high value agricultural use or other mineral exploration use.

Why are site activities low risk?

The site has been carefully selected because, it has excellent natural barriers which act to reduce the consequence of identified risks, even before human engineering solutions have been introduced. The physical emplacement of waste at the site would be undertaken in a very controlled and orderly manner.

The waste materials would have multiple layers of protection before they are placed into the clay pit. When the waste is emplaced into the pit, all the void spaces are backfilled with the kaolin clay which acts as a natural geological barrier (refer to Figure A below). Even in the unlikely event of a spill, the clay has excellent properties to adsorb and/or contain wastes escaping their sealed source.

Figure A – Kaolin clay used as backfill and a natural geological barrier over the emplaced waste

How did this inform the risk assessment?

Due to the site's excellent natural geological and environmental conditions, as well as the proposed engineering design and waste emplacement methods (as shown in the Figure above), allowed the risk assessment to be undertaken without ambiguity.

What were the key risk identified?

In summary, the key risks identified in the Sandy Ridge risk assessment were related to the:

- Transport and release of dangerous and hazardous goods.
- Ignition of dangerous goods.
- Site handling of hazardous wastes.
- Exposure to low levels of radiation.
- Uncontrolled explosions.
- Uncontrolled bushfires.

Chapter 6 of this report provides further detail on the above listed risks.

What was the overall conclusion of the risk assessment?

The risk assessment for Sandy Ridge addressed all aspects of risk throughout the Project's lifecycle. This included, site selection, construction, operation, decommissioning and post-closure.

The overall conclusion reached was that a project of this nature will always have different levels of environmental and social risk. With appropriate licensed and regulated procedures, the transport, construction, operation, decommissioning and post-closure risks can be easily managed and present medium or low risk to humans and the environment.

What are the main commitments (Environmental Management System & Consultation)?

Environmental Management System

Tellus has an existing environmental and safety management system. It is framed around Tellus Holdings Ltd current business activities, which are mainly mineral exploration, contract negotiation and approvals.

The management systems described in Chapter 7 of this report will be revised as Tellus Holdings Ltd expands its business operations into construction and operation of the Sandy Ridge facility.

Revisions of the safety management system will include the matters identified in regulation 558 and Schedule 17 of the WHS Regulations.

Consultation

Under regulation 575 of the WHS Regulations, the operator of a major hazard facility is required to consult with workers at the major hazard facility in the development of the safety case, safety management system and emergency plan.

As the Sandy Ridge facility is a proposed facility, the potential for consultation with workers during the preparation of the safety case outline is limited.

Consultation with workers will be undertaken as Tellus Holdings Ltd expands its business operations into construction and operation of the Sandy Ridge facility.

The consultation will be undertaken during future revisions of the safety case, the development of safety protocols, safety induction of workers, and construction and operation activities.

Future consultation activities will include the matters identified in regulation 574 and regulation 575 of the WHS Regulations.

What is the future review process?

Periodic Safety Reviews, as recommended by the Australian Radiation protection and Nuclear Safety Agency (ARPANSA), will be undertaken. Tellus is proposing PSR's to be undertaken during construction and every five years during operation. A review would be undertaken during decommissioning.

During the Institutional Control Period and post-closure phases, environmental monitoring would be undertaken to the satisfaction of the Western Australian Regulator and ARPANSA.

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ABBREVIATIONS

AADT	Average annual daily traffic
AAPA	Aboriginal Areas Protection Authority
ABS	Australian Bureau of Statistics
AHD	Australian Height Datum
ANZECC	Australian

GLOSSARY

Decommissioning	Administrative and technical actions taken to allow the removal of some or all of the regulatory controls from a facility (except for a facility used for the disposal of radioactive waste which is 'closed' and not 'decommissioned').
Disposal	Emplacement of waste in a purpose-built facility, which will eventually be closed, without any intention of retrieval of waste packages or recovery of the radioactive material in it for any purpose.
Ecosystem	A dynamic complex or plant, animal and micro-organism communities and their non-living environment interacting as a functional unit.
Exempt waste	Contains very low radioactivity and can be stored in the same way as non-radioactive material
High Level Waste	Contains radioactivity high enough to generate significant heat and can be safely stored in deep, stable geological formations (several hundred metres below surface).
Institutional Control	Control of a radioactive waste site by an authority or institution designated under the laws of a jurisdiction. Control may be active (monitoring, surveillance, remedial work) or passive (land use control) and may be a determining factor in the design of a waste management facility (e.g. near surface repository).
Intermediate Level Waste	Contains higher long lives radioactivity can be safely stored at greater depths (up to a few hundred metres below surface).
Low Level Waste	Contains higher short lived radioactivity and low long lived radioactivity and can be safely stored in a near-surface facility.
Natural Environment	A collective term for all of the physical, chemical, and biological conditions within which wild plants and animals normally live (based on the *Environment Protection and Biodiversity Conservation* (EPBC) *Act*).
Nuclear Material	Plutonium except that with isotopic concentration exceeding 80% in plutonium-238; uranium- 233; uranium enriched in the isotope 235 or 233; uranium containing the mixture of isotopes as occurring in nature other than in the form of ore or ore residue; depleted uranium; thorium; any material containing one or more of the foregoing (IAEA Safety Glossary).
Periodic Safety Review	A systematic reassessment of the safety of an existing facility (or activity) carried out at regular intervals to deal with the cumulative effects of ageing, modifications, operating experience, technical developments

	and siting aspects, and aimed at ensuring a high level of safety throughout the service life of the facility (or activity).
Radioactive Material	Material designated in national law or by a regulatory body as being subject to regulatory control because of its radioactivity.
Radioactive Waste	'Radioactive waste' is defined for regulatory purposes as "waste that contains, or is contaminated with, radionuclides at concentrations or activities greater than clearance levels as established by the regulatory body" (IAEA Safety Glossary). Importantly, waste is "material for which no further use is foreseen". Radioactive waste comprises radioactive material in solid, liquid or gaseous form for which no further use is foreseen. Note that only solid radioactive waste is suitable for disposal in near-surface disposal facilities.
Safety Assessment	Before an *Outline Safety Case* report can be prepared, an assessment of all aspects of the proposed Sandy Ridge Facility that are relevant to protection and safety, must be addressed. For an authorised facility like the Sandy Ridge facility, which is likely to be listed a Major Hazard Facility, this includes the: • Siting; • Design; • Construction; • Operation; • Decommissioning; and • Post-closure
Safety Case	The *Outline Safety Case* is a collection of arguments and evidence in support of the safety of a facility or the activities to be undertaken. This report includes the findings of a safety assessment and a statement of risks and management measures which is an ARPANSA regulatory requirement. For a disposal facility, the safety case may relate to a given stage of development. The Sandy Ridge project is at pre-development and as such, an *Outline Safety Case* presents potential hazards and their required management. As the project progresses into future development stages, the *Outline Safety Case* will be developed into a *Detailed Safety Case*, as required by ARPANSA.
Stakeholder	Stakeholder means an interested party — whether a person or a group, etc. — with an interest or concern in ensuring the success of a venture. To 'have a stake in' something, figuratively, means to have something to gain or lose by, or to have an interest in, the turn of events. In this Regulatory Guide, the term does not include the major players in the licensing process (proponent, operator, regulator) but does include other national and regional governments and agencies.
Storage	The emplacement of radioactive waste in a regulated facility that provides for its containment, pending actions relating to its further management or ultimate disposal. Strictly, a 'store' refers to the building

	or structure within a 'storage facility' in which the waste is housed. The 'storage facility' encompasses the store and its surrounding infrastructure within a perimeter 'boundary' including loading bays in the case of a large facility. The entity that is subject to licensing is the 'storage facility'. For a small store, the facility may comprise just the store itself. Throughout this Regulatory Guide, the two terms may be used interchangeably where this usage will not cause any confusion.
Storage Facility	Refer to storage
Very Low Level Waste	Contains very low, short lived radioactivity and can be stored in the same way as non-radioactive material.
Wildlife	An animal or plant living within its natural environment.

1 INTRODUCTION

1.1 Background to this document

Tellus Holdings Ltd (Tellus), an infrastructure project development company, is proposing to develop the Sandy Ridge Project located approximately 75 kilometres (km) northeast of Koolyanobbing, in the Shire of Coolgardie, within the Goldfields Region of Western Australia (Figure 1–1).

The subject of this Outline Safety Case (OSC) is the proposal to develop the Sandy Ridge Facility (the Proposal; the action). The Proposal is to develop a kaolin open cut mine and use the mine voids for the secure storage and isolation of hazardous, intractable and low level radioactive waste in a near surface geological repository. The safe storage and isolation of such wastes is underpinned by the OSC and using Best Available Techniques (BAT) (ICRP, 2012).

Tellus recognised Australia's need for an operational geological repository which is able to store intractable and hazardous wastes long–term, rather than having wastes stored in hundreds of locations across Australia, often in temporary and unsecured locations which do not meet Part 1 Section 3 of the *Australian Radiation Protection and Nuclear Safety Act 1998*.

Western Australia currently has no operating kaolin mines, but an abundance of kaolin deposits. Tellus see an opportunity to combine kaolin mining with waste disposal in a suitable geological repository, as an overall net environmental benefit through the removal of significant environmental risk by providing a cost effective option for the safe storage and safe isolation of hazardous and intractable waste.

1.2 What is a safety assessment?

A safety assessment covers all aspects of an operation that are relevant to protection and safety. In the case of the proposed Sandy Ridge facility, which is likely to be listed a Major Hazard Facility, this includes the following aspects:

- Siting of the facility.
- Design of the facility.
- Construction.
- Operation.
- Decommissioning.
- Post-closure.

The Sandy Ridge project has undertaken a formalised environmental and social risk assessment covering the above aspects. The identified risks and how they relate to safety are presented in this report.

1.3 What is a safety case report?

A safety case report is a collection of either scientific and/or engineering arguments and evidence in support of the safety of a facility or the activities to be undertaken. This report includes the findings of a safety assessment and a statement of risks and management measures which is an ARPANSA regulatory requirement

1.4 Why prepare a safety case report?

The purpose of this OSC report is to demonstrate that the Sandy Ridge Facility can be operated safely and in accordance with the law. This report reflects the findings of a whole of life cycle risk assessment, the development of a safety management system and a range of other supporting material.

1.5 Intended audience

This document is intended to be read, assessed and approved by key Commonwealth and Western Australian government departments. Further to regulatory approval, the language of this document is intended to be read and understood by any member of the public. It is a record of Tellus' justification for the proposed Sandy Ridge facility.

1.6 Operator details

Tellus Holdings would be the operator of the proposed Sandy Ridge Facility.

Tellus Holdings is an Australian developer with a portfolio of geological repository projects. These projects typically involve mining commodities such as rock salt or kaolin clay and then using the mining voids to store waste. This method of waste storage is environmentally sound and is a globally proven business model – with similar facilities operating around the world.

Details of Tellus Holdings are listed in Table 1-1.

Table 1-1 Operator details

Criteria	Description
Name	Tellus Holdings Ltd
ABN	97 138 119 829
CAN	138 119 829
Address	Suite 2, Level 10, 151 Castlereagh Street, Sydney, NSW, 2000
Contact name	Mr Richard Phillips
Contact position	Environment and Approvals Manager
Contact email	richie@tellusholdings.com
Contact number	+61 2 8257 3395

2 APPROACH

2.1 Overview

Tellus has prepared this *Outline Safety Case* (OSC) report for the Sandy Ridge Facility in compliance its duties under relevant Commonwealth and Western Australian laws and guidelines including:

- *Australian Radiation Protection and Nuclear Safety Act 1998*.
- Australian Radiation Protection and Nuclear Safety Regulations 1999.
- *Environment Protection Biodiversity Conservation Act 1999*.
- *Environmental Protection Act 1986*
- Licensing of Radioactive Waste Storage and Disposal Facilities (ARPANSA, 2013)
- *Generating the supporting documentation for an MHF safety report* (Department of Mines and Petroleum 2009).
- *Guide to preparing a safety report for approval by the Chief Officer* (Department of Mines and Petroleum 2008).
- Dangerous Goods Safety (Major Hazard Facilities) Regulations 2007

These and other relevant laws, guidelines and codes of practice are described in Chapter 3.

2.2 Safety assessment

The proposed Sandy Ridge facility is currently at pre-development stage. This stage has involved the following items of work and research:

- Careful site selection.
- Environmental impact assessment in the form of a Public Environmental Review (PER).
- Conceptual site design.
- Conceptual engineering design.
- Proposed Institutional Control Period.

The PER has undertaken detailed scientific and technical research and prepared evidence in the assessment of potential operational hazards (chemical and radioactive). These studies, support the safety of a Sandy Ridge facility because they cover the suitability of the site and the design, construction and operational elements of the facility, the assessment of radiation risks to human health and the environment.

The independent technical review of the PER and this OSC, assures the Regulators that its contents is of a quality that identified safety related issues can be managed appropriately. This safety assessment is an integral part of the safety case.

It has involved the quantification of radiation dose and radiation risks that may arise from day to day activities (refer to Chapter 6). The risk and impact assessment undertaken is a comparison with dose and risk criteria, and provides an understanding of the behaviour of the disposal facility under normal conditions and unlikely events.

Both environmental impact and risk assessments have considered important time frames over which chemical and radioactive waste remains hazardous. The safety assessment is a procedure for evaluating the performance of the proposed Sandy Ridge facility and, in particular, its potential radiological effects on human health and the environment.

Therefore, the assessments undertaken in the PER and the risk assessment presented in Chapter 6 of this report, are supporting evidence for the safety assessment of the Sandy Ridge facility. In addition, the contents of this document and the PER have given due consideration to Part 1, Section 3 of the *Australian Radiation Protection and Nuclear Safety Act 1998* (ARPANS Act) and associated Regulations.

This safety assessment has considered both the period where institutional controls are relied upon and the subsequent period without such controls. The latter being the period where the site is released to the Government following surrender of licence.

2.3 Safety report

In accordance with Regulation 48 of the Australian Radiation Protection and Nuclear Safety (ARPANS) Regulations, which prescribes compliance with the *Code of practice for the Near-Surface Disposal of radioactive Waste in Australia (1992)*, and as a general condition of licence, this OSC report is a document that contains:

- Assessment of risk and proposed methods for the security of radioactive sources.
- Assessment of risk and recommendations for limiting occupational exposure to ionizing radiation.
- Assessment of risk and recommendations for the safety transport of radioactive and chemical material
- Assessment of risk and proposed methods for the disposal of radioactive and chemical materials.
- Assessment of risk and proposed management methods for potential harm to the receiving environment and ecosystems that live within it.

In accordance with Regulation 25(2) of the West Australian *Dangerous Goods Safety (Major Hazard Facilities) Regulations 2007*, a safety report is a document that contains:

- Notifiable information under Schedule 2.
- A risk assessment under regulation 23.
- A safety management system under regulation 24.

These core parts of the OSC are each discussed below. A table cross-referencing this safety case with the relevant provisions of the Regulations is provided as attachment A.1.

2.3.1 Notifiable information

Notifiable information under Schedule 2 of the *Dangerous Goods Safety (Major Hazard Facilities) Regulations 2007*, includes basic information about the operator of the major hazard facility, the activities at the facility, and the dangerous goods at the facility.

Tellus would be the operator of the proposed Sandy Ridge Facility. Information about Tellus is provided in section 1, while information about the activities and dangerous goods at the Sandy Ridge Facility is provided in section 5.

2.3.2 Risk assessment

The approach to the risk assessment was informed through a review of the relevant legislation, policies and guidelines (see Section 3). Through this review it was determined that the appropriate approach would include a qualitative risk assessment undertaken by suitable qualified employees and reviewed by a suitably qualified third party with expertise in geological repositories.

The risk assessment was underpinned by the risk workshop held by Tellus Holdings and involving seven employees from across the organisation. The workshop participants had various expertise in mine operations, mine safety, occupational hygiene, waste management, environmental science, environmental management and environmental law. All participants have had input into planning and design of the proposed Sandy Ridge facility.

Pursuant to Part 1 Section 3 of the ARPANS Act, the objective of the risk assessment was to identify all potential risks to people, property and the environment throughout:

- Construction;
- Operation;
- Decommissioning; and
- Post-closure.

Other risks that did not involve dangerous goods, or did not have the potential to trigger a major incident, were not considered key risks.

The risk assessment presented in this safety report also benefits from a range of other assessments undertaken for the PER. Many of those assessments included safety a key consideration as described above. Assumptions made during the risk assessment are highlighted where relevant. The risk assessment for this report is provided in Section 6.

2.3.3 Safety management system

A safety management system under Regulation 49 of the ARPANS Regulations 1999 and, Regulation 24 of the West Australian Dangerous Goods Safety (Major Hazard Facilities) Regulations 2007, records the policies and procedures for implementing and managing the risk control measures identified in the risk assessment.

2.4 Supporting material

This OSC report is informed by a range of supporting material including:

- Multiple rounds of Government and community consultation.
- Design documentation.
- Geological investigation.
- Environmental research.
- Environmental impact assessment.
- Speciality risk assessments.

The above supporting material is considered to be valid to inform the OSC report and provide necessary information for the *Detailed Safety Case*.

2.4.1 Geological investigation

Tellus Holdings have undertaken a range of geological investigations to provide information on the kaolin resources. Investigations to date include:

- Geology and hydrogeology report (Rockwater, 2015).
- Resource estimation reports (Terra Search 2014; CRM, 2015).
- Regional geology report (Continental Resource Management, 2016).
- Resource drilling programs (Tellus Holdings 2014-2015; 2016).

The geological investigations are discussed further Chapter 4.

2.4.2 Environmental assessment

Environmental assessment of the Sandy Ridge Facility has been carried out to inform:

- Commonwealth Referral of proposed action.
- State Referral of proposed action.
- Environmental scoping document.
- Public environment report.

The environmental scoping document was prepared in consultation with the West Australian (WA) Environment Protection Authority (EPA) to determine the requirements of the public environmental report under the *Environmental Protection Act 1986*. The document was informed by a desktop assessment of the key environmental factors relevant to the Sandy Ridge Facility.

The referral of proposed action was prepared to assist the Commonwealth Department of the Environment (DoE) to determine whether an environmental impact statement was required for the Sandy Ridge Facility under the *Environment Protection and Biodiversity Conservation Act 1999*. The referral of proposed action was informed by a desktop environmental assessment.

The WA EPA and Commonwealth DoE determined that a public environment report would be required in accordance with the bilateral agreement between the Government of Western Australia and the Australian Government.

A public environment report has been prepared for the Sandy Ridge facility in accordance with the environmental scoping document. The public environment report includes detailed assessments of the potential impacts of the Sandy Ridge Facility across various aspects of the environment, based on technical assessments and site surveys. The public environment report of the Sandy Ridge Facility informs the site description in Chapter 4.

2.4.3 Design documentation

The design of the Sandy Ridge Facility is a staged process involving:

- Continuous consultation with Commonwealth and State Regulators.
- Scoping study.
- Pre-feasibility study.
- Definitive feasibility study.

Health, safety and environment have been key considerations at each stage of design. This staged design process has informed the description of the facility summarised in Chapter 5.

2.4.4 Other specialty assessments

The safety case is informed by a number of other specialty assessments, including:

- Long term water infiltration and seepage modelling (CyMod Systems, 2016).
- Baseline radiation and metals assessment (Terra Search, 2016).
- Landform evolution modelling (Landloch, 2016)

Long-term water infiltration and seepage modelling

Tellus commissioned the assessment of long term water infiltration in waste isolation pits utilised flow models to quantify the rate of potential infiltration. The assessment informs the risk assessment in Section 6.

Baseline radiation and metals assessment

Tellus commissioned a baseline radiation and metals assessment. It involved a desktop assessment of geophysical and geochemical data using publicly available information to quantify levels of naturally occurring radioactive materials and metals. The report concluded the Sandy Ridge site's soils do have Naturally Occurring Radioactive Materials and metals but the level are very low.

Landform evolution modelling

Tellus commissioned a landform evolution model to assess the long-term (10,000 years) behaviours and performance of landforms with respect to proposed post-closure infrastructure (waste pits and capping design).

3 REGULATORY FRAMEWORK

3.1 Legislation

3.1.1 Commonwealth legislation

Australian Radiation Protection and Nuclear Safety Act 1998

The *Australian Radiation Protection and Nuclear Safety Act 1998* (ARPNS Act) is the principal law regulating radioactive materials and activities administered by the Australian Government. The object of the law is to protect the health and safety of people, and to protect the environment, from the harmful effects of radiation. The key provisions of the law establish the Australian Radiation Protection and Nuclear Safety Agency establish the Australian Radiation Protection and Nuclear Safety Agency and regulate controlled material, apparatus and facilities.

The Australian Radiation Protection and Nuclear Safety Agency is the regulatory body for Commonwealth agencies. It is noted that the agency is not the regulatory body for activities that not undertaken by the Commonwealth. Instead, these responsibilities are deferred to other authorities that are established in each State or Territory.

The agency produces guidance material on radioactive material and is informed by a range of advisory bodies including the Radiation Health and Safety Advisory Council, Radiation Health Committee, and the Nuclear Safety Committee. The guidance material produced by the Australian Radiation includes guidance on the transport of radioactive material that informs the *Australian Code for the Transport of Dangerous Goods by Road & Rail* (see Section 3.2.2).

Environment Protection and Biodiversity Conservation Act 1999

The *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act)is the principal environmental law administered by the Australian Government. The law regulates actions with regard to matters of national environmental significance, defined as:

- World heritage properties.
- National heritage places.
- Wetlands of international importance (listed under the Ramsar Convention).
- Listed threatened species and ecological communities.
- Migratory species protected under international agreements.
- Commonwealth marine areas.
- Great Barrier Reef Marine Park.
- A water resource, in relation to coal seam gas and large coal mines.

Under the law, any proposed action that is likely to have a significant impact on a matter of national environmental significance must be referred to the Minister for the Environment. The Minister will then make a decision as to whether the action is a 'controlled action' requiring environmental assessment by one a number of means including an environmental impact statement.

A proposed nuclear action must also be referred to the Minister for the Environment and may be subject to the same environmental assessment processes. Nuclear actions include uranium mining, transport of radioactive material and disposal of radioactive material.

If an environmental assessment is triggered by the EPBC Act and State environmental law a single environmental assessment may be prepared to address both requirements if in accordance with bilateral agreements between the Australian Government and the State governments.

National Environment Protection Measures (Implementation) Act 1998

The *National Environment Protection Measures (Implementation) Act 1998* gives force to the national environmental protection measures made by the National Environment Protection Council by requiring their implementation through State regulatory systems. The national environmental protection measures made by the council cover environmental matters including:

- Air Toxics.
- Ambient Air Quality.
- Assessment of Site Contamination.
- Diesel Vehicle Emissions.
- Movement of Controlled Waste between States and Territories.
- National Pollutant Inventory.
- Used Packaging Materials.

3.1.2 State legislation

Environmental Protection Act 1986

The *Environment Protection Act 1986* is the principal environmental planning law administered by the Government of Western Australia. The law enables the WA Environmental Protection Authority to require the preparation of an environmental review for certain proposals. The requirement for an environmental review depends on the scope and scale of the proposal.

The *Environmental Protection Act 1986* is also the principal environmental protection law administered by the Government of Western Australia. The main aspects include:

- Offences for environmental harm.
- Control of clearing of native vegetation.

- Approvals and licenses for prescribed activities.
- Notices, orders and directions for environmental incidents.

Offences for environmental harm include causing pollution or dumping waste. Control of clearing of native vegetation requires a person to apply for a clearing permit and for the permit to be approved prior any clearing taking place. Clearing permits may include conditions to mitigate or manage harm to the environment, or to secure other vegetated areas to offset the loss associated with clearing.

Works and operations for prescribed premises must holds relevant approvals and licenses. Prescribed premises are listed in Schedule 1 of the subordinate *Environmental Protection* and included premises including various mining and waste management premises.

Notices, order and directions may be given to operators – usually in response to environmental harm or contravention of approval conditions.

Dangerous Goods Safety Act 2004

The *Dangerous Goods Safety Act 2004* is the principal dangerous goods law administered by the Government of Western Australia. The purpose of the law is the safe storage, handling and transport of dangerous goods. The relevant provisions of the law include:

- General duties for the storage, handling and transport of dangerous goods.
- Establishment of codes of practice for particular activities.
- Establishment of regulations for particular subjects.

The relevant regulations established under the *Dangerous Goods Safety Act 2004* include:

- Dangerous Goods Safety (General) Regulations 2007.
- Dangerous Goods Safety (Major Hazard Facilities) Regulations 2007.
- Dangerous Goods Safety (Storage and Handling of Non-explosives) Regulation 2007.
- Dangerous Goods Safety (Road and Rail Transport of Non-explosives) Regulations 2007.

The Dangerous Goods Safety (General) Regulations 2007 are general administrative regulations that sets out how dangerous goods are defined and procedures for exemptions or infringements. Dangerous goods are generally defined with reference to the *Australian Dangerous Goods Code*, the United Nations *Recommendations on the Transport of Dangerous Goods* or determinations made by the Chief Officer under the *Dangerous Goods Safety Act 2004*.

The Dangerous Goods Safety (Major Hazard Facilities) Regulations 2007 defines duties for operators of certain types of facilities – including major hazard facilities. Major hazard facilities are defined as places where dangerous goods are present exceeding the critical quantity listed in Schedule 1 of the regulation and classified by decision of the Chief Officer under regulation 21. Under the regulation, an operator of a major hazard facility must prepare a safety report that contains –

- Notifiable information under Schedule 2.
- A risk assessment under regulation 23.
- A safety management system under regulation 24.

Notifiable information under Schedule 2 of the Dangerous Goods Safety (Major Hazard Facilities) Regulations 2007 includes basic information about the operator of the major hazard facility, the activities at the facility, and the dangerous goods at the facility.

A risk assessment under regulation 23 of the Dangerous Goods Safety (Major Hazard Facilities) Regulations 2007 requires the identification of hazards related to dangerous goods, the risks of the hazards causing a major incident and measures to reduce those risks. A major incident is defined as an incident involving a substance listed in Schedule 1 of the Dangerous Goods Safety (Major Hazard Facilities) Regulations 2007 which causes serious harm to people, property or the environment.

A safety management system under regulation 24 of the Dangerous Goods Safety (Major Hazard Facilities) Regulations 2007 records the policies and procedures for implementing and managing the risk control measures identified in the risk assessment.

The Dangerous Goods Safety (Storage and Handling of Non-explosives) Regulation 2007 defines duties for operators of certain types of facilities - including dangerous goods sites. Dangerous goods sites are defined as places where dangerous goods are intended to be loaded, unloaded, stored or handled. Under the regulation, a dangerous goods site must be licensed if dangerous goods are present exceeding the manifest quantity listed in Schedule 1 of the regulation. A risk assessment must also be performed for these dangerous goods sites.

Nuclear Waste Storage and Transportation (Prohibition) Act 1999

The *Nuclear Waste Storage and Transportation (Prohibition) Act 1999* prohibits the storage, disposal or transportation of nuclear waste. Nuclear waste is defined by the law as radioactive material from a nuclear plant or nuclear weapons testing.

Mining Act 1978

The *Mining Act 1978* is the principal mining law administered by Government of Western Australia. The purpose of the law is to regulate mining activities through the granting and conditioning of mining tenements such as prospecting licences, exploration licenses and mining leases.

Under the law, an application for a mining lease must be accompanied by a mining proposal. A mining proposal must be prepared in accordance with the *Guidelines for Mining Proposals in Western Australia* (Department of Mines and Petrol 2006). Under the law and the guidelines a mining proposal must include a mine closure plan, including rehabilitation criteria.

Radiation Safety Act 1975

The *Radiation Safety Act 1975* regulates possession, storage, use, handling and disposal of radioactive substances, irradiating apparatus and certain electronic products.

Under the law, a person must hold a license in order to deal with these regulated items. Licenses may be granted for a range of purposes including medical use, industrial use or research. Separate permits are also required for their disposal.

The *Radiation Safety Act 1975* also establishes the Radiological Council, which is an independent statutory authority that advises and assists WA Government to protect public health and to maintain safe practices in the use of radiation.

The relevant regulations established under the *Dangerous Goods Safety Act 2004* include:

- Radiation Safety (Transport of Radioactive Substances) Regulations 2002.
- Radiation Safety (General) Regulations 1983.
- Radiation Safety (Qualifications) Regulations 1980.

The Radiation Safety (General) Regulations 1983 sets general obligations for licensees under the *Radiation Safety Act 1975*. Section 31A of the regulation requires licensees of facilities that involve the near-surface disposal of radioactive material to do so in accordance with the *Code of practice for the near-surface disposal of radioactive waste in Australia* (see Section 3.2.2).

The Radiation Safety (Transport of Radioactive Substances) Regulations 2002 sets requirements for transport of radioactive material including:

- Preparation of a radiation protection programme for approval by the Radiological Council.
- Compliance with the Code of practice for the safe transport of radioactive material.
- Compliance with the Regulations for the safe transport of radioactive material.

A radiation protection programme is defined in the *Regulations for the safe transport of radioactive material* as “systematic arrangements which are aimed at providing adequate consideration of radiation protection measures”.

Waste Avoidance and Resource Recovery Act 2007

The *Waste Avoidance and Resource Recovery Act 2007* is the principal waste law administered by the Government of Western Australia. The law promotes the efficient use of resources and the management of waste in accordance with the following hierarchy:

- Avoidance of unnecessary resource consumption.
- Resource recovery (including reuse, reprocessing, recycling and energy recovery).
- Disposal.

The law establishes waste authority that administers a waste strategy with regard to activities undertaken by the State. The law also provides for the registration of product stewardship plans for certain producers and for permitting of residential waste services provided by local government.

3.2 Policies and guidelines

3.2.1 International safety policies and guidelines

While international safety requirements of the International Atomic Energy Agency (IAEA) are not mandatory in Australia (ARPANSA, 2013), those that are relevant for a licence application (see below), should be given the appropriate consideration to ensure the highest possible levels of human and environmental safety. The safety of these elements needs to be met throughout the lifecycle (siting, construction, operation, decommissioning, and post-closure) of the storage and disposal of radioactive wastes.

IAEA Specific Safety Requirements Disposal of Radioactive Waste (IAEA SSR-5, 2011)

This guideline addresses safety objectives that are relevant for all phases of a near surface repository. This document lists guidance around the preparation, approval and use of the safety case and safety assessment for a disposal facility.

IAEA General Safety Requirements Safety Assessment for Facilities and Activities (IAES GSR Part 4, 2009)

There are 24 requirements within this safety requirement that list how to perform a safety assessment and should be considered in the assessment of a licence application. Tellus has given due consideration to these points within the contents of this Safety Case.

Requirement 1 of this guideline is of most importance to this Safety Case – *Graded Approach to Safety Assessment*. It states that a graded approach shall be used in determining the scope and level of detail of the safety assessment carried out for any particular facility or activity consistent with the magnitude of the possible radiation risks arising from the facility or activity.

It is expected, that as the proposed Sandy Ridge Safety Case assessment will be developed and become more detailed through stages of the facility's lifecycle. At each stage, it is expected the a Periodic Safety Review (PSR) will be undertaken by ARPANSA and records maintained in line with the requirements of the Commonwealth *Archives Act 1983*.

IAEA General Safety Requirements Predisposal Management of Radioactive Waste (IAES GSR Part 5, 2009)

This guideline stipulates necessary (general) safety requirements that a proponent and a facility must adhere to prior to the commencement of a facility being operational.

International Atomic Energy Agency (IAEA) Fundamental Safety Principles (IAEA SF-1, 2006)

This guideline presents the fundamental safety objective and ten associated safety principles. The fundamental safety objective is to protect people and the environment from harmful effects of ionizing radiation (ARPNS Act). The guideline's objective applies to all radioactive waste storage and disposal facilities and activities (ARPANSA, 2013).

IAEA Waste Safety Requirements Decommissioning of Facilities (GSR Part 6, 2006)

This guideline sets out requirements for activities needed during decommissioning a radioactive site.

European Council Directive 1999/31/EC and 2003/33/EC

European Council Directive 1999/31/EC provides measures, procedures and guidance to reduce as far as possible negative effects of waste facilities on the environment and human health.

Article 11 of the directive describes procedures operators of waste facilities should follow with regard to the acceptance of waste at the facility. The procedures include:

- Checking of waste documentation
- Visual inspection of the waste
- Maintenance of a waste register

The directive also defines procedures for control and monitoring during operations as well as procedures for facility closure and after-case.

European Council Directive 2003/33 establishes criteria for acceptance of waste at waste facilities pursuant to European Council Directive 1999/31/EC. The criteria are typically threshold quantities for contaminants beyond which waste should not be accepted.

3.2.2 ARPANSA guidelines

3.2.2.1 Overview

ARPANSA have a range of publication to promote practices which address Part 1 Section 3 of the *Australian Radiation Protection and Nuclear Safety Act 1998*. That is, to promote practices which protect human health and the environment from potentially harmful effects of radiation. There are three levels of guidance which ARPANSA provide to a proponent who is responsible for the development, implementation and operation of a site specific safety case for a radioactive waste facility. These are:

1. Fundamentals.
2. Codes and Standards.
3. Guides and Recommendations.

Documents considered relevant by Tellus to the proposed Sandy Ridge facility are listed below.

3.2.2.2 Fundamentals

Fundamentals for Protection Against Ionising Radiation (2014).

3.2.2.3 Codes and Standards

Code of Practice for the Safe Transport of Radioactive Material

The *Code* is administered by ARPANSA and establishes uniform requirements for transport (road, rail and waterways) of radioactive material. The code includes provisions for:

- Radiation protection.
- Emergency response.
- Training requirements.
- Packaging requirements.

The code also provides threshold radioactivity levels that would classify a given quantity of radioactive material as exempt under the *Safety Guide for Classification of Radioactive Waste*.

Code of practice for the near-surface disposal of radioactive waste in Australia

The code includes provisions for:

- Site selection - 2.1.
- Safety assessment – refer to Section 2.2.
- Site description – refer to Section 4
- Facility description and design – refer to Section 5.
- Operational practices – refer to Section 5.1.
- Waste acceptance criteria and classification – refer to Section 5.3.
- Radiation protection – refer to Section 0.
- Facility closure.
- Institutional control.
- Financial indemnity.

3.2.2.4 Guides and Recommendations

Guide for Radiation Protection of the Environment (2015)

The purpose of the Guide is to provide best practice guidance on how to assess environmental exposures and demonstrate protection of the environment from the human activities that give rise to such exposures.

Safety Guide for the Classification of Radioactive Waste (2010)

This Safety Guide sets out non-prescriptive, best practice guidance for classifying radioactive waste and is based on IAEA General Safety Guide Classification of Radioactive Waste (No. GSG-1) published in 2009. The Safety Guide is qualitative in nature with the intention being that users will have

appropriate flexibility to classify their waste in accordance with internationally accepted methods and terminology.

Safety Guide for the Predisposal Management of Radioactive Waste (2008)

The purpose of this Safety Guide is to assist regulators, persons responsible for facilities that generate and manage radioactive waste and other specialists in achieving compliance with regulatory requirements. It should also assist in ensuring adequate monitoring, safety assessment and maintenance of radioactive waste in storage for the purpose of ongoing safety and security.

Safety Guide for the Management of Naturally Occurring Radioactive Material (NORM) (2008)

The purpose of the Safety Guide is to assist regulators and industries in managing NORM and assessing the need for radiation protection measures. It takes account of recently developed international guidance on NORM management, and on assessing the need for regulation. It recognises that regulation will not always be the appropriate approach for dealing with NORM, and describes a graded approach to regulation for those cases where a regulatory approach is assessed as being necessary. It includes a detailed procedural assessment of NORM waste associated with the oil and gas sector which is where the majority of Tellus' NORM waste would be derived from.

Recommendations for Intervention in Emergency Situations Involving Radiation Exposure (2004)

Provides guidance on the application of protective measures in planning for and responding to emergency situations in Australia involving radiation exposure.

3.2.1 Other Commonwealth policies and guidelines

Where appropriate, Tellus has used the Commonwealth policies and guidelines listed below, in the preparation of specific environmental, transport, and operational management plans for the proposed Sandy Ridge facility.

Australian code for the transport of dangerous goods by road & rail

The *Australian Code for the Transport of Dangerous Goods by Road & Rail* [1]is developed by the National Transport Commission. The code provides classifies dangerous goods as:

- Class 1 – Explosive.
- Class 2 – Gases.
- Class 3 – Flammable liquids.
- Class 4.1 – Flammable solids, self-reactive substances and solid desensitised explosives.
- Class 4.2 – Substances liable to spontaneous combustion.

[1] http://www.ntc.gov.au/heavy-vehicles/safety/australian-dangerous-goods-code/

- Class 4.3 – Substances which in contact with water emit flammable gases.
- Class 5.1 – Oxidising substances.
- Class 5.2 – Organic peroxides.
- Class 6.1 – Toxic substances.
- Class 6.2 – Infectious substances.
- Class 7 – Radioactive material.
- Class 8 – Corrosive substances.
- Class 9 – Miscellaneous dangerous substances.

The code includes a detailed list of dangerous goods by classification. The code also sets standards for storage and handling of dangerous goods – including packaging, labelling, stowage and restraint, segregation and safety equipment. With regard to Class 7 – Radioactive material, the code refers to the *Code of Practice for the Safe Transport of Radioactive Material*.

National standard for the control of major hazard facilities

The National Occupational Health and Safety Commission has developed the *National Standard for the Control of Major Hazard Facilities* and accompanying *National Code of Practice for the Control of Major Hazard Facilities*. The standard and accompanying code outlines requirements for:

- Identification and classification of major hazard facilities.
- Hazard identification, risk assessment and risk control.
- Preparation of safety reports.
- Training and education.
- Emergency planning.
- Reporting major incidents.
- Worker responsibilities.
- Community information.
- Security of major hazard facilities.

With regard to conducting a risk assessment of a major hazard facility, the *National Code of Practice for the Control of Major Hazard Facilities* states the rigour of the approach should be commensurate with the size and complexity of the facility.

Safe Work Australia guides

Safe Work Australia has developed guides to help operators of major hazard facilities meet their legal obligations. These guides for major hazard facilities include:

- Providing information to the community (Safe Work Australia 2012a).
- Preparation of a safety case (Safe Work Australia 2012b).
- Adequacy of safety measures and control measures (Safe Work Australia 2012c).
- Emergency plans (Safe Work Australia 2012d).
- Notification and determination (Safe Work Australia 2012e).
- Safety assessment (Safe Work Australia 2012f).
- Information, training and instruction (Safe Work Australia 2012g).
- Safety management systems (Safe Work Australia 2012h).
- Developing a safety case outline (Safe Work Australia 2012i).

Safety guide for classification of radioactive waste

The *Safety Guide for Classification of Radioactive Waste* is administered by the Australian Radiation Protection and Nuclear Safety Agency and sets out a scheme for classifying radioactive material that is based primarily on considerations of long term safety and disposal.

The radioactive waste classification in the *Safety Guide for Classification of Radioactive Waste* is reproduced in Table 3-1.

Table 3-1 Radioactive waste classification

Criteria	Description
Exempt waste	Contains very low radioactivity and can be stored in the same way as non-radioactive material
Very low level waste	Contains very low, short lived radioactivity and can be stored in the same way as non-radioactive material
Low level waste	Contains higher short lived radioactivity and low long lived radioactivity and can be safely stored in a near-surface facility
Intermediate level waste	Contains higher long lives radioactivity can be safely stored at greater depths (up to a few hundred metres below surface)
High level waste	Contains radioactivity high enough to generate significant heat and can be safely stored in deep, stable geological formations (several hundred metres below surface)

3.2.2 State policies and guidelines

Guide to preparing a safety report for approval by the Chief Officer

The *Guide to preparing a safety report for approval by the Chief Officer* (Department of Mines and Petroleum 2008) complements the Dangerous Goods Safety (Major Hazard Facilities) Regulations 2007 by providing further detail on the content and structure of a safety report.

Generating the supporting documentation for an MHF safety report

Generating the supporting documentation for an MHF safety report (Department of Mines and Petroleum 2009) provides guidance on the preparation of the safety report.

The document includes guidance on:

- What information to provide about the major hazard facility.
- How to conduct the formal risk assessment.
- Typical elements of a safety management system.

Landfill Waste Classification and Waste Definitions

Landfill Waste Classification and Waste Definitions administered by the WA Government Waste Authority classifies waste to guide acceptance at waste facilities. The waste classification in *Landfill Waste Classification and Waste Definitions* is reproduced in Figure 3-1. The document establishes criteria for the acceptance of waste at waste facilities. The criteria are typically threshold quantities for contaminants beyond which waste should not be accepted.

Figure 3-1 Waste classification

4 SITE DESCRIPTION

4.1 Overview

The Sandy Ridge Facility would be located on approximately 870 hectares of unallocated Crown Land controlled by the Government of Western Australia. The proposed site is not currently utilised for any purpose but is zoned for mining/rural use under the *Land Administration Act 1997*.

The site is about 4 kilometres west of the existing Mt Walton East Intractable Waste Disposal Facility (IWDF) operated by Waste Management (WA) on behalf of the Government of Western Australia. The facility operates intermittently (on a campaign basis) and is not permanently occupied.

The site is otherwise very remote, with no permanently occupied places in close proximity. The nearest permanently occupied places are the Carina Iron Ore Mine Accommodation Camp about 52 kilometres south and Koolyanobbing 75 kilometres south west.

The site is access via Mt Walton East Road off the Great Eastern Highway. Other users of this route include workers at the Intractable Waste Disposal Facility and Carina Iron Ore Mine. Iron ore from the Carina Iron Ore Mine is transported separately on a dedicated haul road.

The site is situated within the Coolgardie Bioregion. This region is arid, with low rainfall and high evaporation. Average daily temperatures are around 19-34°C in summer and 6-18°C in winter. The temperature can reach maximums of around 45°C but can also drop below freezing overnight. Average annual rainfall is around 250 millimetres.

There is no native title claim over the proposed Sandy Ridge site recorded by the Government of Western Australia Land, Approvals and Native Title Unit.

The information below provides a high level summary of the site's baseline environment. More detailed baseline information on the environment is contained within the Sandy Ridge PER.

4.2 Topography

The bioregion is characterised by gently undulating uplands dissected by broad valleys with bands of low greenstone hills. Notable features include Yendilberin Hills running north west to south west and peaking at Mt Walton, about 16 kilometres south of the Sandy Ridge Facility site. The Sandy Ridge Facility site itself is consists of sand plains that are generally flat to gently undulating (Cymod, 2016).

4.3 Geology

4.3.1 Overview

The Sandy Ridge Facility would be situated in the east of the Yilgarn Craton – a very old and stable formation covering about 675,000 square kilometres of southern Western Australia. This formation has been geologically stable for about 2.5 billion years. The stratigraphy of the site is characterised by a sequence of sand, laterite, silcrete, kaolin, saprock and granite (see Table 4-1).

Table 4-1 Typical geological sequence

Strata	Range
Sand	0 – 1m
Laterite	1 – 3m
Silcrete	3 – 5m
Mottled	5 – 7m
Kaolin	7 – 23m
Saprock	23 – 27m
Granite	> 27m

4.3.2 Erosion and weathering

Erosion and weathering at the Sandy Ridge Facility site is very limited: wind erosion is very limited due to vegetation coverage; water erosion is very limited as there are no waterways and limited rainfall; and chemical weathering is very limited as the geology comprises chemically stable end products of long duration weathering processes. It is not expected that these conditions would change within a nominal timeframe of 10 million years (Continental Resource Management 2016).

4.3.3 Geological hazards

The Sandy Ridge Facility site is very stable and has few geological hazards. The site has the lowest possible earthquake rating while there has not been any volcanic activity for over one billion years. There is no evidence of glaciation ever occurring. Tectonic movement at the current rate would not find the project entering a seismically active area for 60 million years.

4.4 Hydrology

There are no waterways at the Sandy Ridge Facility site, however runoff and ponding may occur in during high rainfall events. Runoff is generated by small and localised catchments and follows the natural topography of the site. Ponded water disappears due to evaporation and infiltration.

4.5 Hydrogeology

The Sandy Ridge Facility site is not expected to contain groundwater aquifers. Seven groundwater investigation bores were established at the site and none intersected an aquifer. Some water was encountered at three of the groundwater investigation bores at around 35 metres below ground level. These do not constitute aquifers based on low yield and permeability.

4.6 Flora and fauna

Eucalypt woodland is common in the region of the Sandy Ridge Facility including *E. salmonophloia*, *E. salubris*, *E. transcontinentalis* and *E. longicornis*. Outcrops of granite at middle elevations support *Borya constricta*, with stands of *Acacia acuminata* and *E. loxophleba*. Upland areas are characterised by Mallee eucalypts *E. leptopoda*, *E. platycorys* and *E. scyphocalyx* and scrub heaths *Allocasuarina corniculata, Callitris preissii, Melaleuca uncinata* and *Acacia beauverdiana*.

The vegetation at the site is not considered to be of conservation significance. Three priority ecological communities are listed as potential occurring on the Department of Parks and Wildlife database but are associated with banded iron formations that are not present at the site and do not correlate with the vegetation communities identified through desktop and site observations. These priority ecological communities are Finnerty Range/Mt Dimer/Yendilberin Hills vegetation complex; Hunt Range vegetation complex; and Lake Giles vegetation complex.

4.7 Cultural heritage

No items of cultural heritage significance are recorded at the Sandy Ridge Facility site. A search of the relevant Commonwealth and State heritage databases did not return any relevant listings, while an Aboriginal heritage survey of the site did not identify any items of cultural heritage significance.

5 FACILITY DESCRIPTION

5.1 Overview

5.1.1 Infrastructure

The OSC assesses the lifecycle of proposed site activities at the Sandy Ridge facility with respect to:

- Kaolin surface facilities including:
  - Kaolin run of mine stockpiles.
  - Kaolin product processing and storage.
  - Kaolin analysis laboratory.
- Waste surface facilities including:
  - Waste laydown area.
  - Waste analysis laboratory.
  - Waste storage and packaging.
  - Waste stabilisation and solidification.
- Near surface kaolin mining pits / waste isolation pits.
- Office buildings and maintenance facilities.
- Vehicle and machinery wash-down area.
- Worker accommodation buildings.
- Access and haul roads.
- Water pipeline.

5.1.2 Mining

The Sandy Ridge Facility would function as a kaolin mining and processing facility as well as a waste storage and isolation facility. The facility is proposed on an area of unallocated crown land in Coolgardie, Western Australia – about 75 kilometres north east of Koolyanobbing.

The Sandy Ridge Facility would generate commercial kaolin product from its kaolin mining and processing operations. The kaolin would not contain chemicals exceeding threshold quantities in Schedule 1 of the Dangerous Goods Safety (Storage and Handling of Non-explosives) Regulations 2007 or Schedule 1 of the Dangerous Goods Safety (Major Hazard Facilities) Regulations 2007.

5.1.3 Waste management

The Sandy Ridge Facility would also receive waste for storage and isolation. The waste would be delivered either directly to the facility, via Darwin Business Park or via Brewer Industrial Estate. These waste storage and isolation operations are the subject of this safety report.

It is noted that the Sandy Ridge Facility site has been specifically selected due to its particular physical characteristics that make waste storage and isolation safe and environmentally sound. These characteristics are explained further in section 5.2.

Waste would be delivered to the Sandy Ridge Facility in appropriate labelled and sealed containers within shipping containers by licensed waste transporters. Waste would be initially inspected at the waste laydown area, along with any material safety data sheets. The waste would also be sampled and analysed at the waste analysis laboratory.

Subject to meeting the waste acceptance criteria discussed in section 5.3, shipping containers would be conveyed to waste isolation pits where the waste unpacked and shipping containers returned to the surface. The stored waste would be isolated from the surrounding environmental principally due to the physical characteristics of the site discussed in section 5.2.

The Sandy Ridge Facility would be secured and only authorised personnel would be allowed access. Security cameras would be established and monitored. Check points and identification protocols would be implemented to control access.

The layout of the Sandy Ridge Facility is provided as Attachment A.2, while drawings of specific features are provided as Attachment A.3.

5.2 Isolation of materials

The Sandy Ridge Facility site has been specifically selected due to its particular physical characteristics that make waste storage and isolation safe and environmentally sound, including:

- Very remote from human settlement.
- Broad geological stability of the region.
- Semi-arid climate with excess evaporation.
- Small catchment without waterways or aquifers.
- Low permeability and adsorbent qualities of kaolin.
- Highly impermeable silicrete ceiling above kaolin resource.
- Small contributing catchments with no defined aquifers or waterways.

The Sandy Ridge Facility is very remote from human settlement. The facility is situated about 4 kilometres from the existing Intractable Waste Disposal Facility – however this is facility is not routinely utilised or occupied. The nearest permanently occupied places are Carina Iron Ore Mine

Accommodation Camp about 52 kilometres south and Koolyanobbing 75 kilometres south west. Opportunities for human exposure to waste isolation pits are therefore very limited.

The Yilgarn Craton – the geological region where the Sandy Ridge Facility is located – is very geologically stable. The Yilgarn Craton has been essentially stable for the past 2.4 billion years. It is therefore unlikely that volcanic or tectonic activity would disrupt the Sandy Ridge Facility.

The climate in the region of the facility is semi-arid with evaporation at times outstripping rainfall by a factor of eight. The risk of significant quantities of water flooding the site and then ponding for a sufficient length of time to infiltrate the waste isolation pits is therefore very low.

The Sandy Ridge Facility site is situated near the top of a watershed and as such the local catchment is small. Accordingly, there are no defined aquifers or waterways at the site. Therefore, the volume of water available at the site is low even before the effects of evaporation are considered.

The kaolin bed where the waste isolation pits will be situated has innately low permeability and extends tens if kilometres in every direction at up to 35 metres thickness. Furthermore, kaolin can adsorb and thereby demobilise heavy metals and radionuclides. The kaolin bed is naturally covered by a highly impermeable layer of silcrete. The combined effect of the kaolin bed and silcrete layer is to prevent the infiltration of surface water and migration of contaminants.

These physical characteristics effectively eliminate the possibility of contaminants escaping waste isolation pits and affecting people, property or the environment. Even without considering these characteristics, the waste stored at the Sandy Ridge Facility would be stored within double barrier containers while waste isolation pits would be sealed with engineered barriers once at capacity.

The geological sequence at the Sandy Ridge Facility site is indicatively shown in Figure 5-1

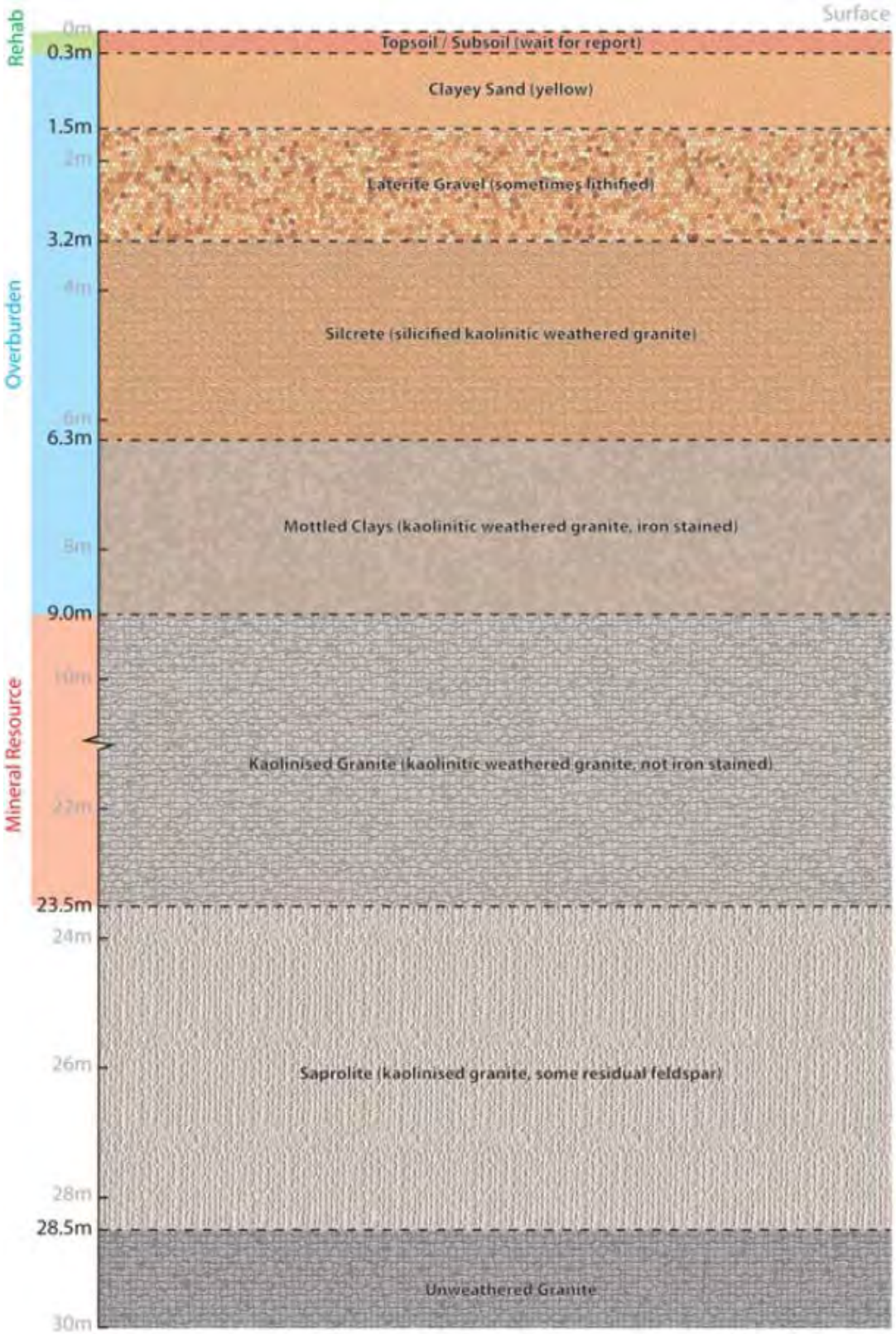

Figure 5-1 **Natural geological multi-barrier isolation**

5.3 Waste acceptance criteria and zoning

5.3.1 Introduction

Waste delivered to the Sandy Ridge Facility would be subject to strict waste acceptance criteria. The criteria were developed in reference to the relevant policy and guidance (see section 3.2).

Once the hazardous properties of waste are determined through the implementation of the waste acceptance criteria, waste would be stored according zoning scheme.

The waste acceptance criteria and complementary zoning criteria would ensure that waste is only accepted when it can be isolated in a safe and environmentally sound manner.

The waste acceptance criteria are described further in section 5.3.2 while the zoning criteria are described further in section 5.3.3.

5.3.2 Waste acceptance criteria

It is normal when establishing waste acceptance criteria for storage and permanent isolation to first determine which wastes under normal circumstances will not be accepted i.e. will be ***excluded***.

The waste acceptance criteria are in keeping with best practice in similar facilities such as the Mt Walton East IWDF and the Andra facility in France.

Wastes that may undergo undesired physical, chemical or biological transformation after they have been deposited will not be accepted at Sandy Ridge. Essentially, the criteria and decision process effectively rule out waste that are:

- Nuclear wastes.
- Gases.
- Liquids[2].
- Explosive materials.
- Highly reactive materials.
- Highly flammable materials.
- Biodegradable materials.

The waste acceptance criteria are implemented through the decision process depicted in Figure 5-2.

[2] *It is noted that sludge or liquid waste would be accepted if it can undergo a process to be incorporated into another waste and remain physically stable subject to additional testing.*

Nuclear wastes

Nuclear or highly radioactive materials would not be accepted under any circumstance.

Low level or very low level radioactive material could be accepted subject to specific risks assessment and control measures.

Gases

Gases will not be accepted at the SRSIF, even if altered into a liquid or solid form (e.g. compressed, liquefied, dissolved, or adsorbed). Permanent isolation cannot be guaranteed, and gas migration will cause a loss of volume within the cell, resulting in subsequent damage to the capping system and allowing water infiltration into the cell.

Liquids

Liquid wastes are to be excluded from the SRSIF, unless they can undergo solidification/stabilisation processing to make them suitable for disposal. It is assumed that containers will eventually fail and allow the liquid waste to seep into the encapsulating clay. Although the adsorbent properties of the surrounding kaolin formation will prevent movement of the wastes off-site, it is possible that the loss of volume could damage the cap and allow infiltration of water into the cell. Similarly, waste sludge's are to be excluded from the site unless treatment can be applied to remove any free liquid.

Explosive materials

The following classes of materials, as defined by *The Australian Code for the Transport of Dangerous Goods by Road and Rail* (2007) are not acceptable in the conditions of storage at Sandy Ridge:

- Class 1.1 – substances and articles that have a mass explosion hazard (a mass explosion is one that affects almost the entire load virtually instantaneously).
- Class 1.2 – substances and articles that have a projection hazard but not a mass explosion hazard.
- Class 1.3 – substances and articles that have a fire hazard and either a minor blast hazard or a minor projection hazard or both, but not a mass explosion hazard. This includes substances and articles that give rise to considerable radiant heat, or that burn one after another, producing minor blast or projection effects or both.

Materials that are not themselves explosive but which have the potential to form or generate an explosive atmosphere of gas or vapour may not be suitable for disposal at the SRSIF. This would depend on several factors such as the rapidity of vapour or gas generation and the reactions involved, and is assessed in Gate 10 of the staged waste acceptance process in **Error! Reference source not found.**.

Highly reactive materials

The following classes of materials, as defined in *The Australian Code for the Transport of Dangerous Goods by Road and Rail* (2007), are not accepted in the conditions of storage:

- Class 5 – Oxidising Substances. Substances that, while in themselves not necessarily combustible, may, generally by yielding oxygen, cause, or contribute to, the combustion of other materials.
- Class 8 – Corrosive substances. Substances that, by chemical action, will cause severe damage when in contact with living tissue, or, in the case of leakage, will materially damage or even destroy, other goods or the means of transport; and may cause other hazards (The Australian Code for the Transport of Dangerous Goods by Road and Rail, 2007, Volume 1).

Verification of the corrosive or oxidising nature of the material may be required, by a combination of chemical (pH) and other corrosivity testing (see Gate 4).

Highly flammable materials

The following classes of materials, as defined in The Australian Code for the Transport of Dangerous Goods by Road and Rail (2007), are not accepted:

- Class 3 – Flammable liquids. Liquids, or mixtures of liquids, or liquids containing solids in solution or suspension (for example, paints, varnishes, lacquers, etc., but not including substances otherwise classified on account of their dangerous characteristics) which give off a flammable vapour at temperatures of not more than 60 °C, closed cup test, or not more than 65.6 °C, open-cup test, normally referred to as the flash point.
- Class 4.1 – Flammable solids. Solids which, under conditions encountered in transport, are readily combustible or may cause or contribute to fire through friction; self-reactive substances which are liable to undergo a strongly exothermic reaction; solid desensitised explosives which may explode if not diluted sufficiently;
- Class 4.2 – Substances liable to spontaneous combustion. Substances which are liable to spontaneous heating under normal conditions encountered in transport, or to heating up in contact with air, and being then liable to catch fire;
- Class 4.3 – Substances which in contact with water emit flammable gases. Substances which, by interaction with water, are liable to become spontaneously flammable or to give off flammable gases in dangerous quantities.

Some substances that are flammable, such as wood and synthetic materials (e.g. contaminated PPE), may be acceptable for disposal if they require an open flame and oxygen for combustion since they will be buried in an environment essentially devoid of both these characteristics.

Biodegradable materials

According to the IWDF *Waste Acceptance Guidelines,* materials that are likely to decompose and produce combustible hazardous gases, or wastes that decompose and become compressible are not suitable for near-surface disposal, since any significant volume reduction could compromise the integrity of the capping system. In addition, gases generated within a waste cell have the potential to create subsurface pathways, which could provide a route for subsequent rainwater ingress to the cell. Such materials include organic, domestic wastes

High level radioactive wastes

High level waste or waste with a radioactivity of $\geq$ 3700 Becquerel per gram would not be accepted at Sandy Ridge. Low level or very low level radioactive material could be accepted subject to risk control measures (see section 6).

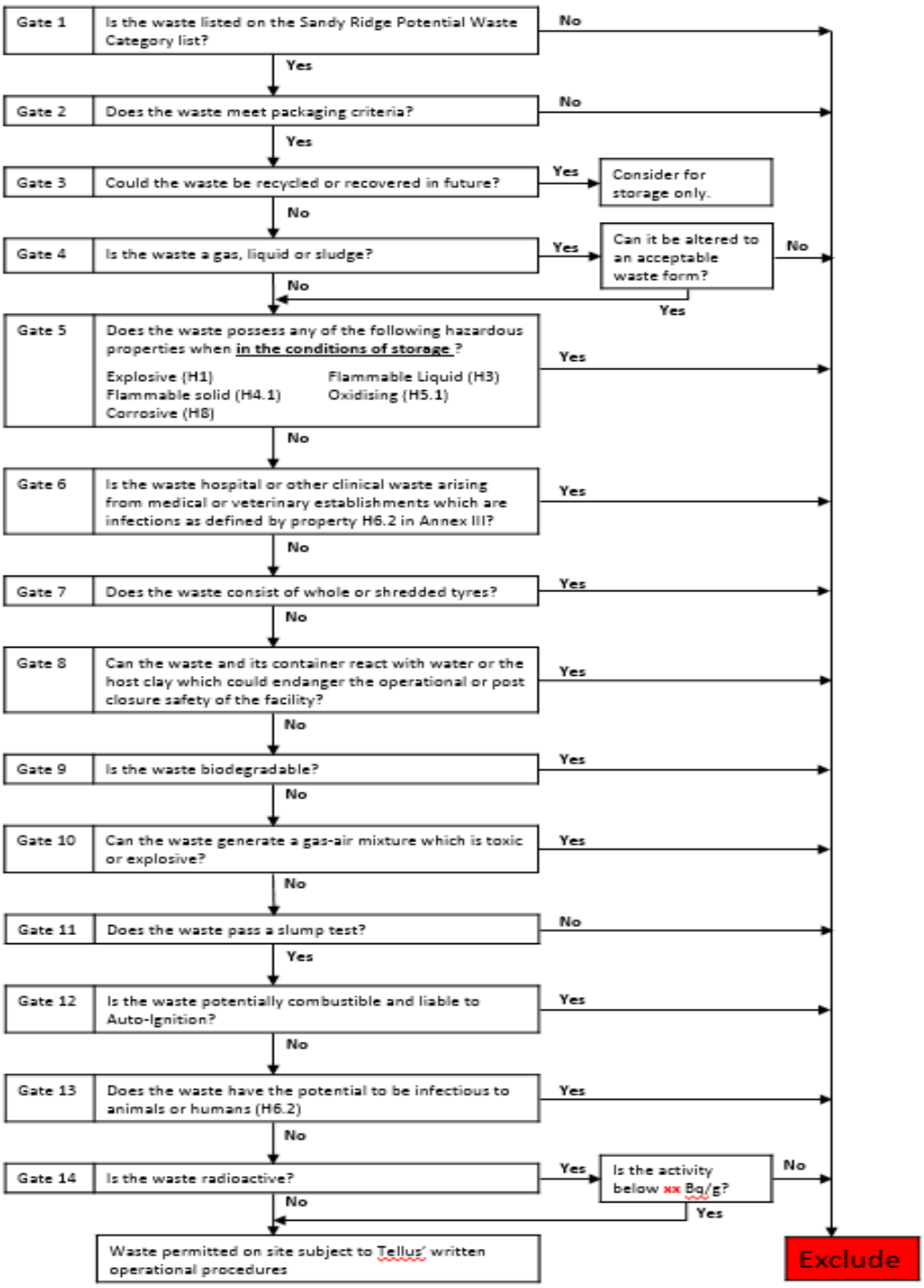

Figure 5-2 Waste acceptance flow chart

5.3.3 Zoning scheme

Once the hazardous properties of waste are determined through the implementation of the waste acceptance criteria, waste would be stored according zoning scheme that ensure:

- Separation of waste with differing hazardous characteristics.
- Separation of acidic and alkaline wastes.
- Separation of waste with other potentially reactive properties.
- Separation of low level or very low level radioactive material.

5.3.4 Accepted waste inventory

The Sandy Ridge Facility would accept a range of wastes up to a maximum licensed quantity of 100,000 tonnes per year. Waste storage and isolation would be made safe and environmentally sound by the physical characteristics of the site (see section 5.2) and the strict waste acceptance criteria (see section 5.3) that would be implemented.

It is expected that some wastes accepted at the Sandy Ridge Facility would contain substances exceeding the thresholds listed in Schedule 1 of the Dangerous Goods Safety (Major Hazard Facilities) Regulations 2007. As such, the Sandy Ridge Facility qualifies as a major hazard facility.

The Sandy Ridge waste inventory will depend on the waste market at the time of operation.

The range and quantity of Schedule 1 chemicals present at the Sandy Ridge Facility at a given time would potentially be less than indicated. This approach ensures the safety case is effective and able to demonstrate that the facility can be operated safely and in compliance with the regulations.

6 RISK ASSESSMENT

6.1 Overview

This section documents the risk assessment undertaken for the Sandy Ridge Facility. The assessment focuses on hazards relating to dangerous goods kept at the Sandy Ridge Facility.

The assessment considers the probability of hazards triggering major incidents and prescribes measures to controls these key risks. The approach is described further in section 2.

The key risks identified in the risk assessment are discussed in the following sections, while the risk register developed through the risk workshop is provided as Attachment A.4.

6.2 Hazards that could cause a major incident

6.2.1 Release of dangerous goods during delivery of waste

Overview of hazard

The delivery of waste at the Sandy Ridge Facility is an activity that could be the cause of a major incident and is therefore considered a key risk. The specific hazard is the release of waste that is a dangerous good in sufficient volume to cause serious harm to people, property or the environment. Releases could be caused by insecure waste stowage, vehicle accident or uncontrolled unloading.

It is noted that Tellus Holdings would not have operational control of waste deliveries outside of the Sandy Ridge Facility site. As such, this risk assessment focuses on risks at the site. Risks subject to the operational control of waste contractors would be made low as reasonably practicable through the process of contractor selection and negotiation of contract terms.

Probability of causing a major incident

The release of waste in sufficient volume to cause serious harm to people, property or the environment is unlikely due to waste containment, waste form and the nature of the site.

Waste would be delivered to the Sandy Ridge Facility in ISO 20’ shipping containers. Within these shipping containers, waste would be stored in double-barrier waste containers such as double-lined bulker bags or PVC bags stored within barrels. The containment of waste in this way would limit the volume of waste that would be released in the event of an accident during delivery.

Waste delivered to the Sandy Ridge Facility would often be in a solid or granular form. The form of the waste would limit its movement in the event of a release. The form of the waste would therefore limit its potential to make contact with people, property or the environment.

The Sandy Ridge Facility site is very remote, with no permanently occupied places in close proximity. The site is arid with no waterways and limited rainfall. As such, there are inherently few areas where people, property or the environment would be harmed in the event of a release of dangerous goods.

Nature of harm to people, property or the environment

In the unlikely event of a release - the nature of harm to people, property or the environment would depend on the type of waste involved. Waste accepted at the Sandy Ridge Facility could include hazardous material with the potential to cause harm to people or the environment.

The scale of harm would likely be limited by the containment of waste, the form of waste and the nature of the site as discussed above. However, the potential consequence of a release of waste are considered serious given the potentially hazardous qualities of the waste.

Risk control measures

The following risk control measures are integral to the planning of the Sandy Ridge Facility and would serve to control the risk of a release of dangerous goods during delivery of waste.

- Implement strict waste acceptance criteria
- Engage with responsible waste producers and transporters that demonstrate an understanding of their waste streams and appropriate risk control measures
- Keep a register of approved waste producers and transporters
- Audit transporters for risk controls that are in place including
    - Delivery of waste in double-barrier waste containers within shipping containers
    - Secure fastening of shipping containers to delivery trucks prior to mobilisation
    - Utilisation of dangerous goods rated trucks, including brake and rollover systems
- Conduct specialty risk assessment for deliveries of higher risk waste deliveries
- Develop clear operational procedures for directing and unloading deliveries
- Ensure all machinery and equipment used in unloading is maintained
- Include fire detection and suppression systems in facility design
- Maintain an emergency response and management plan

It is considered that the above measures would make the risk of a release of dangerous goods during delivery of waste as low as reasonably practicable.

6.2.2 Ignition of dangerous goods during delivery of waste

Overview of hazard

The delivery of waste to the Sandy Ridge Facility is an activity that could be the cause of a major incident and is therefore considered a key risk. The specific hazard is the ignition of waste that is a dangerous good that causes serious harm to people, property or the environment. Ignition could be caused by inappropriate waste stowage, vehicle accident, or uncontrolled unloading.

It is noted that Tellus Holdings would not have operational control of waste deliveries outside of the Sandy Ridge Facility site. As such, this risk assessment focuses on risks at the site. Risks subject to the operational control of waste contractors would be made low as reasonably practicable through the process of contractor selection and negotiation of contract terms.

Probability of causing a major incident

The ignition waste in sufficient volume to cause serious harm to people, property or the environment is unlikely due to waste types, waste containment and the nature of the site.

Waste delivered to the Sandy Ridge Facility would be subject to strict waste acceptance criteria. The waste acceptance criteria are implemented through the decision process depicted in Figure 5-2. The first step in the decision process is to confirm the waste is permissible – before delivery occurs. The decision process would prohibit wastes with particularly hazardous characteristics including those that are explosive or flammable, and would allow for screening of other hazardous wastes.

Waste would be delivered to the Sandy Ridge Facility in ISO 20' shipping containers. Within these shipping containers, waste would be stored in double-barrier waste containers such as double-lined bulker bags or PVC bags stored within barrels. The containment of waste in this way would limit the interaction of waste with the potential to ignite through reaction.

The Sandy Ridge Facility site is very remote, with no permanently occupied places in close proximity. The site is arid with no waterways and limited rainfall. As such, there are inherently few areas where people, property or the environment would be harmed in the event of a release of dangerous goods.

Nature of harm to people, property or environment

In the unlikely event of an ignition - the nature of harm to people, property or the environment would depend on the type of waste involved but be limited by waste acceptance, containment and the nature of the site as discussed above. However, the potential consequence of a release of waste are considered serious given the potentially hazardous qualities of the waste.

Risk control measures

The following risk control measures are integral to the planning of the Sandy Ridge Facility and would serve to control the risk of ignition of dangerous goods during delivery of waste.

- Implement strict waste acceptance criteria
- Engage with responsible waste producers and transporters that demonstrate an understanding of their waste streams and appropriate risk control measures.
- Keep a register of approved waste producers and transporters.
- Audit transporters for risk controls that are in place including.
    - Delivery of waste in double-barrier waste containers within shipping containers
    - Secure fastening of shipping containers to delivery trucks prior to mobilisation

- Utilisation of dangerous goods rated trucks, including brake and rollover systems

- Conduct specialty risk assessment for deliveries of higher risk waste deliveries.
- Develop clear operational procedures for directing and unloading deliveries.
- Ensure all machinery and equipment used in unloading is maintained.
- Include fire detection and suppression systems in facility design.
- Maintain an emergency response and management plan.

It is considered that the above measures would make the risk of ignition of dangerous goods during delivery of waste as low as reasonably practicable.

6.2.3 Exposure to radiation during delivery of waste

Overview of hazard

The delivery of waste at the Sandy Ridge Facility is an activity that could be the cause of a major incident and is therefore considered a key risk. The specific hazard is exposure of radiation at sufficient intensity to cause serious harm to people, property or the environment.

Waste delivered to the Sandy Ridge Facility could include any combination of the wastes that meet the waste acceptance criteria outlined in section 5.3. Some of these wastes could lead to radiation exposure if released. Releases could be caused by inappropriate containment, insecure stowage, vehicle accident or uncontrolled unloading.

It is noted that Tellus Holdings would not have operational control of waste deliveries outside of the Sandy Ridge Facility site. As such, this risk assessment focuses on risks at the site. Risks subject to the operational control of waste contractors would be made low as reasonably practicable through the process of contractor selection and negotiation of contract terms.

Probability of causing a major incident

The exposure of radiation at sufficient intensity to cause serious harm to people, property or the environment is unlikely due to waste type, waste containment and the nature of the site.

Waste delivered to the Sandy Ridge Facility would be subject to strict waste acceptance criteria. The waste acceptance criteria would be implemented through the decision process depicted in Figure 5-2. The first step in the decision process is to confirm the waste is permissible – before delivery occurs. The decision process would prohibit wastes with high radiation from being delivered. Low level or very low level radioactive material could be accepted subject to risk control measures.

Accepted radioactive material would be transported in accordance with the requirements of the Radiation Safety (Transport of Radioactive Substances) Regulations 2002 and related guidelines. The requirements include standards for containment and stowage which reduce risk of exposure.

The Sandy Ridge Facility site is very remote, with no permanently occupied places in close proximity. The site is also arid with no waterways and low rainfall, limiting potential for mobilisation. As such, there are inherently few ways that people, property or the environment would be harmed in the event of exposure to radioactive material.

Nature of harm to people, property or environment

In the unlikely event of exposure to radioactive material - the nature of harm to people, property or the environment would depend on the level of radioactivity but would be limited by the waste type, waste containment and the nature of the site as described above. The consequences of a release of waste are nonetheless considered serious given the potentially hazardous qualities of the waste.

Risk control measures

The following risk control measures are integral to the planning of the Sandy Ridge Facility and would serve to control the risk of a release of dangerous goods during delivery of waste.

- Implement strict waste acceptance criteria
- Engage with responsible waste producers and transporters that demonstrate an understanding of their waste streams and appropriate risk control measures – including compliance with the *Australian code for the transport of dangerous goods by road & rail* and *Code of Practice for the Safe Transport of Radioactive Material*
- Keep a register of approved waste producers and transporters
- Audit transporters for risk controls that are in place including
    - Delivery of waste in double-barrier waste containers within shipping containers
    - Secure fastening of shipping containers to delivery trucks prior to mobilisation
    - Utilisation of dangerous goods rated trucks, including brake and rollover systems
- Conduct specialty risk assessment for deliveries of radioactive material
- Develop clear operational procedures for directing and unloading deliveries
- Ensure all machinery and equipment used in unloading is maintained
- Include fire detection and suppression systems in facility design
- Maintain an emergency response and management plan

It is considered that the above measures would make the risk of a release of dangerous goods during delivery of waste as low as reasonably practicable.

6.2.4 Release of dangerous goods during delivery of fuel

Overview of hazard

The delivery of fuel to the Sandy Ridge Facility is an activity that could be the cause of a major incident and is therefore considered a key risk. The specific hazard is the release of diesel in a sufficient volume to cause serious harm to people, property or environment. Releases could be caused by inadequate fuel stowage, vehicle accidents or uncontrolled unloading.

It is noted that Tellus Holdings would not have operational control of fuel deliveries outside of the Sandy Ridge Facility site. As such, this risk assessment focuses on risks at the site. Risks subject to the operational control of waste contractors would be made low as reasonable practicable through the process of contractor selection and negotiation of contract terms.

Probability of causing a major incident

The release of fuel in sufficient volume to cause serious harm to people, property or the environment is unlikely due to fuel containment and the nature of the site.

Fuel would be transported and unloaded in accordance with the requirements of the *Dangerous Goods Safety Act 2004* and related regulations and guidelines. The requirements include standards for containment, stowage and unloading that would reduce risk of release.

The Sandy Ridge Facility site is very remote, with no permanently occupied places in close proximity. The site is also arid with no waterways and low rainfall, limiting potential for mobilisation. As such, there are inherently few ways that people, property or the environment would be harmed in the event of a release of fuel during delivery.

Nature of harm to people, property or environment

In the unlikely event of a release of fuel - the nature of harm to people, property or the environment would be limited by the fuel containment and the nature of the site as described above. The consequences of a release of fuel are nonetheless considered serious.

Risk control measures

The following risk control measures are integral to the planning of the Sandy Ridge Facility and would serve to control the risk of a release of dangerous goods during delivery of fuel.

- Engage with responsible waste producers and transporters that demonstrate an understanding of their waste streams and appropriate risk control measures– including compliance with the *Australian code for the transport of dangerous goods by road & rail* and *AS 1940-2004 The storage and handling of flammable and combustible liquids*
- Keep a register of approved waste producers and transporters
- Audit transporters for risk controls that are in place for fuel deliveries

- Develop clear operational procedures for directing and unloading fuel
- Ensure all machinery and equipment used in fuel handling is maintained
- Include spill controls such as bunds in design of storage and refuelling areas
- Include fire detection and suppression systems in facility design
- Maintain an emergency response and management plan

It is considered that the above measures would make the risk of a release of dangerous goods during delivery of waste as low as reasonably practicable.

6.2.5 Ignition of dangerous goods during delivery of fuel

Overview of hazard

The delivery of fuel to the Sandy Ridge Facility is an activity that could be the cause of a major incident and is therefore considered a key risk. The specific hazard is the ignition of diesel in a sufficient volume to cause serious harm to people, property or environment. Ignition could be caused by inadequate fuel stowage, vehicle accidents or uncontrolled unloading.

It is noted that Tellus Holdings would not have operational control of fuel deliveries outside of the Sandy Ridge Facility site. As such, this risk assessment focuses on risks at the site. Risks subject to the operational control of waste contractors would be made low as reasonably practicable through the process of contractor selection and negotiation of contract terms.

Probability of causing a major incident

The exposure fuel in sufficient volume to cause serious harm to people, property or the environment in the event of an ignition is unlikely due to fuel containment and the nature of the site.

Fuel would be transported and unloaded in accordance with the requirements of the *Dangerous Goods Safety Act 2004* and related regulations and guidelines. The requirements include standards for containment, stowage and unloading that would reduce risk of exposure.

The Sandy Ridge Facility site is very remote, with no permanently occupied places in close proximity. The site is also arid with no waterways and low rainfall, limiting potential for mobilisation. As such, there are inherently few ways that people, property or the environment would be harmed in the event of an ignition of fuel during delivery.

Nature of harm to people, property or environment

In the unlikely event of a release of fuel - the nature of harm to people, property or the environment would be limited by the fuel containment and the nature of the site as described above. The consequences of a release of fuel are nonetheless considered serious.

Risk control measures

The following risk control measures are integral to the planning of the Sandy Ridge Facility and would serve to control the risk of ignition of dangerous goods during delivery of fuel.

- Engage with responsible fuel transporters that demonstrate an understanding of their waste streams and appropriate risk control measures– including compliance with the *Australian code for the transport of dangerous goods by road & rail* and *AS 1940-2004 The storage and handling of flammable and combustible liquids*
- Keep a register of approved fuel transporters
- Audit transporters for risk controls that are in place
- Develop clear operational procedures for directing and unloading deliveries
- Ensure all machinery and equipment used in unloading is maintained
- Include fire detection and suppression systems in facility design
- Maintain an emergency response and management plan

It is considered that the above measures would make the risk of a release of dangerous goods during delivery of fuel as low as reasonably practicable.

6.2.6 Release of dangerous goods during on site handling of waste

Overview of hazard

The handling of waste at the Sandy Ridge Facility is an activity that could be the cause of a major incident and is therefore considered a key risk. The specific hazard is the release of waste that is a dangerous good in sufficient volume to cause serious harm to people, property or the environment. Releases could be caused by insecure waste stowage, vehicle accident or uncontrolled unloading.

Probability of causing a major incident

The release of waste in sufficient volume to cause serious harm to people, property or the environment is unlikely due to waste containment, waste form and the nature of the site.

Dangerous goods would be handled in accordance with the requirements of the *Dangerous Goods Safety Act 2004* and related regulations and guidelines. The requirements include standards for containment, stowage and unloading that would reduce risk of release.

Waste would be delivered to the Sandy Ridge Facility in ISO 20’ shipping containers. Within these shipping containers, waste would be stored in double-barrier waste containers such as double-lined bulker bags or PVC bags stored within barrels. The containment of waste in this way would limit the volume of waste that would be released in the event of an accident during on site handling.

Waste delivered to the Sandy Ridge Facility would often be in a solid or granular form. The form of the waste would limit its movement in the event of a release. The form of the waste would therefore limit its potential to make contact with people, property or the environment.

The Sandy Ridge Facility site is very remote, with no permanently occupied places in close proximity. The site is arid with no waterways and limited rainfall. As such, there are inherently few areas where people, property or the environment would be harmed in the event of a release of dangerous goods.

Nature of harm to people, property or environment

In the unlikely event of a release – the nature of harm to people, property or the environment would depend on the type of waste involved. Waste accepted at the Sandy Ridge Facility could include toxic material with the potential to cause harm to people or the environment.

The scale of harm would likely be limited by the containment of waste, the form of waste and the nature of the site as discussed above. However, the potential consequence of a release of waste are considered serious given the potentially hazardous qualities of the waste.

Risk control measures

The following risk control measures are integral to the planning of the Sandy Ridge Facility and would serve to control the risk of a release of dangerous goods during handling of waste.

- Implement strict waste acceptance criteria
- Store waste material according to zoning scheme
- Provide extensive training to Sandy Ridge Facility workers
- Enforce appropriate use of personal protective equipment
- Conduct regular toolbox meetings to promote awareness of risks
- Develop clear operational procedures for handling dangerous goods
- Ensure all machinery and equipment used in handling is maintained
- Include spill controls in design of waste isolation pits such as bunds
- Include fire detection and suppression systems in facility design
- Maintain an emergency response and management plan

It is considered that the above measures would make the risk of a release of dangerous goods during delivery of waste as low as reasonably practicable.

6.2.7 Reaction involving dangerous goods during on site handling of waste

Overview of hazard

The handling of waste at the Sandy Ridge Facility is an activity that could be the cause of a major incident and is therefore considered a key risk. The specific hazard is a reaction involving dangerous

goods at sufficient scale or intensity to harm to people, property or the environment. The hazard includes reactions that generate dangerous goods. Reactions could be caused by highly reactive waste, inadequate containment or inappropriate zoning of waste in storage.

Probability of causing a major incident

The reaction of waste at sufficient scale or intensity to cause serious harm to people, property or the environment is unlikely due to waste type, containment, zoning and the nature of the site.

Waste delivered to the Sandy Ridge Facility would be subject to strict waste acceptance criteria. The waste acceptance criteria would be implemented through the decision process depicted in Figure 5-2. The first step in the decision process is to confirm the waste is permissible – before delivery occurs. The decision process would prohibit wastes that are highly reactive from being delivered.

Accepted waste materials would be stored in accordance with a strict zoning scheme. The zoning scheme would ensure that wastes with potentially reactive properties are physically separated. The zoning scheme is described further in section 5.3.3.

The Sandy Ridge Facility site is very remote, with no permanently occupied places in close proximity. The site is also arid with no waterways and low rainfall, limiting potential for mobilisation. As such, there are inherently few ways that people, property or the environment would be harmed in the event of a reaction involving dangerous goods.

Nature of harm to people, property or environment

In the unlikely event of a reaction involving dangerous goods - the nature of harm to people, property or the environment would depend on its scale or intensity but would be limited by the waste type, containment, zoning and the nature of the site as described above. The consequences of a reaction are nonetheless considered serious.

Risk control measures

The following risk control measures are integral to the planning of the Sandy Ridge Facility and would serve to control the risk of reaction involving dangerous goods during handling of waste.

- Implement strict waste acceptance criteria
- Store waste material according to zoning scheme
- Provide extensive training to Sandy Ridge Facility workers
- Enforce appropriate use of personal protective equipment
- Conduct regular toolbox meetings to promote awareness of risks
- Develop clear operational procedures for handling dangerous goods
- Ensure all machinery and equipment used in handling is maintained
- Include spill controls in design of waste isolation pits such as bunds

- Include fire detection and suppression systems in facility design
- Maintain an emergency response and management plan

It is considered that the above measures would make the risk of a release of dangerous goods during delivery of waste as low as reasonably practicable.

6.2.8 Exposure to radiation during on site handling of waste

Overview of hazard

The handling of radioactive waste at the Sandy Ridge Facility is an activity that could be the cause of a major incident and is therefore considered a key risk. The specific hazard exposure to radiation at sufficient intensity to cause serious harm to people, property or the environment.

Waste delivered to the Sandy Ridge Facility could include any combination of the wastes that meet the waste acceptance criteria outlined in section 5.3. Some of these wastes could lead to radiation exposure if released. Exposures could be caused by highly radioactive waste, accidents during handling, inadequate containment or inadequate storage.

Probability of causing a major incident

The exposure of radiation at sufficient intensity to cause serious harm to people, property or the environment is unlikely due to waste type, containment, storage and the nature of the site.

Waste delivered to the Sandy Ridge Facility would be subject to strict waste acceptance criteria. The waste acceptance criteria would be implemented through the decision process depicted in Figure 5-2. The first step in the decision process is to confirm the waste is permissible – before delivery occurs. The decision process would prohibit wastes that are highly radioactive from being delivered. Low level or very low level radioactive material could be accepted subject to risk control measures.

Accepted radioactive material would be handled in accordance with the requirements of the *Radiation Safety Act 1975* and associated related regulations and guidelines. The requirements include standards for containment and storage which reduce risk of exposure.

The Sandy Ridge Facility site is very remote, with no permanently occupied places in close proximity. The site is also arid with no waterways and low rainfall, limiting potential for mobilisation. As such, there are inherently few ways that people, property or the environment would be harmed in the event of exposure to radioactive material.

Nature of harm to people, property or environment

In the unlikely event of exposure to radioactive material - the nature of harm to people, property or the environment would depend on the level of radioactivity but would be limited by the waste type, waste containment and the nature of the site as described above. The consequences of a release of waste are nonetheless considered serious given the potentially hazardous qualities of the waste.

Risk control measures

The following risk control measures are integral to the planning of the Sandy Ridge Facility and would serve to control the risk of exposure to radiation during on site handling of waste.

- Implement strict waste acceptance criteria
- Store waste material according to zoning scheme
- Provide extensive training to Sandy Ridge Facility workers
- Enforce appropriate use of personal protective equipment
- Conduct regular toolbox meetings to promote awareness of risks
- Develop clear operational procedures for handling radioactive waste – including compliance with the *Code of practice for the near-surface disposal of radioactive waste in Australia*
- Ensure all machinery and equipment used in handling is maintained
- Include spill controls in design of waste isolation pits such as bunds
- Include fire detection and suppression systems in facility design
- Maintain an emergency response and management plan

It is considered that the above measures would make the risk of a release of dangerous goods during delivery of waste as low as reasonably practicable.

6.2.9 Release of dangerous goods during on site handling of fuel

Overview of hazard

The handlings of fuel at the Sandy Ridge Facility is an activity that could be the cause of a major incident and is therefore considered a key risk. The specific hazard is the release of diesel in a sufficient volume to cause serious harm to people, property or environment. Releases could be caused by inadequate fuel storage or uncontrolled unloading.

Probability of causing a major incident

The release of fuel in sufficient volume to cause serious harm to people, property or the environment is unlikely due to fuel storage, unloading and the nature of the site.

Fuel would be handled in accordance with the requirements of the *Dangerous Goods Safety Act 2004* and related regulations and guidelines. The requirements include standards for storage and unloading that would reduce risk of release.

The Sandy Ridge Facility site is very remote, with no permanently occupied places in close proximity. The site is also arid with no waterways and low rainfall, limiting potential for mobilisation. As such, there are inherently few ways that people, property or the environment would be harmed in the event of a release of fuel during delivery.

Nature of harm to people, property or environment

In the unlikely event of a release of fuel - the nature of harm to people, property or the environment would be limited by fuel storage, unloading and the nature of the site as described above. The consequences of a release of fuel are nonetheless considered serious.

Risk control measures

The following risk control measures are integral to the planning of the Sandy Ridge Facility and would serve to control the risk of a release of dangerous goods during handling of waste.

- Provide extensive training to Sandy Ridge Facility workers
- Enforce appropriate use of personal protective equipment
- Conduct regular toolbox meetings to promote awareness of risks
- Develop clear operational procedures for refuelling activities
- Ensure all machinery and equipment used in fuel handling is maintained
- Include spill controls such as bunds in design of storage and refuelling areas
- Include fire detection and suppression systems in facility design
- Maintain an emergency response and management plan

It is considered that the above measures would make the risk of a release of dangerous goods during delivery of waste as low as reasonably practicable.

6.2.10 Ignition of dangerous goods during on site handling of fuel

Overview of hazard

On site handling of fuel to the Sandy Ridge Facility is an activity that could be the cause of a major incident and is therefore considered a key risk. The specific hazard is the ignition of diesel in a sufficient volume to cause serious harm to people, property or environment. Ignition could be caused by inadequate fuel stowage, vehicle accidents or uncontrolled unloading.

It is noted that Tellus Holdings would not have operational control of fuel deliveries outside of the Sandy Ridge Facility site. As such, this risk assessment focuses on risks at the site. Risks subject to the operational control of waste contractors would be made low as reasonably practicable through the process of contractor selection and negotiation of contract terms.

Probability of causing a major incident

The exposure fuel in sufficient volume to cause serious harm to people, property or the environment in the event of an ignition is unlikely due to fuel containment and the nature of the site.

Fuel would be transported and unloaded in accordance with the requirements of the *Dangerous Goods Safety Act 2004* and related regulations and guidelines. The requirements include standards for containment, stowage and unloading that would reduce risk of exposure.

Fuel storage facilities would be designed and operated in accordance with the relevant Australian standards such as *AS 1940-2004 The storage and handling of flammable and combustible liquids* and would incorporate a sump with capacity to contain any accidental spills.

The Sandy Ridge Facility site is very remote, with no permanently occupied places in close proximity. The site is also arid with no waterways and low rainfall, limiting potential for mobilisation. As such, there are inherently few ways that people, property or the environment would be harmed in the event of an ignition of fuel during delivery.

Nature of harm to people, property or environment

In the unlikely event of a release of fuel - the nature of harm to people, property or the environment would be limited by the fuel containment and the nature of the site as described above. The consequences of a release of fuel are nonetheless considered serious.

Risk control measures

The following risk control measures are integral to the planning of the Sandy Ridge Facility and would serve to control the risk of ignition of dangerous goods during on site handling of fuel.

- Engage with responsible fuel transporters that demonstrate an understanding of their waste streams and appropriate risk control measures– including compliance with the *Australian code for the transport of dangerous goods by road & rail* and *AS 1940-2004 The storage and handling of flammable and combustible liquids*
- Keep a register of approved fuel transporters
- Audit transporters for risk controls that are in place
- Develop clear operational procedures for directing and unloading deliveries
- Ensure all machinery and equipment used in unloading is maintained
- Include fire detection and suppression systems in facility design
- Maintain an emergency response and management plan

It is considered that the above measures would make the risk of a release of dangerous goods during on site handling of fuel as low as reasonably practicable.

6.2.11 Reaction involving dangerous goods during on site waste treatment

Overview of hazard

The treatment of waste at the Sandy Ridge Facility is an activity that could be the cause of a major incident and is therefore considered a key risk. The specific hazard is a reaction involving dangerous

goods at sufficient scale or intensity to harm to people, property or the environment. The hazard includes reactions that generate dangerous goods. Reactions could be caused during treatment procedures to stabilise waste in line with the waste acceptance criteria.

Probability of causing a major incident

The reaction of waste at sufficient scale or intensity to cause serious harm to people, property or the environment is unlikely due to waste type, treatment procedures and the nature of the site.

Waste delivered to the Sandy Ridge Facility would be subject to strict waste acceptance criteria. The waste acceptance criteria would be implemented through the decision process depicted in Figure 5-2. The first step in the decision process is to confirm the waste is permissible – before delivery occurs. The decision process would prohibit wastes that are highly reactive from being delivered.

Waste accepted at the Sandy Ridge Facility site may require treatment procedures to stabilise the waste in line with the waste acceptance criteria. Such treatment would typically involve solidification or removal of liquid. These or any other treatment procedures would be carried out by suitably qualified professionals and in accordance with industry standard practices.

The Sandy Ridge Facility site is very remote, with no permanently occupied places in close proximity. The site is also arid with no waterways and low rainfall, limiting potential for mobilisation. As such, there are inherently few ways that people, property or the environment would be harmed in the event of a reaction involving dangerous goods.

Nature of harm to people, property or environment

In the unlikely event of a reaction involving dangerous goods - the nature of harm to people, property or the environment would depend on its scale or intensity but would be limited by the waste type, containment, zoning and the nature of the site as described above. The consequences of a reaction are nonetheless considered serious.

Risk control measures

The following risk control measures are integral to the planning of the Sandy Ridge Facility and would serve to control the risk of reaction involving dangerous goods during waste treatment.

- Implement strict waste acceptance criteria
- Provide extensive training to Sandy Ridge Facility workers
- Enforce appropriate use of personal protective equipment
- Conduct regular toolbox meetings to promote awareness of risks
- Develop clear operational procedures for treating dangerous goods
- Ensure all machinery and equipment used in treatment is maintained
- Include fire detection and suppression systems in facility design

- Maintain an emergency response and management plan

It is considered that the above measures would make the risk of a reaction involving dangerous goods during waste treatment as low as reasonably practicable.

6.2.12 Release of dangerous goods from waste isolation pits

Overview of hazard

The storage of waste in isolation pits at the Sandy Ridge Facility is an activity that could be the cause of a major incident and is therefore considered a key risk. The specific hazard is the release of waste that is a dangerous good in sufficient volume to cause serious harm to people, property or the environment. Releases could be caused by structural failure or migration of water.

Probability of causing a major incident

The release of waste at sufficient scale or intensity to cause serious harm to people, property or the environment is unlikely due to waste type, form, containment and the nature of the site.

Waste delivered to the Sandy Ridge Facility would be subject to strict waste acceptance criteria. The waste acceptance criteria would be implemented through the decision process depicted in Figure 5-2. The first step in the decision process is to confirm the waste is permissible – before delivery occurs. The decision process would prohibit wastes with particularly hazardous characteristics.

Waste delivered to the Sandy Ridge Facility would often be in a solid or granular form. The form of the waste would limit its movement in the event of a release. The form of the waste would therefore limit its potential to make contact with people, property or the environment.

Waste would be stored in double-barrier waste containers such as double-lined bulker bags or PVC bags stored within barrels. The containment of waste in this way would limit the volume of waste that would be released in the event of a release within waste isolation pits.

The physical characteristics of the Sandy Ridge Facility site effectively eliminate the possibility of contaminants escaping waste isolation pits and affecting people, property or the environment. The isolation of waste at the Sandy Ridge Facility is described further in section 5.2.

The Sandy Ridge Facility site is very remote, with no permanently occupied places in close proximity. The site is also arid with no waterways and low rainfall, limiting potential for mobilisation. As such, there are inherently few ways that people, property or the environment would be harmed in the event of a reaction involving dangerous goods.

Nature of harm to people, property or environment

In the unlikely event of a release – the nature of harm to people, property or the environment would depend on the type of waste involved. Waste accepted at the Sandy Ridge Facility could include hazardous material with the potential to cause harm to people or the environment.

The scale of harm would likely be limited by the type and form of the waste, the containment of the waste and the nature of the site as discussed above. However, the potential consequence of a release of waste are considered serious given the potentially hazardous qualities of the waste.

Risk control measures

The following risk control measures are integral to the planning of the Sandy Ridge Facility and would serve to control the risk of a release of dangerous goods during handling of waste.

- Implement strict waste acceptance criteria
- Store waste material according to zoning scheme
- Provide extensive training to Sandy Ridge Facility workers
- Enforce appropriate use of personal protective equipment
- Conduct regular toolbox meetings to promote awareness of risks
- Develop clear operational procedures for handling dangerous goods
- Ensure all machinery and equipment used in handling is maintained
- Include spill controls in design of waste isolation pits such as bunds
- Include fire detection and suppression systems in facility design
- Maintain an emergency response and management plan

It is considered that the above measures would make the risk of a release of dangerous goods from waste isolation pits as low as reasonably practicable.

6.2.13 Reaction involving dangerous goods at waste isolation pits

Overview of hazard

The storage of waste in isolation pits at the Sandy Ridge Facility is an activity that could be the cause of a major incident and is therefore considered a key risk. The specific hazard is a reaction involving dangerous goods at sufficient scale or intensity to harm to people, property or the environment. The hazard includes reactions that generate dangerous goods. Reactions could be caused following a release of dangerous goods from waste isolation pits.

Probability of causing a major incident

The reaction of waste at sufficient scale or intensity to cause serious harm to people, property or the environment is unlikely due to waste type, form, containment, zoning and the nature of the site.

Waste delivered to the Sandy Ridge Facility would be subject to strict waste acceptance criteria. The waste acceptance criteria would be implemented through the decision process depicted in Figure 5-2. The first step in the decision process is to confirm the waste is permissible – before delivery occurs. The decision process would prohibit wastes that are highly reactive from being delivered.

Waste delivered to the Sandy Ridge Facility would often be in a solid or granular form. The form of the waste would limit its movement in the event of a release. The form of the waste would therefore limit its potential to make contact with reactive materials.

Waste would be stored in double-barrier waste containers such as double-lined bulker bags or PVC bags stored within barrels. The containment of waste in this way would limit the volume of waste that would be released in the event of a release within waste isolation pits.

Accepted waste materials would be stored in accordance with a strict zoning scheme. The zoning scheme would ensure that wastes with potentially reactive properties are physically separated. The zoning scheme is described further in section 5.3.3.

The Sandy Ridge Facility site is very remote, with no permanently occupied places in close proximity. The site is also arid with no waterways and low rainfall, limiting potential for mobilisation. As such, there are inherently few ways that people, property or the environment would be harmed in the event of a reaction involving dangerous goods.

Nature of harm to people, property or environment

In the unlikely event of a reaction involving dangerous goods - the nature of harm to people, property or the environment would depend on its scale or intensity but would be limited by the waste type, form, containment, zoning and the nature of the site as described above. The consequences of a reaction are nonetheless considered serious.

Risk control measures

The following risk control measures are integral to the planning of the Sandy Ridge Facility and would serve to control the risk of a release of dangerous goods during handling of waste.

- Implement strict waste acceptance criteria
- Store waste material according to zoning scheme
- Provide extensive training to Sandy Ridge Facility workers
- Enforce appropriate use of personal protective equipment
- Conduct regular toolbox meetings to promote awareness of risks
- Develop clear operational procedures for handling dangerous goods
- Ensure all machinery and equipment used in handling is maintained
- Include spill controls in design of waste isolation pits such as bunds
- Include fire detection and suppression systems in facility design
- Maintain an emergency response and management plan

It is considered that the above measures would make the risk of a reaction of dangerous goods at waste isolation pits as low as reasonably practicable.

6.2.14 Exposure to radiation from waste isolation pits

Overview of hazard

The handling of radioactive waste at the Sandy Ridge Facility is an activity that could be the cause of a major incident and is therefore considered a key risk. The specific hazard exposure to radiation at sufficient intensity to cause serious harm to people, property or the environment.

Waste delivered to the Sandy Ridge Facility could include any combination of the wastes that meet the waste acceptance criteria outlined in section 5.3. Some of these wastes could lead to radiation exposure if released. Exposures could be caused by highly radioactive waste or inadequate storage and isolation in waste isolation pits.

Probability of causing a major incident

The exposure of radiation at sufficient intensity to cause serious harm to people, property or the environment is unlikely due to waste type, waste storage and the nature of the site.

Waste delivered to the Sandy Ridge Facility would be subject to strict waste acceptance criteria. The waste acceptance criteria would be implemented through the decision process depicted in Figure 5-2. The first step in the decision process is to confirm the waste is permissible – before delivery occurs. The decision process would prohibit wastes that are highly radioactive from being delivered. Low level or very low level radioactive material could be accepted subject to risk control measures.

Accepted radioactive material would be handled in accordance with the requirements of the *Radiation Safety Act 1975* and associated related regulations and guidelines. The requirements include standards for containment and storage which reduce risk of exposure.

The Sandy Ridge Facility site is very remote, with no permanently occupied places in close proximity. The site is also arid with no waterways and low rainfall, limiting potential for mobilisation. As such, there are inherently few ways that people, property or the environment would be harmed in the event of exposure to radioactive material.

Nature of harm to people, property or environment

In the unlikely event of exposure to radioactive material - the nature of harm to people, property or the environment would depend on the level of radioactivity but would be limited by the waste type, waste storage and the nature of the site as described above. The consequences of a release of waste are nonetheless considered serious given the potentially hazardous qualities of the waste.

Risk control measures

The following risk control measures are integral to the planning of the Sandy Ridge Facility and would serve to control the risk of exposure to radiation from waste isolation pits.

- Implement strict waste acceptance criteria
- Store waste material according to zoning scheme

- Provide extensive training to Sandy Ridge Facility workers
- Enforce appropriate use of personal protective equipment
- Conduct regular toolbox meetings to promote awareness of risks
- Develop clear operational procedures for handling radioactive waste – including compliance with the *Code of practice for the near-surface disposal of radioactive waste in Australia*
- Ensure all machinery and equipment used in handling is maintained
- Include spill controls in design of waste isolation pits such as bunds
- Include fire detection and suppression systems in facility design
- Maintain an emergency response and management plan

It is considered that the above measures would make the risk of a release of dangerous goods during delivery of waste as low as reasonably practicable.

6.2.15 Uncontrolled explosion at blast site or explosive store

Overview of hazard

The use of explosives during the construction of the Sandy Ridge Facility is an activity that could cause a major incident and is therefore considered a key risk. The specific hazard is an uncontrolled explosion at a blast site or the explosive store at sufficient intensity to cause serious harm to people, property or the environment. Uncontrolled explosions could be caused by inadequate blast design, inadequate control of blasting operations, or inadequate storage of explosives.

Probability of causing a major incident

An uncontrolled explosion at a blast site or explosive store at sufficient intensity to cause serious harm to people, property or the environment is unlikely due to the requirements for blast design, control of blasting operations, storage of explosives and the nature of the site.

Blasting during the construction of the Sandy Ridge Facility is an activity that would be carefully designed and controlled. Blast design refers to the intensity of the explosive used in a given blast. The blast design for a given activity would be the minimum necessary to achieve the construction outcome. Explosives would be controlled and stored by suitably qualified professionals and in accordance with industry standard practices.

The Sandy Ridge Facility site is very remote, with no permanently occupied places in close proximity. The site is also arid with no waterways and low rainfall, limiting potential for mobilisation. As such, there are inherently few ways that people, property or the environment would be harmed in the event of an uncontrolled explosion.

Nature of harm to people, property or environment

In the unlikely event of an uncontrolled explosion the nature of harm to people, property or the environment would depend on the blast design as described above. The potential consequence of a uncontrolled explosion are nonetheless considered serious.

Risk control measures

The following risk control measures are integral to the planning of the Sandy Ridge Facility and would serve to control the risk of an uncontrolled explosion at a blast site or the explosive store.

- Ensure handling of explosives is undertaken in accordance with legislation
- Develop clear operational procedures for explosive use and storage
- Include fire detection and suppression systems in facility design
- Maintain an emergency response and management plan

It is considered that the above measures would make the risk of an uncontrolled explosion at a blast site or explosive store as low as reasonably practicable.

6.2.16 Release of dangerous goods due to natural disaster

Overview of hazard

Natural disasters include bushfire, earthquake, cyclone or flood could be the cause of a major incident and are therefore considered a key risk. The specific hazard is a natural disaster that results in the release of a dangerous good in sufficient volume to cause serious harm to people, property or the environment. Releases could be caused by structural failure or migration of water.

Probability of causing a major incident

The release of waste in sufficient volume to cause serious harm to people, property or the environment is unlikely due to waste containment, waste form and the nature of the site.

Waste would be delivered to the Sandy Ridge Facility in ISO 20’ shipping containers. Within these shipping containers, waste would be stored in double-barrier waste containers such as double-lined bulker bags or PVC bags stored within barrels. The containment of waste in this way would limit the volume of waste that would be released in the event of a natural disaster.

Waste delivered to the Sandy Ridge Facility would often be in a solid or granular form. The form of the waste would limit its movement in the event of a release. The form of the waste would therefore limit its potential to make contact with people, property or the environment.

The physical characteristics of the Sandy Ridge Facility site effectively eliminate the possibility of contaminants escaping waste isolation pits and affecting people, property or the environment. The isolation of waste at the Sandy Ridge Facility is described further in section 5.2.

The Sandy Ridge Facility site is very remote, with no permanently occupied places in close proximity. The site is arid with no waterways and limited rainfall. As such, there are inherently few areas where people, property or the environment would be harmed in the event of a release of dangerous goods.

Nature of harm to people, property or environment

In the unlikely event of a release – the nature of harm to people, property or the environment would depend on the type of waste involved. Waste accepted at the Sandy Ridge Facility could include hazardous material with the potential to cause harm to people or the environment.

The scale of harm would likely be limited by the type and form of the waste, the containment of the waste and the nature of the site as discussed above. However, the potential consequence of a release of waste are considered serious given the potentially hazardous qualities of the waste.

Risk control measures

The following risk control measures are integral to the planning of the Sandy Ridge Facility and would serve to control the risk associated with natural disasters.

- Include fire detection and suppression systems in facility design
- Maintain an emergency response and management plan

It is considered that the above measures would make the risk of a release of dangerous goods due to a natural disaster as low as reasonable practicable.

6.3 Other risks

Other risks that did not involve dangerous goods or did not have the potential to trigger a major incident were not considered key risks. These risks were nonetheless documented and assessed in the risk register included as Attachment A.4.

7 SAFETY MANAGEMENT SYSTEM

7.1 Overview

The existing safety management system is framed around Tellus Holdings Ltd current business activities, which are mainly mineral exploration, contract negotiation and approvals.

The safety management system described here will be revised as Tellus Holdings Ltd expands its business operations into construction and operation of the Sandy Ridge facility.

Tellus Holdings Ltd operates integrated quality, environmental management and health and safety management systems in accordance with the relevant standards:

- ISO 9001 Quality management systems
- ISO 14001 Environmental management systems
- AS/NZS 4801 Occupational health and safety management systems

Revisions of the safety management system will include the matters identified in Regulation 49 of the ARPANS Regulations and Regulation 558 and Schedule 17 of the WA WHS Regulations.

7.2 Policies and objectives

Tellus Holdings Ltd implements a range of policies and associated objectives including:

- Health & safety
- Environmental management
- Community relations
- Fitness for work
- Smoking & ignition source
- Workplace rehabilitation
- Sustainability development
- Quality
- Sponsorship

These policies include a commitment for continual review and improvement. Tellus Holdings Ltd policies are provided on their website – www.tellusholdings.com

7.3 Institution control period

Institutional Control is the period in which control of a radioactive waste site, or major hazard facility, is controlled by an authority or institution designated under the laws of a jurisdiction. Control may be active (monitoring, surveillance, remedial work) or passive (land use control) and

may be a determining factor in the design of a waste management facility (e.g. near surface repository).

At this stage of pre-development, an Institutional Control Period for planned active institutional controls has not yet been agreed or established for the proposed Sandy Ridge facility. Based on international and national research, and the current ICP for the Mt Walton East IWDF, Tellus propose a 100 year ICP for the Sandy Ridge facility.

The safety assessment will be maintained and updated during the operational and active institutional control period over Sandy Ridge's lifetime, taking into account increased experience and monitoring results.

7.4 Further development

The safety management system described here will be further developed as Tellus Holdings Ltd expands its business operations into construction and operation of the Sandy Ridge facility. This further development would benefit from ongoing work including detailed design and include:

- Revision of policies and objectives
- Detailed development of operation controls
- Detailed development of emergency response plan
- Consultation with workers at the Sandy Ridge Facility
- Ongoing performance reviews and auditing of safety management system.

8 EMERGENCY PLAN

Under regulation 557 of the WHS Regulations, the operator of a major hazard facility is required to prepare an emergency plan. The emergency plan is based on:

- Industry standards and regulatory guidance.
- Professional expertise within Tellus Holdings Ltd.
- Hazard identification and safety assessment.

A summary of the emergency plan for the proposed Sandy Ridge facility is presented below and detailed in Attachment A.8.

9 CONSULTATION

9.1 Overview

Tellus is currently in the pre-development stage of the Sandy Ridge proposal. This stage involves conceptual design, environmental impact assessment and approvals management. During this stage, Tellus has undertaken regular consultation with key government stakeholders at the Commonwealth and State Departments.

Tellus has also undertaken two rounds of regional community consultation at Kalgoorlie and Coolgardie. The Community "drop-in" sessions have focused on delivering information on the scope of the Sandy Ridge project including illustrations of the proposed Sandy Ridge facility.

Under regulation 575 of the WHS Regulations, Tellus is required to consult with workers at the Sandy Ridge facility in the development of the safety case, safety management system and emergency plan.

As Sandy Ridge is a proposed facility, the potential for consultation with workers during the preparation of the outline safety case is limited.

If the proposal is approved, consultation with workers will be undertaken as Tellus Holdings Ltd expands its business operations into construction and operation of the Sandy Ridge facility.

Future consultation will be undertaken during PSR's of the safety case as recommended by ARPANSA. The development of safety protocols, safety induction of workers, and construction and operation activities will also be undertaken throughout the various lifecycles of the project.

Future consultation activities will include the matters identified in regulation 574 and regulation 575 of the WHS Regulations.

10 CONCLUSION

The purpose of this OSC report is to demonstrate that the Sandy Ridge Facility can be operated safely and in accordance with the law.

This OSC reflects the findings of a whole of life cycle risk assessment, the development of a safety management system and a range of other supporting material.

The OSC report will be periodically reviewed as Tellus moves into construction and operations or otherwise as stipulated in regulation 30 of the Dangerous Goods Safety (Major Hazard Facilities) Regulations 2007. Periodic reviews of the safety report would involve consultation with employees, including those directly involved in construction and operation of the Sandy Ridge Facility.

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http://www.safeworkaustralia.gov.au/sites/SWA/about/Publications/Documents/666/Safety%20Case%20Demonstrating%20the%20Adequacy.pdf

Safe Work Australia 2012d

Safe Work Australia 2012e
http://www.safeworkaustralia.gov.au/sites/SWA/about/Publications/Documents/668/Notification%20and%20Determination.pdf

Safe Work Australia 2012f
http://www.safeworkaustralia.gov.au/sites/SWA/about/Publications/Documents/669/Safety%20Assessment.pdf

Safe Work Australia 2012g
http://www.safeworkaustralia.gov.au/sites/SWA/about/Publications/Documents/670/Information,%20Training%20and%20Instruction.pdf

Safe Work Australia 2012h
http://www.safeworkaustralia.gov.au/sites/SWA/about/Publications/Documents/671/Safety%20Management%20Systems.pdf

Safe Work Australia 2012i
http://www.safeworkaustralia.gov.au/sites/SWA/about/Publications/Documents/676/DevelopingASafetyCaseOutline.pdf

Terra Search 2014, Mineral Resource Estimate Sandy Ridge Kaolin Deposit Goldfield Region Western Australia, Commercial in confidence.

Terra Search 2016, Baseline Radiation and Metals Report, Commercial in confidence.

12 ATTACHMENTS

A.1 Tellus outline safety case checklist

Dangerous Goods Safety (Storage and Handling of Non-explosives) Regulations 2007	Cross-reference
26.Licence, applying for	
(1)A person may apply to the Chief Officer to grant a licence.	
(2)The application must be in an approved form and be accompanied by —	
(a)a location plan showing the position of the dangerous goods site relative to any roads, railways and buildings; and	
(b)the risk assessment that would be required by regulation 48 for the site if it were licensed; and	
(c)the manifest, and the dangerous goods site plan, that would be required by regulation 78 for the site if it were licensed; and	
(d)any other relevant document that is required by the approved form; and	
(e)unless a fee would be payable under the Dangerous Goods Safety (Major Hazard Facilities) Regulations 2007 regulation 34 in respect of the site if the licence were granted, the annual fee for the first year of the licence; and	
(f)if the application is not accompanied by a certificate issued under subregulation (3), a checking fee equal to the amount (if any) required to be paid under paragraph (e).	
(3)In addition to any document that is required to accompany the application, it may be accompanied by a certificate that complies with subregulation (4) and is signed by a person approved by the Chief Officer.	
(4)A certificate given by a person under subregulation (3) must certify that the person —	
(a)has read the application; and	
(b)is satisfied the application complies with subregulation (2); and	
(c)has read the risk assessment; and	
(d)is satisfied the risk assessment —	
(i)identifies all the risks to people, property and the environment in relation to the dangerous goods that would be on the site to which the licence would relate; and	
(ii)identifies all reasonably practicable measures to minimise those risks; and	
(e)is satisfied the manifest complies with Schedule 3 Division 2; and	
(f)is satisfied the dangerous goods site plan complies with Schedule 3 Division 3.	
48.Risk assessment, requirements as to	
[(1)deleted]	
(2)The operator of a dangerous goods site, at which more than the manifest quantity of dangerous goods are stored, must ensure that a risk assessment is made of the dangerous goods stored or handled at the site and that a record is kept of the assessment.	

(2A)For the purposes of subregulation (2), in making a risk assessment of the dangerous goods stored or handled at a site the operator of the site may make a judgment in relation to the assessment of the risk posed by a hazard and the risk control measures for the hazard by reference to compliance with a code of practice approved under section 20 of the Act.	

Dangerous Goods Safety (Major Hazard Facilities) Regulations 2007	Cross-reference
Part 5 — Safety reports	
23.Risk assessment, operator of major hazard facility to prepare	
(1)The operator of a major hazard facility must prepare a risk assessment for the facility.	
(2)A risk assessment for a facility is a document that —	
(a)identifies all hazards relating to dangerous goods at the facility as it exists, or as the operator expects it will exist, at the relevant time; and	
(b)for each hazard, assesses —	
(i)the probability of the hazard causing a major incident; and	
(ii)the nature of the harm to people, property and the environment that is likely to result from the occurrence of that incident; and	
(c)for each hazard, identifies the measures (risk control measures) that will eliminate or, if it is not reasonably practicable to eliminate, that will reduce so far as reasonably practicable —	
(i)the probability of the hazard causing a major incident; and	
(ii)the harm to people, property and the environment that is likely to result from the occurrence of that incident; and	
(d)records the method of reasoning used to determine the matters referred to in paragraphs (a) to (c); and	
(e)has been prepared in consultation with employees and records the details of the consultation; and	
(f)is in a form acceptable to the Chief Officer.	
(3)A risk assessment is prescribed to be a safety management document for the purposes of the definition of safety management document in the Act section 3(1).	
24.Safety management system, operator of major hazard facility to prepare	
(1)The operator of a major hazard facility must prepare a safety management system for the facility	
(2)A safety management system for a facility is a document that —	
(a)records the policies and procedures for implementing and managing the risk control measures identified in the risk assessment for the facility, including the procedures referred to in Schedule 4; and	
(b)has been prepared in consultation with employees and records the details of the consultation; and	
(c)is in a form acceptable to the Chief Officer.	

(3)A safety management system is prescribed to be a safety management document for the purposes of the definition of safety management document in the Act section 3(1).	
25.Safety report, operator of major hazard facility to prepare	
(1)The operator of a major hazard facility must prepare a safety report for the facility.	
(2)A safety report for a facility is a document that —	
(a)contains the notifiable information for the facility as it exists, or as the operator expects it will exist, at the relevant time; and	
(b)identifies the risk assessment prepared for the facility and states where the risk assessment is available for inspection by the Chief Officer; and	
(c)identifies the safety management system prepared for the facility and states where the safety management system is available for inspection by the Chief Officer; and	
(d)is in a form acceptable to the Chief Officer.	
(3)A safety report is prescribed to be a safety management document for the purposes of the definition of safety management document in the Act section 3(1).	
26.Safety report, application for approval of	
(1)An application for approval of a safety report for a facility must —	
(a)be made to the Chief Officer in an approved form; and	
(b)if it is the first application for approval of a safety report for the facility — be accompanied by the relevant fee specified in Schedule 3 clause 1.	
Schedule 2 — Notifiable information	
The following information is notifiable information —	
(a)if the operator of the place is a corporation, the corporation's full corporate name, trading name, Australian Company Number, registered address and place of business and the nature of the corporation's business;	
(b)if the operator of the place is an individual, the person's full name, residential address and business address, any business name used by the person and the nature of the person's business;	
(c)the location of the place;	
(d)land use and zoning for the area surrounding the place;	
(e)for each kind of dangerous goods at the place, its name, a copy of its material safety data sheet and the quantity at the place;	
(f)the nature of the business or other activity conducted at the place, including the nature of the presence of dangerous goods in the course of conducting the business or activity;	
(g)the number of employees at the place;	
(h)plans showing the layout of the place and where dangerous goods are to be stored, handled or transported within that place.	
Schedule 4 — Procedures to be included in safety management system	
1.Skills etc. of employees, procedures to ensure	

The procedures for ensuring that each employee who fills an employee position to which a task is allocated under the safety management system has the necessary skills and knowledge to undertake all tasks for which he or she has responsibility under the safety management system.	
2.Operation etc. of plant etc., procedures for	
(1)The procedures for —	
(a)ensuring the safe operation of plant; and	
(b)ensuring that plant is properly maintained; and	
(c)shutting down or decommissioning plant.	
(2)The procedures for isolating the whole or part of the facility if an emergency occurs.	
(3)The procedures for managing alarm systems.	
3.Security, procedures to ensure	
The procedures for preventing unauthorised acts that could cause a major incident and for preventing acts intended to cause a major incident.	
4.Safety information, procedures to ensure employees are given	
(1)The procedures for informing employees about —	
(a)the risk assessment; and	
(b)the safety management system.	
(2)The procedures for informing persons who are not employees, but who are present at the facility, of the safety measures they are required to take while at the facility.	
(3)The procedures for ensuring the community, local governments for the districts in which the community resides and emergency services are informed about —	
(a)the use of dangerous goods at the facility; and	
(b)the risk assessment; and	
(c)the actions members of the community should take if a dangerous situation or major incident occurs.	
5.Risk control measures, procedures to ensure monitoring of etc.	
(1)In this clause — risk control measures has the meaning given in regulation 23(2)(c).	
(2)Procedures for monitoring the effectiveness of risk control measures.	
(3)Procedures for monitoring the effectiveness of, and compliance with, the safety management system.	
(4)Procedures for using the information obtained from monitoring to improve safety at the facility.	

A.2 Conceptual facility layout

A.3 Facility drawings

To be completed upon completion of detailed design.

A.4 Risk assessment

Risk Number	Environmental Aspect	Sources of Risk (Hazard)	Potential Environmental Impact (Worst case)	Pre–management risk	Management and Mitigation Measures	Post–management Risk		Residual risk
						Likelihood	Consequence	
1	**Transport of hazardous/intractable waste.**	Chemical spill (40 t) from the shipping container. Chemical spill onto roads.	Death and/or acute or chronic illness in humans and biota exposed to the spill.	Extreme	Waste packaged in bulka bags/drums. Bulka bags/drums transported inside shipping container. Shipping container securely fastened to truck. Dangerous goods (DG) rated trucks (e.g. better brakes, rollover systems) are used only. Trucks travel on sealed roads or controlled site access roads. Transport contractor on Tellus Register of Approved Transporters. Audits of transport contractor's procedural controls. For high risk loads (e.g. arsenic trioxide) individual risk assessment and transport management plan. Emergency Response and Management Plan.	Rare	Catastrophic	High
2	**Explosions.**	Fuel storage facility, storage and use of gas. Diesel fuel tank and piping reticulation. Explosives magazine.	Degradation of air quality (localised). Death/injury of humans and biota within the vicinity of the blast zone or in the path of the fire. Creates bushfire.	Extreme	Fuel storage facilities and systems designed to meet relevant Code. Inspection to ensure compliance including maintenance. Firebreaks. Firefighting equipment. Operational procedures. Hot work permits. Restricted access to the explosives store (i.e. must hold shot firer licence).	Rare	Major	High
3	**Transport of hazardous/intractable waste.**	Truck crash.	Death and injury to humans.	High	Trucks travel on sealed main roads only. Transport contractor on Tellus Register of Approved Transporters. Well maintained trucks. Approved, experienced and licensed drivers. Audits of transport contractor's procedural controls. Emergency Response and Management Plan. Police, emergency services.	Rare	Catastrophic	High
4	**Transport of hazardous/intractable waste.**	Chemical spill (e.g. flyash/ SPL) on the road, into surrounding environment (e.g. river).	Death and/or injury to fauna and flora.	High	Waste packaged as appropriate to level of hazard. Bulka bags/drums transported inside shipping container. Shipping container securely fastened to truck. DG rated trucks (e.g. better brakes,	Possible	Moderate	High

Risk Number	Environmental Aspect	Sources of Risk (Hazard)	Potential Environmental Impact (Worst case)	Pre–management risk	Management and Mitigation Measures	Post–management Risk Likelihood	Post–management Risk Consequence	Residual risk
					rollover systems) are used only. Trucks travel on sealed roads or controlled site access roads. Transport contractor on Tellus Register of Approved Transporters. Audits of transport contractor's procedural controls. For high risk loads (e.g. arsenic trioxide) individual risk assessment and transport management plan. Emergency Response and Management Plan.			
5	**Transport of hazardous/intractable waste.**	Collision with native fauna.	Road kill of Threatened/Priority fauna.	High	Trucks travel on sealed main roads only. Transport contractor on Tellus Register of Approved Transporters. Well maintained trucks. Approved, experienced and licensed drivers. Audits of transport contractor's procedural controls. Report to DPAW and DotE. Where feasible control speed and use headlights.	Possible	Moderate	High
6	**Creation of mine pits.**	Clearing native vegetation.	Loss of native vegetation.	High	Avoid Priority species. Engineering design to minimise amount of vegetation to be cleared. Supervision of clearing. Operational Procedure. Regular toolbox meeting. Training of Operators.	Almost Certain	Insignificant	High
7	**Creation of firebreak.**	Clearing native vegetation.	Opportunity for weeds to establish.	High	Weed monitoring and removal.	Almost Certain	Insignificant	High
8	**Transport of radioactive waste.**	Radioactive waste spill (200L drum).	Humans within the vicinity of the spill will receive a one off higher dose of radiation above background levels.	High	Small quantities received on average annually. Drums transported inside shipping container. Shipping container securely fastened to truck. Priority given to transporting on heavy haulage routes. For all radioactive waste an individual risk assessment is completed. Disposal permit issued by government. Transport contractor on Tellus Register of Approved Transporters. Audits of transport contractor's procedural controls. Emergency Response and Management Plan. Inform Radiation Health Branch WA.	Unlikely	Moderate	Moderate

Risk Number	Environmental Aspect	Sources of Risk (Hazard)	Potential Environmental Impact (Worst case)	Pre–management risk	Management and Mitigation Measures	Post–management Risk		Residual risk
						Likelihood	Consequence	
9	**Presence of infrastructure (e.g. turkeys nest, landfill, mine voids).**	Attraction of birds, mammals, vermin and feral animals to water source. Fauna falling into pit/cell. Presence of vermin carrying disease at landfill, being eaten by predators.	Injury or death of Threatened/Priority fauna.	High	Fencing of contaminated water pond. Fencing around landfill. Covering of landfill once the trench is full. Weekly litter inspection and clean-up. Weekly toolbox meeting. Training of operators. Operational bunding around cell. Ramps into and out of cell. Daily inspection of water ponds for trapped/injured fauna. Daily inspections of access roads for roadkill.	Unlikely	Moderate	Moderate
10	**Naturally occurring events.**	Bushfire.	Injury of workers and site visitors. Toxic smoke plume. Contaminated fire water. Soil contamination.	High	Emergency Response and Management Plan. Low fuel load in woodlands. Firebreaks. Firefighting facilities onsite. Minimal flammable waste, facilities and goods onsite.	Rare	Moderate	Moderate
11	**Introduction of weeds.**	Incoming waste carriers. Incoming supply vehicles and 4wds. Incoming site visitors, staff vehicles. Bird poo.	Establishment of weeds on the site and competition for resources (e.g. water) with native vegetation.	High	Weed monitoring procedures. Inspections of light vehicles and brush downs. Mining plant wash down before its used onsite. Weed removal where necessary.	Likely	Insignificant	Moderate
12	**Accidental fire within infrastructure.**	Flammable goods packed into shipping container. Vehicle fire in cell. Fire in buildings.	Release of toxic gas, adverse health impacts to workers/public/fauna.	High	Equipment maintenance. Fire detection/ suppression systems. Design codes for waste storage. Operational procedures. Regular toolbox meetings. Training of operators. Chemical wastes stored in shipping containers. Use of diesel engines instead of petrol in storage areas. Multiple waste storages areas in container hardstand.	Rare	Moderate	Moderate
13	**Handling of hazardous/intractable waste.**	Chemical spill during offloading of waste from ADT into cell. Chemical spill during manoeuvring of waste package into place in the cell.	Death of worker in the cell.	Extreme	PPE. Training of operators. Regular toolbox meetings. Operating procedures. Restricted access to the cell. Recirculating air throughout cabs. JSAs specific to waste being handled. Equipment maintained. Secondary egress from cell. Everyone in the cell immediately evacuates.	Unlikely	Minor	Low
14	**Creation of cell and waste disposal progressing.**	Surface water runoff into cell.	Generation of leachate and degradation of groundwater.	Extreme	Roof canopy over open cell. Operational bunding around cell,	Rare	Insignificant	Low

Risk Number	Environmental Aspect	Sources of Risk (Hazard)	Potential Environmental Impact (Worst case)	Pre–management risk	Management and Mitigation Measures	Post–management Risk Likelihood	Post–management Risk Consequence	Residual risk
					drains into V drain and sump. Levees to divert surface water flow. Backfill around waste packages with high matric suction potential. Primary containment in place in each waste package (e.g. liner in bulka bag).			
15	**Handling of hazardous/intractable waste.**	Chemical spill during unloading/reloading of waste from/into shipping container in Waste Inspection Shed. Chemical spill during sampling and testing of waste package in laboratory.	Death and/or acute or chronic illness in humans exposed to the spill.	High	Operating procedures. Training of operators. Regular toolbox meetings. PPE. Regular equipment maintenance. Visual assessment. Safety shower. Spill kits. First aiders/first aid kit. Evacuation procedure.	Rare	Minor	Low
16	**Handling of hazardous/intractable waste.**	Vehicle collision with ADT. Loss of containment from shipping container subsequent spill of solids.	Localised soil contamination. Damage to vegetation. Toxic dust dispersal affecting vegetation/fauna off the development envelope.	High	Operating procedures. Training of operators. Regular toolbox meetings. Onsite traffic management. Speed limits. Two-way communications. Regular equipment maintenance. Visual assessment. Spill kit.	Rare	Minor	Low
17	**Handling of radioactive waste.**	NORMs spill during unloading/reloading of waste from/into shipping container in Waste Inspection Shed.	Humans within the vicinity of the spill will receive a one off higher dose of radiation above background levels.	High	Operating procedures. Training of operators. Regular toolbox meetings. PPE. Regular equipment maintenance. Visual assessment. Safety shower. Spill kits. First aiders/first aid kit. Dose meters on workers. Radiation measurements.	Rare	Minor	Low
18	**Handling of radioactive waste.**	Gamma exposure during offloading of waste from ADT into shaft.	Humans within the vicinity of the shaft above with higher dose of radiation above background levels or chemical exposure.	High	Operating procedures. Training of operators. Regular toolbox meetings. Engineering design. Dose meters. Radiation measurements. Exclusion zones.	Rare	Insignificant	Low
19	**Wash down of shipping containers.**	Contaminated wash water washes off the wash down pad. Dust on hardstand from, residual of wash down. Containment overflows during extreme rainfall event. Liner faulty/fails.	Soil contamination.	High	Operating procedures. QA/QC testing on liner. Engineering design (500mm freeboard, ponds sufficient capacity). Shallow monitoring bores. Contain the overflow through secondary sump.	Unlikely	Minor	Low

Risk Number	Environmental Aspect	Sources of Risk (Hazard)	Potential Environmental Impact (Worst case)	Pre–management risk	Management and Mitigation Measures	Post–management Risk Likelihood	Post–management Risk Consequence	Residual risk
					Clean-up/disposal of contaminated soil.			
20	**Creation of mine pits.**	Blasting. Physical removal of topsoil, subsoil and kaolin.	Dust emissions affecting workers. Dust emissions settling on plant leaves, affecting photosynthesis and potentially killing plants. Noise emissions affecting workers. Noise emissions temporarily or permanently damaging the hearing of fauna in the vicinity of the blast.	High	Operating procedures. Blasting conducted once per year, duration of a few seconds. PPE for workers.	Unlikely	Insignificant	Low
21	**Construction and operation of water pipeline.**	Leak/spill of saline water.	Death of vegetation through osmosis of saline water.	High	Design controls to monitor flow through pipeline, any loss will immediately trigger an alarm in the process control unit. Close isolation valves. Cease pumping water. Inspect water pipeline and repair damaged section.	Unlikely	Minor	Low
22	**Use of saline water for dust suppression**	Watering of native vegetation along roadsides.	Uptake of saline/brackish water and death of vegetation.	High	Use a dribble bar on the back of the water cart instead of a spray bar. Equipment maintenance. Operational procedures.	Unlikely	Minor	Low
23	**Fencing of the waste cells.**	Exclusion of fauna from potential habitat.	Forced translocation of fauna into other habitat and increased predation in new habitat. Potential for injury/death of Threatened/Priority fauna.	High	Fences to be removed following revegetation of cells.	Rare	Insignificant	Low
24	**Waste Laboratory.**	Minor spill of sample during testing of waste.	Radiation exposure of workers. Injury (e.g. chemical burn) to workers.	High	Building enclosed and contains fume hoods. PPE. Operational procedures for waste testing. Training of operators. Regular toolbox meetings.	Unlikely	Minor	Low
25	**Water retention ponds.**	Leak/crack in pond liners.	Release of contaminated water to underlying and surrounding soils and potentially damage vegetation associated with those soils.	High	Shallow monitoring bores. Low hydraulic conductivity means water will not move far from the spill site. Contain and clean-up the spill. Operational procedure for management of contaminated soils.	Unlikely	Insignificant	Low
26	**Naturally occurring events.**	Earthquakes (size 3)	Slight subsidence of cell, consolidates backfill and potential creates a void.	High	Post event inspection and records kept. Repair cap if needed. Subsidence monitoring.	Possible	Insignificant	Low
27	**Naturally occurring events.**	Cyclones/flood	Increased rainfall at the site, overflow of contaminated water ponds which may impact surrounding soils, cause widespread flooding of contaminated surface water and injure/kill biota. Cell fills with water and leachate generated	High	Small quantities of water. 24 hour duration. Pumping out of ponds prior to cyclone. Roof canopy over open cell. Operational bunds around cells. Waste still in shipping containers.	Unlikely	Insignificant	Low

Risk Number	Environmental Aspect	Sources of Risk (Hazard)	Potential Environmental Impact (Worst case)	Pre–management risk	Management and Mitigation Measures	Post–management Risk Likelihood	Post–management Risk Consequence	Residual risk
			and then overflows to surrounding environment.		Waste disposal halted if cyclone expected.			
28	**Aboriginal heritage.**	Destruction of aboriginal heritage site and/or cultural association. E.g. clearing native vegetation of significance, excavating land of significance, and storing waste on significant land.	Degradation of heritage value of the local area.	High	Aboriginal heritage pre-construction survey. Operational procedure for encountering aboriginal cultural material. Contact WA Police if skeletal material is uncovered.	Rare	Minor	Low
29	**Malleefowl mound.**	Construction of pipeline. Construction of road and plant.	Removal or damage to an active nesting mound.	High	Malleefowl survey pre-construction to identify new active mounds. Re-design pipeline route to avoid mound. Report disturbance to an active mound to DPAW and DotE.	Rare	Insignificant	Low
30	**Landform.**	Change in landform by placing domed caps up to 5m higher than the landscape.	Ponding around the toe of the landform. Erosion.	Moderate	Engineering design. Engineering design as constructed plans demonstrated cell backfilling/capping competently constructed. Long term erosion modelling. Revegetation present.	Unlikely	Insignificant	Low
31	**Transport of chemical and radioactive waste.**	Leak of liquid material (e.g. NORM and/or hydrocarbons) from shipping container.	Humans within the vicinity of the leaked material may receive a one off higher dose of radiation above background levels or chemical exposure.	Low	Waste packaged as appropriate to level of hazard. Trucks travel on sealed roads or controlled site access roads. Transport contractor on Tellus Register of Approved Transporters. DG rated trucks (e.g. carry clean-up equipment and drivers are trained to manage a leak). Audits of transport contractor's procedural controls. Truck parked up. Source of the leak is investigated and contained. Clean-up undertaken. Emergency Response and Management Plan.	Rare	Insignificant	Low
32	**Subsurface waste disposal**	Permanent isolation of waste over geological time.	Gamma radiation exposure at the surface on surrounding humans, soils, flora and vegetation and fauna.	Low	Safety Case and Safety Assessment. Baseline radiation survey. Engineering design - depth of burial in shaft and materials used in construction. Institutional control period.	Rare	Insignificant	Low
33	**Creation of mine pits**	Alteration to surface water runoff.	Changes hydrology (quality and quantity) and effects on downstream vegetation.	Low	High infiltration rate (500mm/day). High evaporation rate (2400mm/year). Vegetation likely to be dependent only on landing rainfall, not runoff. Vegetation adapted to low rainfall (<250mm/year).	Rare	Insignificant	Low

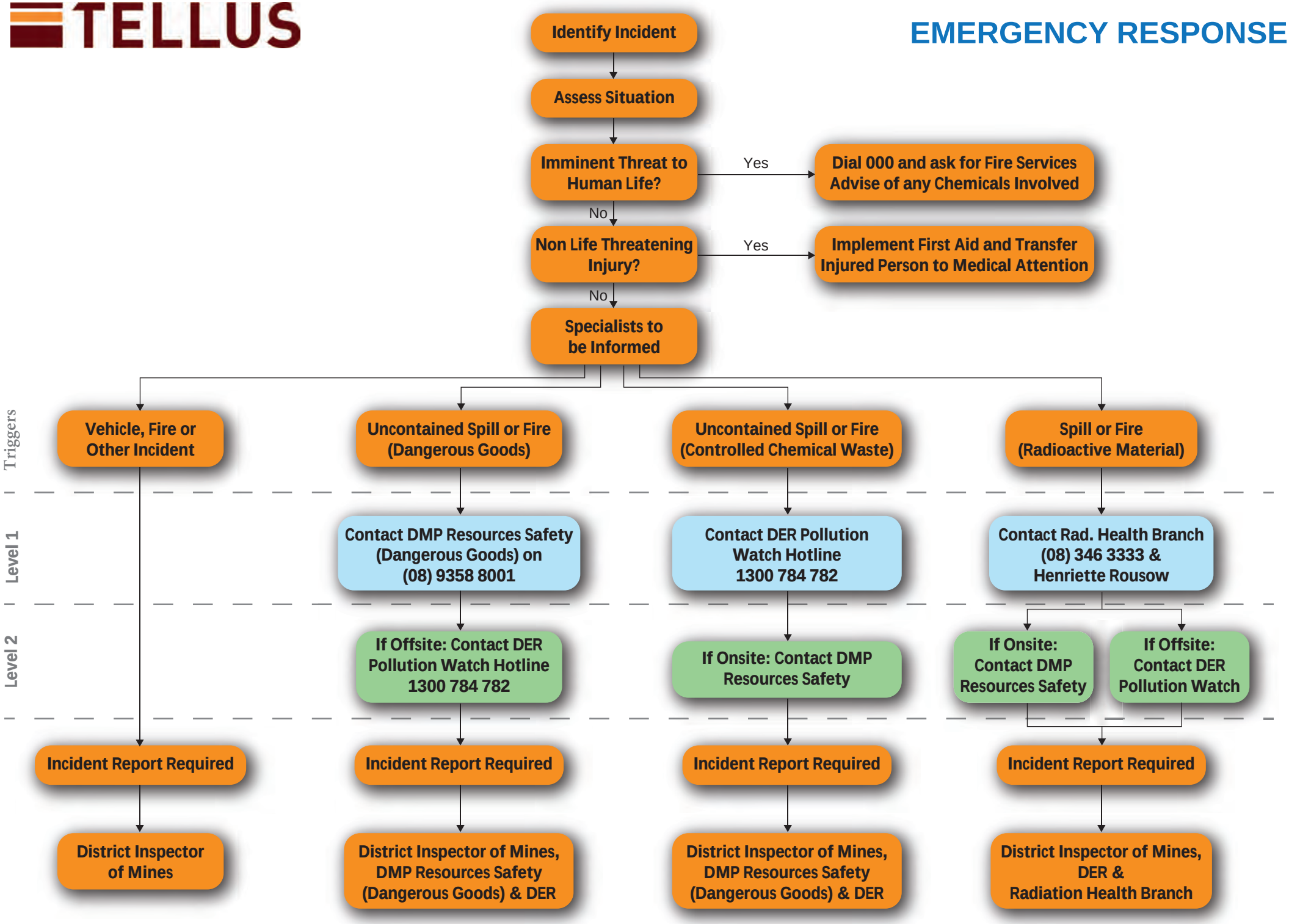
Risk Number	Environmental Aspect	Sources of Risk (Hazard)	Potential Environmental Impact (Worst case)	Pre–management risk	Management and Mitigation Measures	Post–management Risk		Residual risk
						Likelihood	Consequence	
34	**Kaolin Process Plant**	Operation of the plant. Incorrect disposal of wastes (e.g. waste oil, oily rags)	Dust emissions affecting workers. Dust emissions settling on plant leaves, affecting photosynthesis and potentially killing plants. Noise emissions affecting workers. Noise emissions temporarily or permanently damaging the hearing of fauna in the vicinity. Hydrocarbon contamination of soils.	Low	Wet process. Building enclosed and contains dust extraction system (e.g. baghouse). PPE. Noise levels monitored to comply with OHS Regulations. Operational procedures. Training of operators. Regular toolbox meetings. Oily waste disposed offsite.	Rare	Insignificant	Low
35	**Water abstraction from Carina pit**	Create a cone of depression within the Carina pit.	Change to groundwater aquifer (quality and quantity) at Carina pit	Low	Measurements of quality and drawdown of the water within the pit. Monitor abstraction volumes. Groundwater modelling to confirm cone of depression.	Unlikely	Insignificant	Low
36	**Failure of waste cell containment, cell instability/collapse during operations.**	Placement of liquid/gas waste packages into the cell. Over time voids are created in the cell. Generation of leachate as water infiltrates the cell. Failure of cell wall and/or cap. Faulty design. Faulty construction - waste package placement/backfill. Differential settlement. Earthquake. Intentional disturbance to the cell to retrieve radioactive material.	Degradation of groundwater quality.	Low	Seepage rate low. High evaporation rate. High evapotranspiration rates. High energy hydrological environment. Large unsaturated zone and storage capacity beneath each cell. Backfill material is unsaturated and can store water. No aquifer within weathered granite. No groundwater dependent vegetation, Threatened species or TECs/PECs. Engineering design/site selection based on international best practice for near surface geological repositories. Operational procedures for appropriate wastes and waste acceptance criteria. Training of operators. Subsidence monitoring of cap. Groundwater monitoring.	Rare	Insignificant	Low
37	**Waste package comprising a sealed source arrives with an activity concentration >3,700 Bq/g arrives at the site.**	The waste package exceeds the waste acceptance criteria and will not be <370 Bq/g at the end of the institutional control period (300 years).	Potential exposure of workers during handling of the waste package.	Low	Disposal permit issued. Proforma issued. Inspection and measurement of all sealed sources on arrival at site. Dose meters attached to workers.	Rare	Minor	Low
38	**Waste package comprising a sealed source arrives with a half-life greater than 30 years and is placed in the cell.**	The waste package exceeds the waste acceptance criteria and will not be <370 Bq/g at the end of the institutional control period (300 years).	Acute or chronic radiation exposure possible to the public utilising the land in 300 years' time.	Low	Disposal permit issued. Proforma issued. Inspection and measurement of all sealed sources on arrival at site. Depth of burial. Operational procedures.	Rare	Insignificant	Low
39	**Erection of buildings**	Kaolin processing plant will be the tallest building.	Change to visual amenity of people conducting nature based tourism activities in	Low	Normal travel routes on existing roads will not be affected by Tellus	Rare	Insignificant	Low

Risk Number	Environmental Aspect	Sources of Risk (Hazard)	Potential Environmental Impact (Worst case)	Pre–management risk	Management and Mitigation Measures	Post–management Risk		Residual risk
						Likelihood	Consequence	
		Tourists will not be allowed to enter the mine site.	Mount Manning Range Nature Reserve, Mount Manning - Helena - Aurora Ranges Conservation Park. Interference with scientific studies in existing and proposed reserve system.		operations. 10 km distance from nearest existing reserve (Mount Manning Range) and unlikely the kaolin processing plant will be visible from this distance. There is not expected to be an encounter with scientists within ex-Jaurdi Pastoral Lease, given operations will be outside of the Lease area.			
40	**Surface water**	Leak or spill from a waste package.	Degradation of water quality.	Low	Minimal volumes of surface water that will be present at the time of a spill/leak (i.e. surface water flows only in extreme rainfall events). Various barriers around, and integrity of, the waste package itself. Factors that affect leachability of solid waste. Unloading of waste packages within enclosed warehouses with bunded concrete floors. Distance to nearest receptor (48 km away).	Rare	Insignificant	Low

A.5 Emergency Plan

TELLUS

EMERGENCY RESPONSE



Outline Operating Strategy

TELLUS

TELLUS

SANDY RIDGE FACILITY
OUTLINE OPERATING STRATEGY

Final Report | November 2016

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Document control

Rev	Issue date	Description	Originator	Checked	Approved
1	08/11/2016	Outline Operating Strategy	C Dorrington	R Phillips	

Disclaimer

This Outline Operating Strategy has been prepared as part of the Sandy Ridge Public Environmental Review (PER)which has been prepared for submission to the Western Australian Environmental Protection Authority for the purpose of the Minister for Environment making a determination regarding whether to approve Tellus Holding Limited's Proposal under the Western Australian Environmental Protection Act 1986. This PER has been developed for this purpose only, and no one other than the Environmental Protection Authority or the Minister should rely on the information contained in this PER to make any decision.

In preparing the draft Public Environmental Review (PER) Tellus has relied on information provided by specialists' consultants, government agencies and other third parties available during the preparation period. Tellus has not fully verified the accuracy or completeness except where expressly acknowledged in the draft PER.

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ABBREVIATIONS

ADG Code	Australian Dangerous Goods Code
ADT	Articulated dump truck
HLW	high level waste
ILW	Intermediate level waste
LLW	Low level waste
PER	Public Environmental Review
MCP	Mine Closure Plan
NATA	National Association of Testing Authorities
NEPM	National Environment Protection Measure
PPE	personal protective equipment
TETS	Tellus Electronic Tracking System
VLLW	very low level waste
VSLW	very short lived waste
WAC	waste acceptance criteria

GLOSSARY

Controlled waste	controlled waste means any matter that is — (a) within the definition of waste in the NEPM for the Movement of Controlled Waste between States and Territories; and *(b)* listed in Schedule 1 of the *Environmental Protection (Controlled Waste) Regulations 2004*
Customer	The owner of the waste. This may include a Waste Management Contractor company.
High level waste	HLW Has high levels of activity that generates significant quantities of heat by radioactive decay that needs to be considered in the design of a disposal facility.
Institutional Control Period	Following closure of the disposal facility, public access to, or alternative use of, the site shall be restricted for a predetermined period of time.
Intermediate level waste	Contains increased quantities of long-lived radionuclides and needs an increase in the containment and isolation barriers compared to LLW. ILW needs no provision for heat dissipation during storage and disposal. Long- lived radionuclides such as alpha emitters will not decay to a level of activity during the time for which institutional controls can be relied upon.
Intractable waste	Waste which is a management problem by virtue of its toxicity or chemical or physical characteristics which make it difficult to dispose of or treat safely, and is not suitable for disposal in Class I, II, III and IV landfill facilities.
Low level waste	LLW may include short lived radionuclides at higher levels of activity concentration, and also long-lived radionuclides, but only at relatively low levels of activity concentration. LLW covers a very wide range of radioactive waste, from waste that does not require any shielding for handling or transportation up to activity levels that require more robust containment and isolation periods of up to a few hundred years. LLW is generated in industry, hospitals and nuclear facilities and comprise of contaminated laboratory items such as paper, clothing, plastic and glassware, soil, smoke detectors, medicinal and industrial materials.

Register	Tellus' register of Transport Contractors who are approved for transport of hazardous wastes to the Sandy Ridge site.
Transport contractor	A Transport Contractor or commercial freight service. The Transport Contractor includes the principal company, all vehicles and operators and independent sub-contractors.
Very low level waste	VLLW does not need a high level of containment and isolation. Concentrations of longer-lived radionuclides in VLLW are generally very limited. Typical waste in this class includes soil and rubble with low activity concentration levels. Substantial amounts of waste arise from the operation of medical, industrial or research facilities with activity concentration levels in the region of or slightly above the levels specified for the exemption of material from regulatory control. Other such waste, containing naturally occurring radionuclides, may originate from the mining or processing of ores and minerals.
Very short lived waste	Waste with a very short half–life. This is mainly hospital waste, containing very-short-lived radionuclides (i.e. with half-lives that are less than 100 days), used for diagnostic or therapeutic purposes. Because of their very short half-lives, this waste is stored temporarily, for a period ranging from several days to several months and long enough for their radioactivity to decay. It is then disposed of as conventional waste.
Waste Management Contractor	A waste management services company, which may also include a Transport Contractor service.

1 INTRODUCTION

1.1 Background

This Operating Strategy has been prepared as an appendix to the Sandy Ridge Project Public Environmental Review (PER). The Sandy Ridge Project comprises two components; mining of kaolin clay for export and permanent storage of hazardous, intractable and low level radioactive waste in mine voids. Tellus will gain approval to mine kaolin under the *Mining Act 1978* and store hazardous and intractable waste under the *Environmental Protection Act 1986*.

The operational management of the kaolin clay mining will be documented in the Sandy Ridge Project Mining Proposal and the Mine Closure Plan required under the *Mining Act 1978*. The Mine Closure Plan is included as an appendix to the PER also.

Tellus recognise that the operational management of the waste aspect of the Sandy Ridge Project is likely to be of higher risk, and of greater regulator and community interest, hence this Operating Strategy was prepared to communicate Tellus' proposed strategies for handling and permanent isolation of hazardous, intractable and low level radioactive waste (LLW).

1.2 Objective

The objective of this Operating Strategy is to provide regulators and the community with an outline of the high–level operations management proposed for the Sandy Ridge Project.

2 OPERATIONAL LIFECYCLE

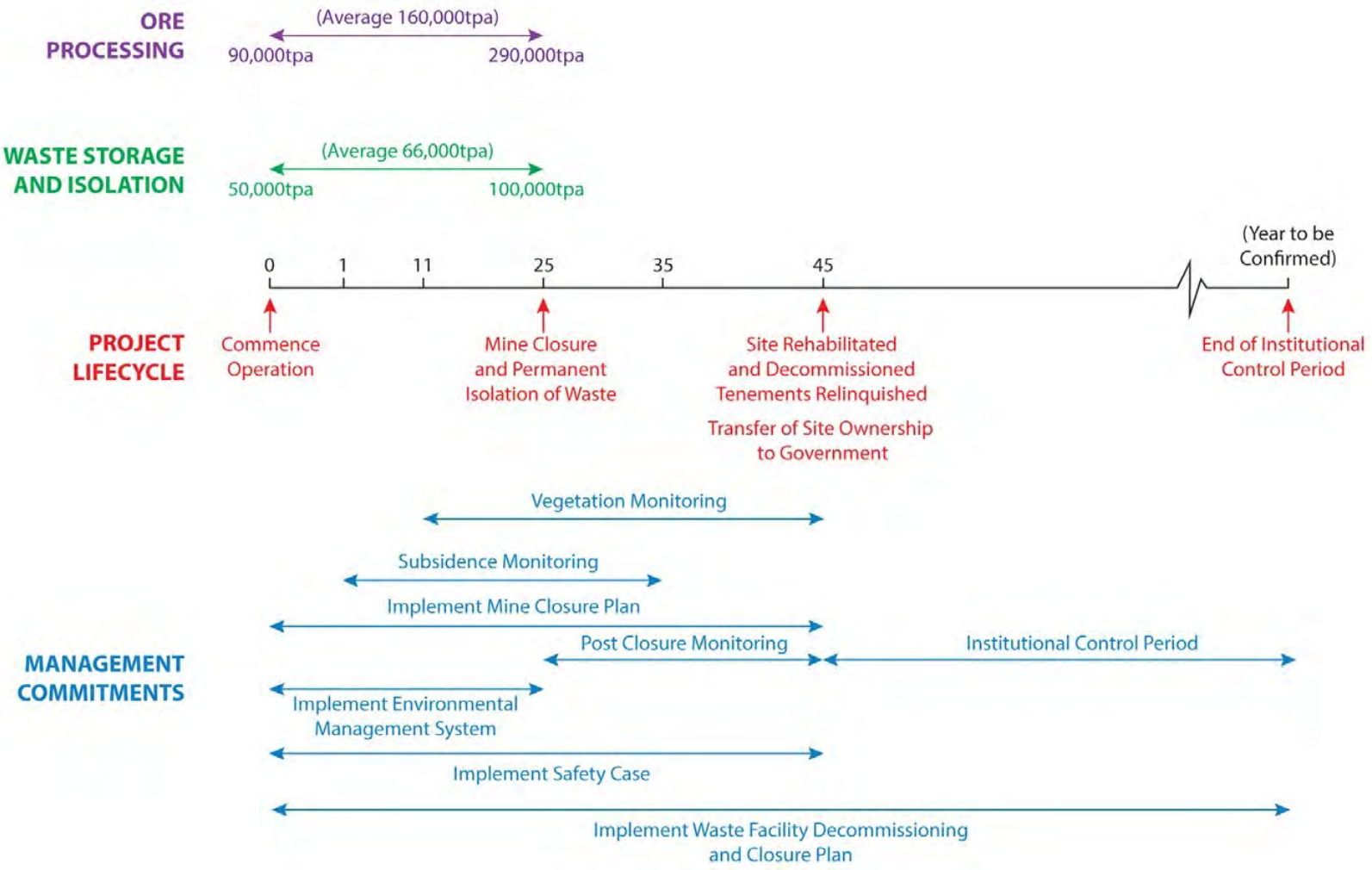
2.1 Lifecycle and milestones

Based on the currently proven kaolin clay resources estimates, enough kaolin is located within the exploration lease (E16/440) for the project to have a 52 year life. However for financial evaluation the Proposal assumes a project life of only 25 years.

Table 2–1 Project Milestones (25 Year Project Life)

Year	Milestone
1	At the completion of year one, the initial mine pit would have been excavated, with ore stockpiled ready for processing and up to 50,000 t of waste placed in the cell. How much waste is placed in the cell may vary due to the initial ramp-up of the business. Once the waste cell is full, the cap is completed and subsidence monitoring of the cell commences.
11	Subsidence monitoring finishes on the first cell. Topsoil is re-spread and seeded, and vegetation established. Vegetation monitoring commences. Other cells completed during the previous decade are continuing to be monitored for subsidence.
21	Vegetation monitoring finishes on the first cell, which is considered rehabilitated. Other cells completed during the previous two decades are continuing to be monitored for subsidence and vegetation growth.
25	At the completion of year 25, up to 7,250,000 t of ore would have been processed, and up to 2,500,000 t of hazardous, intractable and low–level radioactive waste would have been stored. Unless Tellus wishes to continue operations and an extension of the approval and licence is granted), mining and waste storage would cease. In accordance with the Waste Facility Decommissioning and Closure Plan (WFDCP), the cells would have been backfilled and capped, with various stages of rehabilitation and subsidence monitoring in progress.
35	Subsidence monitoring on all cells is completed.
37	Relinquishment of tenements under the *Mining Act 1978*. All mining related infrastructure has been decommissioned and surfaces revegetated in accordance with the Mine Closure Plan (MCP).
45	Vegetation monitoring on all cells is completed. Proposed development envelope is rehabilitated and infrastructure decommissioned. Transfer of Sandy Ridge to the state government along with financial provision for the management of the site during the institutional control period.
325	State of Western Australia controls Sandy Ridge for the institutional control period (as described in the PER).

Figure 2-1 The Sandy ridge Project life cycle



3 SANDY RIDGE GOVERNANCE HIERARCHY

The hierarchy of authority for implementation of the Sandy Ridge Project is illustrated in Figure 3–1 and described below. Each tier affects the way the next tier is implemented and thereby affects the running of the waste and mining aspects of the project.

Project Approvals – Five approvals outline conditions that affect the operational management of the Sandy Ridge Project. These include the Ministerial Statement (issued by the Minister for Environment; Heritage), Conditions of the Lease (issued by the Minister for Lands), Mining Lease and Miscellaneous Leases (issued by Department of Mines and Petroleum (DMP), Shire of Coolgardie planning approval and Commonwealth approval under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act).

Licences, Registrations and Permits –Additional approvals to construct and operate the waste aspect of the Sandy Ridge Project will present a set of conditions to be considered and adhered to during construction and operations phases:

- a Works Approval and Licence under the *Environmental Protection Act 1986* – the facility will be a prescribed premise (category 66) under Schedule 1 of the *Environmental Protection Regulations*.
- A Registration / Licence under the *Radiation Safety Act 1975.*
- Permit to Possess Nuclear Material under the *Nuclear Non-Proliferation (Safeguards) Act 1987.*
- Radiation Management Plan approval under *Mines Safety and Inspection Regulations 1995*.
- Mining Proposal and Mine Closure Plan under the *Mining Act 1978*.
- Dangerous Goods Storage Licence issued under the *Mining Act 1978*.
- A Licence to Take Water issued under the *Rights in Water Irrigation Act 1914*.
- General Purpose Lease and easements issued under the *Lands Administration Act 1997*.
- Planning approval issued under the *Planning and Development Act 2005*

Note: Any licences, registrations, permits or approvals relating solely to the mining aspect have not been included in the list above given this list relates to the waste aspect of the project only.

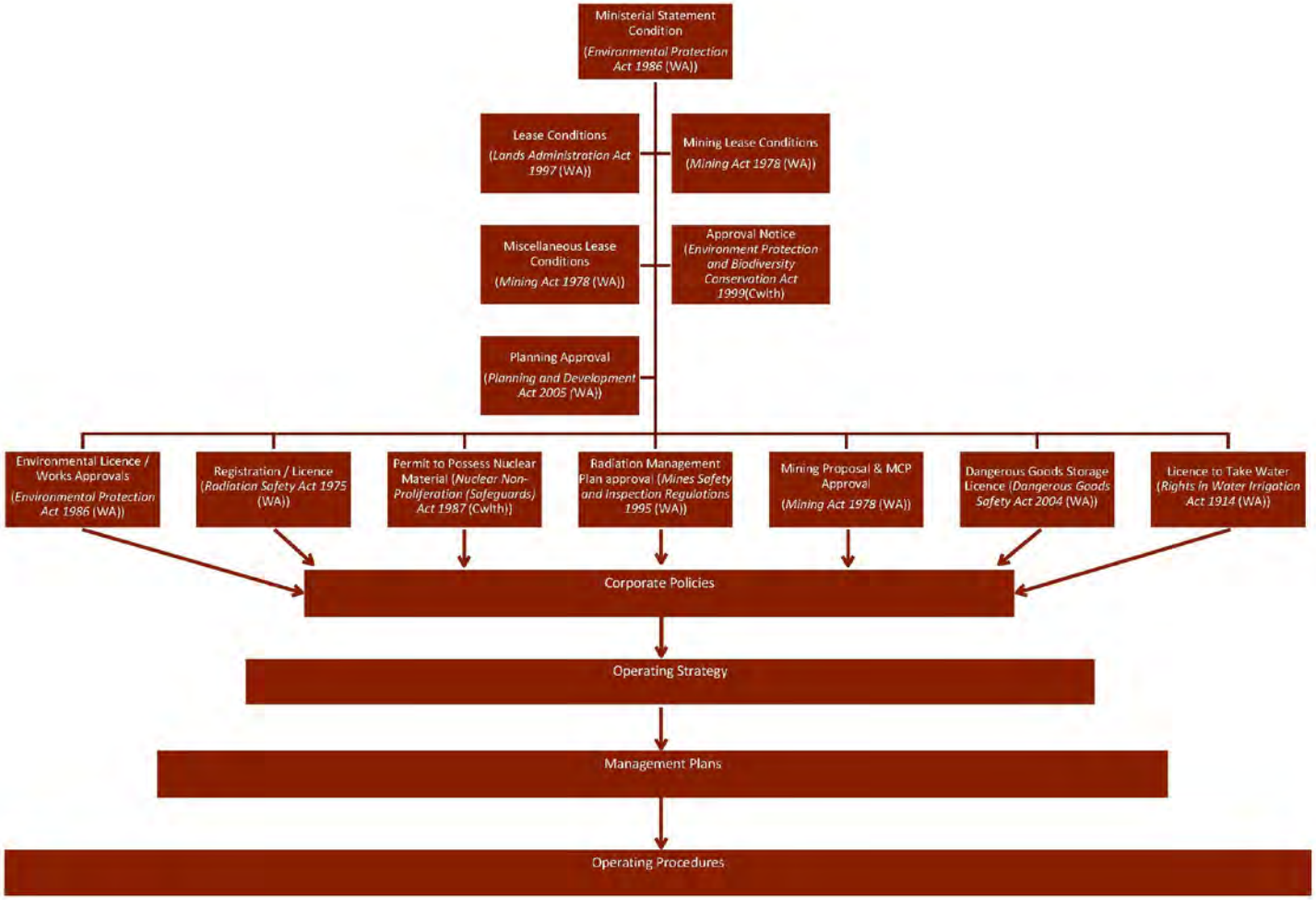
Tellus Corporate Policies – These policies are broad guidelines that detail how Tellus and its employees will act in implementing the Sandy Ridge Project.

Operating Strategy – This explains high–level management details on how the waste will be handled and disposed of in cells

Management Plans – These management plans will dictate how individual aspects of the waste disposal process will operate in order to reduce risks to the environment and people to as low as practicable.

Operating Procedures – The individual elements of the day to day operations will be set out in operating procedures to guide workers on performing the tasks required by management plans.

Figure 3-1 Governance Hierarchy



4 CUSTOMER REQUEST FOR DISPOSAL OF CHEMICAL AND RADIOACTIVE WASTE

Once a customer has requested and filled in the Chemical Waste Proforma (Appendix A.1) and/or the Radioactive Waste Proforma (Appendix A.2), Tellus administration will review the waste proforma in accordance with *SROP-01 Assessment of Waste Proforma Procedure*. The waste proforma will be examined to confirm it meets the acceptance criteria outlined below. If the waste is deemed acceptable it will be transported to Sandy Ridge by the customer's logistics company.

4.1 Acceptance criteria

Solid and liquid chemical waste which will not be accepted includes:

- No documentation – waste not accepted.
- Unexpected delivery with/without waste documentation – waste not accepted.
- Waste Proforma which lists NEPM codes E100, G100, K100, K110, K130, K140, K190, R100, R120, R140 or T200 – waste not accepted.
- Waste Proforma which lists WA Controlled Waste Categories E100, E120, E130, G100, K100, K110, K210, K230, K140, K190, K200, R100, R120 or R140 – waste not accepted.
- Waste Proforma which lists Explosive materials as a constituent of the waste — dangerous goods of **Class 1** (of ADG Code) – waste not accepted.
- Waste Proforma which lists Gases – dangerous goods of **Class 2** (of ADG Code) – waste not accepted.
- Waste Proforma which lists Flammable Liquids as a constituent of the waste – dangerous goods of **Class 3** (of ADG Code) – waste not accepted.
- Waste Proforma which lists Flammable Solids as a constituent of the waste – dangerous goods of **Class 4** (of ADG Code) – waste not accepted

Radioactive waste must meet the following criteria in order to be accepted at the facility:

- Only LLW and some ILW that meet the waste acceptance criteria will be accepted for disposal. Refer to Radioactive Waste Acceptance Guide (Hygiea Consulting, 2016) for waste acceptance criteria.

If wastes in the list above can be treated and conditioned to remove the characteristics which make them unacceptable for storage in the geological repository, then they may be considered for acceptance on a case by case basis.

5 TRANSPORT OF WASTE TO SANDY RIDGE

5.1 General principles of waste transport

Customers with small quantities of waste will be encouraged to use the services of Waste Management Contractors or Transport Contractors who have the ability to collect and consolidate waste packages, so as to minimise the number of vehicles travelling with hazardous wastes and to achieve economies of scale. The general principles of waste transport are:

- The Transport Contractor shall have in place procedures and equipment to respond to accidents, spills or fires that may occur during transport.
- Satellite tracking should be considered for consignments above a certain risk level.
- Rail transport should be used where feasible.
- A multi-barrier system of containment should be used for all waste packages, with the outer-most layer being an international standard shipping container (preferably 20 foot standard dimensions).
- When identifying wastes prior to transport, the Customer shall provide as a minimum a Materials Safety Data Sheet (MSDS) and a NEPM code identifier for the waste.
- Wastes shall be transported in accordance with all relevant codes, guidelines and Acts of any State or Territory through which the waste will travel.
- A 'disposal permit' is required for LLW from Radiation Health WA, and sealed source wastes would only be packaged suitable for transport, not final disposal which would be done at Sandy Ridge.

5.2 Register of transport contractors

Tellus will maintain a *Register of Transport Contractors* and their demonstrated capabilities for carrying various types of waste. A Transport Contractor will only remain on the Register for a limited period of time before being required to re-qualify and hence be re-instated onto the register.

Tellus, or an independent competent sub–consultant, will carry out an audit of a Transport Contractor's licences, systems and practices at any time in order for the contractor to remain on Tellus' Register. Failure to comply will result in that Transport Contractor being removed from the Register, but does not preclude the Transport Contractor from being re–instated to the Register upon passing future audits. Tellus reserves the right to remove a Transport Contractor from the Register at any time and for any reason.

The Transport Contractor will need to meet the following requirements to be listed on the *Register of Transport Contractors*:

- Be licensed to carry controlled waste in any State through which it transports the controlled waste.
- Pass regular compliance audits of management systems and operational practices. The systems and practices shall be appropriate for the type of waste being carried.

5.3 Roles and communication

The roles and communication between Tellus, the waste customer and the Transport Contractor is outlined in Table 5–1 below.

Table 5–1 Roles and communication

Step	Communication	Role
1	A **Customer** contacts **Tellus** to obtain a waste proforma (see appendices of Operating Strategy) and advises of the preferred time and date of delivery.	Customer
2	**Tellus** sends a copy of the waste proforma.	Tellus
3	**Customer** sends back the completed waste proforma.	Customer
4	**Tellus** reviews the waste proforma in accordance with *SROP-01 Assessment of Waste Proforma Procedure*. The waste proforma will be examined to confirm it meets the waste acceptance criteria (WAC). Tellus advises the customer on the price for accepting the waste, issues Tellus' required standards as prescribed in *SROP–05 Transport Standards*, and advises the Customer on other contractual issues pertaining to storage or permanent isolation certificates. If the waste proforma does not meet the WAC **Tellus** advises the Customer to pre-treat and / or package the waste so that it does meet the WAC. If the waste does require pre-treatment or packaging which the Customer cannot carry out themselves, they may be advised to use the services of an established and reputable Waste Management Contractor (e.g. Toxfree). If the waste proposed to be sent to Sandy Ridge is radioactive waste, the additional steps outlined in Table 2 will be undertaken.	Tellus
5	When the waste is in a suitable form and packaging for transport, the **Customer** then arranges freight of the waste using a Transport Contractor.	Customer
6	If the Customer does not already have established service contracts with a Transport Contractor, **Tellus** will recommend one.	Tellus
7	The **Customer** advises Tellus of the proposed Transport Contractor.	Customer
8	**Tellus** will confirm that the proposed Transport Contractor meets the requirements of *SROP–05 Transport Standards* and is listed on the *Register of Transport Contractors* who have been regularly audited by Tellus for compliance with various levels of hazardous waste transport licencing across all States and Territories of Australia.	Tellus

Step	Communication	Role
	If the Transport Contractor is not listed on the *Register of Transport Contractors* Tellus will advise the Customer, and waste will not be accepted if this Transport Contractor is used.	
9	The **Customer** (or their **Transport Contractor**) will obtain and complete forms and submit to government to meet state, territory and federal legislation requirements for transport of waste through each state and/or territory. A copy of the approval from each regulator will be sent electronically to Tellus before the agreed waste delivery date.	Customer / Transport Contractor
10	The **Customer** (or their **Transport Contractor**) shall complete and submit an Environmental Risk Assessment (ERA) for the transport of waste to Tellus. A copy of the ERA will be will be sent electronically to Tellus before the agreed waste delivery date.	Customer / Transport Contractor
11	A Customer Dispatch Notice will be issued by **Tellus** to the Customer once the above documentation is provided and considered satisfactory, to allow delivery of the waste to Sandy Ridge. The date and time of delivery to Sandy Ridge will be mutually agreed at this point.	Tellus
12	Once the **Customer** (or their **Transport Contractor**) is in possession of the Customer Dispatch Notice the waste can be transported to Sandy Ridge.	Customer / Transport Contractor
13	The **Transport Contractor** advises Tellus of when the consignment has departed the Customer's premises, and confirms the expected delivery date and time.	Transport Contractor
14	The truck transporting shipping containers will enter the facility and be weighed on the weighbridge and the driver will proceed to the front gate office. Documentation will be checked in accordance with *SROP-02 Review of Waste Documentation Procedure*. The following actions will occur: • If the documentation is not provided or is incomplete, Tellus will be unable to confirm that its packaging and transport standards have been met, and the truck will either be turned away from the site or directed to the hardstand while any uncertainties or discrepancies are resolved. • If the documentation meets Tellus' packaging and transport standards the waste carrier will be externally audited.	Tellus

5.4 Indicative transport routes

The primary modes of transport for waste transfer to Sandy Ridge will be trucks carrying shipping containers by road. The preferred transport routes for Transport Contractors from each capital city would follow the National Land Transport Network (Department of Infrastructure and Regional Development, 2014) determined under the *National Land Transport Act 2014*. Maps of the network are available at http://investment.infrastructure.gov.au/whatis/network/.

6 WASTE HANDLING AND DISPOSAL PROCESS

6.1 Front gate and weighbridge – external audit

The truck transporting shipping containers will enter the facility and be weighed on the weighbridge and the driver will proceed to the front gate office. Documentation will be checked in accordance with *SROP-02 Review of Waste Documentation Procedure*. The following actions will occur:

- If the documentation is not provided or is incomplete, Tellus will be unable to confirm that its packaging and transport standards have been met, and the truck will either be turned away from the site or directed to the hardstand while any uncertainties or discrepancies are resolved.
- If the documentation meets Tellus' packaging and transport standards the waste carrier will be externally audited.

Scenario 1 External audit

A logistics company (ACME Solutions) arrives with complete documentation but a shipping container containing arsenic trioxide has been hit by a kangaroo and the container has a large dent in the side, but nothing is leaking from the container. The delivery is considered accepted and is sent to the hardstand.

Scenario 2 No documentation and external audit

Using the *SROP-03 External Shipping Container Audit Procedure*, the operator at the front gate will confirm:

- No visible damage to the shipping container(s).
- No evidence of material leaking from the shipping container(s).
- Gamma radiation levels on the surface of the shipping container(s) will be measured in accordance with procedure *SROP-04 Gamma Radiation Monitoring*.
- Various points of the truck will be inspected.

If the truck does not meet Tellus' required standards as prescribed in *SROP–05 Transport Standards*, it will be quarantined in a holding bay, away from areas in which people are working, and Tellus will liaise with the waste customer regarding the discrepancy.

Once confirmed that the shipping container meets Tellus' transport standards, it will be moved to the hardstand.

6.2 Hardstand – external audit

Trucks will park temporarily on the hardstand whilst the shipping container is transferred to the hardstand. The shipping container remains closed. An external audit is undertaken in accordance with *SROP-03 External Shipping Container Audit* as soon as practical.

If the shipping container is confirmed to be damaged or leaking Tellus will move it directly into the Waste Inspection Area to conduct an internal audit (see Section 4.1.4) and remove the leaking/damaged waste packages. Clean-up of leaked material on the hardstand will be in accordance with *SROP-06 Spill Cleanup Procedure*.

Otherwise the shipping container will remain on the hardstand until the operators of the Waste Inspection Area are ready to receive it.

6.3 Waste inspection area audit

The shipping container will be lifted onto the Waste Inspection Area dock and one end of the container opened to allow access for the internal audit. The audit will be conducted in accordance with *SROP-07 Internal Shipping Container Audit*.

A number of waste packages will be removed from the shipping container and placed on the floor of the Waste Inspection Area. Radiation of the waste packages will be checked in accordance with *SROP–04 Gamma Radiation Monitoring* and will confirm if the emissions match those expected based on the customer's waste proforma. If the radioactivity recorded is higher than expected based on the information provided by the waste customer, the following actions will occur:

1. The radiation meter will be re-calibrated in accordance with manufacturer's specifications.
2. The radioactivity of the waste package(s) will be recorded again.
3. If the recording is still higher than expected, but below the acceptance criteria limits (see Radioactive Waste Acceptance Guide (Hygiea Consulting, 2016)) then the waste packages will be moved to the Radioactive Waste Warehouse. Tellus will liaise with the waste customer to confirm the reason for the discrepancy and if satisfactory, an Acceptance Certificate will be issued.
4. If the recording is still higher than expected, and above the acceptance criteria limits, treatment options and cost involved will be discussed with the waste customer. If unable to treat and reduce the radioactivity to within acceptable levels, Tellus will be unable to place the waste package in the cell (as this will contravene approvals issued for the site) and the waste customer will be contacted to organise removal of the waste package from the site. The waste packages may be temporarily stored in the Radioactive Waste Warehouse until this is organised.

Following checking of the packages for radioactivity, sampling of these waste packages will occur in accordance with *SROP-08 Sampling of Wastes*, and each sample will undergo checks against the customer's documentation and laboratory testing.

The waste package will be audited against the customer's waste proforma to confirm the volume and type of waste delivered is as described in the customer's documentation. The outcome of the review of documentation will be:

- If the documentation is incomplete or does not match the waste that has arrived, the package is replaced into the shipping container, the container is closed, and is moved back to a section of the hardstand pending liaison with the waste customer.
- If documentation is complete, the waste packages will be inspected for damage and leaks. If the packaging is damaged significantly the pallet will be held in a safe and secure manner (in accordance with *SROP–09 Damaged or Leaking Waste Package Procedure*) whilst a solution is agreed to with the waste customer.

Tellus will make safe any damaged or leaking waste package as soon as possible to minimise worker exposure to the waste.

Make Safe

The off-specification waste management section of the Waste Inspection Area will be fully enclosed with controlled ventilation to allow materials in leaking or unsuitable packaging to be re-packaged or wastes to be treated to ensure they are suitable for placement in a cell. Pre–treatment options are described in Section 6.5.

Following internal audit of the shipping container, all waste packages examined will be repacked into the container. The shipping container will either be:

- Transferred directly to the cell for disposal.
- Sent to the hardstand to await placement as per the Cell Schedule (described further below).
- Sent to the Radioactive Waste Warehouse for temporary storage.

6.4 Laboratory testing

Composite and random samples of the newly arrived waste packages will be collected and tested in the onsite laboratory. Testing will ensure the chemicals sent are as per the waste customer's documentation.

The onsite laboratory will be accredited by the National Association of Testing Authorities (NATA) for the analysis to be performed. Chemical analysis will be performed in accordance with the laboratory methods accredited by NATA. The laboratory will produce sample results which will be stored in the Tellus Electronic Tracking System (TETS) alongside the waste customer's proforma and NEPM documentation.

Once the sample results match the customer's documentation, the remnants of the sample, the previously removed waste packages, equipment contaminated by the sample and the lab analyst's personal protective equipment (PPE) will be repacked into the shipping container and the container closed. The shipping container is transferred back to the hardstand. The shipping container remains on the hardstand until it is scheduled to be moved into the waste cell.

Scenario 4: Analysis of Arsenic Trioxide Waste Packages

Waste packages that the waste customer claims contain arsenic trioxide are sampled. These samples are analysed using the Tellus laboratory method THLM-01 Metals in Soils by ICPOES. This method has been accredited by NATA. The results of the analysis indicate the samples contain between 5% and 60% arsenic. This matches:

a) The description of the waste provided on the waste proforma
b) The customer supplied laboratory certificate, which indicates similar concentrations.

The testing confirms that the waste that arrived matches the customer's documentation and can processed to the next step in the waste disposal process.

6.5 Pre – treatment of wastes

Tellus may accept some wastes at the facility which are flammable, explosive, corrosive, biodegradable or reactive which will require pre-treatment or conditioning before being placed in the disposal cell to ensure that they do not compromise cell integrity. Possible pre-treatment processes may include one or more of the following:

- Crushing and/or screening to ensure that the particle sizes of materials would not result in excessive voids being created (e.g. for pot liner materials).
- Solidification and stabilisation using pozzolanic cement, fly-ash or kaolinitic materials.
- Centrifugation or filtering to remove excess moisture.
- Evaporation and biological conditioning

Scenario 5: Pre–treatment of pipework containing scale

ACME Solutions delivers a 200L drum containing multiple pieces of pipe from an oil platform located on the North West Shelf. The pipes contain a build-up of scale on their inner surfaces. The scale is radioactive due to the presence of small amounts of naturally occurring uranium and thorium (i.e. NORMs). As the pipes are open at each end, there is potential for air voids to be created if they were placed directly in the radioactive shaft. Therefore the pipework would be pre–treated by filling each pipe with pozzolanic cement and then cementing the pipes within the 200L drum. The drum is then considered a solid radioactive waste and is acceptable to be disposed of in the radioactive shaft.

6.6 Acceptance certificate

Once the waste load has been audited, tested and verified, an Acceptance Certificate will be issued to the customer (in accordance with *SROP–10 Issuing Waste Acceptance Certificate*). At this point the ownership of the waste is still with the customer, but the Acceptance Certificate will provide the customer with confidence that the waste has been accepted at the facility for storage and isolation in the geological repository.

6.7 Transfer of shipping container into cell

Tellus will program the placement of waste into the disposal cell in based on the nature of the waste and planning of the cell layout to store waste of similar characteristics in designated areas of the cell. This further reduces the possibility of interactions between wastes of different types. The order of placement will be programed and documented in the Cell Scheduler.

When the Cell Scheduler indicates that a particular container is scheduled for placement, it will be loaded onto a Waste Haul Articulated dump truck (ADT) and driven into the cell. The shipping container will be removed from the Waste Haul ADT and placed on the floor of the cell adjacent to the designated disposal area. The shipping container will be opened and the pallets of waste packages removed in accordance with *SROP-11 Unpacking of Shipping Container and Placement of Waste Package in Cell.*

Waste packages will be placed into the allocated section and tightly packed together to minimise void space between containers. Backfilling of void spaces will be undertaken in a manner that ensures that all voids are completely filled. Refer to *SROP-12 Backfilling Procedure*.

6.8 Monitoring

Subsidence monitoring of each backfilled and capped cell is undertaken in accordance with *SROP–13 Subsidence Monitoring*. Radon monitoring of the surface of each cell is undertaken in accordance with *SROP–14 Radon Monitoring.*

7 OCCUPATIONAL EXPOSURE MONITORING

Exposure of workers to the various occupational health hazards on site will be monitored and controlled in accordance with a risk based occupational hygiene program. This monitoring program will include radiation monitoring in accordance to the SROP15–Occupational radiation monitoring to ensure no employee is exposed above the annual exposure limit and that exposure levels are kept as low as reasonably achievable.

8 MANAGEMENT PLANS AND OPERATING PROCEDURES

The Management Plans and Operating Procedures that will guide the operations are listed in Table 8–1.

Table 8–1 Management Plans and Operating Procedures

Management Plans	
SRMP-01	Radiation Waste Management Plan
SRMP-02	Mine Closure Plan
SRMP-03	Waste Facility Decommissioning and Closure Plan
SRMP-04	Emergency Management and Response Plan
SRMP-05	Project Management Plan
SRMP-06	Class II Landfill Post Closure Management Plan
SRMP-07	Drinking Water Quality Management Plan
SRMP-08	Radioactive Waste Acceptance Guide
SRMP-09	Construction Environmental Management Plan
SRMP-10	Operation Environmental Management Plan
Operating Procedures	
SROP-01	Assessment of Waste Proforma
SROP-02	Review of Waste Documentation
SROP-03	External Shipping Container Audit
SROP-04	Gamma Radiation Monitoring
SROP-05	Transport Risk Assessment
SROP-06	Spill Clean-up
SROP-07	Internal Shipping Container Audit
SROP-08	Sampling of Wastes
SROP-09	Damaged and Leaking Waste Package
SROP-10	Issuing Waste Acceptance Certificate
SROP-11	Unpacking of Shipping Container and Placement of Waste Package in Cell
SROP-12	Backfilling
SROP-13	Subsidence Monitoring
SROP-14	Radon Monitoring
SROP-15	Occupational Radiation Monitoring

9 ROLES AND RESPONSBILITIES

Table 9–1 lists the roles and responsibilities of the Tellus Sandy Ridge (SR) team.

Table 9–1 Roles and Responsibilities

Role	Responsibility
SR Waste Acceptance Manager	• Initial point of contact with waste customer. • Issues waste proforma. • Reviews all requests for waste disposal in accordance with *SROP-01 Assessment of Waste Proforma Procedure.* • Issues certificates in accordance with *SROP-10 Issuing Waste Acceptance Certificate.*
SR Site Supervisor	• Responsible for meeting the requirements of the governance hierarchy (Section 3). • Supervision of all personnel onsite, to ensure their roles are undertaken correctly. • Responsible for implementing *SROP–15 Occupational Radiation Monitoring*. • Training of all personnel onsite. • Liaise with Tellus Corporate.
SR Front Gate and Weighbridge Operators	• Initial point of contact with waste carrier on arrival at site. • Checks documentation in accordance with *SROP-02 Review of Waste Documentation Procedure* and *SROP–05 Transport Standards*. • Undertakes external audits in accordance with *SROP-03 External Shipping Container Audit Procedure.*
SR Waste Inspectors and Disposal Operators	• Directs waste carrier on hardstand or to Waste Inspection Area. • Conduct audits in accordance with *SROP-03 External Shipping Container Audit* and *SROP-07 Internal Shipping Container Audit.* • Cleanup spills in accordance with *SROP-06 Spill Cleanup Procedure.* • Checks documentation in accordance with *SROP-02 Review of Waste Documentation Procedure*. • Implements *SROP–09 Damaged and Leaking Waste Package Procedure* as required. • Unpacks shipping container in cells as per *SROP-11 Unpacking of Shipping Container and Placement of Waste Package in Cell.*

Role	Responsibility
	• Places waste in cell section or dedicated shaft (radioactive waste) in accordance with *SROP-11 Unpacking of Shipping Container and Placement of Waste Package in Cell.* • Backfills and compacts each placed section in accordance with *SROP-12 Backfilling Procedure*.
SR Laboratory Technicians	• Sample waste packages in accordance with *SROP-08 Sampling of Wastes*. • Complete laboratory analysis as per NATA accredited methods. • Provide results to SR Waste Acceptance Manager.
SR Radiation Safety Officer	• First check of waste carrier at front gate in accordance with *SROP–04 Gamma Radiation Monitoring.* • Implementation of the *SRMP-01 Radiation Waste Management Plan.*
Earthmoving Contractor	• Excavation of mine pits. • Capping of cell.
SR Environmental Manager	• Complete subsidence monitoring in accordance with *SROP–13 Subsidence Monitoring.* • Complete radon monitoring in accordance with *SROP-14Surface radon monitoring*. • Reporting to regulator on non-compliances with approval conditions.

10 REFERENCES

Department of Infrastructure and Regional Development, 2014, *National Land Transport Network 2014–Road*, available at: http://investment.infrastructure.gov.au/whatis/network/images/National_Land_Transport_Network_2014_-_Road.pdf

Hygiea Consulting, 2016, *Radioactive Waste Acceptance Guide*

11 APPENDICES

A.1 Chemical Waste Proforma

CHEMICAL WASTE PROFORMA

All sections of this waste proforma must be filled in by the applicant prior to lodgement.

Application (TETS) Number: (Tellus Use Only)	
APPLICANT INFORMATION	
Applicant Name and ABN / ACN:	
Applicant Address:	
Applicant Contact Person and Contact Details:	
Requested date for delivery (if approved by Tellus):	
WASTE INFORMATION	
Origin of waste (indicate name of waste-producing facility):	
Volume:	kL
Weight:	tonnes
Waste Form (circle one):	Solid Liquid[1] Gas
Description of previous treatment/conditioning of waste:	
Is a copy of a NATA accredited laboratory certificate attached that contains a comprehensive analysis of the waste?:	Yes No
Identify/describe waste constituents:	
TRANSPORT INFORMATION	
***National Environment Protection (Movement of Controlled Waste between States and Territories) Measure 1998 (as amended)* Code:**	
WA Controlled Waste Category:	
Australian Dangerous Good Class:	
Transport Mode:	
Transport Provider:	
Does the Truck meet Tellus Standards?[2]:	
Describe the waste package and container:	
Any specific additional information advice, especially procedures and warnings related to accidental damage to the container;	
ENDORSEMENT	
Signature of Applicant:	
Date:	

[1] including sludge and pastes

[2] Refer to *SROP–05 Transport Standards*

A.2 Radioactive Waste Proforma

RADIOACTIVE WASTE PROFORMA

All sections of this waste proforma must be filled in by the applicant prior to lodgement.

Application (TETS) Number: (Tellus Use Only)	
APPLICANT INFORMATION	
Applicant Name and ABN / ACN:	
Applicant Address:	
Applicant Contact Person and Contact Details:	
Requested date for delivery (if approved by Tellus):	
WASTE INFORMATION	
Origin of waste:	
Present location of waste:	
Source/material description:	
Radioisotope(s):	
Half-life:	
Type of radiation emitted (circle one):	Alpha beta gamma neutron
Current date:	
Current activity:	
Waste Form (circle one):	Solid Liquid[3] Gas
Source type (circle one):	Sealed Unsealed
Is it a special form of radioactive material (circle one):	Yes No
If yes to the above question, provide further information:	Expiry date of special form certificate: Special form certificate number:
Volume of source/material for disposal: (may need to include container and/or shielding volume)	
Length of time source/material used/registered:	
Purpose/use of source/material:	
Is a chemical analysis of the waste attached?:	Yes No
Has a Disposal Permit been issued by the Western Australian Radiological Council: (if yes, please attach)	Yes No
If relevant provide details on the source:	Manufacturer: Manufactured date: Serial number: Initial activity: Radiological Council Registration No:

[3] including sludge and pastes

Application (TETS) Number: (Tellus Use Only)			
RADIOLOGICAL ASSESSMENT			
Radioisotope	**Activity (GBq)**	**Volume (L)**	**Activity fraction of 200L drum**

TRANSPORT INFORMATION	
***National Environment Protection (Movement of Controlled Waste between States and Territories) Measure 1998 (as amended)* Code:**	
WA Controlled Waste Category:	
Australian Dangerous Good Class:	
Transport Mode:	
Transport Provider:	
Does the Truck meet Tellus Standards?[4]:	
Describe the waste package and container:	
Any specific additional information advice, especially procedures and warnings related to accidental damage to the container;	
ENDORSEMENT	
Signature of Applicant:	
Date:	

Environmental Management Policy

TELLUS

TELLUS

TELLUS HOLDINGS LTD

ABN 97 138 119 829

Environmental Management Policy

Tellus is committed to reducing the impact of its operations on the environment.

We maintain and continuously improve an Environmental Management System that complies with the requirements of the International Standards ISO 14001:2004.

We acknowledge that as a mining organisation we can minimise the negative impact on the environment through land management, rehabilitation and using our offsets policy as a strategic tool to enhance the ecological values of the land on which we are working. We will strive to be a role model for responsible and sustainable environmental behaviour of our staff and suppliers.

The Key Principles and Actions underpinning our Environmental Management Policy are:

- Incorporate environmental management as part of our business activities;
- Monitor and measure our environmental performance to ensure continual improvement.
- Periodically review, feedback and improve our Environmental Policy and Procedures

Our Environmental objectives are to:

- operate in a responsible manner that respects the environment at all stages of our business;
- encourage new ways of minimising our environmental impacts;
- strengthen our partnerships with stakeholders to achieve our objectives and obligations;
- strive to effectively manage resources, reduce waste and eliminate or minimise adverse environmental effects and risks associated with our operations;
- meet and, where appropriate, exceed applicable environmental laws, statutory obligations and relevant voluntary codes of practice;
- protect natural, historic and culturally significant sites;

To achieve these objectives we shall act to:

- ensure that all people who work or visit our projects and operations are aware of and have the necessary skills to fulfil their environmental obligations;
- openly communicate our environmental performance with our workforce, government and the wider community.
- Ensure high levels of management and staff involvement in achieving stated objectives.

Tellus' Environmental Management Policy is applicable to our directors and employees. It expresses our ongoing commitment to understand, abide by and regularly review these Key Principles and Actions.

Tellus Board

Approval Dated: Feb 2013

Duncan van der Merwe (CEO)

SHEC002

Waste Facility Decommissioning & Closure Plan

TELLUS

SANDY RIDGE FACILITY WASTE FACILITY DECOMMISSIONING AND CLOSURE PLAN

Draft Report |August 2016

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Waste Facility Decommissioning and Closure Plan – V0.1	V0.1 (Draft)	Aurora Environmental	24 December 2015	Tellus Holdings Ltd
Waste Facility Decommissioning and Closure Plan – V0.2	V0.2 (Draft)	Aurora Environmental	18 April 2016	Tellus Holdings Ltd

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ABBREVIATIONS

AHD	Australian Height Datum
AWS	Automated weather station
BGL	below ground level
DER	Department of Environment Regulation
dS/cm	deciSiemens per centimeter
DPAW	Department of Parks and Wildlife
EC	electrical conductivity
EILs	ecological investigation levels
EMS	Environmental management system
EPA	Environmental Protection Authority
EPBC Act	*Environment Protection and Biodiversity Conservation Act 1999* (Commonwealth)
ha	hectare
ICP	institutional control period
IWDF	Intractable waste disposal facility
km	kilometres
kL	kilolitres
km/hr	kilometre per hour
L	litres
L/s	litres per second
m	metre
meq/100g	milliequivalent of hydrogen per 100g of dry soil
mg	milligram
mg/kg	milligram per kilogram
mg/L	milligrams per litre

MMDD	maximum modified dry density
mm/day	millimetres per day
mm/hr	millimetres per hour
m/s	metres per second
MCP	Mine Closure Plan
PER	Public Environmental Review
TDS	total dissolved solids
SMDD	standard modified dry density
t	tonne
TDS	total dissolved solids
WC Act	*Wildlife Conservation Act 1950* (WA)
WFDCP	Waste Facility Decommissioning and Closure Plan

1 INTRODUCTION

The decommissioning and long–term closure of a Class V waste disposal facility is a pioneer activity in Australia and there are few references at international level to provide guidance on appropriate practice. Tellus Holdings Ltd (Tellus) has prepared this Waste Facility Decommissioning and Closure Plan (WFDCP) to propose decommissioning and closure activities for the Sandy Ridge Project (herein referred to as the 'Facility').

The design and planning is based on the foundation that safety of people is of paramount importance and equally important is the minimisation of risks on the environment for geological time (10,000 years +).

1.1 Purpose and objective

The purpose of this WFDCP is to provide regulators and the community with an outline of the decommissioning and closure activities proposed for the Facility.

The objective of the WFDCP is to provide a decommissioning procedure and a passive management regime which will ensure that there is minimal risk of the release of contaminants (chemical or radioactive) into the surrounding environment or being disturbed by either natural process or anthropogenic activities.

1.2 Scope

Tellus has prepared two closure plans for Sandy Ridge. The two plans address the closure requirements for the two key components of the proposal as described below:

- **Mining** – information relating to mine closure for tenement relinquishment is outlined in the Mine Closure Plan (MCP) required under the *Mining Act 1978* (WA).
- **Waste Cells** – information relating to the waste cells is set out in the WFDCP (this document).

The elements of the Sandy Ridge Project that are covered in this WFDCP are listed in Table 1–1.

Table 1-1 Elements of the Sandy Ridge Project and location of information regarding decommissioning and closure

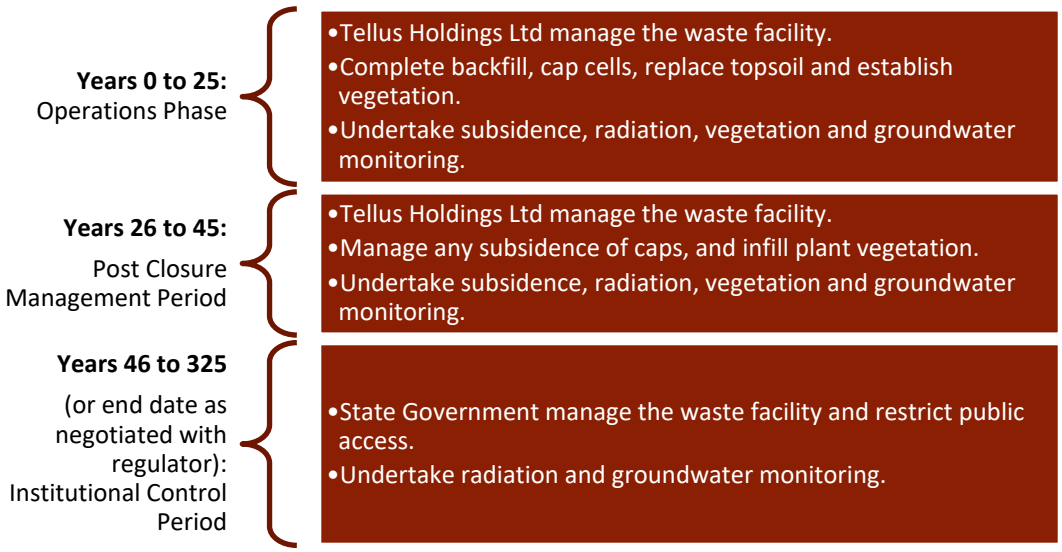
PHYSICAL ELEMENTS	MCP	WFDCP
Class V/Class IV cell closure	X	✓
Front gate office and amenity building	X	✓
Water pipeline	X	✓
Roof canopy	X	✓
Underground storage area	X	✓
Radioactive waste warehouse	X	✓
Accommodation camp	✓	X
Class II landfill	✓	X
Internal roads	✓	X

PHYSICAL ELEMENTS	MCP	WFDCP
Waste inspection area	✓	X
Container hardstand	✓	X
Weighbridge	✓	X
ROM pad	✓	X
Diesel fuel tank, piping reticulation and bowser	✓	X
Waste laboratory	✓	X
Kaolin laboratory	✓	X
Kaolin processing plant	✓	X
Washdown pad and washdown treatment and storage system	✓	X
Water tanks	✓	X
Contractors offices, laydown yard and maintenance workshop	✓	X
Kaolin products storage warehouse	✓	X
Saline water ponds	✓	X
Explosive ordinance building	✓	X
Sewage treatment systems	✓	X
LNG facility	✓	X
Switchroom and generators	✓	X

1.2.1 Phases of Facility closure

The phases of management for closure of the Facility are illustrated in Figure 1–1 below.

Figure 1–1 Phases of closure



1.3 Location and layout of the facility

The Sandy Ridge Project is located approximately 75 kilometres (km) north-east of Koolyanobbing, in the Goldfields region of Western Australia (Figure 1–2). Access is via a 100 km road to the Mount Walton East Intractable Waste Disposal Facility (IWDF) (Crown Reserve No. 44102) that extends northward from Great Eastern Highway; a 4.5 km portion of a westward access road extending towards Mount Dimer and a 5.3 km dedicated site access road extending northwards to the mining lease (Figure 1–3).

1.4 Ownership

The land is vacant Crown Land. Tellus received advice that the best approach to providing suitable tenure for the site is for Department of Lands to lease the land under a Crown Lease. This land will then be leased to Tellus for a period to be agreed (currently expected to be years 0 to 56).

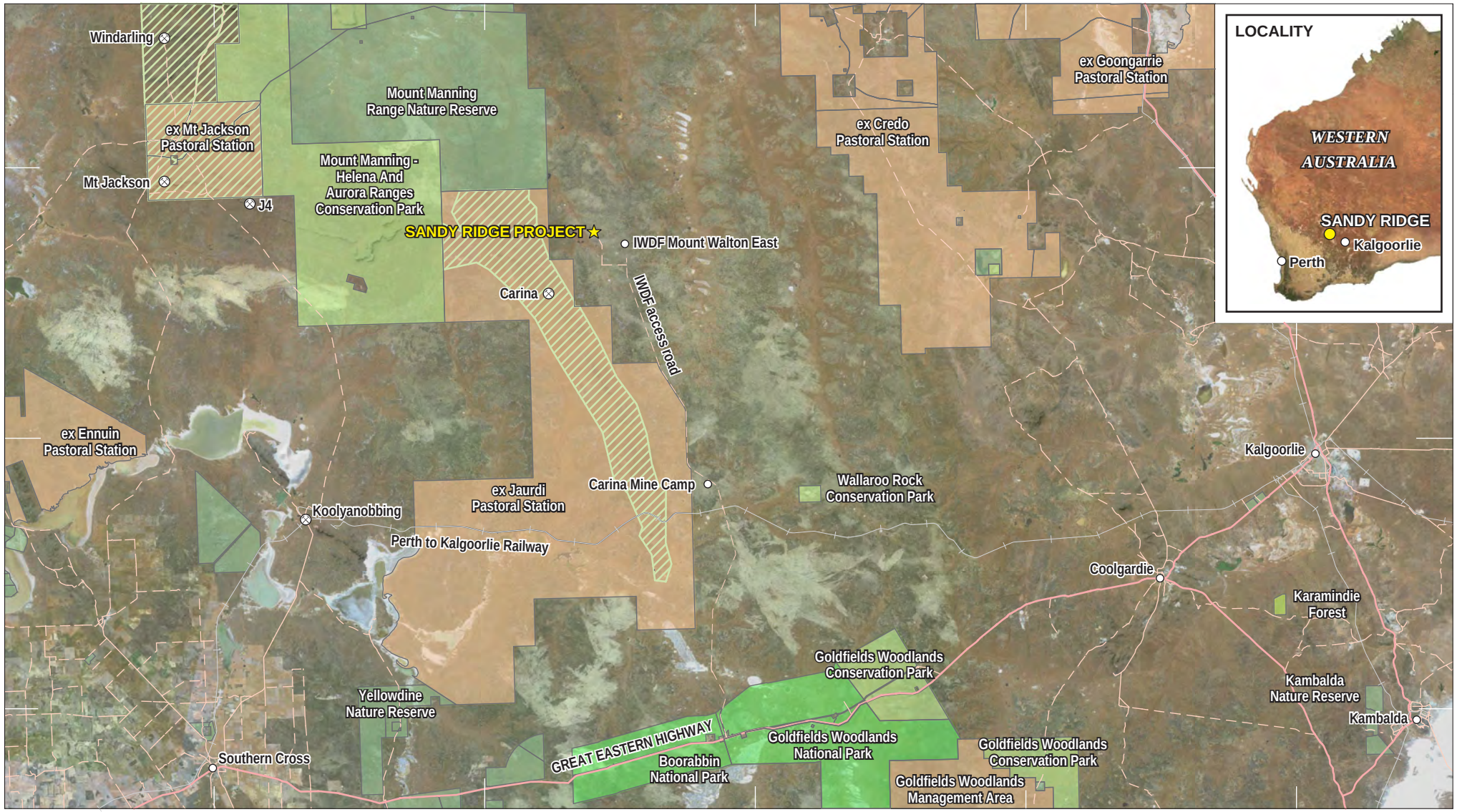
1.5 Review

The WFDCP is a 'live' document, with gaps in information to be filled as the proposal progresses through the design/planning stage to the construction and operations phase.

This WFDCP will be reviewed and revised as appropriate by Tellus every three years or such other time as specified in writing by the Environmental Protection Authority (EPA) or Department of Environment Regulation (DER). The next review date is anticipated to be as soon as possible following Ministerial Approval in order to include relevant conditions or requirements regarding closure.

Next Review:

As soon as possible following Ministerial Approval in order to include relevant conditions or requirements regarding closure.



Legend:
- Iron Ore Mine
- Rail
- Major Road
- Minor Road

DPaW Managed Lands:
- Conservation Park
- Former Leasehold
- National Park
- Nature Reserve
- Proposed Conservation and Mining Reserve
- State Forest

Client: TELLUS

0 20km
Scale 1:1,000,000
MGA94 (Zone 51)
CAD Ref: g2294_PER_01_01.dgn
Date: Jan 2016 | Rev: H | A4

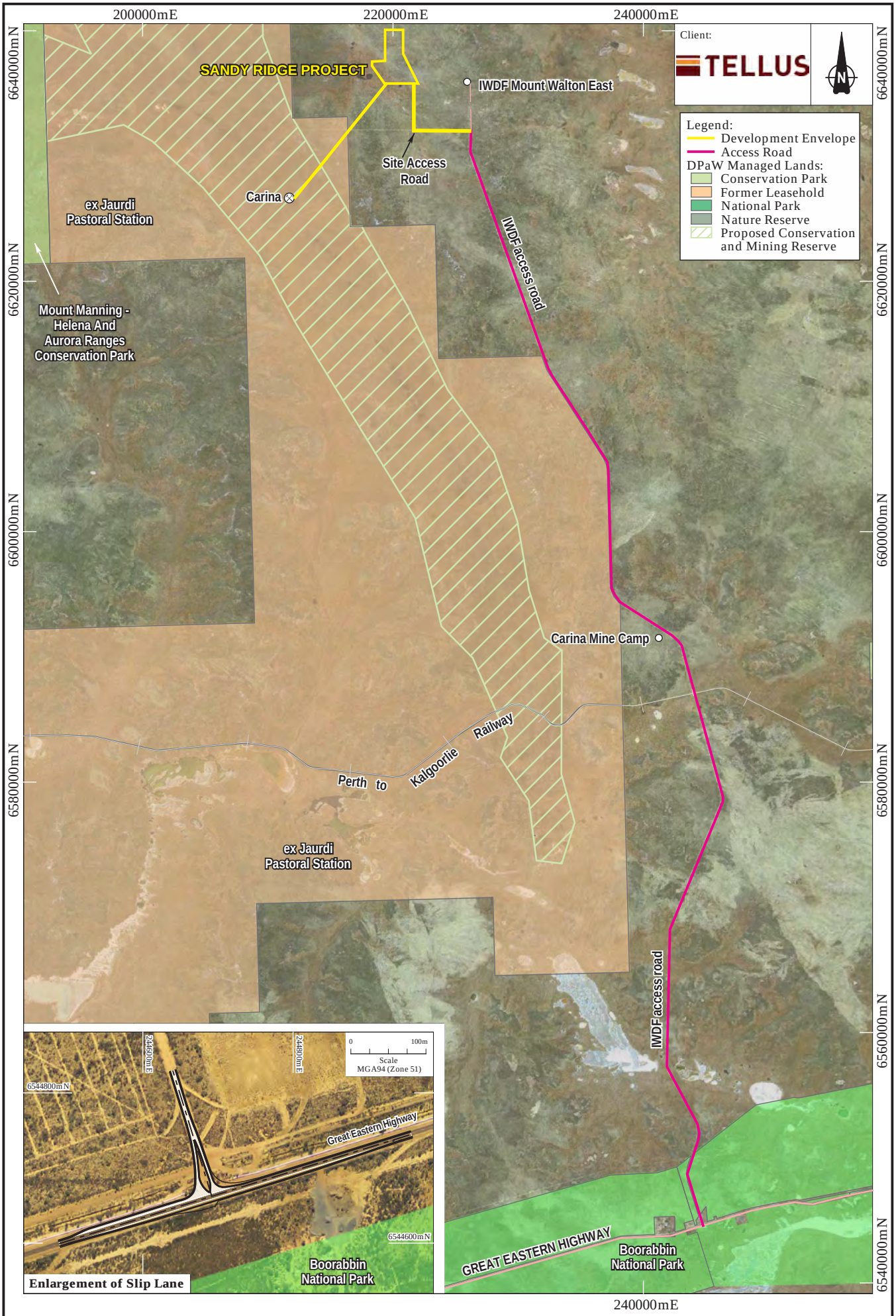
Aurora environmental
Author: C. Dorrington | AE Ref: THO2014-003
Drawn: CAD Resources ~ www.cadresources.com.au
Tel: (08) 9246 3242 ~ Fax: (08) 9246 3202

Sandy Ridge Project

Regional Location

Public Environmental Review

Figure: **1-2**



0 5km

Scale 1:400,000
MGA94 (Zone 51)

CAD Ref: g2294_PER_01_03.dgn

Date: January 2016 | Rev: H | A4

Aurora environmental

Author: C. Dorrington | AE Ref: THO2014-003

Drawn: CAD Resources ~ www.cadresources.com.au
Tel: (08) 9246 3242 ~ Fax: (08) 9246 3202

Sandy Ridge Project

Access to Sandy Ridge

Public Environmental Review

Figure:

1-3

2 CLOSURE OBLIGATIONS AND COMMITMENTS

2.1 Legal obligations register

All legal obligations relevant to rehabilitation and closure of cells at the Facility are identified in the Legal Obligations Register (Table 2–1). Note: this register will be updated following receipt of environmental approvals.

Table 2-1 Legal obligations register

Ministerial Statement (No and Date)		
Condition No	**Condition**	
Works Approval (No and Date) Relates to Tenement No: XX		
Condition	**Aspect Related to Closure**	
***Environmental Protection Act 1986* Licence No: Category:**		
Condition	**Aspect Related to Closure**	

3 STAKEHOLDER ENGAGEMENT

Tellus recognise the importance of engaging with stakeholders for the Facility closure planning, to achieve acceptable environmental outcomes, manage stakeholder expectations and eliminate or avoid potential risks associated with closure.

3.1 Stakeholder identification

'Stakeholders' are defined as both internal and external parties who are likely to affect, to be affected by or to have an interest in closure planning and outcomes. The stakeholders for the Facility are:

Internal

- The Tellus Board and Corporate Executive
- Project Leader – Michael Ingram
- Environment & Approvals Manager – Richard Phillips

External

- Institutional control period (ICP) government manager – To be confirmed.
- Environmental Regulators – Western Australian DER, currently represented by Manager Licensing Waste Industries (North), Commonwealth Department of the Environment, Department of Health (Radiation Safety Branch).
- Ex–Jaurdi pastoral lease land manager – Western Australian Department of Parks and Wildlife (DPAW), currently represented by Area Manager North and Goldfields.
- Other interested government agencies – Department of Mines and Petroleum, Department of Water, and Department of Health (Environmental Health Branch).
- Local Government – Shire of Coolgardie, represented by the Chief Executive Officer.
- Local community members or groups.
- Interested Non–government organisations.
- Adjacent Landholders – Department of Finance, Building Management and Works Branch – manager of the Mount Walton East IWDF and IWDF access road.
- Adjacent Landholders – Department of Lands (for vacant crown land) and DPAW for lands vested in them (e.g. former Jaurdi Pastoral lease).
- Mineral Resources – Operator of the Carina Iron Ore Mine.

3.2 Stakeholder engagement register

A summary of stakeholder engagement in relation to closure of the Facility is listed in Table 3–1. This engagement register will be updated every three years during scheduled reviews of this document.

Table 3-1 Stakeholder engagement register

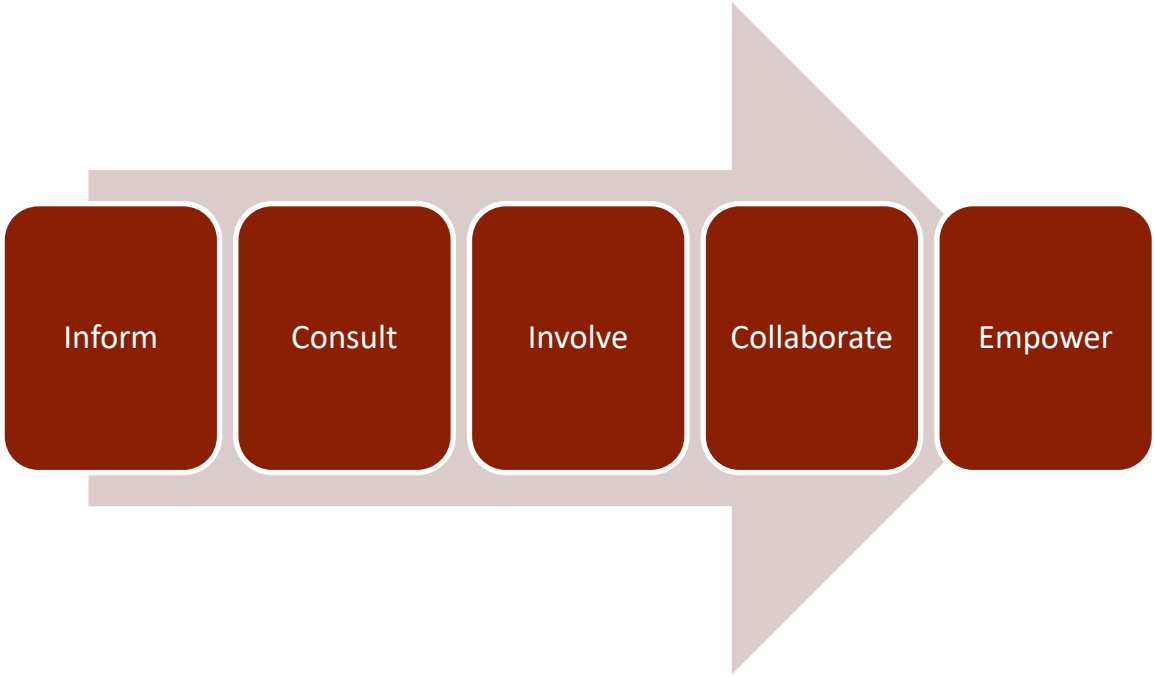
Stakeholder	CONSULTATION DATE	CONSULTATION METHOD	STAKEHOLDER COMMENTS/ISSUE	TELLUS RESPONSE	STAKEHOLDER RESPONSE
DMP (Environmental Branch – Team Leader Minerals Kalgoorlie) and DER (Manager Waste North and Senior Environmental Officer)	19 November 2015	Meeting	• Consider if a 10 year subsidence monitoring is appropriate for the Sandy Ridge Project. • The Mine Closure Plan and Waste Facility Closure and Decommissioning Plan should both outline Tellus' position on revegetation of the surface of the domed clay cap. • Waste Facility Closure and Decommissioning Plan will include a commitment for review of the document every 3 years. • The Mine Closure Plan and Waste Facility Closure and Decommissioning Plan should both outline Tellus' position on fencing and how maintenance is ensured long-term.	These items have been considered in this WFDCP.	The justification for a 10 year subsidence monitoring program is provided in Section 7. Vegetation establishment is described in Section 7. The requirement for a 3 yearly review of this document is incorporated into Section 1.5. Fencing is described in Section 7.

3.2.1 Stakeholder engagement strategy

Purpose of Communication

For closure to be effective, engagement with stakeholders is required at every phase of the Sandy Ridge Project. The Community Engagement and Development Handbook (DITR, 2009) outlines two frameworks generally implemented by miners to engage with the community and stakeholders. Tellus considers the International Association of Public Participation (IAP2) process (illustrated in Figure 3–1) as the appropriate framework for the Sandy Ridge Project, as it allows for a continuum of consultation with stakeholders.

Figure 3–1 Continuum of engagement



Tellus has interpreted the purpose of each type of engagement in Plate 2 as described below:

- **Inform** – providing information about the Facility.
- **Consult** – direct conversation on specific areas of risk and opportunity in relation to closure.
- **Involve** – interactive mode between Tellus and the stakeholder to achieve a common closure outcome.
- **Collaborate** – Stakeholder-driven consultation on aspects of closure.
- **Empower** – participation in planning and decision-making, not only on issues related to operational impacts, but also on decisions regarding the community's future once the Facility has closed.

In the initial stages of closure planning, Tellus is most likely to inform stakeholders of the plans for closure. As the Facility develops and is operational, there will be a move towards the consult, involve

and collaborate forms of engagement. Nearing the end of the Facility life, there may be opportunities to empower stakeholders. The appropriate purpose of communication will be evaluated during each engagement event, and reflected upon during the three yearly review of this document.

Methods of Communication

A single or multiple methods may be used to communicate with stakeholders, depending on the purpose of the communication. Several methods are listed in Table 3–2.

Table 3-2 Communication methods

Purpose	Method
Inform	information booths, media releases, newsletters, brochures, mail out programs, websites and hotlines.
Consult	Public meetings, discussion groups, polls, surveys and focus groups.
Involve and Collaborate	Workshops and discussion groups, learning circles, interviews, reference groups and community consultative committees.
Empowerment	Site visits, direct phone calls and electronic mail.

Targeted Communication

The consultation to be undertaken prior to the submission of the next revision of this WFDCP includes:

1. Discussions internally within Tellus to agree on any required changes to the document.
2. Tellus will consult with each external stakeholder to gain feedback.
3. The list of required changes will be discussed with all external stakeholders with the aim of achieving agreement.
4. Once agreed, Tellus will make the changes to the document.

The revised document will be issued to all external stakeholders for comment, and their comments considered in a newer version.

Documentation

All stakeholder engagement, regardless of purpose or form, will be recorded in Table 3–1.

4 CLOSURE OBJECTIVES

4.1 Post waste facility land use

The post waste facility land use following the cessation of waste disposal is to leave the site vacant, with Crown Lease tenure in place to ensure no future incompatible activities can occur at this location, due to the presence of buried waste that will not breakdown over time (for example if arsenic trioxide is buried, arsenic will still be present thousands of years later).

The waste cells landform is expected to comprise three areas, of rows of capped cells, as shown in Figure 4–1. The topography will be slightly elevated, approximately 5 m AHD higher than the surrounding landscape. The integration with the surrounding topography is shown in Appendix A.1.

Figure 4–1 Final landform

4.2 Closure objectives

The regulator of a Class V Waste Facility in Western Australia (currently DER) has no published closure requirements for Class V landfill sites, but based on consultation with DER, closure requirements will centre on the post-closure monitoring and management of potential emissions and discharges.

Tellus will also discuss the closure objectives with the ICP government manager.

The closure objectives proposed are:

1. Structurally stable, non-eroding disposal cells.
2. No emissions or discharges from the cells following capping.
3. Establish vegetation on the cell caps.

To demonstrate that closures objectives have been met, Tellus will need to meet the completion criteria outlined in Section 4.3, and provide evidence to regulators as stipulated.

4.3 Completion criteria

4.3.1 Basis for development

Whilst the Sandy Ridge Project is in the conceptual phase of planning, the completion criteria have been developed based on the technical environmental studies completed of the development envelope and an understanding of the criteria for securing intractable and hazardous waste in a near surface repository based on the following guidance:

- *Design, Construction, Operation and Surveillance of Repositories for Solid Radioactive Wastes in Shallow – Ground* (International Atomic Energy Agency, 1984).
- *Classification and Disposal of Radioactive Waste in Australia – Consideration for Near Surface Burial in an Arid Area* (ARPANSA, 2010).
- *Code of Practice for the near-surface disposal of radioactive waste in Australia* (NHMRC, 1992).

Tellus recognise that closure of a near surface repository for geological time is a pioneer activity in Western Australia, and as such there are no published guidelines applicable to the closure of a Class V landfill. In Western Australia, closure activities are frequently associated with mines, and guidelines associated with mine closure are therefore the nearest form of guidance on criteria to be met at closure. Therefore in developing completion criteria for the Facility, Tellus has considered the requirements of the *Guidelines for Preparing Mine Closure Plans* (DMP & EPA, 2015).

Tellus understand that completion criteria should:

- Specific enough to reflect a unique set of environmental, social and economic circumstances.
- Measurable to demonstrate that rehabilitation is trending towards analogue indices.
- Achievable or realistic so that the criteria being measured is attainable.
- Relevant to the objectives that are being measured and flexible enough to adapt to changing circumstances without compromising objectives.
- Time-bound so that the criteria can be monitored over an appropriate time frame to ensure the results are robust for ultimate relinquishment.

4.3.2 Development of completion criteria

In developing completion criteria for the Sandy Ridge Project, specific importance was placed on the EPA and DMP's objectives for mine closure:

'rehabilitated mines to be (physically) safe to humans and animals, (geo-technically) stable, (geo–chemically) non-polluting / non-contaminating, and capable of sustaining an agreed post–mining land use'

Specific targets (i.e. completion criteria) are developed for three reasons:

- To allow effective reporting and auditing during the life of the Facility.
- On achievement, they represent an endpoint for closure activities where the site can be considered by internal and external stakeholders as 'rehabilitated[1]'.

The indicative completion criteria for the Sandy Ridge Project are presented in Table 4–1.

Table 4-1 Indicative completion criteria

Objective	Indicative Completion Criteria	Measurement Tool
Structurally stable, non–eroding disposal cells.	No subsidence of pits over the subsidence monitoring period.	Subsidence monitoring results provided in the Annual Environmental Report.
No emissions or discharges from the cells following capping.	No significant erosion of the cell caps. No radiation (gamma and radon) emissions greater than the acceptable public health levels. No adverse effects on groundwater.	Results of erosion, radiation, and groundwater monitoring will be provided in the Annual Environmental Report.
Establish vegetation on the cell caps.	At the completion of revegetation monitoring period vegetation composition is comparable to the species diversity/richness and structure of the analogue site. All plants used in rehabilitation to be of local provenance. No declared pests[2] to be introduced into the area.	Results of vegetation monitoring will be provided in the Annual Environmental Report.

[1] Defined in the MCP guidelines (DMP & EPA, 2015) as 'the return of disturbed land to a safe, stable, non–polluting / non–contaminating landform in an ecologically sustainable manner that is productive and self–sustaining consistent with the agreed post–mining land use'.

[2] Declared pests are defined under the *Biosecurity and Agriculture Management Act 2007* and have the meaning (a) a prohibited organism; or
(b) an organism for which a declaration under section 22(2) is in force.

5 TECHNICAL STUDIES

The Sandy Ridge Project is currently in the conceptual stage of planning therefore baseline data collected has been specifically to inform the environmental impact assessment. A summary of the reports completed to date and the data available is provided in Table 5–1.

Table 5-1 Baseline data collected to date

Aspect	Report Title and Author	Data available
Climate and weather observations	A weather station has been installed at the site and is operational. Daily and monthly data summaries are available to download from: www.weathermation.net.au.	Weather observation data on: Wind speed (maximum and average). Average wind direction. Maximum peak wind gust. Relative humidity (maximum, minimum and average). Air temperature (maximum, minimum and average). Rainfall (total and maximum). Data collected from 8 May 2015 to present on a daily basis.
Flora and Vegetation	Sandy Ridge Project, Exploration Tenement E16/440 Level 1 Flora and Vegetation Survey (PGV Environmental 2015)	Level 1 Flora and Vegetation Survey (desktop review).
	Sandy Ridge Project, Exploration Tenement E16/440 Flora and Vegetation Survey (PGV Environmental, 2016)	Level 2 Flora and Vegetation Survey (desktop review and field survey). Sampling of 25 non–permanent 20m by 20m quadrats and several traverses through proposed road and water pipeline alignments.
Fauna	Level 1 Fauna Survey (Terrestrial Ecosystems, 2015)	Level 1 Fauna Study (desktop review and reconnaissance survey).
	Targeted Malleefowl Survey (BCE, 2016)	Historical malleefowl mound locations.
Soils	Sandy Ridge Project Soil Assessment (Landloch, 2015a)	Characterisation of soil types. Soil chemical and physical analysis results. Available topsoil and subsoil resource.

Aspect	Report Title and Author	Data available
		Soil management techniques.
Hydrogeology	Hydrogeological Studies for the Sandy Ridge Project Drilling, Permeability Testing and Potential Water Sources Report (Rockwater, 2015)	Desktop review of previous hydrogeological investigations. Drilling and Monitoring Bore Construction methodology. Monitoring bore permeability tests. Description of hydrogeology. Water Supply Assessment.
Hydrology	Sandy Ridge Kaolinite Project Surface Water Assessment and Management Plan (Rockwater, 2016a) Sandy Ridge Kaolinite Project Surface Water Assessment and Management Plan: Addendum (Rockwater, 2016b)	Surface Catchment Hydrology. Surface Catchment Runoff Hydraulics. Water Management Requirements.
Geotechnical Assessment of Cell Design	Report on Geotechnical Assessment Sandy Ridge Project Goldfields, WA (Douglas Partners, 2015)	Permeability of Compacted Iron Stained Kaolinised Granite and Kaolin Stream Waste. Compaction of Backfilling Materials and Backfilling Methodology. Capping Layer Compaction and Methodology.
Aboriginal Heritage	Report on an Aboriginal Heritage Survey of Tellus Sandy Ridge Project (John Cecchi Heritage Management Consultancy, 2015)	Ethnographic background. Archaeological background. Survey methodology and results.
Characterisation of the clay capping material	Characterisation of the clay capping material from the Sandy Ridge Mine Site (Landloch, 2015b)	Chemical and physical analysis of kaolin capping material.
Landform Evolution Modelling	Sandy Ridge Landform Evolution Modelling (Landloch, 2016)	Erosion potential of the materials used for capping and evolution of the landform over 10,000 years.

5.1 Climate and weather observations

The Proposal falls within the bioclimatic category defined in Beard (1990) as 'semi desert Mediterranean' and averages approximately 250 mm of rainfall per annum. The proposed development envelope lies just to the south of one of the driest regions in Western Australia and does not receive enough rainfall to allow the regular production of crops. The closest Bureau of Meteorology weather station to the proposed development envelope is located at Menzies,

approximately 110 km to the northeast. Table 5–2 summarises the Bureau of Meteorology's data for Menzies from around the last 100 years (BoM, 2015).

Table 5-2 Menzies climate data

Statistics	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Mean Maximum Temperature													
Mean maximum temperature (°C)	35.1	33.9	31.1	26.2	21.3	17.7	17	19	23.1	26.8	30.7	33.9	26.3
Highest maximum temperature (°C)	46.2	45.6	45	39.4	33.9	28.3	28.3	31.1	36.4	40.8	42.9	45.2	46.2
Lowest maximum temperature (°C)	16.8	17.8	14.9	12.8	10.9	9.4	7.2	9.4	10.2	11.8	15.1	15	7.2
Minimum Temperature													
Mean minimum tempera	19.7	19.4	17.2	13.4	9.3	6.7	5.3	6.1	8.6	11.7	15.5	18.2	12.6

Statistics	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
ture (°C)													
Highest minimum temperature (°C)	31	28.9	30.3	24	20.2	18.9	14.5	17.9	23.3	25	27.2	29.4	31
Lowest minimum temperature (°C)	11.7	10	7.6	1.1	-1.4	-4.8	-4	-3	-0.6	0.6	3.4	6.8	-4.8
Rainfall													
Mean rainfall (mm)	22.3	32.1	26.3	21.5	25.7	27.7	22.7	19.6	10.5	11.3	14.8	15.5	250

Source: BoM (2015a)

An Automated Weather Station (AWS) was setup within the proposed development envelope in May 2015. It has been recording hourly average data on; wind speed and direction, total rainfall, relative humidity and air temperatures since 8 May 2015. Table 5–3summarises the data collected to date (March 2016).

Table 5-3 Sandy Ridge weather station data

Data	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	Annual
Maximum Temperature													

Data	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	Annual
Mean maximum temperature (°C)	20.7	20.2	18.7	19.8	31.2	31.6	32.4	34.1	34.1	33.0	30.0		
Highest maximum temperature (°C)	24	25.5	22.8	28.7	32.7	39.2	40.8	41.6	41.9	42.8	39.5		
Lowest maximum temperature (°C)	16	13.2	13.8	9.6	15.9	21.2	22.2	25.8	25.9	23.6	18.0		
Minimum Temperature													
Mean minimum temperature (°C)	4.1	4.6	3.1	5.3	5.8	12.1	14.5	15.3	18.4	15.8	16.4		
Highest minimum temperature (°C)	12	11.8	11.9	13.7	14.7	20.4	20.0	21.0	24.4	23.7	23.2		
Lowest minimum temperature (°C)	0	0	0	0.03	0.03	4.2	4.5	5.46	12.1	9.5	8.1		
Rainfall													
Total rainfall (mm)	0.6	21.8	23.2	31.2	0	3.6	22.2	26.4	70.8	35	35.2		

5.2 Flora and vegetation

Key findings:

50 Threatened and Priority species located within 20 km radius of the mining lease.

Desktop review indicated 25 Priority species possible occur in the mining lease. None of these species are listed as Threatened under the EPBC Act or WC Act.

- 97 species from 27 Families and 50 Genera were recorded. The most common Families were the Myrtaceae (21 species), Fabaceae (13 species), Proteaceae (8 species) and Asteraceae (8

species). The Genera with the most species were Acacia (11), Eucalyptus (8), Grevillea (7) and Melaleuca (5).

- No introduced species (declared pests under the *Biosecurity and Agricultural Management Act 2007*) were recorded.
- No Threatened (Declared Rare) species listed under the *Wildlife Conservation Act 1950* (WC Act 1950) or *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act 1999) were recorded.
- One Priority 3 species, *Calytrix creswellii*, was recorded at one location in *Acacia resinimarginea* Open Heath on loamy sand in the middle of the pits/cells area. Numerous plants were recorded in the quadrat and nearby.
- One Priority 3 species, *Lepidosperma lyonsii*, was recorded on the proposed pipeline route between the Mount Dimer Road and the tenement. Several plants were recorded in *Eucalyptus pileata*/*Acacia resinimarginea* Shrub Mallee/Open Heath vegetation.
- Five populations of the undescribed sedge species, *Lepidosperma sp*., were recorded in *Acacia resinimarginea* dominated vegetation on the site. The species is likely to be more widespread on the site than the populations recorded. The species was not able to be identified to specific level but was not considered to be any of the three Priority species previously recorded in the vicinity of the site. The taxonomy of Lepidosperma is being reviewed by the Western Australian Herbarium staff (R. Barrett) and until those results are published the Lepidosperma recorded on the site should be treated as potentially having some conservation value.
- Most of the vegetation in the survey area belongs to Beard vegetation association 437 'Shrublands; mixed acacia thicket on sandplain' with the southwestern area belonging to association 141 'Medium woodland; York gum, salmon gum and gimlet'
- The vegetation condition was assessed as 'Excellent' using the Bush Forever condition scale.

5.3 Fauna

Key findings:

- Two fauna habitats were mapped within the mining lease and miscellaneous licence; open eucalypt woodland and shrublands.
- Most of the mining lease and miscellaneous licence is in Good to Very Good condition with the exception of vehicle tracks in the proposed pits/cells and infrastructure disturbance areas.
- Potential for 22 fauna species of conservation significance to occur within the mining lease and miscellaneous licence.
- Four of these species are listed as Threatened and two as Migratory under the EPBC Act. None of these species have previously been recorded within the mining lease and miscellaneous licence.

- No malleefowl or active mounds were observed during the targeted survey. Old mounds were evident, with 63 identified during the survey of various ages and in varying states of degradation. Most were little more than circular raised areas of gravel, potentially unused for decades or centuries.
- Two rainbow bee-eaters were observed during the survey; however as the nesting period had finished for the season it was assumed the birds were just passing through (M. Bamford, pers.comm).

5.4 Soils

Key findings:

- The field assessment identified two soil types; Deep Yellow Sand and Red Sandy Duplexes.
- The Deep Yellow Sand is associated with the higher relief areas of low sandy dune systems. The pH of the Deep Yellow Sand is strongly acidic.
- The Red Sandy Duplex is associated with the lower-lying areas of the exploration lease, potentially broad areas of through going drainage, and consequently are areas of net erosion. The Red Sandy Duplexes were found at shallow depths (<0.3m BGL) over a tightly packed laterite ferricrete. The pH of the Red Sandy Duplex was neutral at surface to alkaline at depth.
- A description of each soil type is listed in Table 5–4 and Table 5–5, and the physical and chemical laboratory test results are provided in Table 5–6.

Table 5-4 Characteristics of the red sandy duplexes

Property	Inspection Site Description
Brief description	Shallow dark red/brown sand over sandy clay loam
Soil samples	Pit 1, Pit 2
Gradients	Gently undulating
Soil Landscape	Norseman
Soil classification	Petroferric Kandosol
Surface coarse fragments	0-20% abundance sub-angular pebbles to small rocks
Surface condition	Soft to moderate
Permeability	Moderate (surface), slow (subsurface)
Water repellent	No
Drainage	Sheet wash and low relief drainage lines
Soil depth (cm)	**Soil Profile Description**
0-5	A_1 Dark red-brown (2.5YR-2.5/4), weakly structured, sand, <5% coarse pebble fragments, pH 7 (field)
5-20	A_2 Dark red-brown (2.5YR-3/6), weakly structured, loamy sand, <2% coarse pebble fragments, pH 7 (field)
20-30	A_2 Dark red-brown (10R-3/6), weakly structured, sandy clay loam, <2% coarse pebble fragments, pH 8 (field)
>30	Very hard pale laterite/ferricrete of unknown depth

Table 5-5 Characteristics of the deep yellow sands

Property	Inspection Site Description
Brief description	Deep yellow acidic sand
Soil samples	Pit 3, Pit 4
Gradients	Flat to gently undulating
Soil Landscape	Norseman
Soil classification	Yellow Orthic Tenosol
Surface coarse fragments	<2%
Surface condition	Soft
Permeability	Moderate to high
Water repellent	No
Drainage	Surface sheet
Soil depth (cm)	**Soil Profile Description**
0-5	A_1 yellow red (7.5YR-6/6), massive, sand, few coarse fragments, pH ~4.5 (field)
>15	B_2 Dark red (7.5YR-7/6), massive, loamy sand, few coarse fragments, pH ~4.5 (field)

Table 5-6 Chemical and physical soil test results

Analyses		Unit	Sample ID					
			Red Sandy Duplexes			*Deep Yellow Sands*		
			Pit 2-1	**Pit 2-2**	**Pit 2-3**	**Pit 4-1**	**Pit 4-2**	**Pit 4-3**
			5cm	**20cm**	**30cm**	**5cm**	**20cm**	**50cm**
$pH_{1:5}$		pH units	7	7.06	8.89	4.92	4.37	4.21
Electrical conductivity ($EC_{1:5}$)		dS/cm	0.02	0.02	0.17	0.03	0.02	0.02
Total nitrogen		mg/kg	205	104	249	232	206	470
Total phosphorus		mg/kg	<75	<75	<75	<75	<75	<75
Organic carbon		%	0.47	0.20	0.28	0.73	0.41	0.17
Plant Available Nutrients	Phosphorus - Colwell	mg/kg	13.8	5.4	5.1	5.9	3.6	3.5
	Potassium – Colwell	mg/kg	218	28.2	208	44.3	22.6	46.7
	Sulphur – KCl	mg/kg	4.1	3.8	8.3	8.5	11.8	26.0
	Copper – DTPA	mg/kg	0.34	Not detected	Not detected	0.32	Not detected	Not detected
	Iron – DTPA	mg/kg	7.3	Not detected	Not detected	25.1	Not detected	Not detected
	Manganese – DTPA	mg/kg	2.3	Not detected	Not detected	0.9	Not detected	Not detected
	Zinc - DTPA	mg/kg	0.2	Not detected	Not detected	0.2	Not detected	Not detected
Exchangeable Cations	Calcium	meq/100g	2.49	2.18	9.52	0.92	0.62	0.51
	Magnesium	meq/100g	0.46	0.71	3.38	0.25	0.15	0.13
	Potassium	meq/100g	0.33	0.36	1.75	0.31	0.34	0.26
	Sodium	meq/100g	0.14	0.10	1.2	0.14	0.13	0.09
	Aluminium	meq/100g	0.04	0.01	0.02	0.006	0.36	0.37
	Effective Cation	meq/100g	3.5	3.4	15.9	1.7	1.6	1.4

Analyses		Unit	Sample ID					
	Exchange Capacity							
	Exchangeable Sodium Percentage	%	4.1	2.9	7.6	8.4	7.9	6.4
Particle Size Distribution of Fine Fraction	Coarse Sand 0.2-2.0mm	%	70.4	67.3	49.2	70.3	68.9	57.7
	Fine sand 0.02-0.2mm	%	26.5	29.6	29.1	23.8	22.5	33.8
	Silt 0.002-0.02mm	%	0.4	0.4	0.4	2.2	0.4	2.2
	Clay <0.002mm	%	2.7	2.7	21.3	3.6	8.2	6.3
Dispersion Index		Class	3	3	2	7	6	6

5.5 Hydrogeology

Key findings:

- The Sandy Ridge Project is in an area underlain by granitic rocks where there is a thick weathering profile. Little or no groundwater has been intersected within the mining lease, in either the mineral exploration drilling or the 2015 investigation programme conducted by Rockwater. One mineral exploration hole intersected damp kaolinite within the planned mining area.
- Three holes located in areas of greater depth to fresh granite, in the west and south-western parts of the pits/cells area, intersected small quantities of moderately saline groundwater (6,000 to 7,000 mg/L TDS). Airlift water yields ranged from zero to about 0.03 L/s, and permeabilities of the water-bearing zones were low, showing they do not constitute an aquifer.
- The kaolinite and weathered granite are indicated to be of low to moderately low permeability (0.02 to 0.99 m per day, or 2.3×10^{-7} to 1.2×10^{-5} m per second). Permeability values for the dry holes should be taken as first estimates and are probably higher than actual values, because of limitations of the test method.
- The most practical source of water for the project appears to be the Carina iron ore mine, located 12 km south-west of Sandy Ridge in the Yendilberin Hills, where there is abundant water available from the pit and/or dewatering bores (up to 3,000 kL/d). The water has a salinity of about 33,000 mg/L TDS. It is highly unlikely that accessing water from Carina mine will have any additional impact at Carina because the volume sought is small and this water would in any case have been lost by evaporation and seepage. Also, the mine is remote (at least 10 km) from other groundwater users (except Mineral Resources).

5.6 Hydrology

Key findings:

- The planned mining area is unaffected by any major flow paths, and surface water management is only required for short–term flows during rare high rainfall events. These flows are generally from small local catchments which drain residual runoff after infiltration losses to low-lying depressions. Generally water will only be retained for very short periods in the depressions due to continuing infiltration loss. Water could pond for longer periods if the depressions are clay pans. Evaporation will contribute to the loss of ponded water.
- Based on the maximum recorded rainfalls in the area and typical infiltration rates for sandy and sandy loam soils, it is concluded that the peak flows estimated using the only Rational Method for the arid interior region of WA are grossly over-estimated. However, the Rational Method was used in the hydraulic analysis for conceptual design of flood management works.
- Site observations of actual flows following rainfall events should be collected as they will play an important role in refining the water management requirements in the detailed design stage.
- It is recommended that two levees L14a to L18a and L8a to L7a (Figure 2 of Rockwater 2015c) be constructed to divert peak flows around the mining and plant areas. The natural topography along these levees would require minimal grading.

5.7 Aboriginal heritage

Key finding:

- No sites of aboriginal heritage were identified during the survey.

5.8 Geotechnical assessment of cell design

Key findings:

- The results of the tests indicate a permeability of between 5.7 x 10^{-8} m per second and 6.4 x 10^{-8} m per second (approximately 5 mm per day to 5.5 mm per day) for the iron stained kaolinised granite and between 1.6 x 10-8 m per second and 3.0 x 10^{-8} m per second (approximately 1.4 mm per day to 2.5 mm per day) for the kaolinitic material rejected from the processing plant.
- Granular filling to be placed within 2% of optimum moisture and compacted to 90% of maximum modified dry density (MMDD).
- Compaction testing carried out using a nuclear density gauge in accordance with *AS 1289.5.8.1*.
- The capping layer should be compacted to an average of 98% standard maximum dry density (SMDD), and the minimum compaction should be 95% MMDD.

5.9 Characteristics of the clay capping material

Key findings:

- Kaolin is relatively benign in terms of its chemical characteristics. Some samples were slightly acidic and saline, but most trended towards neutral to non–saline.
- All metals analysis were below ecological investigation levels (DEC, 2010) and this suggests there is no pre–existing contamination present in the samples analysed.
- The material is fine textured, has low permeability (0.26 – 1.2 mm/hr), and may potentially be hardsetting, indicating it may potentially erode.
- The physical and chemical characteristics of the clay capping material is listed in Table 5–7.

Table 5-7 Clay capping physical and chemical characteristics

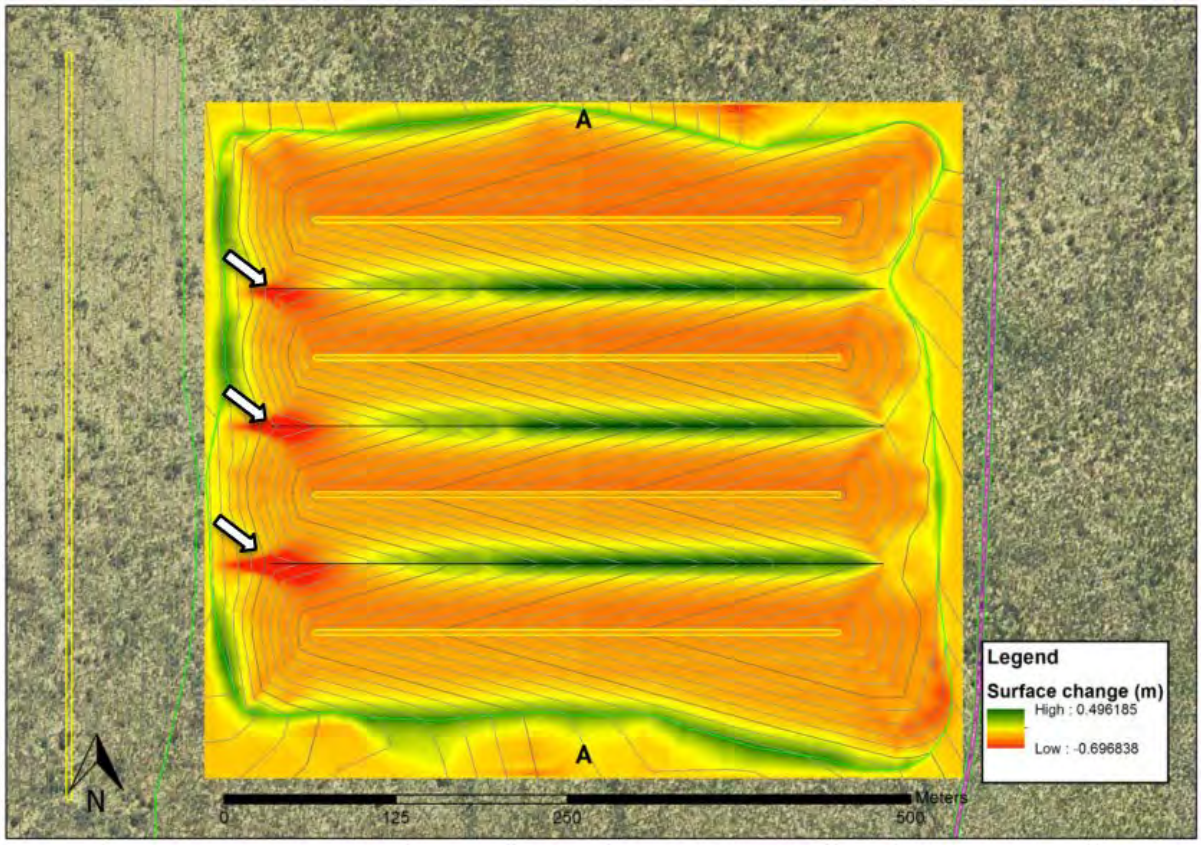
Property		Unit	TC1	TC2	TC3	TC4	TC5	TC6
pH		pH units	6.72	6.91	6.59	6.51	5.75	6.59
Electrical conductivity		dS/cm	0.48	0.40	0.74	1.17	0.19	0.60
Exchangeable Cations	Calcium	meq/100g	0.69	0.74	0.72	0.55	0.49	0.71
	Magnesium	meq/100g	1.43	1.64	1.29	0.77	1.28	1.03
	Potassium	meq/100g	0.23	0.30	0.14	0.08	0.11	0.08
	Sodium	meq/100g	0.50	1.39	0.31	0.13	0.91	0.13
	Aluminium	meq/100g	0.01	0.01	0.01	0.01	0.01	0.01
	Effective Cation Exchange Capacity	meq/100g	2.8	4.1	2.5	1.5	2.8	2.0
	Exchangeable Sodium Percentage	%	17.4	34.1	12.5	8.4	32.4	6.49
Particle Size Distribution of Fine Fraction	Coarse Sand 0.2-2.0mm	%	50.3	33.2	49.1	39.0	46.3	39.4
	Fine sand 0.02-0.2mm	%	32.6	37.4	22.3	38.3	24.9	38.8
	Silt 0.002-0.02mm	%	13.8	28.1	10.8	16.4	14.5	18.4
	Clay <0.002mm	%	3.2	1.3	17.7	6.3	14.3	3.4
Plant Available Water		%	14	18	7	12	10	16
Dispersion Index		Class	6	6	6	6	6	6
Saturated Hydraulic Conductivity		mm/hr	0.46	0.26	1.20	0.29	0.50	0.45
Arsenic		mg/kg	<5	<5	<5	<5	<5	<5
Barium		mg/kg	<10	<10	<10	<10	<10	<10
Beryllium		mg/kg	<1	<1	<1	<1	<1	<1
Boron		mg/kg	<50	<50	<50	<50	<50	<50
Cadmium		mg/kg	<1	<1	<1	<1	<1	<1
Chromium		mg/kg	7	4	3	5	<2	<2
Cobalt		mg/kg	<2	<2	<2	<2	<2	<2
Copper		mg/kg	<5	<5	<5	<5	<5	<5
Lead		mg/kg	<5	<5	<5	<5	<5	<5
Manganese		mg/kg	<5	<5	<5	<5	<5	<5
Nickel		mg/kg	3	2	<2	2	<2	<2
Selenium		mg/kg	<5	<5	<5	<5	<5	<5
Vanadium		mg/kg	<5	10	<5	<5	<5	<5
Zinc		mg/kg	<5	<5	8	20	<5	7
Mercury		mg/kg	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1

5.10 Landform evolution modelling

Key findings:

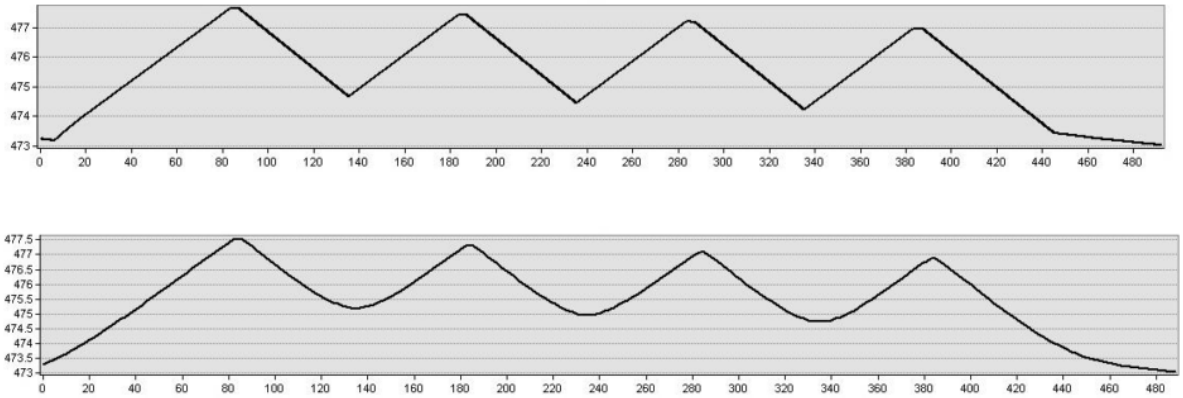
- The Facility design of 5 m high cells (i.e. landforms) with 3 degree batters covered with a deep layer of topsoil is predicted to be erosionally stable over the very long term. This is due to the permeability of the topsoil, arid climate, and a gently sloping design.
- There is predicted to be relatively little change to the Facility surface over the simulation period (10,000 years). Typically less than 200 mm is eroded from the cell batter slopes and deposited in between cells with a maximum of 500 mm deposition predicted (Figure 5–1).

Figure 5–1 SIBERIA model 10,000 year results for long term landscape evolution of cells



The predicted original surface and the surface after 10,000 year simulation is shown in Figure 5–2.

Figure 5–2 SIBERIA model results cross section for the original surface (top) and at 10,000 years (bottom). Axis in meters.



6 RISKS IDENTIFIED FOR CELL CLOSURE

A risk assessment has been undertaken for all aspects of the Facility closure, in accordance with the procedures outlined in the Australian and New Zealand Standards *AS/NZS ISO 31000:2009* Risk *Management–Principles and Guidelines* (SAI Global, 2009) and *HB 203:2012 (Managing Environment-Related Risk)(* SAI Global, 2012), using Tellus' Risk Assessment Matrix (Appendix A.3).

The sources of risks, environmental aspects and potential environmental impacts, as defined by *HB 203:2012* were identified in a workshop attended by the Sandy Ridge Project Leader and Aurora Environmental representatives. The identified environmental aspects were categorised into 'planned' that is those aspects which Tellus know will occur during closure, and those that are 'unplanned' and may credibly occur during closure, but which Tellus has no control over the frequency of occurrence. The identified potential environmental impact is based on the 'worst–case' credible impact.

Qualitative risk analysis was then undertaken, based on the likelihood of the potential environmental impact occurring. Analysis of the inherent risk was undertaken assuming no management/mitigation controls were in place. The group then discussed appropriate management and mitigation measures that would be implemented to reduce the likelihood or consequence, and then analysed the final residual risk.

The outcome of the risk assessment included the identification of 6 planned and 9 unplanned credible risks. This included:

- 3 – High residual risks.
- 1 – Moderate residual risks.
- 11 – Low residual risks.

The risks relating specifically to closure of the Facility are summarised in Table 6–1, with the full risk assessment (including other risks presented in the Mine Closure Plan) presented in Appendix A.3.

The high and moderate risks were evaluated following the workshop by the Sandy Ridge Project Leader, whom concluded that the occurrence of high and moderate risks were outside of Tellus' control due to them being naturally occurring events, or people entering the site without permission. For these risks no treatment was considered necessary, other than maintaining the proposed controls.

Table 6-1 Closure risk register

Environmental Aspect	Sources of Risk (Hazard)	Potential Environmental Impact (Worst case)	Pre-treatment risk	Management and Mitigation Measures	Post-treatment Risk		Residual risk
					Likelihood	Consequence	
Naturally occurring events.	Earthquake (major - with surface displacement)	Cracking of cap, water infiltration and contamination plume.	High	Multiple layer cap design; thickness and self-sealing ability of kaolinite in capping layers; near surface geology and climatic conditions result in net upward water movement in top 6m. Front end loader to fix immediately.	Rare	Major	High
Naturally occurring events.	Bushfire during institutional control period	Injury or death of Threatened/Priority fauna. Damage or death of revegetation.	High	Drying climate, low fuel load.	Almost certain	Insignificant	High
Terrorist attack	Plane crash, bombing of the cells.	Expulsion of chemical and radioactive waste from the cell to the surface and into the atmosphere.	High	Movement detectors positioned at the waste cells, remoteness of the location, depth of cover (i.e. 7m of capping layers before waste package layer), low incentive, and consequence to effort scale poor.	Rare	Major	High
Unauthorised access to the site	Unrestricted public access (e.g. holes in fencing) and	Injury or death of individual fauna by falling into cell containing	Moderate	Perimeter fence. Institutional control on exploration activities (i.e.	Rare	Moderate	Moderate

Environmental Aspect	Sources of Risk (Hazard)	Potential Environmental Impact (Worst case)	Pre-treatment risk	Management and Mitigation Measures	Post-treatment Risk		Residual risk
					Likelihood	Consequence	
	accidental deep excavation/drilling into the cell. Mineral exploration.	chemical waste, cell becomes unstable and collapses inwards.		government can prevent exploration).			
Direct rainfall events	Low saturated hydraulic conductivity (0.26 - 1.2mm/hr) of kaolin will result in high rainfall runoff, causing erosion.	Erosion of the domed clay cap, water infiltration into the cell, plume of contamination release which could affect flora and vegetation.	Low	Place topsoil/subsoil (minimum 1.7m thick) over clay cap. Infiltration rate low. Front end loader to fix cap. Deeper cap lower in waste cell. Clay is dry and will absorb any water. Bunding and V drains around cell cap.	Rare	Insignificant	Low
Surface water runoff	Low saturated hydraulic conductivity (0.26 - 1.2mm/hr) of kaolin will result in high rainfall runoff, causing erosion.	Erosion of the domed clay cap, water infiltration into the cell, plume of contamination release which could affect flora and vegetation.	Low	Place topsoil/subsoil (minimum 1.7m thick) over clay cap. Infiltration rate low. Front end loader to fix cap. Deeper cap lower in waste cell. Clay is dry and will absorb any water. Bunding and V drains around cell cap.	Rare	Insignificant	Low
Decommissioning of the site	Movement of plant and collision with fauna.	Injury or death of Threatened/Priority fauna.	Low	Speed limit <20km/hr.	Rare	Insignificant	Low

Environmental Aspect	Sources of Risk (Hazard)	Potential Environmental Impact (Worst case)	Pre-treatment risk	Management and Mitigation Measures	Post-treatment Risk		Residual risk
					Likelihood	Consequence	
Decommissioning of the site	Overturned truck/removal of tanks, forget to drain hydrocarbon lines.	Hydrocarbon spill and soil contamination.	Low	Front end loader onsite, cleanup procedures, extent is limited by absorptive nature of the clay, presence of silcrete layer. Adequate planning of demolition. Education of contractors.	Unlikely	Insignificant	Low
Fencing of the waste cells	Exclusion of fauna from potential habitat.	Forced translocation of fauna into other habitat and increased predation in new habitat. Potential for injury/death of Threatened/Priority fauna.	Low	Removal of fencing following Post Closure Management Period.	Rare	Insignificant	Low
Monitoring of the site	People accessing the site to complete monitoring.	Accidental fire (e.g. cigarette butt) leading to loss of vegetation.	Low	Education of contractors on fire prevention methods, vegetation is sparse and unlikely to be high fuel load.	Rare	Minor	Low
Vegetation growing on domed clay cap.	Plant roots, permeability pathways created.	Potential penetration of roots into cap, water infiltration	Low	Thickness of all capping layers. Kaolin is a poor growth medium,	Rare	Insignificant	Low

Environmental Aspect	Sources of Risk (Hazard)	Potential Environmental Impact (Worst case)	Pre-treatment risk	Management and Mitigation Measures	Post-treatment Risk		Residual risk
					Likelihood	Consequence	
		into the cell, plume of contamination release which could affect flora and vegetation.		regular monitoring and removal of vegetation that does grow.			
Failure of waste cell containment, cell instability/collapse.	Loss of volume or void space occurs. Backfill not completed correctly. Waste package contains liquid/gas. Generation of leachate as water infiltrates the cell.	Infiltration of liquid to surrounding clay and ultimately into groundwater, contaminating the water. Toxic plume within the aquifer affecting groundwater dependent vegetation, potentially Threatened/Priority flora and fauna species.	Low	Subsidence monitoring, groundwater monitoring bores around cells.	Rare	Insignificant	Low
Decommissioning of the site	Footprint of removed infrastructure not rehabilitated	Generation of dust (potentially contaminated) which affects sensitive receptors.	Low	Contribution to Mining Rehabilitation Fund (refer to MCP) and Tellus insurances.	Rare	Insignificant	Low
Naturally occurring events.	Earthquake (minor - no surface displacement)	Slight subsidence of cell	Low	Multiple layer cap design; thickness and self-sealing ability of kaolinite in capping	Rare	Insignificant	Low

Environmental Aspect	Sources of Risk (Hazard)	Potential Environmental Impact (Worst case)	Pre-treatment risk	Management and Mitigation Measures	Post-treatment Risk		Residual risk
					Likelihood	Consequence	
				layers; near surface geology and climatic conditions result in net upward water movement in top 6m.			
Introduction of weeds	Incoming vehicles to monitor the site.	Establishment of weeds on the site and competition for resources (e.g. water) with native vegetation.	Low	Inspection/brushdown of exterior of car before entering site. Brushdown of car between revegetation areas. Weed removal where they become established.	Rare	Insignificant	Low

7 OPERATIONS PHASE

7.1 Status Year 0 to 25

The operations phase is the period where active cells are:

- backfilled and capped as outlined in Section 7.2 (chemical waste cells) and 7.3 (chemical and radioactive waste cells).
- validated, in terms of the cell design as outlined in Section 7.4.
- monitored for subsidence as described in Section 7.5.
- overlayed with soil as described in Section 7.7.
- vegetated as described in Section 7.8.

In addition the following activities occur at the Facility:

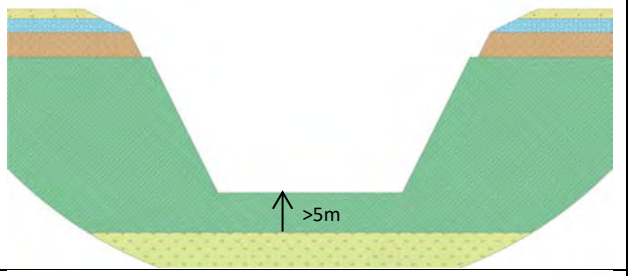
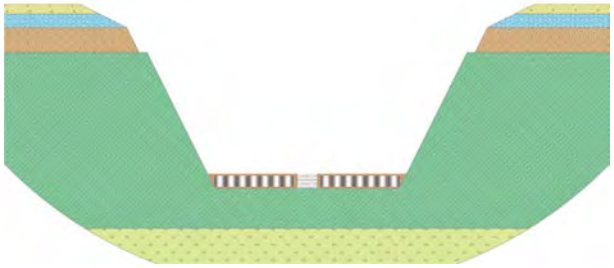
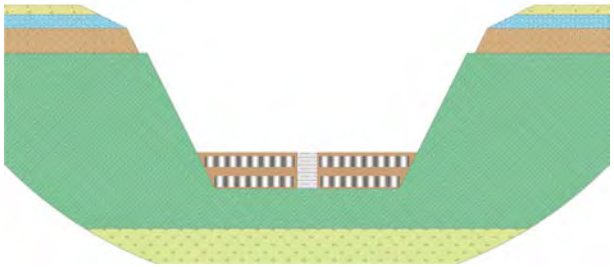
- radiation monitoring is conducted as described in Section 7.9.
- groundwater monitoring is conducted as described in Section 7.10.
- fencing around the cells is maintained as described in Section 7.11.

The cells will be rehabilitated in accordance with the schedule provided in Section 7.5. The rehabilitation schedule for the underground storage area is provided in Section 7.12.

7.2 Backfill and capping of chemical waste cells

The typical closure process for each chemical waste cell is outlined in Table 7–1 below. Note that a roof canopy will be in place until the waste packages are completely capped by kaolin clay.

Table 7-1 Closure of chemical waste cells

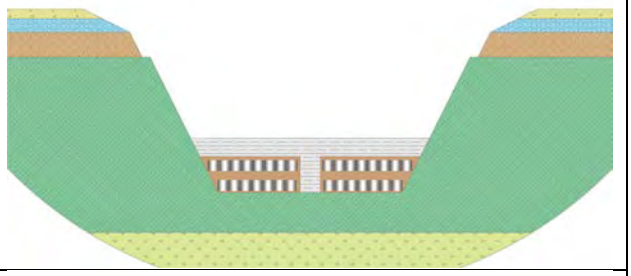
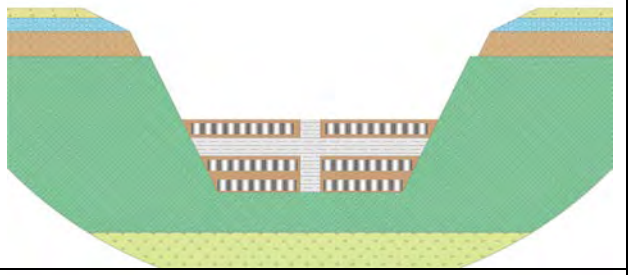
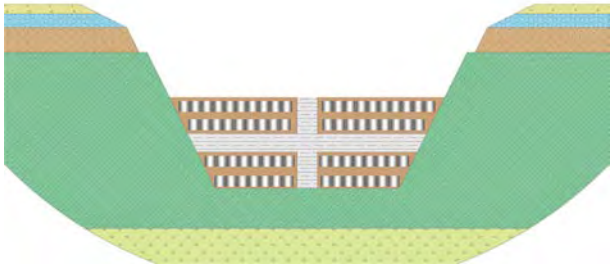
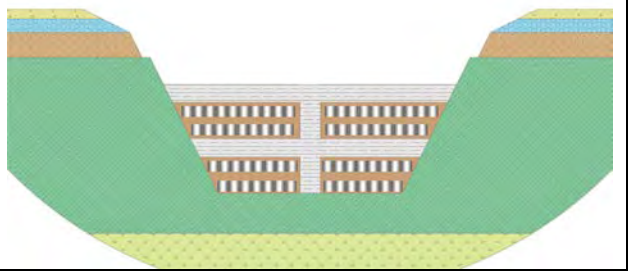
The bottom of the mine void will be a minimum of 5 m above the unweathered granite bedrock.	
A base layer of waste is placed on the floor of the mine void. Wastes of different types are segregated by internal compacted kaolin walls which are 5 m wide. The height of each waste layer and barrier wall is the equivalent of the height of a waste package, typically 0.9 m. Waste packages are placed tightly next to each other in a row. Granular material is backfilled between and around the waste packages to fill any air spaces.	
A thin (300 mm minimum) layer of compacted granular material is placed over the waste layer. Compaction testing will be carried out in accordance with *AS1289.5.8.1* to confirm material is compacted to the density required by the engineering design. The next layer of chemical waste packages is placed on the kaolin compacted layer along with the 5 m wide kaolin separation barrier.	

LEGEND - Cell Backfill

- Mottled clays compacted to 95%mmdd
- Mixed laterite and silcrete and clayed sand compacted to 95%mmdd, Max particle size 40mm
- Waste sand backfilled around drums/bags compacted to 90%mmdd

LEGEND - Existing Ground

- Clayed sand
- Laterite
- Silcrete
- Mottled clays (iron stained kaolinised granite)
- Kaolinised granite
- Unweathered granite

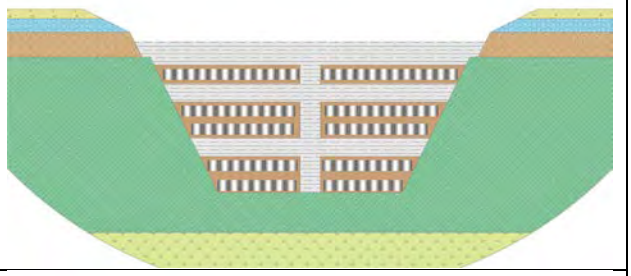
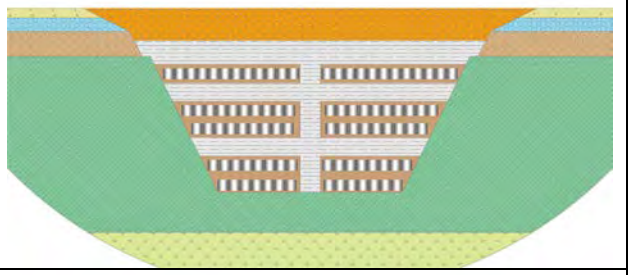
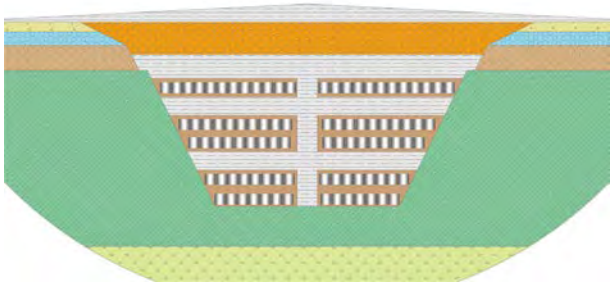
A 3 m thick capping layer of kaolin is compacted onto the second waste layer.	
The next layer of waste packages is tightly placed on the thick capping layer and backfilled with granular material to exclude air pockets and voids. The separation barrier is maintained in the middle of the cell.	
A thin (300 mm minimum) layer of compacted granular material is placed over the waste layer. Compaction testing will be carried out in accordance with *AS1289.5.8.1* to confirm material is compacted to the density required by the engineering design. The next layer of chemical waste packages is placed on the kaolin compacted layer along with the 5 m wide kaolin separation barrier.	
A 3 m thick capping layer of kaolin is compacted onto the fourth waste layer.	

LEGEND - Cell Backfill

- Mottled clays compacted to 95%mmdd
- Mixed laterite and silcrete and clayed sand compacted to 95%mmdd, Max particle size 40mm
- Waste sand backfilled around drums/bags compacted to 90%mmdd

LEGEND - Existing Ground

- Clayed sand
- Laterite
- Silcrete
- Mottled clays (iron stained kaolinised granite)
- Kaolinised granite
- Unweathered granite

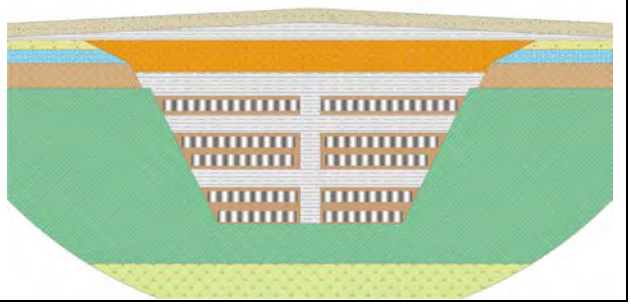
A fifth layer of waste is placed in the cell. A 3 m thick kaolin cap is placed on the waste packages and keyed into the surrounding clay.	
A 4 m thick layer of compacted crushed silcrete and laterite material, with some kaolinised granite or clayey sand is placed between the kaolin cap and the natural ground surface.	
Compacted kaolin clay dome cap is placed over the cell. The final capping layer is formed of compacted kaolinised granite material (permeability approximately 6.0 x 10^{-8} m/s (Douglas Partners, 2015)) and placed in the form of a dome, so as to shed stormwater from the structure into perimeter V drains, which flow to a sump. The cap will have a 1:20 gradient and be an approximately thickness of 2 m in the middle, thinning as it slopes to integrate into the landscape. Subsidence monitoring of the cap will commence.	

LEGEND - Cell Backfill

- Mottled clays compacted to 95%mmdd
- Mixed laterite and silcrete and clayed sand compacted to 95%mmdd, Max particle size 40mm
- Waste sand backfilled around drums/bags compacted to 90%mmdd

LEGEND - Existing Ground

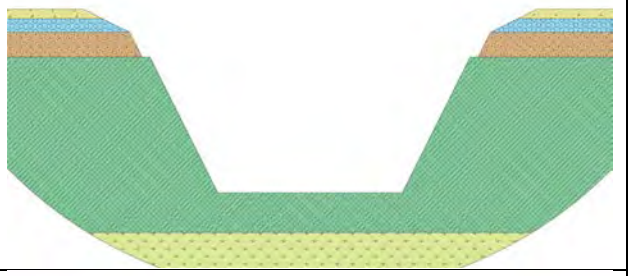
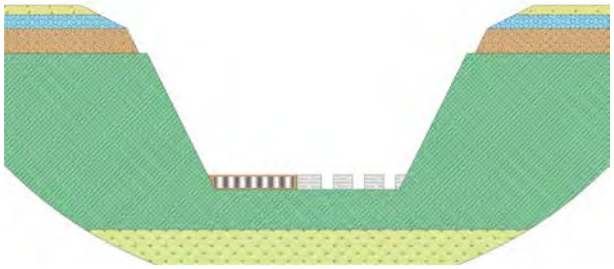
- Clayed sand
- Laterite
- Silcrete
- Mottled clays (iron stained kaolinised granite)
- Kaolinised granite
- Unweathered granite

Subsoil and topsoil is replaced on the cap after the cessation of subsidence monitoring. This layer will be a minimum of 1.7 m thick.	

7.3 Closure of co–disposed chemical and radioactive waste cells

The closure process for each cell is outlined in Table 7–2 below.

Table 7-2 Closure of chemical waste and radioactive waste cells

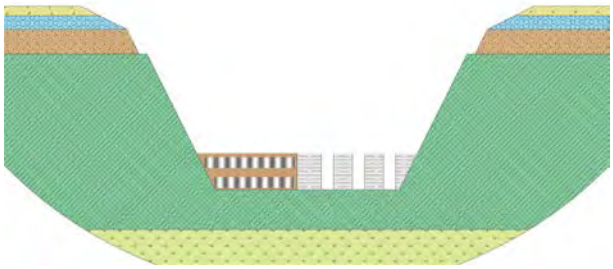
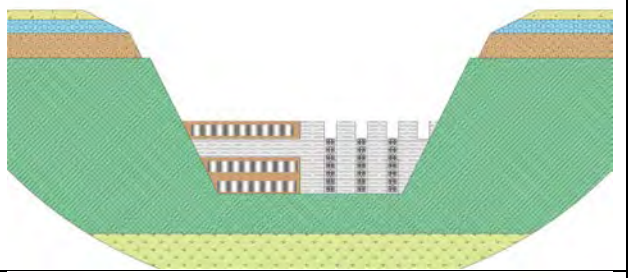
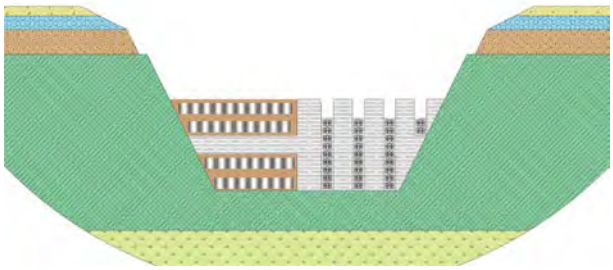
The bottom of the mine void will be a minimum of 5 m above the unweathered granite bedrock.	
A base layer of waste is placed on one side the floor of the mine void. Wastes of different types are segregated by internal compacted kaolin walls which are 5 m wide. The height of each waste layer and barrier wall is the equivalent of the height of a waste package, typically 0.9 m. Waste packages are placed tightly next to each other in a row. Granular material is backfilled between and around the waste packages to fill any air spaces. The shafts for radioactive waste are constructed approximately 3 m apart from	

LEGEND - Cell Backfill

- Mottled clays compacted to 95%mmdd
- Mixed laterite and silcrete and clayed sand compacted to 95%mmdd, Max particle size 40mm
- Waste sand backfilled around drums/bags compacted to 90%mmdd

LEGEND - Existing Ground

- Clayed sand
- Laterite
- Silcrete
- Mottled clays (iron stained kaolinised granite)
- Kaolinised granite
- Unweathered granite

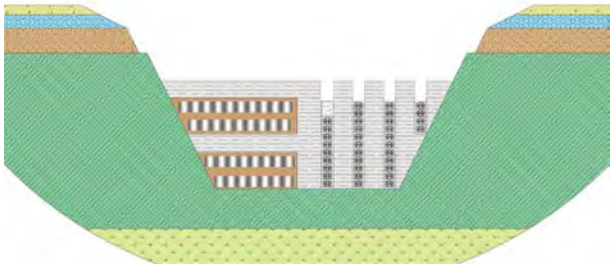
each other and with a 5 m barrier between the shafts and the chemical waste layer.	
A thin (300 mm minimum) layer of compacted granular material is placed over the chemical waste layer. Compaction testing will be carried out in accordance with *AS1289.5.8.1* to confirm material is compacted to the density required by the engineering design. The next layer of chemical waste packages is placed on the kaolin compacted layer along with the 5 m wide kaolin separation barrier. The shafts for radioactive waste continue to be constructed.	
A 3 m thick capping layer of kaolin is compacted onto the second waste layer. The shafts for radioactive waste continue to be constructed.	
The next layer of waste packages is tightly placed on the thick capping layer and backfilled with granular material to exclude air pockets and voids. The separation barrier is maintained in the middle of the cell. The radioactive waste is lowered into the shafts. Between each radioactive waste package a 200 mm layer of kaolin is compacted into place.	

LEGEND - Cell Backfill

- Mottled clays compacted to 95%mmdd
- Mixed laterite and silcrete and clayed sand compacted to 95%mmdd, Max particle size 40mm
- Waste sand backfilled around drums/bags compacted to 90%mmdd

LEGEND - Existing Ground

- Clayed sand
- Laterite
- Silcrete
- Mottled clays (iron stained kaolinised granite)
- Kaolinised granite
- Unweathered granite

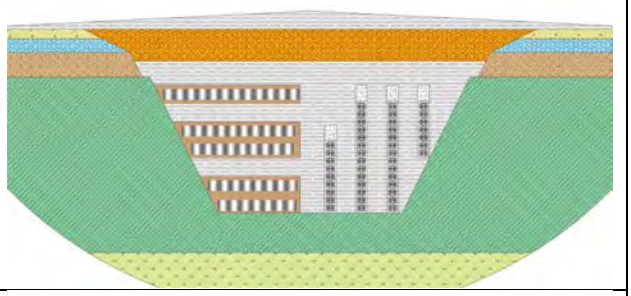
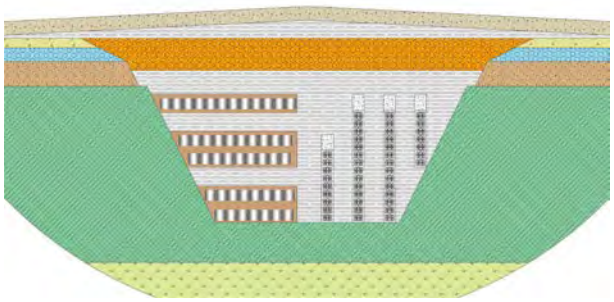
A thin (300 mm minimum) layer of compacted granular material is placed over the chemical waste layer. Compaction testing will be carried out in accordance with *AS1289.5.8.1* to confirm material is compacted to the density required by the engineering design. The next layer of chemical waste packages is placed on the kaolin compacted layer along with the 5 m wide kaolin separation barrier. Radioactive waste continues to be lowered into the shafts. Between each radioactive waste package a 200 mm layer of kaolin is compacted into place.	
A 3 m thick capping layer of kaolin is compacted onto the fourth waste layer. Radioactive waste continues to be lowered into the shafts. Between each radioactive waste package a 200 mm layer of kaolin is compacted into place.	
A fifth layer of waste is placed in the cell. Concrete lids are fitted into each radioactive shaft. A 3 m thick kaolin cap is placed on the waste packages and concrete lids and is keyed into the surrounding clay.	

LEGEND - Cell Backfill

- Mottled clays compacted to 95%mmdd
- Mixed laterite and silcrete and clayed sand compacted to 95%mmdd, Max particle size 40mm
- Waste sand backfilled around drums/bags compacted to 90%mmdd

LEGEND - Existing Ground

- Clayed sand
- Laterite
- Silcrete
- Mottled clays (iron stained kaolinised granite)
- Kaolinised granite
- Unweathered granite

A 4 m thick layer of compacted crushed silcrete and laterite material, with some kaolinised granite or clayey sand is placed between the kaolin cap and the natural ground surface.	
Compacted kaolin clay dome cap is placed over the cell. The final capping layer is formed of compacted kaolinised granite material (permeability approximately 6.0 x 10^{-8} m/s (Douglas Partners, 2015)) and placed in the form of a dome, so as to shed stormwater from the structure into perimeter V drains, which flow to a sump. The cap will have a 1:20 gradient and be an approximately thickness of 2 m in the middle, thinning as it slopes to integrate into the landscape. Subsidence monitoring of the cap will commence.	
Subsoil and topsoil is replaced on the cap after the cessation of subsidence monitoring. This layer will be a minimum of 1.7 m thick.	

7.3.1 Alternative closure designs considered

Underground

Mining Plus (2015) was engaged to assess the costs and practicalities of a shallow underground development to store radioactive waste in a secure environment, being separate to the main waste isolation cell system proposed. The underground workings considered were to be just below the silcrete layer and would be accessed by a box-cut. A main drive provides access to shorter 'room' drives. Use of the silcrete as the sole 'roof' is not considered practical as the silcrete is of variable thickness. The underside of the silcrete is also too close to the surface for storage of higher activity radioactive wastes.

LEGEND - Cell Backfill

- Mottled clays compacted to 95%mmdd
- Mixed laterite and silcrete and clayed sand compacted to 95%mmdd, Max particle size 40mm
- Waste sand backfilled around drums/bags compacted to 90%mmdd

LEGEND - Existing Ground

- Clayed sand
- Laterite
- Silcrete
- Mottled clays (iron stained kaolinised granite)
- Kaolinised granite
- Unweathered granite

The method of excavation would be by mini-excavator fitted with a rotating bit, with the broken material mucked out and trammed to the surface by front end loader. Due to the ground conditions, the mining can only progress one metre before the walls and roof must be shot-creted. The cost of such a development method was calculated and determined to be un-economical.

Vertical shaft sinking

Vertical shaft sinking was also assessed by Mining Plus (2015) as a method of creating secure storage of smaller quantities of radioactive waste. A conceptual design is provided in Appendix A.4. The shafts would be constructed either using an auger type piling rig or by conventional means, with the shafts being un-lined when used for waste storage. Waste in drums would be lowered into the shafts, with placement able to be halted between waste deliveries and the active shaft temporarily closed with a steel cap at the surface and / or a poured concrete plug on the last layer of waste. There is little cost difference between the two methods and diameters of shafts. Mobilisation costs for shaft sinking are a significant portion of the cost for this method of disposal and the unit cost calculated above is based upon a large number of shafts being constructed during the one mobilisation event.

LEGEND - Cell Backfill

- Mottled clays compacted to 95%mmdd
- Mixed laterite and silcrete and clayed sand compacted to 95%mmdd, Max particle size 40mm
- Waste sand backfilled around drums/bags compacted to 90%mmdd

LEGEND - Existing Ground

- Clayed sand
- Laterite
- Silcrete
- Mottled clays (iron stained kaolinised granite)
- Kaolinised granite
- Unweathered granite

7.4 Validation of waste cell designs

The Safety Case and Safety Assessments drive the safety of the Facility and the appropriate cell design to ensure humans and the environment are not exposed to unacceptable risks over geological time. As part of the continual improvement and evolving best practice, Tellus will validate the cell design by conducting soil temperature and moisture monitoring, and conducting vegetation establishment trials on cell caps. These are described in more detail below.

7.4.1 Soil temperature and moisture monitoring

Soil moisture probes and other instrumentation have been installed at various depths above the silcrete to establish soil moisture profiles during rain events and subsequent dry periods. This data will be used to calibrate any unsaturated flow models that are developed in the future.

7.4.2 Trial covers

Tellus will consider conducting trials involving the creation of a domed kaolin cap (but without the waste cell beneath it), and experimenting with replacement of topsoils and attempting to grow vegetation under different variables (e.g. fertiliser rates, water application, seed mix combinations, weed management).

7.5 Cells rehabilitation schedule

For the purposes of closure in this WFDCP, the surface of each cell will be domed, with a 1 in 20 gradient, and have in place a layer of topsoil and subsoil to a height of up to 5m AHD above the surrounding land surface, and the landform will be integrated with natural contours to the extent possible.

It is anticipated that nominally one cell will be completed and closed each year during the operations phase (25 years). Table 7–3 shows the multi-staged schedule for backfilling, capping and monitoring each cell as the operation progresses. It is envisaged that each cell will be monitored for 10 years for subsidence, topsoil replaced and vegetated, and that vegetation monitored for 10 years.

At the end of the monitoring period, it is assumed that the completion criteria (Table 4–1) will be met. As per the schedule in Table 7–3, the first cell will be considered ‘closed’ in year 21 and the last cell will be considered ‘closed’ in year 45. Those cells in Table 7–3 that will continue to be monitored during the Post Closure Management Period (described further in Section 8) are listed in *italics*.

Table 7-3 Cells rehabilitation schedule

Cell	Backfilled and Domed Cap	Subsidence Monitoring (10 years)	Topsoil Replacement and Vegetation Establishment	Revegetation Monitoring (10 years)	Predicted Year Completion Criteria Met
1	Year 1	Year 1 -11	Year 11	Year 11 -21	Year 21
2	Year 2	Year 2-12	Year 12	Year 12-22	Year 22

Cell	Backfilled and Domed Cap	Subsidence Monitoring (10 years)	Topsoil Replacement and Vegetation Establishment	Revegetation Monitoring (10 years)	Predicted Year Completion Criteria Met
3	Year 3	Year 3-13	Year 13	Year 13-23	Year 23
4	Year 4	Year 4-14	Year 14	Year 14-24	Year 24
5	Year 5	Year 5-15	Year 15	Year 15-25	Year 25
6	Year 6	Year 6-16	Year 16	Year 16-*26*	*Year 26*
7	Year 7	Year 7-17	Year 17	Year 17-*27*	*Year 27*
8	Year 8	Year 8-18	Year 18	Year 18-*28*	*Year 28*
9	Year 9	Year 9-19	Year 19	Year 19-*29*	*Year 29*
10	Year 10	Year 10-20	Year 20	Year 20-*30*	*Year 30*
11	Year 11	Year 11-21	Year 21	Year 21-*31*	*Year 31*
12	Year 12	Year 12-22	Year 22	Year 22-*32*	*Year 32*
13	Year 13	Year 13-23	Year 23	Year 23-*33*	*Year 33*
14	Year 14	Year 14-24	Year 24	Year 24-*34*	*Year 34*
15	Year 15	Year 15-25	Year 25	Year 25-*35*	*Year 35*
16	Year 16	Year 16-*26*	*Year 26*	*Year 26-36*	*Year 36*
17	Year 17	Year 17-*27*	*Year 27*	*Year 27-37*	*Year 37*
18	Year 18	Year 18-*28*	*Year 28*	*Year 28-38*	*Year 38*
19	Year 19	Year 19-*29*	*Year 29*	*Year 29-39*	*Year 39*
20	Year 20	Year 20-*30*	*Year 30*	*Year 30-40*	*Year 40*
21	Year 21	Year 21-*31*	*Year 31*	*Year 31-41*	*Year 41*
22	Year 22	Year 22-*32*	*Year 32*	*Year 32-42*	*Year 42*
23	Year 23	Year 23-*33*	*Year 33*	*Year 33-43*	*Year 43*
24	Year 24	Year 24-*34*	*Year 34*	*Year 34-44*	*Year 44*
25	Year 25	Year 25-*35*	*Year 35*	*Year 35-45*	*Year 45*

7.6 Subsidence monitoring

For the first 10 years of the cell cap being in place (without topsoil or vegetation), it will be monitored for subsidence. This would be evident by:

- Slumping of the cap.
- Cracking or unusual deformation of the cap.
- Ponding of water on the domed cap or development of preferential pathways leading to erosion or rilling.

The 10 year monitoring period for cap stability was selected based on information on the exposed clay caps at the adjacent IWDF, where only one clay cap exhibited minor and localised subsidence and this occurred within 5 years. For conservatism, Tellus has adopted an extended initial subsidence monitoring period of 10 years. In addition, advice from Douglas Partners (geotechnical engineers) indicates that over the 10 year period, it is expected that more than 95% of residual settlement will have occurred providing a high degree of confidence that the structure of the waste body is unlikely to undergo any further significant vertical deformation.

In addition, Tellus will place a metallic mesh or grid on top of the clay dome before overlaying the soil so that the profile of the clay dome can be monitored using ground penetrating radar if required after placement of the top soil.

Subsidence monitoring will be undertaken annually from the closure date of each individual cell. Monitoring will consist for taking photographs from a fixed locations and completion of an accurate survey pickup of the cap. Measurements of the erosion of the clay domes (surface geometry, location and depth) and any subsidence features (number and depth) will be recorded. Any cracks/rills will be immediately repaired to return the cap to the correct profile.

7.7 Soil replacement

7.7.1 Methodology

On completion of the 10 year subsidence period and assuming that a geotechnical assessment confirms that the cap is stable, soil will be replaced on the clay caps. If the clay dome is not passed as stable, then an additional period of monitoring or remedial works may be required before the soil cover can be placed.

The maximum height of the soil layer will typically be 1.7 m at the centre of the cap. This will grade at a 3° slope for approximately 100m. From a cell area of 7,200 m^2 the volumes of subsoil (20 cm depth) and topsoil (10 cm depth) available for use will be:

- Topsoil –720 m^3
- Subsoil – 1440 m^3

The topsoil and subsoil are deep yellow sands, described by Landloch (2015a), with the remainder of the soil layer comprised of laterite, silcrete and overburden excavated deeper within the pits. An

abundance of this material will be available. The subsoil and topsoil will be replaced on the top of the soil layer, as this material contains nutrients available for plant growth. Topsoil will be ripped ready for seeding/planting.

It should be noted that the topsoil from the construction of cell 11 will be directly placed on cell 1, rather than being stockpiled to improve its viability as a growing medium. This direct replacement will continue (i.e. topsoil from cells 12 to 25 will be replaced on cells 2 to 15). The topsoil from the initial 10 cells will be stockpiled, and managed to maintain a seed bank, and potentially mixed with topsoil being directly replaced to ensure viable topsoil is available to be placed on cells 16 to 25.

7.8 Vegetation establishment and monitoring

7.8.1 Research

Prior to the establishment of vegetation research will be undertaken on the following aspects:

- Research and investigation of successful techniques/methods for revegetation of land in arid climates.
- Research on the species listed in the PER to determine:
  - environmental cues to break dormancy.
  - flowering times.
  - seed collection methods.
  - viability of seed before or after storage.
  - optimum timing of sowing.
  - potential germination rates in the field.
  - germination enhancement technologies.
  - whether irrigation and fertilising would assist growth or be detrimental to overall survival.
  - probable survival rates of the seedlings.
- Research on amendments to the soils, specifically looking at increasing the pH and fertilisty of the Deep Yellow Sands.

As described in Section 7.4.2 trials will be setup to assist research and investigations into the appropriate vegetation cover for the caps.

7.8.2 Establishment

Vegetation will be established in accordance with a documented revegetation establishment procedure. This procedure will also describe the monitoring procedure and performance measures to assess growth and success over time. This procedure will include information on:

- Re-seeding/planting tubestock with species of local provenance. The species list of appropriate native species will be based on the best information available at the time of planting. The current species list is provided in Appendix A.3 of the PER.
- Weed management during revegetation, including mitigation measure for regrowth and competition of weeds with native revegetated species.
- Irrigation of vegetation if required during the establishment phase. The use of irrigation will be avoided as far as possible by selecting local, drought tolerant specifies and planting/seeding during the cooler wetter months.
- Fertilising vegetation during the establishment phase.
- Establishment of analogue vegetation sites in deep yellow sands elsewhere on the mining tenement. An analogue site is an unmined feature against which a mined feature may be compared (DITR, 2006).

7.8.3 Monitoring

Methodology

The methodology appropriate for monitoring vegetation from year 26 to 36 will be based on the considered industry practice at the time. Currently the methodologies used by the industry include:

- **Point / Line intercept** — Uses a large number of observations to estimate cover values with high precision.
- **Quadrat monitoring** – Square or rectangle areas in the vegetation are examined and information regarding cover, frequency and diversity are collected.
- **Landscape Function Analysis** — measures the patchiness and quality of patch zones along a transect.
- **Plotless– vegetation monitoring** — the Point Centered Quarter method estimates density.A set of points (usually positioned along a transect to traverse the area) is initially selected. The area around each point is divided into four 90° quadrants, and the plant closest to the point in each quadrant is identified. The distance between the central point and selected plant in each quadrant is measured, and then averaged across the four to represent the distance at each sample point. At the conclusion of data collection, the average distance for all sample points is calculated (University of Arizona, 2016).
- **Photo–point monitoring** – photos are taken at fixed locations every monitoring event to visually see the change in vegetation.
- **Remote sensing** – a drone or similar may be used to look at the rehabilitation from a 'birds eye view'. GIS data can be collected and compared between monitoring events to see the change in vegetation cover.

- **Relevés method** – a list of plants in a delimited plot of vegetation, with information on species cover and a substrate and other abiotic features of the plot (Minnesota Department of Natural Resources, 2013).
- **Diameter at breast (DBH) height** – used as a measure of tree maturity, involves measuring the breast and height of a tree.

The method chosen will be part of an integrated approach designed for the specific climate of the site. The method or combination of methods will be repeatable (and auditable) and supported by studies and scientific literature. The methodology will also be discussed with the regulator prior to implementation.

Quality control

An analogue site is an unmined feature against which a mined feature may be compared (DITR, 2006). Two analogue sites, one in Deep Yellow Sand and one in Red Sandy Duplex soil types will be setup and monitored, as per the same methodology as the rehabilitation sites. The purpose of the analogue sites will be to act as a control site, and used for comparison of monitored parameters.

Monitoring frequency

Monitoring of all revegetated areas will be conducted on an annual basis for the first three to five years to determine initial establishment, then on a reduced frequency until completion criteria are achieved. Ideally, monitoring should be conducted at the same time each year following rains.

Reporting of results

Results will be graphed against historical monitoring results. Graphs and raw data will be included in Annual Environmental Reports to the DMP. An assessment of the results of the monitoring in relation to achieving the completion criteria will be discussed in Annual Environmental Reports for each revegetated area.

Remedial strategy

Targeted remediation of poor–performing rehabilitation areas may be necessary. Tellus will consult a botanist to determine the appropriate remedial strategy for rehabilitation should the results of the monitoring not be trending towards the completion criteria. Remedial strategies may include; amendments to the soil, more seed broadcasting, weed management and feral animal controls.

7.9 Radiation monitoring

The aim of the monitoring programme is to:

- Demonstrate regulatory compliance.
- Assessment of the efficiency of work practices and engineering controls in preventing and limiting employee and public exposure to radiation.
- Provide data to enable knowledgeable radiation protection decision-making.

The general procedures are:

- To conduct area gamma and airborne activity surveys to define general baseline radiation levels before the project is started.
- To conduct area gamma and airborne activity surveys before finalising the preliminary earthworks phase to confirm that sufficient material has been removed and to confirm no spread of contamination to neighbouring areas
- To comprehensively monitor people who work in the areas by:
    - Individual gamma monitoring to determine external γ-radiation.
    - Random personal dust sampling to determine airborne radioactivity.
- To conduct assessments of doses received by employees and the critical group.
- To ensure action levels are not exceeded.
- To investigate and correct any situation that results in an action level being exceeded.
- To adopt practical preventive measures at all times to limit the exposure of all persons.

The purpose of the Environmental program is to ensure that radiological impact to the local environment and to members of the public is minimal. This program is usually accomplished by area monitoring (dust and water monitoring, and area γ-surveys).

The environmental monitoring program is adapted based on on-going interpretation of results and risk assessments before disposal and waste acceptance. The following environmental radiation monitoring programme (Table 6) will be followed as a minimum to ensure that the operations have no detrimental effect on the environment.

Table 7-4 Radiation monitoring schedule summary

Monitoring type	Type of monitoring	Type of radiation	Pre-operational	Baseline (operational)
Dust Monitoring	Environmental high volume dust samples	LLA	1/year from 6 representative locations.	2/year from representative locations.
Radon	Track etch	RnDP	1/ year from 3 locations.	2/year for first 3 years of operation – then as per determined risk.
Area γ-Monitoring	Pre disposal background gamma levels	γ-survey	Pre clearance survey before cell is mined.	Pre disposal (mined out pit), after disposal and after final capping.
	Boundary gamma surveys	γ-survey	Once off.	Annually.
	Equipment contamination clearance	α, β, γ-survey		As required before equipment that might be contaminated leave site.
Waste storage	Radiation store	γ-survey		Quarterly.
	Stockpiles	γ-survey		2/year.

7.10 Groundwater monitoring

Annual monitoring of static groundwater levels will be conducted in seven groundwater bores (listed in Table 7–4). Results will be graphed against historical monitoring results. Graphs and raw data will be included in Annual Environmental Reports to the DER. If sufficient groundwater is detected to allow sampling, samples will be collected and analysed for suite of parameters, based on the available information at the time on what wastes have been stored.

Table 7-5 Groundwater Monitoring Bores

Bore ID	Location (Zone 51J) Easting	Northing	Depth (mAHD)	(mbtoc)	Screened Interval (mAHD)	(mbtoc)	Lithology of screened inteerval
SRMB146	219888	6637794	458	30.5	434.38 – 428.38	24.5 – 30.5	Kaolinite and deeply weathered granite
SRMB147	219890	6638007	458	20.6	444.28 – 438.28	14.6 – 20.6	Kaolinite (saprock)
SRMB148	219702	6637808	457	24.3	439.7 – 433.7	18.3 – 24.3	Kaolinite (weathered granite)
SRMB149	220238	6637886	463	22.9	447.25 – 441.25	16.9 – 22.9	Weathered granite
SRMB150	219372	6638392	455	49	416.07 – 407.07	40 – 49	Weathered and fresh granite
SRMB151	219681	6638402	457	44.7	418.88 – 412.88	38.7 – 44.7	Moderately to slightly weathered granite
SRMB152	219499	6637606	455	38.4	423.14 – 417.14	32.4 – 38.4	Weathered granite

7.11 Fencing

Fencing will be maintained around the cells for the Operations Phase (i.e. years 0–25). Weekly inspections of the perimeter fence will be undertaken to carry out maintenance where required. After cyclonic events or heavy rainfall events, the perimeter fence will be checked and maintenance completed if required.

7.12 Underground storage area closure work program

At the cessation of waste disposal underground the entry points to the underground storage area will be made safe and secure and fenced off with signage to prevent restricted access. Exposed ground would be ripped, vegetated and fertilised and then monitored for a period of 10 years.

A description of the rehabilitation schedule for the underground storage area is outlined in Table 7–5.

Table 7-6 Underground storage area rehabilitation schedule

Task	Year
Last use of the underground storage area	Year 25
All entry points to the underground storage area will be made safe and secure and fenced off with signage to prevent restricted access.	Year 25
Ripping of soil surface	Year 26
Spread of growth medium	Year 26
Establishment of vegetation	Year 26
Monitoring of vegetation (10 years)	Year 26– Year 36
Completion Criteria Met	Year 37

7.13 Storage of Records

The *Code of practice for the near-surface disposal of radioactive waste in Australia* (NHMRC, 1992) details the records and inventory keeping required:

Detailed records shall be kept by the operator and by the appropriate authority of all waste consigned to, and received at the facility. For each shipment the waste generator, the type of waste, its volume and weight, and the nature and concentration of nuclides in the waste shall be recorded. Any conditioning of the waste shall also be recorded.

Details of any accidents and incidents at the facility shall be kept together within information on the impact on personnel, the public and environment.

The occupational exposure records of all employees exposed to radiation in the course of their work shall be retained in a form specified by the appropriate authority. All data from environmental and area monitoring at and around the facility shall also be retained.

Furthermore site records shall be kept at least until the end of the institutional control period in two widely separated locations, one of which shall be the appropriate State or Federal government archives, and shall include:

- The location of any disposal structures.
- The location of the waste packages or containers within the structures and the date of their emplacement.
- Detailed of the contents of waste packages or containers.
- Details of the backfilling and cover materials.

Detailed records regarding each waste load (type of waste, its volume and weight, the nature and concentration of nuclides and any conditioning of the waste) will be entered and monitored through Tellus' electronic tracking system on a daily basis.

Tellus will operate two management systems in which details of any accidents and incidents at the Facility will be recorded:

- Occupational Health and Safety Management System (OHSAS 18001 compliant) – records on impacts to workers or the public and data on exposure to radiation will be retained in this system.
- Environmental Management System (ISO 14001 complaint) – records on impacts to the environment, environmental and area data will be retained in this system.

Tellus also operate a Quality Management System (ISO 9001 compliant) which will be implemented during the operation of the Facility to ensure consistent documentation, record keeping and business processes.

Site records will be maintained electronically in the three management systems listed above during the operation of the site.

It is envisaged that the records pertaining to the operation and closure of the site will be provided in hardcopy and electronic form to the key regulatory agencies and the State Archive.

8 POST CLOSURE MANAGEMENT PHASE

8.1 Status Year 26 to 45

On the basis that waste disposal will be completed by Year 25, the status of the following elements at this point of the project lifecycle is as follows:

- Subsidence monitoring will be in progress for 10 cells, and this monitoring will continue in accordance with Section 7.5 until year 35.
- Topsoil replacement will be in progress for 10 cells, in accordance with the soil management procedure.
- Vegetation establishment will be in progress for 10 cells, in accordance with the revegetation establishment procedure.
- Vegetation monitoring will be in progress for 20 cells, conducted in accordance with Section 7.8.3 and this monitoring will continue until year 45.
- All infrastructure on the site will have been decommissioned and the associated impact footprints rehabilitated in accordance with the Mine Closure Plan. The exception is the front office and amenities building, radioactive waste warehouse, water pipeline and associated infrastructure (e.g. reverse osmosis system, water tanks, pumps) which will remain onsite until decommissioned (see Section 8.2).

Figure 8–1 provides a conceptual layout of the site in Year 26 to 45.

The main activities towards the end of the Post Closure Management Phase are the decommissioning of the Facility and handover of the site to the State Government. These activities are described in further detail below.

8.2 Waste facility decommissioning program

8.2.1 Water pipeline and associated infrastructure

Approaching the time for handover of the Facility to the State Government a decision will be made regarding whether the water pipeline is removed and how it is removed or whether it is to remain in place. A section of the water pipeline traverses the ex–Jaurdi pastoral lease, and if removal of the pipeline is the chosen option, it will need to be discussed with DPAW to minimise impacts to the surrounding vegetation.

The rehabilitation activities for the water pipeline route and footprints of associated equipment would include ripping of the soil surface and seeding or planting with tubestock. The area would be irrigated and fertilised in accordance with the planted species requirements for growth. Equipment (pumps, tanks etc.) would be removed from the site.

Figure 8–1 Infrastructure remaining onsite

8.2.2 Fences

All fences on the site will be taken down and removed from the site at year 45. Fences will only remain in place if agreed to with the appropriate authority for institutional control.

8.2.3 Administration building

Approaching the time for handover of the Facility to the State Government a decision will be made regarding whether the administration building, which will include bathroom and kitchen facilities, will be removed or remain for the ICP.

The weighbridge and gate at the entrance to the Facility will be dismantled and removed. The internal parking and roads will be broken up and the bitumen removed. Both areas will be spread with topsoil, deep ripped and revegetated.

8.2.4 Radioactive waste warehouse

The radioactive waste warehouse will be decommissioned (all equipment removed) and the concrete pad removed, topsoil ripped and vegetation established.

8.2.5 Financial provisioning

Financial provisioning information for the Facility decommissioning program is provided in Table 8–1. Cost estimates were calculated in an MS® Excel spreadsheet as part of Tellus' overall financial planning of the project, and the final estimates are provided in Table 8–1.

The costings provided are based on the size of areas (as defined during the pre–feasibility phase of the project development) and 2016 rates. Rates account for; supply, labour, construction equipment and freight. The rate multiplied by the size of the area (quantity) provides a cost estimate. This cost estimate is then considered in terms of growth over 45 years (i.e. growth of the quantity) to account for any change to the size of areas to be closed.

Tellus recognise the importance of updating the financial provisioning cost estimates with each revision of the WFDCP, to ensure closure is included in Tellus annual financial budgets.

8.2.6 Monitoring of revegetated footprints

Monitoring of revegetation footprints will occur during the ICP under the control of the appropriate authority.

8.3 Handover to State Government

8.3.1 Transfer arrangements

Tellus will maintain a package of insurances to cover an agreed set of circumstances based on an independent risk assessment which identifies all credible risks and the cost of remedial works that

would be required as consequence of these risks being evidenced. Tellus will provide the necessary funding to transition these insurance arrangements to the State Government for the term of the ICP.

Stored electronic records (required by Section 7.13) will be transferred to the state archives and federal archives, or to the location agreed to between Tellus and the State Government.

8.4 Financial provision during ICP

Tellus propose to transfer responsibility of the site to State Government with the appropriate financial resources to cover ongoing management through the ICP. Tellus will transfer an agreed sum of money into an escrowed fund to cover the cost of managing the site. The amount of funding transferred will be determined based on an independent assessment by a competent consultant and will be agreed with the relevant Government agencies.

9 INSTITUTIONAL CONTROL PERIOD – STATE GOVERNMENT MANAGEMENT

9.1 Status Year 46 to 325

The status at year 46 assumes a handover of the Facility has occurred to the appropriate authority within the State Government. The State Government will complete the following activities during the ICP (defined in Section 9.2):

- Vegetation monitoring of the Facility infrastructure footprints until the vegetation meets the completion criteria outlined in Table 4–1.
- Continue radiation and groundwater monitoring of the Facility.
- Restrict public access to, or alternative use of, the Facility.
- Maintain records of the wastes buried at the Facility.
- Assess land use post–institutional control period to ensure it is compatible with stored intractable waste.

9.2 Definition of institutional control

Institutional control is defined by the *Code of practice for the near–surface disposal of radioactive waste in Australia* (NHMRC, 1992) as the control of a former waste disposal site by the appropriate authority in order to restrict access to and use of the site, and to ensure an on-going knowledge that the site has been used for the disposal of radioactive waste.

The ICP, as defined by NHMRC (1992), is the period following closure of the disposal facility where public access to, or alternative use of, the site shall be restricted for a predetermined period of time. The ICP shall be established before the commencement of disposal of operations (i.e. disposal of radioactive waste) and should not be less than 100 years.

The appropriate authority to determine the institutional control period for Sandy Ridge is the Radiological Council of Western Australia. As per NHMRC (1992) the Radiological Council of Western Australia may vary the institutional control period according to the usage of the facility.

It should be noted that the institutional control relates to radioactive waste only. Should radioactive waste disposal at Sandy Ridge never eventuate, then the site would not be subject to an ICP.

9.3 Appropriate authority

As Tellus is a private company and does not own the land, at an agreed milestone in the ICP, responsibility for the Sandy Ridge facility is proposed to be transferred to the Western Australian Government. The site will then be managed by a government agency determined by the State Government. This agency would then be recognised as the appropriate authority for institutional

control. As part of the transfer of responsibility from Tellus to the State Government, Tellus will also provide ample funding through an escrowed fund arrangement to cover management costs likely to be incurred by Government.

Government is the only practical option to be the appropriate authority for institutional control given:

- The nature of the wastes is such that they must be contained securely for geological time.
- The extended length of the institutional control period (100 to 300 years).
- The land in question is a Crown Reserve.
- The Government exists in perpetuity, whereas it is feasible or even likely that at some future date Tellus may no longer exist.

The Government therefore is in the best position to restrict access to and use of the site, and to ensure on-going knowledge is retained in state archives for future populations to access as required.

9.4 Monitoring requirements

9.4.1 Vegetation monitoring

Vegetation monitoring will be required of the cell caps and the footprints of the facility infrastructure (Section 9.4.1). The methodology for vegetation monitoring will be in accordance with best practice at the time monitoring is to be carried out (i.e. in five decades time).

9.4.2 Radiation monitoring

Refer to Section 7.9

9.4.3 Groundwater monitoring

Annual monitoring of static groundwater levels in seven groundwater bores (listed in Table 9–1) will be conducted. Results will be graphed against historical monitoring results. Graphs and raw data will be included in Annual Environmental Reports to the Reserve manager.

Table 9-1 Groundwater monitoring bores

BORE ID	LOCATION (Zone 51J) EASTING	NORTHING	DEPTH (mAHD)	(mbtoc)	SCREENED INTERVAL (mAHD)	(mbtoc)	LITHOLOGY OF SCREENED INTERVAL
SRMB146	219888	6637794	458	30.5	434.38 – 428.38	24.5 – 30.5	Kaolinite and deeply weathered granite
SRMB147	219890	6638007	458	20.6	444.28 – 438.28	14.6 – 20.6	Kaolinite (saprock)
SRMB148	219702	6637808	457	24.3	439.7 – 433.7	18.3 – 24.3	Kaolinite (weathered granite)
SRMB149	220238	6637886	463	22.9	447.25 – 441.25	16.9 – 22.9	Weathered granite
SRMB150	219372	6638392	455	49	416.07 – 407.07	40 – 49	Weathered and fresh granite
SRMB151	219681	6638402	457	44.7	418.88 – 412.88	38.7 – 44.7	Moderately to slightly weathered granite
SRMB152	219499	6637606	455	38.4	423.14 – 417.14	32.4 – 38.4	Weathered granite

9.5 Management requirements

9.5.1 Restrict Public Access

The State Government will need to put in place access restrictions to avoid the public utilising the site. The mechanism to achieve this will need to be discussed within government to find the appropriate solution at the commencement of the State Government's management of the Facility.

9.5.2 Records Storage

Maintain and make publically available stored records kept by Tellus (see Section 7.13). These records should be held for access by future generations to ensure knowledge is passed on regarding the location of buried chemical wastes. This will avoid potential human health impacts long–term by the accidental excavation of wastes.

9.5.3 Post–institutional control land use

Any proposed new use for the former site should be compatible with the presence of intractable chemical waste at greater than 7 m beneath the surface.

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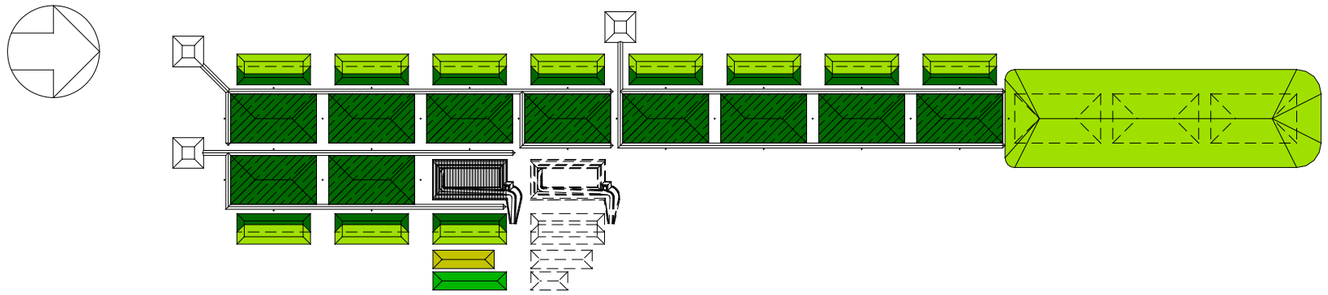
APPENDICES

A.1 General arrangement of cells

NOTES

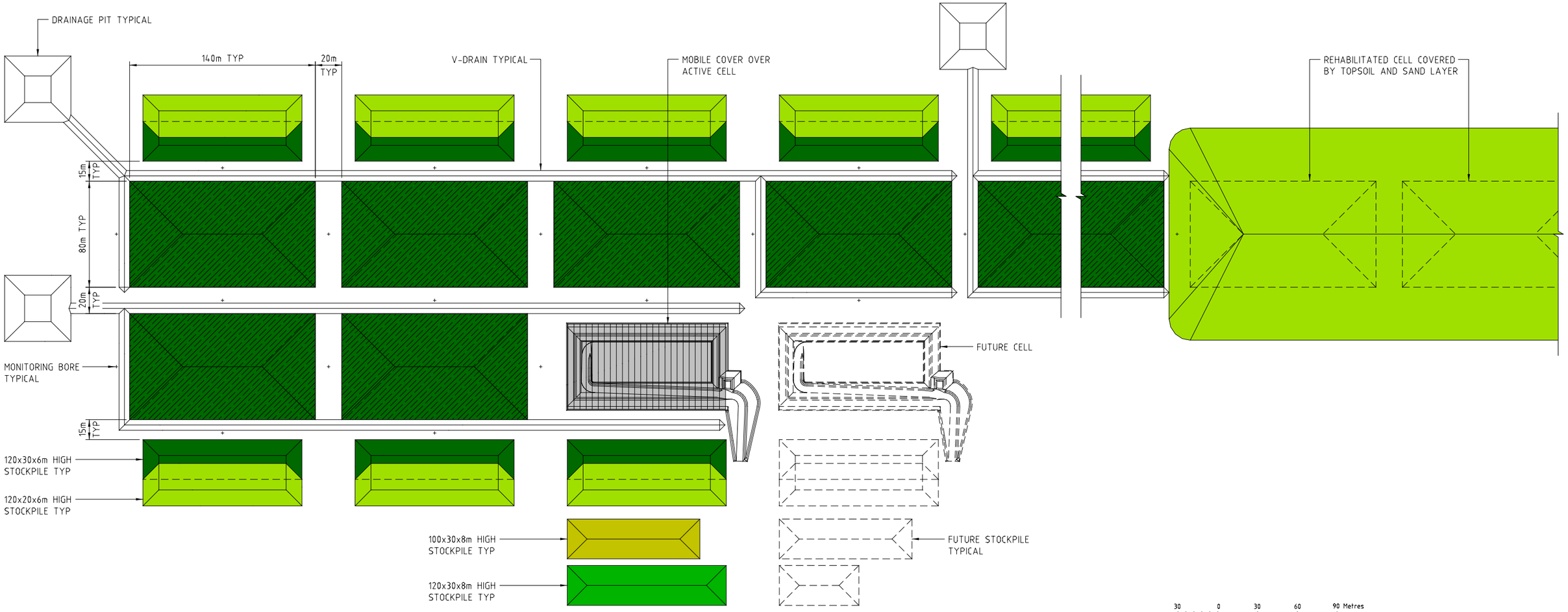
1. LAYOUT DESIGN IS PRELIMINARY ONLY.



OVERALL LAYOUT PLAN
SCALE 1:5000

LEGEND - STOCKPILES AND BACKFILL

- MOTTLED CLAYS
- YELLOW SAND AND TOPSOIL
- CRUSHED SILCRETE AND LATERITE
- KAOLINISED GRANITE
- MOTTLED CLAYS COMPACTED TO 95%MMDD BACKFILL



LAYOUT PLAN
SCALE 1:1500

30 0 30 60 90 Metres
SCALE 1 : 1500

100 0 100 200 300 Metres
SCALE 1 : 5000

INFORMATION ONLY
NOT FOR CONSTRUCTION

CLIENT DRG No.

REF DRG No	TITLE	REV	BY	DATE	DESCRIPTION	CHKD	ENG
		A	BK	15.09.15	ISSUED FOR INTERNAL AND CLIENT REVIEW	JL	IWB

CLIENT: TELLUS

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DRAWN	B KLEMICK	08.09.15
CHKD		
DES ENG		
PROJ ENG		
CLIENT		

TITLE
TELLUS SANDY RIDGE
PRE-FEASIBILITY STUDY
WASTE ISOLATION CELL
OVERALL LAYOUT

PROJECT No		SCALE	DRG No	REV
C5409	A1	1:1500	C5409-6310-CE-005	A

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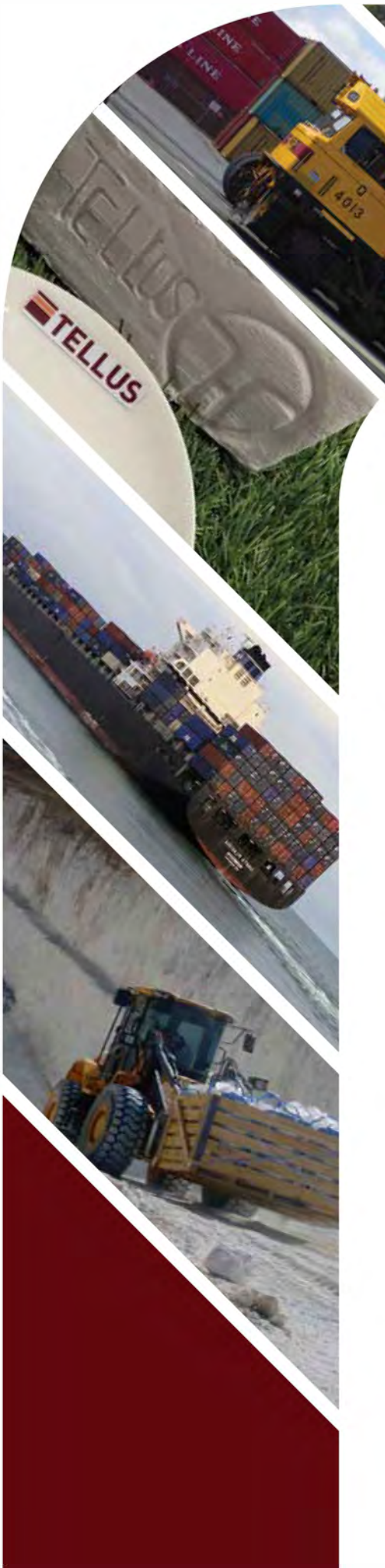
A.2 Risk matrix and assessment



TELLUS

Sandy Ridge Facility
Environmental Risk Assessment

June 2016

SANDY RIDGE FACILITY ENVIRONMENTAL RISK ASSESSMENT

Draft Report | June 2016

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DISTRIBUTION

Report File Name	Report Status	Author	Date	Distribution
Environmental Risk Assessment –V0.1	V0.1 (Draft)	Aurora Environmental	15 February 2016	Tellus Holdings Ltd
Environmental Risk Assessment –V0.2	V0.2 (Draft)	Aurora Environmental	12 April 2016	Tellus Holdings Ltd
Environmental Risk Assessment	vA	Tellus Holdings Ltd	7 June 2016	OEPA

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ABBREVIATIONS

ADT	Articulated dump truck
Bq/g	Bequerels per gram
DotE	Department of the Environment (Cwlth)
DG	Dangerous goods
DPAW	Department of Parks and Wildlife (WA)
EMS	Environmental Management System
EP Act	*Environmental Protection Act 1986* (WA)
EPBC Act	*Environment Protection and Biodiversity Conservation Act 1999* (Cwlth)
JSA	Job safety analysis
mm	millimetre
PEC	Priority Ecological Community
PER	Public Environmental Review
PPE	personal protective equipment
QA	quality assurance
QC	quality control
TEC	Threatened Ecological Community

1 INTRODUCTION

Tellus Holdings Limited (Tellus) proposes to construct and operate the Sandy Ridge Project. The details of the Sandy Ridge Project are provided in the *Sandy Ridge Project Public Environmental Review* (PER) (Tellus, 2016).

The environmental risks associated with the operational aspects of the project have been assessed by the project team at a workshop. The outcomes of the workshop are documented in this report.

Risks associated with closure were addressed at a separate workshop. The outcomes of that workshop are presented in the Mine Closure Plan and Waste Facility Decommissioning and Closure Plan. These plans are appended to the PER.

2 METHODOLOGY

Tellus adopted the international (*ISO 31000:2009*) and national (*AS/NZS ISO 31000:2009*) (SAI Global, 2009) standard processes for managing environment–related risks. An environmental risk assessment has been undertaken for all operational aspects of the project, in accordance with the procedures outlined in *AS/NZS ISO 31000:2009 Risk Management–Principles and Guidelines* and the handbook *HB 203:2012 Managing Environment–Related Risk* (SAI Global, 2012), using Tellus' Risk Assessment Matrix (AppendixA.1). The risk assessment process is illustrated in Figure 2–1.

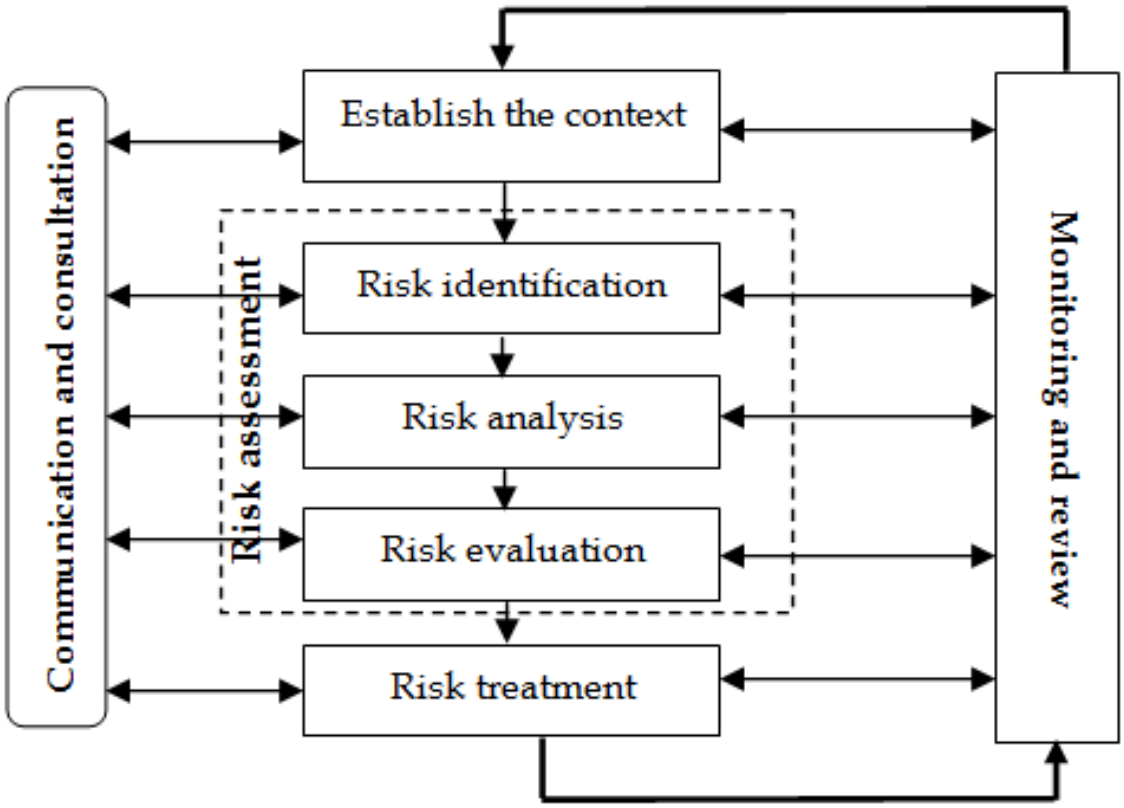


Figure 2–1 Risk assessment process as outlined in HB 203:2012

Each step of the process is described below.

3 ESTABLISH THE CONTEXT

As the project is proposed to be located within Western Australia, the definition of 'environment' for the purpose of the environmental risk assessment was the definition provided under the Western Australian *Environmental Protection Act 1986* (EP Act):

***environment**, subject to subsection (2), means living things, their physical, biological and social surroundings, and interactions between all of these (*Part 1, section 3, subsection 1).

For the purposes of the definition of environment in subsection (1), the social surroundings of man are his aesthetic, cultural, economic and social surroundings to the extent that those surroundings directly affect or are affected by his physical or biological surroundings (Part 1, section 3, subsection 2).

The project is also being assessed by the Commonwealth Department of the Environment (DotE) under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act). Section 528 of the EPBC Act defines environment to include:

(a) ecosystems and their constituent parts, including people and communities; and

(b) natural and physical resources; and

(c) the qualities and characteristics of locations, places and areas; and

(d) Heritage values of places; and

(e) the social, economic and cultural aspects of a thing mentioned in paragraph (a), (b), or (c).

The EPBC Act's definition for environment was also considered in establishing the context of the risk assessment.

The glossary of other terminology used during the environmental risk assessment was as per *HB 203:2012 Managing Environment–Related Risk* as listed below:

Consequence	includes cascade effects and impacts to the organization's business and activities arising from environmental-related issues (e.g. regulatory fines, clean-up costs, and damaged reputation as well as enhanced reputation, continued licence to operate, and regulatory approvals).
Environmental Aspect	element of an organization's activities, products or services that can interact with the environment.
Environmental impact	any change to the environment, whether adverse or beneficial, wholly or partially resulting from an organization's activities, products or services.
Hazard	source of potential harm.

Likelihood	chance of something happening, whether defined, measured or determined objectively or subjectively, qualitatively or quantitatively, and described using general terms or mathematically.
Risk	the effect of uncertainty on objectives.
Risk Source	a tangible or intangible element that alone or in combination has the intrinsic potential to give rise to risk.

4 RISK ASSESSMENT

4.1 Risk identification

The sources of risks, environmental aspects and potential environmental impacts, as defined by *HB 203:2012* were identified in a workshop attended by the Tellus Project Leader, Tellus Environment and Approvals Manager, Tellus Engineer, and Aurora Environmental representatives. The identified environmental aspects were categorised into 'planned' that is those aspects which Tellus know will occur during the project, and those that are 'unplanned' and may credibly occur during the project, but which Tellus has no control over the frequency of occurrence. The identified potential environmental impact is based on the 'worst–case' credible impact.

4.2 Risk analysis

Qualitative risk analysis was used to evaluate the significance of the likelihood of the consequence (Table 4–1). Analysis of the inherent risk was undertaken assuming no management/mitigation controls were in place. The group then discussed appropriate management and mitigation measures that would be implemented to reduce the likelihood or consequence, and then analysed the final residual risk.

Table 4–1 Environmental risk register

Risk Number	Environmental Aspect	Sources of Risk (Hazard)	Potential Environmental Impact (Worst case)	Pre–management risk	Management and Mitigation Measures	Post–management Risk		Residual risk
						Likelihood	Consequence	
1	**Transport of hazardous/intractable waste.**	Chemical spill (40 t) from the shipping container. Chemical spill onto roads.	Death and/or acute or chronic illness in humans and biota exposed to the spill.	Extreme	Waste packaged in bulka bags/drums. Bulka bags/drums transported inside shipping container. Shipping container securely fastened to truck. Dangerous goods (DG) rated trucks (e.g. better brakes, rollover systems) are used only. Trucks travel on sealed roads or controlled site access roads. Transport contractor on Tellus Register of Approved Transporters. Audits of transport contractor's procedural controls. For high risk loads (e.g. arsenic trioxide) individual risk assessment and transport management plan. Emergency Response and Management Plan.	Rare	Catastrophic	High
2	**Explosions.**	Fuel storage facility, storage and use of gas. Diesel fuel tank and piping reticulation. Explosives magazine.	Degradation of air quality (localised). Death/injury of humans and biota within the vicinity of the blast zone or in the path of the fire. Creates bushfire.	Extreme	Fuel storage facilities and systems designed to meet relevant Code. Inspection to ensure compliance including maintenance. Firebreaks. Firefighting equipment. Operational procedures. Hot work permits. Restricted access to the explosives store (i.e. must hold shot firer licence).	Rare	Major	High
3	**Transport of hazardous/intractable waste.**	Truck crash.	Death and injury to humans.	High	Trucks travel on sealed main roads only. Transport contractor on Tellus Register of Approved Transporters. Well maintained trucks. Approved, experienced and licensed drivers. Audits of transport contractor's procedural controls. Emergency Response and Management Plan. Police, emergency services.	Rare	Catastrophic	High
4	**Transport of hazardous/intractable waste.**	Chemical spill (e.g. flyash/ SPL) on the road, into surrounding environment (e.g. river).	Death and/or injury to fauna and flora.	High	Waste packaged as appropriate to level of hazard. Bulka bags/drums transported inside shipping container. Shipping container securely fastened to truck. DG rated trucks (e.g. better brakes, rollover systems) are used only. Trucks travel on sealed roads or	Possible	Moderate	High

Risk Number	Environmental Aspect	Sources of Risk (Hazard)	Potential Environmental Impact (Worst case)	Pre–management risk	Management and Mitigation Measures	Post–management Risk		Residual risk
						Likelihood	Consequence	
					controlled site access roads. Transport contractor on Tellus Register of Approved Transporters. Audits of transport contractor's procedural controls. For high risk loads (e.g. arsenic trioxide) individual risk assessment and transport management plan. Emergency Response and Management Plan.			
5	**Transport of hazardous/intractable waste.**	Collision with native fauna.	Road kill of Threatened/Priority fauna.	High	Trucks travel on sealed main roads only. Transport contractor on Tellus Register of Approved Transporters. Well maintained trucks. Approved, experienced and licensed drivers. Audits of transport contractor's procedural controls. Report to DPAW and DotE. Where feasible control speed and use headlights.	Possible	Moderate	High
6	**Creation of mine pits.**	Clearing native vegetation.	Loss of native vegetation.	High	Avoid Priority species. Engineering design to minimise amount of vegetation to be cleared. Supervision of clearing. Operational Procedure. Regular toolbox meeting. Training of Operators.	Almost Certain	Insignificant	High
7	**Creation of firebreak.**	Clearing native vegetation.	Opportunity for weeds to establish.	High	Weed monitoring and removal.	Almost Certain	Insignificant	High
8	**Transport of radioactive waste.**	Radioactive waste spill (200L drum).	Humans within the vicinity of the spill will receive a one off higher dose of radiation above background levels.	High	Small quantities received on average annually. Drums transported inside shipping container. Shipping container securely fastened to truck. Priority given to transporting on heavy haulage routes. For all radioactive waste an individual risk assessment is completed. Disposal permit issued by government. Transport contractor on Tellus Register of Approved Transporters. Audits of transport contractor's procedural controls. Emergency Response and Management Plan. Inform Radiation Health Branch WA.	Unlikely	Moderate	Moderate
9	**Presence of infrastructure (e.g. turkeys nest, landfill, mine voids).**	Attraction of birds, mammals, vermin and feral animals to water source. Fauna falling into pit/cell.	Injury or death of Threatened/Priority fauna.	High	Fencing of contaminated water pond. Fencing around landfill. Covering of landfill once the trench is	Unlikely	Moderate	Moderate

Risk Number	Environmental Aspect	Sources of Risk (Hazard)	Potential Environmental Impact (Worst case)	Pre–management risk	Management and Mitigation Measures	Post–management Risk		Residual risk
						Likelihood	Consequence	
		Presence of vermin carrying disease at landfill, being eaten by predators.			full. Weekly litter inspection and clean-up. Weekly toolbox meeting. Training of operators. Operational bunding around cell. Ramps into and out of cell. Daily inspection of water ponds for trapped/injured fauna. Daily inspections of access roads for roadkill.			
10	**Naturally occurring events.**	Bushfire.	Injury of workers and site visitors. Toxic smoke plume. Contaminated fire water. Soil contamination.	High	Emergency Response and Management Plan. Low fuel load in woodlands. Firebreaks. Firefighting facilities onsite. Minimal flammable waste, facilities and goods onsite.	Rare	Moderate	Moderate
11	**Introduction of weeds.**	Incoming waste carriers. Incoming supply vehicles and 4wds. Incoming site visitors, staff vehicles. Bird poo.	Establishment of weeds on the site and competition for resources (e.g. water) with native vegetation.	High	Weed monitoring procedures. Inspections of light vehicles and brush downs. Mining plant wash down before its used onsite. Weed removal where necessary.	Likely	Insignificant	Moderate
12	**Accidental fire within infrastructure.**	Flammable goods packed into shipping container. Vehicle fire in cell. Fire in buildings.	Release of toxic gas, adverse health impacts to workers/public/fauna.	High	Equipment maintenance. Fire detection/ suppression systems. Design codes for waste storage. Operational procedures. Regular toolbox meetings. Training of operators. Chemical wastes stored in shipping containers. Use of diesel engines instead of petrol in storage areas. Multiple waste storages areas in container hardstand.	Rare	Moderate	Moderate
13	**Handling of hazardous/intractable waste.**	Chemical spill during offloading of waste from ADT into cell. Chemical spill during manoeuvring of waste package into place in the cell.	Death of worker in the cell.	Extreme	PPE. Training of operators. Regular toolbox meetings. Operating procedures. Restricted access to the cell. Recirculating air throughout cabs. JSAs specific to waste being handled. Equipment maintained. Secondary egress from cell. Everyone in the cell immediately evacuates.	Unlikely	Minor	Low
14	**Creation of cell and waste disposal progressing.**	Surface water runoff into cell.	Generation of leachate and degradation of groundwater.	Extreme	Roof canopy over open cell. Operational bunding around cell, drains into V drain and sump. Levees to divert surface water flow. Backfill around waste packages with high matric suction potential.	Rare	Insignificant	Low

Risk Number	Environmental Aspect	Sources of Risk (Hazard)	Potential Environmental Impact (Worst case)	Pre–management risk	Management and Mitigation Measures	Post–management Risk		Residual risk
						Likelihood	Consequence	
					Primary containment in place in each waste package (e.g. liner in bulka bag).			
15	**Handling of hazardous/intractable waste.**	Chemical spill during unloading/reloading of waste from/into shipping container in Waste Inspection Shed. Chemical spill during sampling and testing of waste package in laboratory.	Death and/or acute or chronic illness in humans exposed to the spill.	High	Operating procedures. Training of operators. Regular toolbox meetings. PPE. Regular equipment maintenance. Visual assessment. Safety shower. Spill kits. First aiders/first aid kit. Evacuation procedure.	Rare	Minor	Low
16	**Handling of hazardous/intractable waste.**	Vehicle collision with ADT. Loss of containment from shipping container subsequent spill of solids.	Localised soil contamination. Damage to vegetation. Toxic dust dispersal affecting vegetation/fauna off the development envelope.	High	Operating procedures. Training of operators. Regular toolbox meetings. Onsite traffic management. Speed limits. Two-way communications. Regular equipment maintenance. Visual assessment. Spill kit.	Rare	Minor	Low
17	**Handling of radioactive waste.**	NORMs spill during unloading/reloading of waste from/into shipping container in Waste Inspection Shed.	Humans within the vicinity of the spill will receive a one off higher dose of radiation above background levels.	High	Operating procedures. Training of operators. Regular toolbox meetings. PPE. Regular equipment maintenance. Visual assessment. Safety shower. Spill kits. First aiders/first aid kit. Dose meters on workers. Radiation measurements.	Rare	Minor	Low
18	**Handling of radioactive waste.**	Gamma exposure during offloading of waste from ADT into shaft.	Humans within the vicinity of the shaft above with higher dose of radiation above background levels or chemical exposure.	High	Operating procedures. Training of operators. Regular toolbox meetings. Engineering design. Dose meters. Radiation measurements. Exclusion zones.	Rare	Insignificant	Low
19	**Wash down of shipping containers.**	Contaminated wash water washes off the wash down pad. Dust on hardstand from, residual of wash down. Containment overflows during extreme rainfall event. Liner faulty/fails.	Soil contamination.	High	Operating procedures. QA/QC testing on liner. Engineering design (500mm freeboard, ponds sufficient capacity). Shallow monitoring bores. Contain the overflow through secondary sump. Clean-up/disposal of contaminated soil.	Unlikely	Minor	Low

Risk Number	Environmental Aspect	Sources of Risk (Hazard)	Potential Environmental Impact (Worst case)	Pre–management risk	Management and Mitigation Measures	Post–management Risk		Residual risk
						Likelihood	Consequence	
20	**Creation of mine pits.**	Blasting. Physical removal of topsoil, subsoil and kaolin.	Dust emissions affecting workers. Dust emissions settling on plant leaves, affecting photosynthesis and potentially killing plants. Noise emissions affecting workers. Noise emissions temporarily or permanently damaging the hearing of fauna in the vicinity of the blast.	High	Operating procedures. Blasting conducted once per year, duration of a few seconds. PPE for workers.	Unlikely	Insignificant	Low
21	**Construction and operation of water pipeline.**	Leak/spill of saline water.	Death of vegetation through osmosis of saline water.	High	Design controls to monitor flow through pipeline, any loss will immediately trigger an alarm in the process control unit. Close isolation valves. Cease pumping water. Inspect water pipeline and repair damaged section.	Unlikely	Minor	Low
22	**Use of saline water for dust suppression**	Watering of native vegetation along roadsides.	Uptake of saline/brackish water and death of vegetation.	High	Use a dribble bar on the back of the water cart instead of a spray bar. Equipment maintenance. Operational procedures.	Unlikely	Minor	Low
23	**Fencing of the waste cells.**	Exclusion of fauna from potential habitat.	Forced translocation of fauna into other habitat and increased predation in new habitat. Potential for injury/death of Threatened/Priority fauna.	High	Fences to be removed following revegetation of cells.	Rare	Insignificant	Low
24	**Waste Laboratory.**	Minor spill of sample during testing of waste.	Radiation exposure of workers. Injury (e.g. chemical burn) to workers.	High	Building enclosed and contains fume hoods. PPE. Operational procedures for waste testing. Training of operators. Regular toolbox meetings.	Unlikely	Minor	Low
25	**Water retention ponds.**	Leak/crack in pond liners.	Release of contaminated water to underlying and surrounding soils and potentially damage vegetation associated with those soils.	High	Shallow monitoring bores. Low hydraulic conductivity means water will not move far from the spill site. Contain and clean-up the spill. Operational procedure for management of contaminated soils.	Unlikely	Insignificant	Low
26	**Naturally occurring events.**	Earthquakes (size 3)	Slight subsidence of cell, consolidates backfill and potential creates a void.	High	Post event inspection and records kept. Repair cap if needed. Subsidence monitoring.	Possible	Insignificant	Low
27	**Naturally occurring events.**	Cyclones/flood	Increased rainfall at the site, overflow of contaminated water ponds which may impact surrounding soils, cause widespread flooding of contaminated surface water and injure/kill biota. Cell fills with water and leachate generated and then overflows to surrounding environment.	High	Small quantities of water. 24 hour duration. Pumping out of ponds prior to cyclone. Roof canopy over open cell. Operational bunds around cells. Waste still in shipping containers. Waste disposal halted if cyclone expected.	Unlikely	Insignificant	Low

Risk Number	Environmental Aspect	Sources of Risk (Hazard)	Potential Environmental Impact (Worst case)	Pre–management risk	Management and Mitigation Measures	Post–management Risk		Residual risk
						Likelihood	Consequence	
28	**Aboriginal heritage.**	Destruction of aboriginal heritage site and/or cultural association. E.g. clearing native vegetation of significance, excavating land of significance, and storing waste on significant land.	Degradation of heritage value of the local area.	High	Aboriginal heritage pre-construction survey. Operational procedure for encountering aboriginal cultural material. Contact WA Police if skeletal material is uncovered.	Rare	Minor	Low
29	**Malleefowl mound.**	Construction of pipeline. Construction of road and plant.	Removal or damage to an active nesting mound.	High	Malleefowl survey pre-construction to identify new active mounds. Re-design pipeline route to avoid mound. Report disturbance to an active mound to DPAW and DotE.	Rare	Insignificant	Low
30	**Landform.**	Change in landform by placing domed caps up to 5m higher than the landscape.	Ponding around the toe of the landform. Erosion.	Moderate	Engineering design. Engineering design as constructed plans demonstrated cell backfilling/capping competently constructed. Long term erosion modelling. Revegetation present.	Unlikely	Insignificant	Low
31	**Transport of chemical and radioactive waste.**	Leak of liquid material (e.g. NORM and/or hydrocarbons) from shipping container.	Humans within the vicinity of the leaked material may receive a one off higher dose of radiation above background levels or chemical exposure.	Low	Waste packaged as appropriate to level of hazard. Trucks travel on sealed roads or controlled site access roads. Transport contractor on Tellus Register of Approved Transporters. DG rated trucks (e.g. carry clean-up equipment and drivers are trained to manage a leak). Audits of transport contractor's procedural controls. Truck parked up. Source of the leak is investigated and contained. Clean-up undertaken. Emergency Response and Management Plan.	Rare	Insignificant	Low
32	**Subsurface waste disposal**	Permanent isolation of waste over geological time.	Gamma radiation exposure at the surface on surrounding humans, soils, flora and vegetation and fauna.	Low	Safety Case and Safety Assessment. Baseline radiation survey. Engineering design - depth of burial in shaft and materials used in construction. Institutional control period.	Rare	Insignificant	Low
33	**Creation of mine pits**	Alteration to surface water runoff.	Changes hydrology (quality and quantity) and effects on downstream vegetation.	Low	High infiltration rate (500mm/day). High evaporation rate (2400mm/year). Vegetation likely to be dependent only on landing rainfall, not runoff. Vegetation adapted to low rainfall (<250mm/year).	Rare	Insignificant	Low
34	**Kaolin Process Plant**	Operation of the plant. Incorrect disposal of wastes (e.g. waste oil, oily rags)	Dust emissions affecting workers. Dust emissions settling on plant leaves, affecting photosynthesis and potentially killing	Low	Wet process. Building enclosed and contains dust extraction system (e.g. baghouse).	Rare	Insignificant	Low

Risk Number	Environmental Aspect	Sources of Risk (Hazard)	Potential Environmental Impact (Worst case)	Pre–management risk	Management and Mitigation Measures	Post–management Risk		Residual risk
						Likelihood	Consequence	
			plants. Noise emissions affecting workers. Noise emissions temporarily or permanently damaging the hearing of fauna in the vicinity. Hydrocarbon contamination of soils.		PPE. Noise levels monitored to comply with OHS Regulations. Operational procedures. Training of operators. Regular toolbox meetings. Oily waste disposed offsite.			
35	**Water abstraction from Carina pit**	Create a cone of depression within the Carina pit.	Change to groundwater aquifer (quality and quantity) at Carina pit	Low	Measurements of quality and drawdown of the water within the pit. Monitor abstraction volumes. Groundwater modelling to confirm cone of depression.	Unlikely	Insignificant	Low
36	**Failure of waste cell containment, cell instability/collapse during operations.**	Placement of liquid/gas waste packages into the cell. Over time voids are created in the cell. Generation of leachate as water infiltrates the cell. Failure of cell wall and/or cap. Faulty design. Faulty construction - waste package placement/backfill. Differential settlement. Earthquake. Intentional disturbance to the cell to retrieve radioactive material.	Degradation of groundwater quality.	Low	Seepage rate low. High evaporation rate. High evapotranspiration rates. High energy hydrological environment. Large unsaturated zone and storage capacity beneath each cell. Backfill material is unsaturated and can store water. No aquifer within weathered granite. No groundwater dependent vegetation, Threatened species or TECs/PECs. Engineering design/site selection based on international best practice for near surface geological repositories. Operational procedures for appropriate wastes and waste acceptance criteria. Training of operators. Subsidence monitoring of cap. Groundwater monitoring.	Rare	Insignificant	Low
37	**Waste package comprising a sealed source arrives with an activity concentration >3,700 Bq/g arrives at the site.**	The waste package exceeds the waste acceptance criteria and will not be <370 Bq/g at the end of the institutional control period (300 years).	Potential exposure of workers during handling of the waste package.	Low	Disposal permit issued. Proforma issued. Inspection and measurement of all sealed sources on arrival at site. Dose meters attached to workers.	Rare	Minor	Low
38	**Waste package comprising a sealed source arrives with a half-life greater than 30 years and is placed in the cell.**	The waste package exceeds the waste acceptance criteria and will not be <370 Bq/g at the end of the institutional control period (300 years).	Acute or chronic radiation exposure possible to the public utilising the land in 300 years' time.	Low	Disposal permit issued. Proforma issued. Inspection and measurement of all sealed sources on arrival at site. Depth of burial. Operational procedures.	Rare	Insignificant	Low
39	**Erection of buildings**	Kaolin processing plant will be the tallest building. Tourists will not be allowed to enter the mine site.	Change to visual amenity of people conducting nature based tourism activities in Mount Manning Range Nature Reserve, Mount Manning - Helena - Aurora Ranges Conservation Park.	Low	Normal travel routes on existing roads will not be affected by Tellus operations. 10 km distance from nearest existing reserve (Mount Manning Range) and unlikely the kaolin processing plant	Rare	Insignificant	Low

Risk Number	Environmental Aspect	Sources of Risk (Hazard)	Potential Environmental Impact (Worst case)	Pre–management risk	Management and Mitigation Measures	Post–management Risk		Residual risk
						Likelihood	Consequence	
			Interference with scientific studies in existing and proposed reserve system.		will be visible from this distance. There is not expected to be an encounter with scientists within ex-Jaurdi Pastoral Lease, given operations will be outside of the Lease area.			
40	**Surface water**	Leak or spill from a waste package.	Degradation of water quality.	Low	Minimal volumes of surface water that will be present at the time of a spill/leak (i.e. surface water flows only in extreme rainfall events). Various barriers around, and integrity of, the waste package itself. Factors that affect leachability of solid waste. Unloading of waste packages within enclosed warehouses with bunded concrete floors. Distance to nearest receptor (48 km away).	Rare	Insignificant	Low

4.3 Risk evaluation

The outcome of the risk assessment included the identification of 40 credible risks, of these 28 are planned (i.e. elements of Tellus activities that will interact with the environment) and 12 are unplanned (unexpected interactions with the environment). With the implementation of management and mitigation measures, the division of the residual risks for the project were:

- 7 – High residual risks.
- 5 – Moderate residual risks.
- 28 – Low residual risks.

The residual risks were evaluated using the Tellus risk criteria (Table 4–2).

Table 4–2 Risk criteria

	Extreme	**Unacceptable** further management review required to reduce risk.
	High	**Tolerable** if management determine and accepts risk has been reduced to as low as reasonably practicable.
	Moderate	**Acceptable** with management review for continuous improvement.
	Low	**Acceptable** no further management required.

As stated in *HB 203:2012 Managing Environment–Related Risk:*

'Tolerable' refers to the willingness to live with a risk to secure benefits, on the understanding that it is being properly controlled. 'Tolerability' does not mean 'acceptability'. Tolerating a risk does not mean that it is regarded as negligible, or something that can be ignored, but rather as something that should be kept under review such that if and when feasible and appropriate it can be reduced still further.

'Acceptable' relates to risks that do not need further treatment at this stage. The expression acceptable level of risk refers to the level at which it is decided that further action is not worthwhile, e.g. additional effort will not result in significant reductions in risk levels.

5 RISK TREATMENT

The purpose of risk treatment is to achieve objectives by managing uncertainty as effectively as possible. As no 'Extreme' risks have been identified, and the residual risk levels for all hazards have been evaluated as **Tolerable** or **Acceptable** it is considered no further treatment of risks is required at this stage.

In future environmental risk assessments, if the risk profile is elevated to 'Extreme' risk treatment will be undertaken by Tellus.

6 MONITORING AND REVIEW

Monitoring and review of the environmental risks associated with the project will be conducted using the following methods:

1. Monitor the environment itself – monitoring requirements specified in the PER and the Environmental Management System (EMS) will be undertaken. The outcomes of the monitoring, and any new risks identified will be outlined in future risk assessments.
2. Monitor and respond to losses and incidents – incidents which occur during the construction and operations phase, that potentially lead to environmental harm, will be documented and reviewed.
3. Monitor the implementation of the Emergency Response and Management Plan and where possible continuously improve the procedures outlined in the plan.
4. Use internal and external audits in accordance with EMS requirements.

7 REFERENCES

SAI Global, 2009, *AS/NZS ISO 31000:2009 Risk Management–Principles and Guidelines,* available at: http://infostore.saiglobal.com/store/details.aspx?ProductID=1378670

SAI Global, 2012, *HB 203:2012 Managing Environment–Related Risk,* available at: http://infostore.saiglobal.com/store/details.aspx?ProductID=1516912

APPENDIX

A.1 Risk matrix

Consequence descriptors

Consequences	Insignificant	Minor	Moderate	Major	Catastrophic
Safety and Health	Near miss / hazard.	First aid treatment required.	Medical treatment required, no lost time.	Lost time injury(s) (LTIs).	Potential fatality / multiple LTIs.
Regulatory	No breach of works approval/licence/approval condition	Breach of one works approval/licence/approval condition.	Injunction under the EPBC Act. Infringement notice issued under the EP Act. Breach of several licence conditions/ministerial statement conditions/proponent commitment.	Directed environmental audits under the EPBC Act. Environmental Field Notice, Caution Notice, Management Letter or Non Compliance Notice issued under the EP Act.	Civil and criminal penalties under the EPBC Act and EP Act. Suspension or revocation of works approval/licence.
Pollution	No noise emitted from operation. Minor spill cleaned up in hours to days. No residual contamination following clean-up, no effect on watercourses, water bodies or aquifers.	Low level of noise emitted but not received at noise sensitive premise. Contamination of a watercourse, water body and/or aquifer, cleaned up in days to months.	Moderate level of noise emitted but expected to be below Noise Regulation limits at noise sensitive premises. Massive contamination of a watercourse, water body or aquifer, with clean-up over months to years.	High level of noise emitted and expected to be above the Noise Regulation limits at noise sensitive premises. Massive irreverable contamination of a watercourse, water body or aquifer.	Noise emitted causes temporary or permanent hearing loss. Toxic release off site with massive detrimental effect. Massive pollution with significant remedial work required. Global media interest.
Flora / Fauna	Damage to flora. Death or Injury of individual fauna.	Damage to priority flora. Death or injury of individual priority fauna. Destruction of fauna habitat.	Damage to Threatened/declared rare flora. Destruction of priority flora species. Death of priority fauna species. Death or injury of individual Threatened or Migratory fauna. Damage of critical fauna habitat.	Damage to critically endangered flora. Destruction of Threatened/declared rare flora species. Destruction of critical fauna habitat. Death or injury of individual critically endangered fauna.	Extinction of fauna species. Extinction of flora species. Destruction of critical habitat.

Consequences	Insignificant	Minor	Moderate	Major	Catastrophic
Socio / Political	Localised temporary impact	Localised, short term impact, closure of access roads, temporary loss of amenity.	Localised, long term impact but manageable. Evacuation of site and closure of neighbouring operations.	Localised, long term impact with unmanageable outcomes. Evacuation of site, and people within 200 km of the site, closure of major highway.	Long term regional or national impact, permanent isolation from the site and region.
Heritage	Damage or disturbance occurring near to (but not at) an Aboriginal Site. Access to an Aboriginal Site lost for up to two weeks.	Unauthorised access to or interference with an Aboriginal Site (e.g. movement of an artefact) without causing damage. Access to an Aboriginal Site lost for up to one month.	Minor damage to an Aboriginal Site or to an artefact at an Aboriginal Site. Access to Aboriginal Site lost for up to three months.	Major damage to an Aboriginal Site or to an artefact at an Aboriginal Site. Access to Aboriginal Site lost for up to six months.	Destruction of an Aboriginal Site or an artefact at an Aboriginal Site. Permanent loss of access to an Aboriginal Site.
Financial / Legal	<$50,000	$50,000 - 250,000	$250,000 - 400,000	$400,000 - 10M	>$10m

Likelihood descriptors

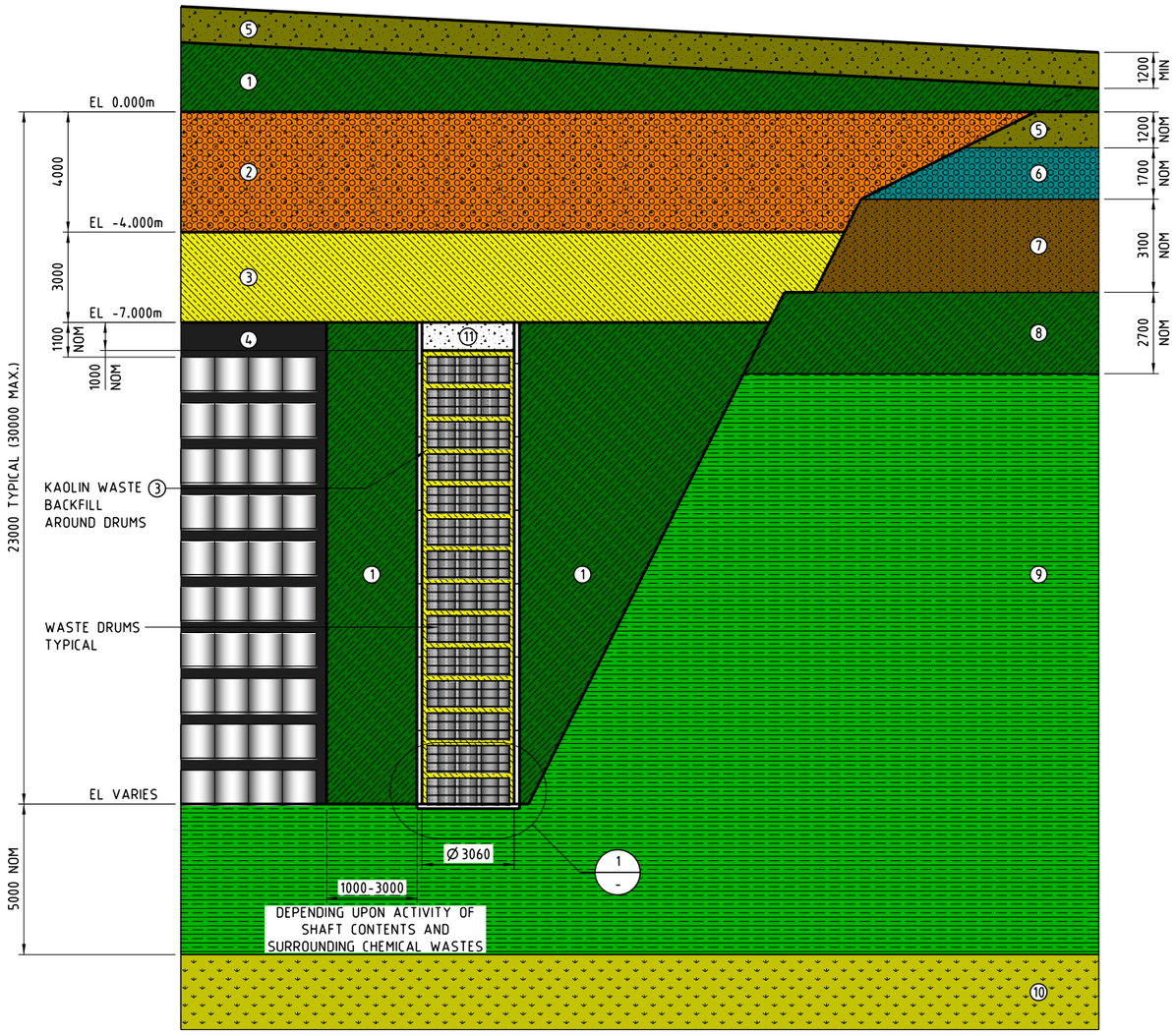
Rare	Unlikely	Possible	Likely	Almost Certain
5%	20%	50%	80%	95%
Highly unlikely to occur on this project	Given current practices and procedures, this incident is unlikely to occur on this project	Incident has occurred on a similar project	Incident is likely to occur on this project	Incident is very likely to occur on this project, possibly several times

Risk matrix				Consequence				
				Insignificant	Minor	Moderate	Major	Catastrophic
				1	2	3	4	5
Likelihood	A	Almost Certain	95%					
	B	Likely	80%					
	C	Possible	50%					
	D	Unlikely	20%					
	E	Rare	5%					

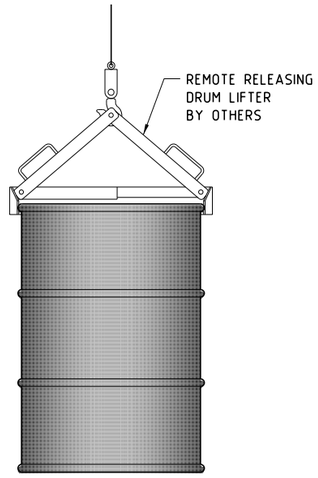
Risk criteria

	Extreme	**Unacceptable** further management review required to reduce risk.
	High	**Tolerable** if management determine and accepts risk has been reduced to as low as reasonably practicable.
	Moderate	**Acceptable** with management review for continuous improvement.
	Low	**Acceptable** no further management required.

A.3 Vertical shaft drawing



TYPICAL SECTION

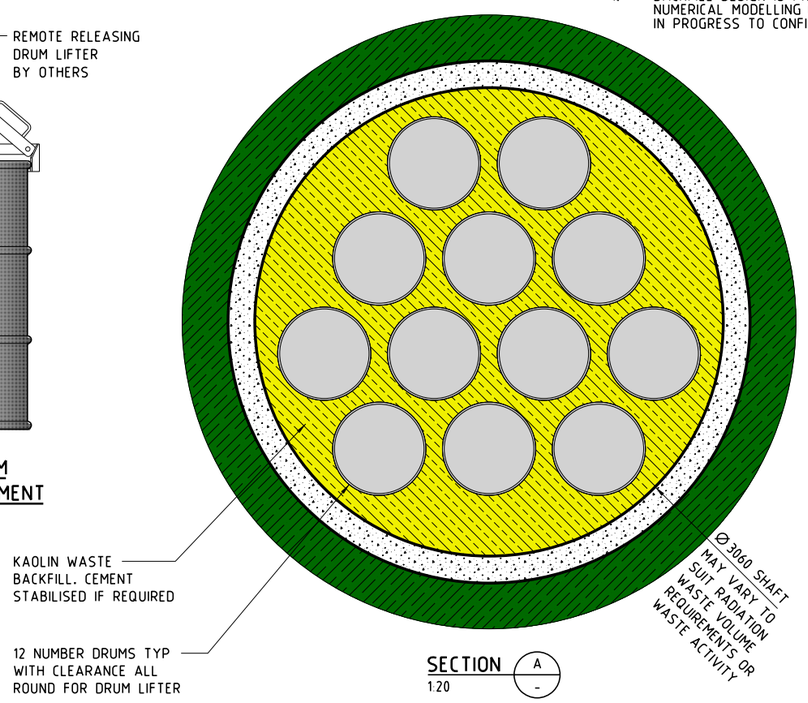


TYPICAL DRUM LIFTING ARRANGEMENT

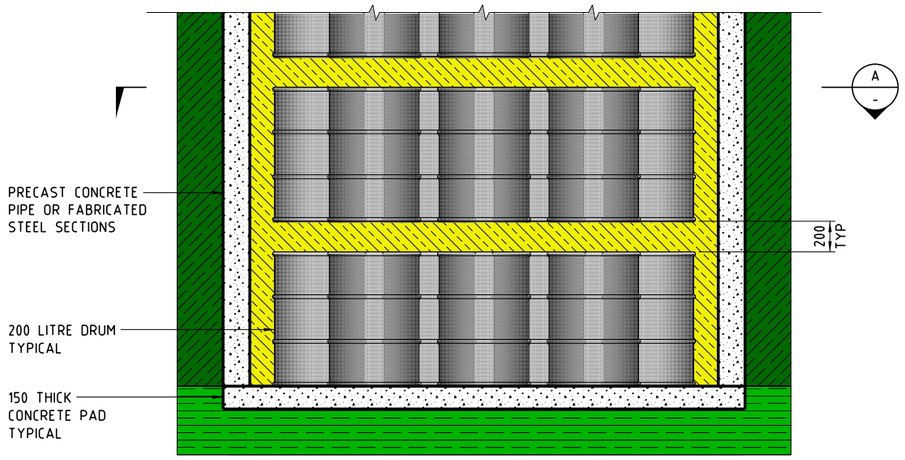
SCALE 1:10

NOTES

1. BACKFILL DESIGN IS PRELIMINARY ONLY. NUMERICAL MODELLING CALCULATION IS IN PROGRESS TO CONFIRM DESIGN.



SECTION A / -
1:20



DETAIL 1 / -
1:20

LAYER LEGEND - CELL AND SHAFT BACKFILL

- ① MOTTLED CLAYS COMPACTED TO 95%MMDD
- ② MIXED LATERITE AND SILCRETE AND CLAYEY SAND COMPACTED TO 95%MMDD, MAX. PARTICLE SIZE 40mm
- ③ KAOLIN WASTE COMPACTED TO 90%MMDD
- ④ WASTE SAND BACKFILLED AROUND DRUMS/BAGS COMPACTED TO 90%MMDD
- ⑪ CEMENT STABILISED COMPACTED KAOLINISED GRANITE

LAYER LEGEND - EXISTING GROUND

- ⑤ CLAYEY SAND
- ⑥ LATERITE
- ⑦ SILCRETE
- ⑧ MOTTLED CLAYS (IRON STAINED KAOLINISED GRANITE)
- ⑨ KAOLINISED GRANITE
- ⑩ UNWEATHERED GRANITE

LAYER LEGEND - SURFACE REHABILITATION

- ⑤ CLAYEY SAND

0.2 0.1 0 0.2 0.4 0.6 Metres
SCALE 1 : 10

0.4 0.2 0 0.4 0.8 1.2 Metres
SCALE 1 : 20

2 1 0 2 4 6 Metres
SCALE 1 : 100

INFORMATION ONLY
NOT FOR CONSTRUCTION

CLIENT DRG No.

REF DRG No	TITLE	REV	BY	DATE	DESCRIPTION	CHKD	ENG
		B	AL	27.11.15	FINAL REHABILITATION SURFACE ADDED	JL	
		A	BK	02.09.15	ISSUED FOR INTERNAL AND CLIENT REVIEW	JL	

CLIENT: TELLUS

ONYX PROJECTS
Level 1, Parmelia House | 191 St Georges Terrace | Perth, WA 6000 | Australia
ph (08) 6467 2900 fax (08) 6467 2949 www.onyxprojects.com

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	BY	DATE
DRAWN	B KLEMICK	02.09.15
CHKD		
DES ENG		
PROJ ENG		
CLIENT		

PROJECT No: C5409

TITLE: TELLUS SANDY RIDGE PRE-FEASIBILITY STUDY WASTE ISOLATION SHAFT IN CELL BACKFILL GENERAL ARRANGEMENT

A1 | SCALE 1:100 UNO | DRG No C5409-6310-CE-004 | REV B

Mine Closure Plan

TELLUS

SANDY RIDGE FACILITY
MINE CLOSURE PLAN

Final Report | November 2016

Q No	Mine Closure Plan (MCP) checklist	Y/N NA	Page No.	Comments	Changes from previous version	Page No.	Summary
1	Has the Checklist been endorsed by a senior representative within the tenement holder/operating company? (See bottom of Checklist.)	Y					
Public Availability							
2	Are you aware that from 2015 all MCPs will be made publicly available?	Y					
3	Is there any information in this MCP that should not be publicly available?	N					
4	If "Yes" to Q3, has confidential information been submitted in a separate document/section?						
Cover Page, Table of Contents							
5	Does the MCP cover page include: • Project Title • Company Name • Contact Details (including telephone numbers and email addresses) • Document ID and version number • Date of submission (needs to match the date of this checklist)	Y	Cover page				
Scope and Purpose							
6	State why the MCP is submitted (as part of a Mining Proposal or a reviewed MCP or to fulfil other legal requirements)	Y	1				
Project Summary							

Q No	Mine Closure Plan (MCP) checklist	Y/N NA	Page No.	Comments	Changes from previous version	Page No.	Summary
7	Does the project summary include; • Land ownership details (include any land management agency responsible for the land / reserve and the purpose for which the land / reserve (including surrounding land) is being managed) • Location of the project; • Comprehensive site plan(s); • Background information on the history and status of the project.	Y	4–8				
Legal Obligations and Commitments							
8	Does the MCP include a consolidated summary or register of closure obligations and commitments?	Y	18				
Stakeholder Engagement							
9	Have all stakeholders involved in closure been identified?	Y	19				
10	Does the MCP include a summary or register of historic stakeholder engagement been provided, with details on who has been consulted and the outcomes?	Y	20				
11	Does the MCP include a stakeholder consultation strategy to be implemented in the future?	Y	23				
Post-mining land use(s) and Closure Objectives							
12	Does the MCP include agreed post-mining land use(s), closure objectives and conceptual landform design diagram?	Y	25				
13	Does the MCP identify all potential (or pre-existing) environmental legacies, which may restrict the post mining land use (including contaminated sites)?	N		The land is a greenfields site.			
Development of Completion Criteria							
14	Does the MCP include an appropriate set of specific completion criteria and/ closure performance indicators?	Y	28				

Q No	Mine Closure Plan (MCP) checklist	Y/N NA	Page No.	Comments	Changes from previous version	Page No.	Summary
Collection and Analysis of Closure Data							
15	Does the MCP include baseline data (including pre-mining studies and environmental data)?	Y	30				
16	Has materials characterisation been carried out consistent with applicable standards and guidelines (e.g. GARD Guide)?	Y	38				
17	Does the MCP identify applicable closure learnings from benchmarking against other comparable mine sites?	N		This version of the MCP is conceptual/preliminary and does not include benchmarking.			
18	Does the MCP include a gap analysis/risk assessment to determine if further information is required in relation to closure of each domain or feature?	Y	40				
19	Does the MCP identify all key issues impacting mine closure objectives and outcomes including potential contamination impacts?	Y	41				
20	Does the MCP include information relevant to mine closure for each domain or feature?	Y	45–54				
21	Does the MCP identify any potential environmental legacies, which may restrict the post mining land use (including contaminated sites)?	N		The land is a greenfields site.			
Management of Closure Issues							
22	Does the MCP include proposed management or mitigation options to deal with these issues?	Y	41				
23	Does the MCP include the process, methodology, and rationale been provided to justify identification and management of the issues?	Y	41				

Q No	Mine Closure Plan (MCP) checklist	Y/N NA	Page No.	Comments	Changes from previous version	Page No.	Summary
Closure Implementation							
24	Does the MCP include a summary of closure implementation strategies and activities for the proposed operations or for the whole site?	Y	45				
25	Does the MCP include a closure work program for each domain or feature?	Y	45				
26	Does the MCP contain site layout plans to clearly show each type of disturbance as defined in Schedule 1 of the MRF Regulations?	Y	Figure 2–3				
27	Does the MCP contain a schedule of research and trial activities?	Y	55				
28	Does the MCP contain a schedule of progressive rehabilitation activities?	Y	55				
29	Does the MCP include details of how unexpected closure and care and maintenance) will be handled?	Y	60				
30	Does the MCP contain a schedule of decommissioning activities?	Y	52				
31	Does the MCP contain a schedule of closure performance monitoring and maintenance activities?	Y	62				

Q No	Mine Closure Plan (MCP) checklist	Y/N NA	Page No.	Comments	Changes from previous version	Page No.	Summary
Closure Monitoring and Maintenance							
32	Does the MCP contain a framework, including methodology, quality control and remedial strategy for closure performance monitoring including post-closure monitoring and maintenance?	Y	62				
Financial Provisioning for Closure							
33	Does the MCP include costing assumptions and financial methodology, provision to resource closure implementation and monitoring?	Y	64				
34	Does the MCP include a process for regular review of the financial provision?	Y	3				
Management of Information and Data							
35	Does the MCP contain a description of management strategies including systems, and processes for the retention of mine records?	Y	65				

Corporate endorsement:

"I hereby certify that to the best of my knowledge, the information within this Mine Closure Plan and checklist is true and correct and addresses all the requirements of the Guidelines for the Preparation of a Mine Closure Plan approved by the Director General of Mines.

Name: DUNCAN VAN DER MERWE Signed:

Position: MANAGING DIRECTOR Date: 25/11/2016

(NB: The corporate endorsement must be given by tenement holder(s) or a senior representative authorised by the tenement holder(s), such as a Registered Manager or Company Director).

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Document control

Rev	Issue date	Description	Originator	Checked	Approved
1	08/11/2016	Mine Closure Plan	C. Dorrington	R Phillips	

Disclaimer

This Mine Closure Plan is submitted as part of the Sandy Ridge Public Environmental Review (PER) which has been prepared for submission to the Western Australian Environmental Protection Authority for the purpose of the Minister for Environment making a determination regarding whether to approve Tellus Holding Limited's Proposal under the Western Australian Environmental Protection Act 1986. This PER has been developed for this purpose only, and no one other than the Environmental Protection Authority or the Minister should rely on the information contained in this PER to make any decision.

In preparing the draft Public Environmental Review (PER) Tellus has relied on information provided by specialists' consultants, government agencies and other third parties available during the preparation period. Tellus has not fully verified the accuracy or completeness except where expressly acknowledged in the draft PER.

The PER has been prepared for information purposes only; and, to the full extent permitted by law, Tellus, in respect of all persons other than the Environmental Protection Authority or the Minister, makes no representation and gives no warranty or undertaking, expressed or implied, in respect of the information contained in the PER and does not accept responsibility and is not liable for any loss or liability whatsoever arising as a result of any person acting or refraining from acting on any information contained in the PER.

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ABBREVIATIONS

BGL	below ground level
cm	centimetre
DER	Department of Environment Conservation
DMP	Department of Mines and Petroleum
dS/cm	deciSiemens per centimeter
EC	electrical conductivity
EILs	ecological investigation levels
EMS	Environmental management system
EPA	Environmental Protection Authority
EPBC Act	*Environment Protection and Biodiversity and Conservation Act 1999* (Cwlth)
ha	hectare
IWDF	Intractable waste disposal facility
JORC	Joint Ore Reserves Committee
km	kilometre
km/hr	kilometre per hour
L/s	litres per second
m	metre
meq/100g	milliequivalent of hydrogen per 100g of dry soil
mg/kg	milligram per kilogram
mg/L	milligrams per litre
MMDD	maximum modified dry density
mm/day	millimetres per day
mm/hr	millimetres per hour
m/s	metres per second

MCP	Mine Closure Plan
PER	Public Environmental Review
RLE	rehabilitation liability estimate
ROM	run of mine
SMDD	standard modified dry density
t	tonne
TDS	total dissolved solids
WC Act	*Wildlife Conservation Act 1950* (WA)
WFDCP	Waste Facility Decommissioning and Closure Plan

1 SCOPE AND PURPOSE

1.1 Purpose

Tellus Holdings Ltd (Tellus) has prepared this Mine Closure Plan (MCP) to guide activities associated with mine closure. The MCP is submitted as part of formal environmental assessment of the Sandy Ridge Project (the Proposal) under Part IV of the *Environmental Protection Act 1986*.

Rehabilitation and decommissioning is considered a key integrating factor and therefore as per Environmental Protection Authority (EPA) *Environmental Protection Bulletin No. 19 EPA involvement in mine closure* (EPA, 2015) both the EPA and the Department of Mines and Petroleum (DMP) will assess this MCP. This MCP has been provided as an appendix to the Sandy Ridge Project Public Environmental Review (PER).

The Proposal is in the planning and design phase; therefore, this MCP is conceptual in the level of detail provided. The MCP will be updated every three years during the operations phase of the mine, to ensure by the time closure occurs, useful and detailed closure information is included.

1.2 Scope

The Sandy Ridge Project comprises two components:

- mining of kaolin clay for export.
- storage and permanent isolation of hazardous, intractable and low level radioactive waste in mine voids.

Tellus will obtain approval to mine kaolin under the *Mining Act 1978* and store hazardous and intractable waste under the *Environmental Protection Act 1986*.

Hazardous and intractable waste disposal is regulated by the Department of Environment Regulation (DER) under Part V of the *Environmental Protection Act 1986*. The regulation of the disposal of these wastes is considered outside of the scope of the *Mining Act 1978* and the disposal process of wastes into mine voids is therefore not included in the scope of this MCP. Once the first placement of waste into a mine void occurs, it is no longer considered a mine pit and is referred to as a waste cell, with the assumption it is a Class V landfill regulated by the DER.

Disposal of radioactive tailings into mine voids is a more common activity, associated with uranium and mineral sands mines. However, the disposal of radioactive waste is not commonplace, and considered outside the scope of the *Mining Act 1978*. Radioactive waste disposal is regulated by the Radiological Council of Western Australia, under the *Radiation Safety Act 1975*. The disposal process of radioactive wastes into mine voids is therefore not included in the scope of this MCP.

The scope of this MCP includes:

- Rehabilitation of disturbed surface areas of the mining lease (M16/540) and associated miscellaneous licences (pending).
- Decommissioning of infrastructure listed in Table 1–1 used to operate the mine located on mining lease (M16/540) and associated miscellaneous licences (pending).

It should be noted that the waste aspect of the Sandy Ridge Project, specifically details relating to the closure of waste handling infrastructure and backfilling of cells with waste are set out in the Waste Facility Decommissioning and Closure Plan (WFDCP) (Tellus, 2016).

Table 1–1 Elements of the Sandy Ridge Project and location of information regarding decommissioning and closure

Physical elements	MCP	WFDCP
Class V/Class IV cell closure	✗	✓
Front gate office and amenity building	✗	✓
Water pipeline	✗	✓
Roof canopy	✗	✓
Underground storage area	✗	✓
Radioactive waste warehouse	✗	✓
Accommodation camp	✓	✗
Class II landfill	✓	✗
Internal roads	✓	✗
Waste inspection area	✓	✗
Container hardstand	✓	✗
Weighbridge	✓	✗
ROM pad	✓	✗
Diesel fuel tank, piping reticulation and bowser	✓	✗
Waste laboratory	✓	✗
Kaolin laboratory	✓	✗
Kaolin processing plant	✓	✗
Washdown pad and washdown treatment and storage system	✓	✗
Water tanks	✓	✗
Contractors offices, laydown yard and maintenance workshop	✓	✗
Kaolin products storage warehouse	✓	✗
Saline water ponds	✓	✗
Explosive ordinance building	✓	✗
Sewage treatment systems	✓	✗
LNG facility	✓	✗
Switchroom and generators	✓	✗

This MCP has been structured in accordance with the *Guidelines for Preparing Mine Closure Plans* (DMP and EPA, 2015).

1.3 Phases of mine closure

The phases of mine closure are illustrated in Figure 1–1 below.

Figure 1–1 Phases of closure

Years 20 to 25:
Construction and Operations Phase

- Tellus Holdings Ltd manage the mine.
- Pits created, ore excavated.
- Infrastructure and roads constructed.
- Ore processed, kaolin products produced and sold.

Years 26 to 37:
Rehabilitation Phase

- Tellus Holdings Ltd manage the mine.
- No kaolin produced.
- Deep ripping/establishment of vegetation on all domains.
- Removal of mining infrastructure.
- Tenements relinquished.

1.4 Review

The MCP is a 'live' document, with gaps in information to be filled as the Project progresses through the design/planning stage to the construction and operations phase.

The *Mining Act 1978* requires that a MCP be reviewed and resubmitted to the DMP every three years or such other time as specified in writing by the DMP. The next review date is anticipated to be as soon as possible following Ministerial Approval in order to include relevant conditions or requirements regarding closure.

Next Review:

As soon as possible following Ministerial Approval in order to include relevant conditions or requirements regarding closure.

2 PROJECT SUMMARY

2.1 Location

The Sandy Ridge Project is located approximately 75 kilometres (km) north-east of Koolyanobbing, in the Goldfields region of Western Australia (Figure 2–1). Access is via a 100 km road to the Mount Walton East Intractable Waste Disposal Facility (IWDF) (Access Reserve No. 44102) that extends northward from Great Eastern Highway; a 4.5 km portion of a westward access road extending towards Mount Dimer and a 5.3 km dedicated site access road extending northwards to the mining lease (Figure 2–2).

2.2 Land ownership

The land is vacant Crown Land. Tellus received advice that the best approach to providing suitable tenure for the site is for Department of Lands to lease the land under a Crown Lease. This land will then be leased to Tellus for a period to be agreed (currently expected to be years 0 to 56).

2.3 Mining tenure

Tellus have access to the land through a mining lease (M16/540) and miscellaneous licences (pending) issued under the *Mining Act 1978* as shown on Figure 2–3.

2.4 Postal address, site address and contact details

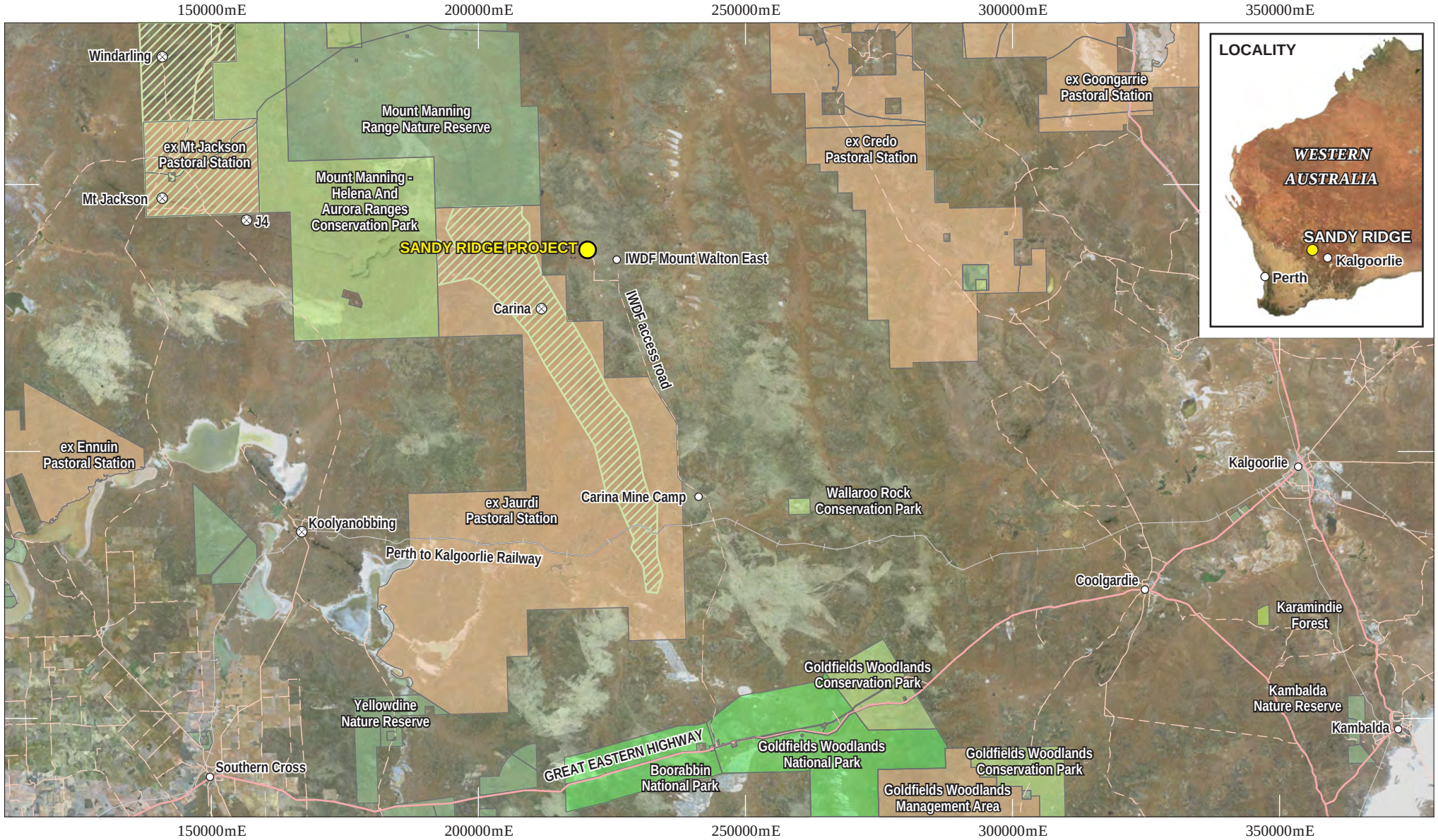
The Proponent's details are:

Postal Address

Tellus Holdings Ltd
Suite 2, Level 10
151 Castlereagh Street
Sydney NSW 2000
Tel: +61 2 8257 3395

The key contact for the Proponent is:

Mr Richard Phillips
Environment and Approvals Manager
Suite 2, Level 10
151 Castlereagh Street
Sydney NSW 2000
Tel: +61 2 8257 3395
Email: richie@tellusholdings.com



Legend:
- Iron Ore Mine
- Rail
- Major Road
- Minor Road

DPaW Managed Lands:
- Conservation Park
- Former Leasehold
- National Park
- Nature Reserve
- Proposed Conservation and Mining Reserve
- State Forest

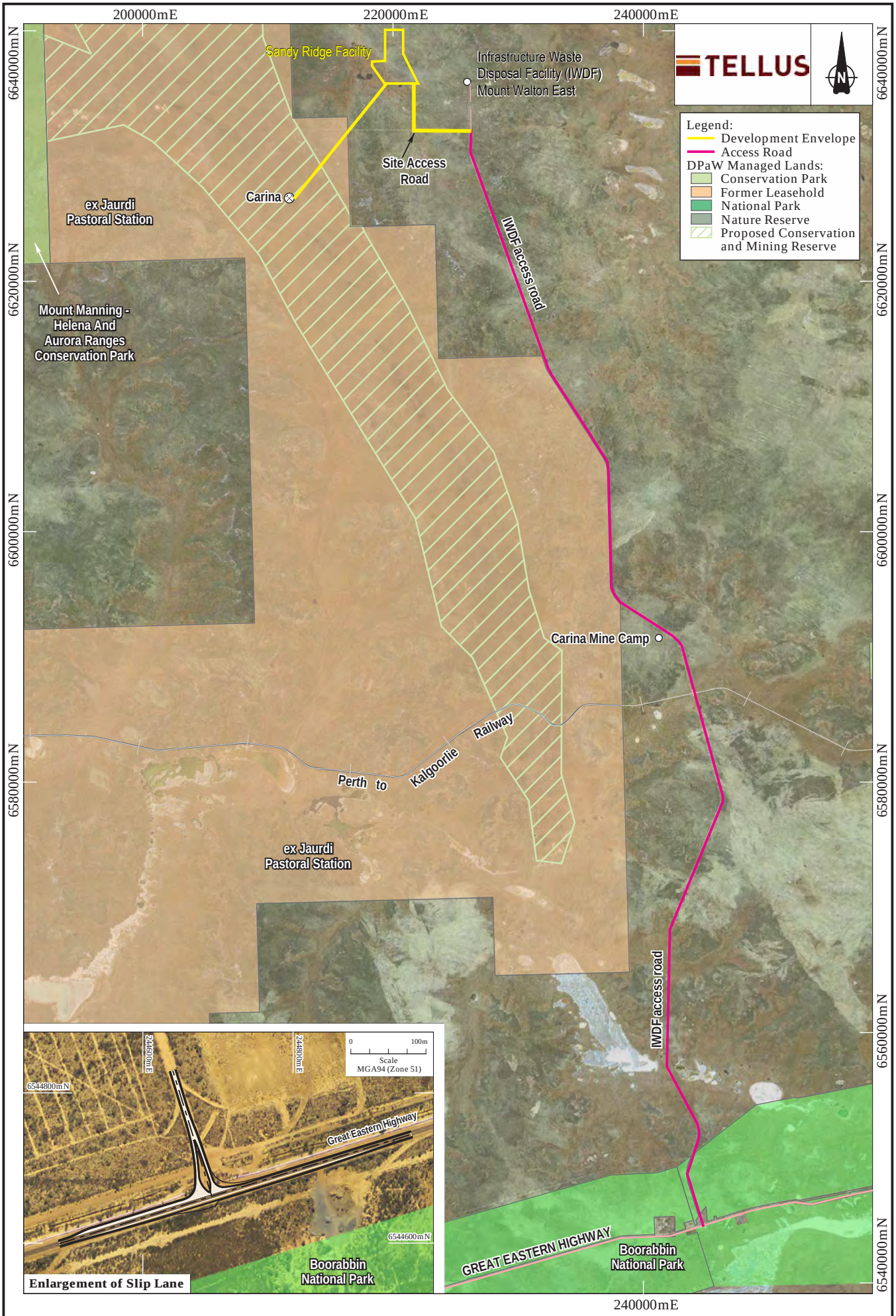
TELLUS

0 20km
Scale 1:1,000,000
MGA94 (Zone 51)
CAD Ref: g2294_PER_01_01.dgn
Date: Nov 2016 | Rev:1 | A4

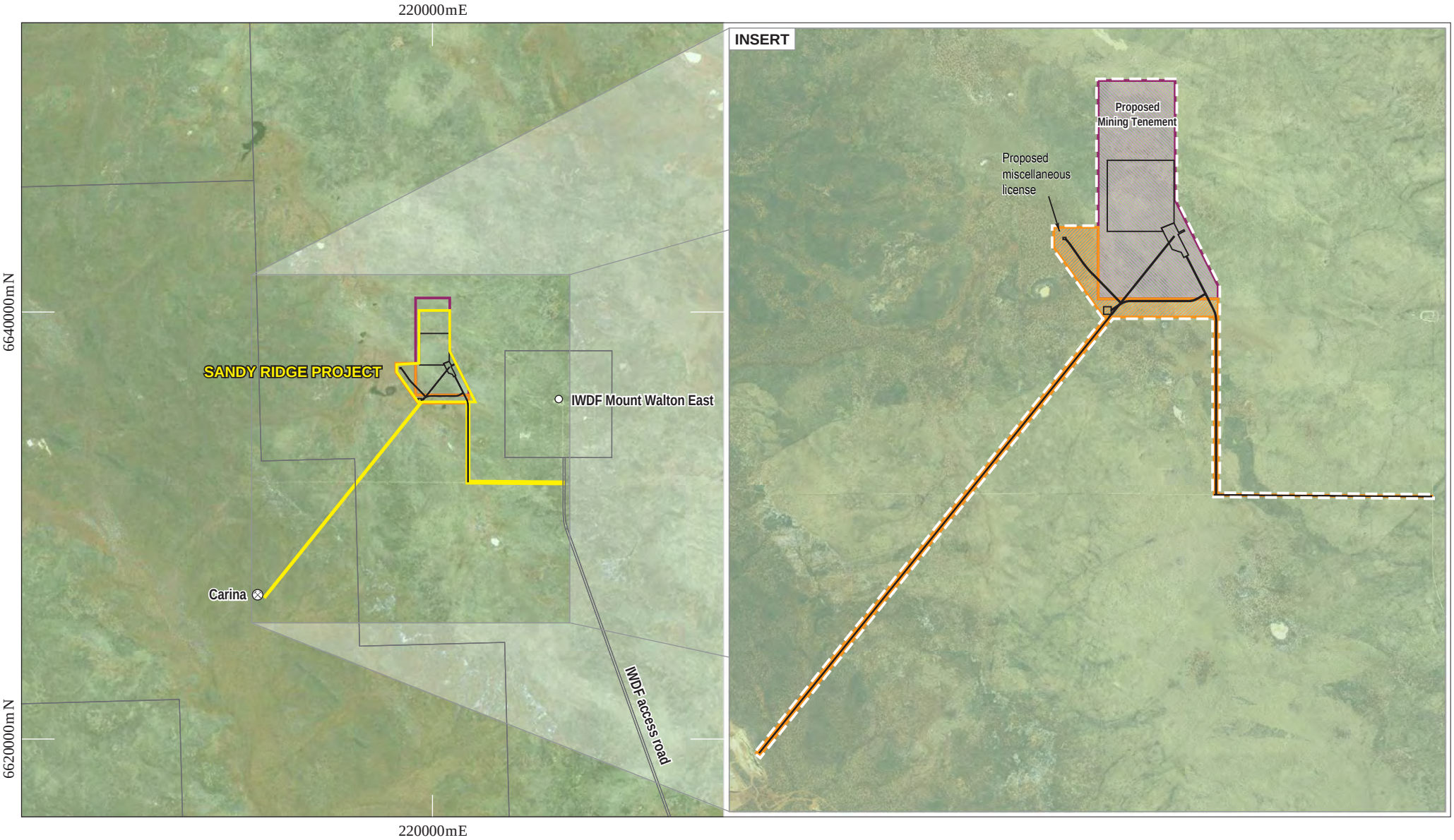
Aurora environmental
Author: C. Dorrington | AE Ref: THO2014-003
Drawn: CAD Resources ~ www.cadresources.com.au
Tel: (08) 9246 3242 ~ Fax: (08) 9246 3202

Sandy Ridge Facility
Regional location
Public Environmental Review

Figure:
2-1



0 5km Scale 1:400,000 MGA94 (Zone 51)	Aurora environmental	Sandy Ridge Facility	Figure:
CAD Ref: g2294_PER_01_03.dgn	Author: C. Dorrington | AE Ref: THO2014-003	**Access to Sandy Ridge**	**2-3**
Date: November 2016 | Rev:1 | A4	Drawn: CAD Resources ~ www.cadresources.com.au Tel: (08) 9246 3242 ~ Fax: (08) 9246 3202	**Public Environmental Review**	



Legend:
- Infrastructure
- Development Envelope
- Proposed Mining Tenement
- Proposed Miscellaneous Licence
- Indicative Reserve Area
- Scheme Zoning - Rural / Mining Area

Notes
- Scheme Zoning supplied by DoP (2015)

TELLUS

0 5km
Scale 1:250,000
MGA94 (Zone 51)
CAD Ref: g2294_PER_05_02.dgn
Date: Nov 2016 | Rev: B | A4

Author: C. Dorrington | AE Ref: THO2014-003
Drawn: CAD Resources ~ www.cadresources.com.au
Tel: (08) 9246 3242 ~ Fax: (08) 9246 3202

Sandy Ridge Facility

Landuse, tenure and zoning

Public Environmental Review

Figure:

2-3

2.5 Project history

The Sandy Ridge Project is a greenfields project, with no previous development or mining of the land. Exploration lease (E16/440) (Figure 2–3) was granted in 2013 for a 5 year period (expires 22 January 2018). Tellus has drilled 206 holes across the exploration lease.

Exploration drilling has outlined a Joint Ore Reserves Committee (JORC) Inferred Mineral Resource of 17.6 million tonnes kaolinite, with 9.5 million tonnes classified as ceramic grade and 8.1 million tonnes classified as paint grade. A 17.6 million tonne resource is likely to provide sufficient ore for at least a 25 year mine life.

2.6 Overview of operations

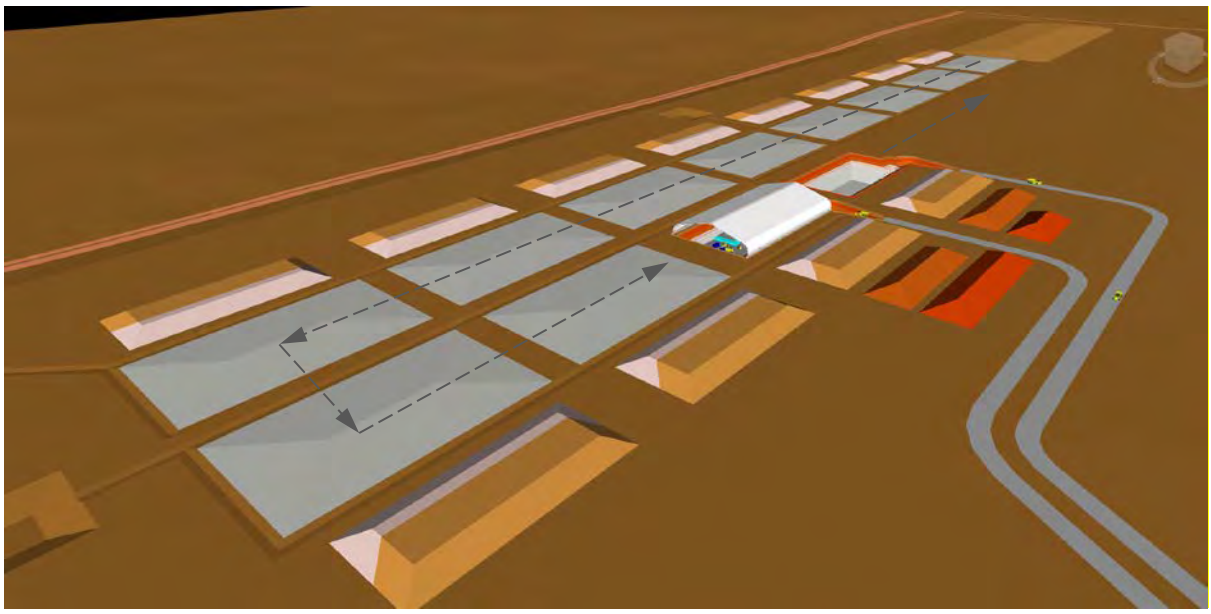
2.6.1 Mining method

Mining would be carried out in campaigns on a frequency commensurate with the volume of wastes to be isolated. The frequency of mining campaigns is likely to commence at one every year, but the actual frequency is dependent on the depth of mining in each area, the demand for kaolin products and the timing of waste deliveries. Mining campaigns could be as frequent as twice per year but are typically expected to occur at a rate of one every 12 to 18 months. Depending upon the depth of mine pit, a single waste cell would hold approximately 30,000 to 75,000 tonnes of waste material.

2.6.2 Sequence of pits

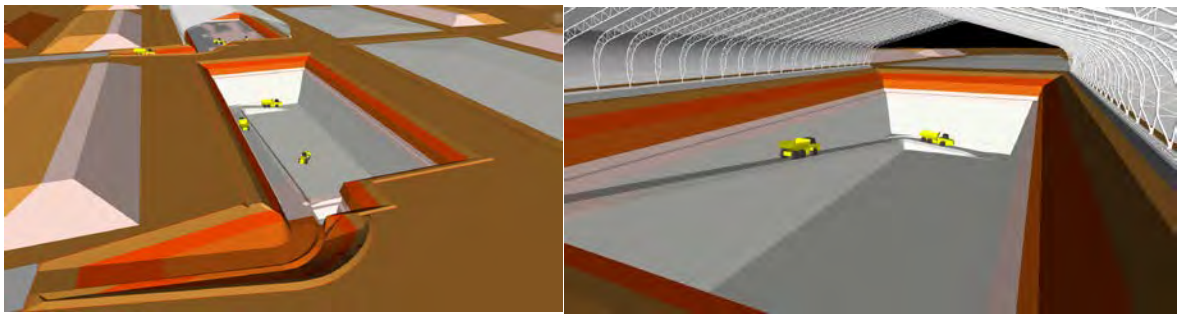
Pits would be constructed in sequence along a common axis as far as possible, before stepping sideways one pit width and returning in the opposite direction (Figure 2–4).

Figure 2–4 Conceptual layout of mine pits/cells



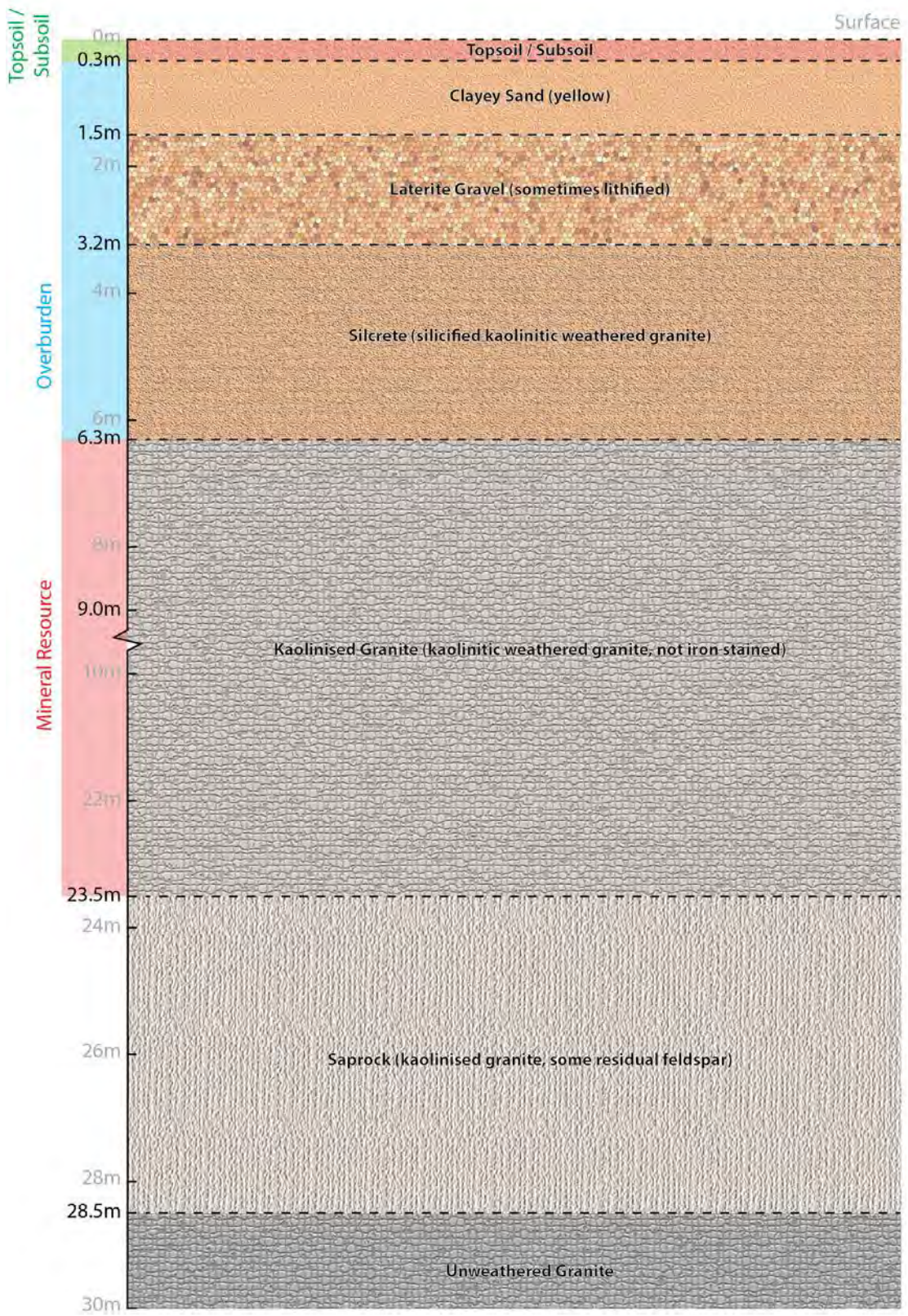
Current mine planning is for approximately 25 cells to be constructed. Each mine pit and waste cell would be nominally 120 m long and 60 m wide and 23 m deep (depending on local stratigraphy and could be a maximum depth of 30 m). The cell would be covered by a roof canopy, consisting of a steel lattice frame with a fabric covering with an approximate width of 65 m and length of 120 m. This allows the roof canopy to be relocated from one pit to the next on temporary rail tracks. The purpose of the roof is to exclude rainfall from entering the waste cell during the waste storage and isolation operation (Figure 2–5). There are some waste types which may be placed in a cell without a roof as the materials being placed are not immediately leachable, such as some contaminated soils and contaminated equipment. Any such cell construction would be designed with a drainage sump to enable pumping-out of any direct precipitation whilst the cell is open.

Figure 2–5 Conceptual view of pit being mined and then pit with roof canopy



A cross section of a typical mine pit is shown in Figure 2–6. Based on exploration drilling results the average overburden (sandy clay, laterite gravel and silcrete) thickness is 6 m. Beneath the overburden, the kaolinised granite (i.e. the mineral resource) is on average 17 m thick (6 m to 23 m depth). Beneath the kaolin zone is a saprock zone (kaolinite, including some incompletely weathered granite). Below the saprock zone (23.5 m to 28.5 m) is un-weathered granite (beyond 28.5 m). Note that the transitions between geological units are gradational and identification of boundaries is very subjective.

Figure 2–6 Geological cross section of a typical mine pit

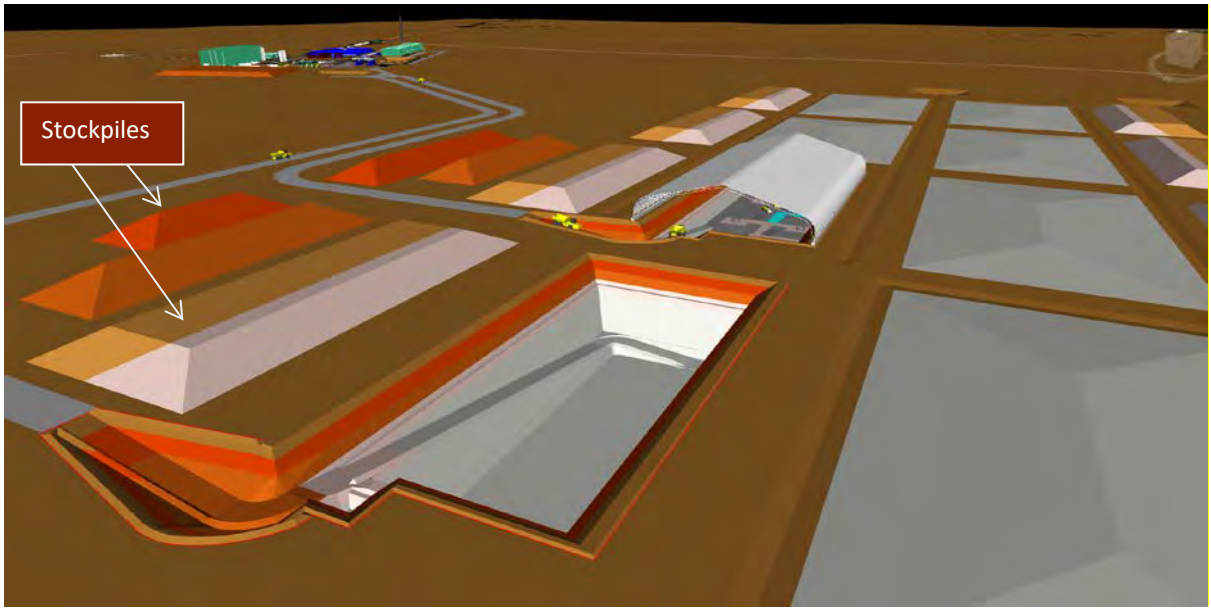


2.6.3 Mining Method

The principal mining method would be open cut to extract overburden and kaolin ore. The surface area of each kaolin pit would be cleared of vegetation. Cleared vegetation would be stockpiled and re–used in rehabilitation. The cell would then be opened by excavation of the topsoil, subsurface soil and laterite, followed by carefully controlled blasting using explosives of the hard, dense silcrete layer that overlays the kaolin and removal by excavator and truck.

The kaolin would then be recovered by conventional earthmoving equipment. Based on drilling results, the kaolin ore is very dry at approximately 10 % moisture, and is free-digging. The kaolin overburden and ore mining plant fleet is likely to consist of a front end loader, excavator and articulated dump trucks. The dump trucks would deposit the kaolin in stockpiles adjacent to each pit or the kaolin process plant. Overburden would be stockpiled adjacent to the cells in readiness for backfilling (Figure 2–7).

Figure 2–7 Stockpiles adjacent to cells



Separate stockpiles of different grades of kaolin ore would be located adjacent to the kaolin processing plant or each pit.

2.6.4 Excavation to the pit base

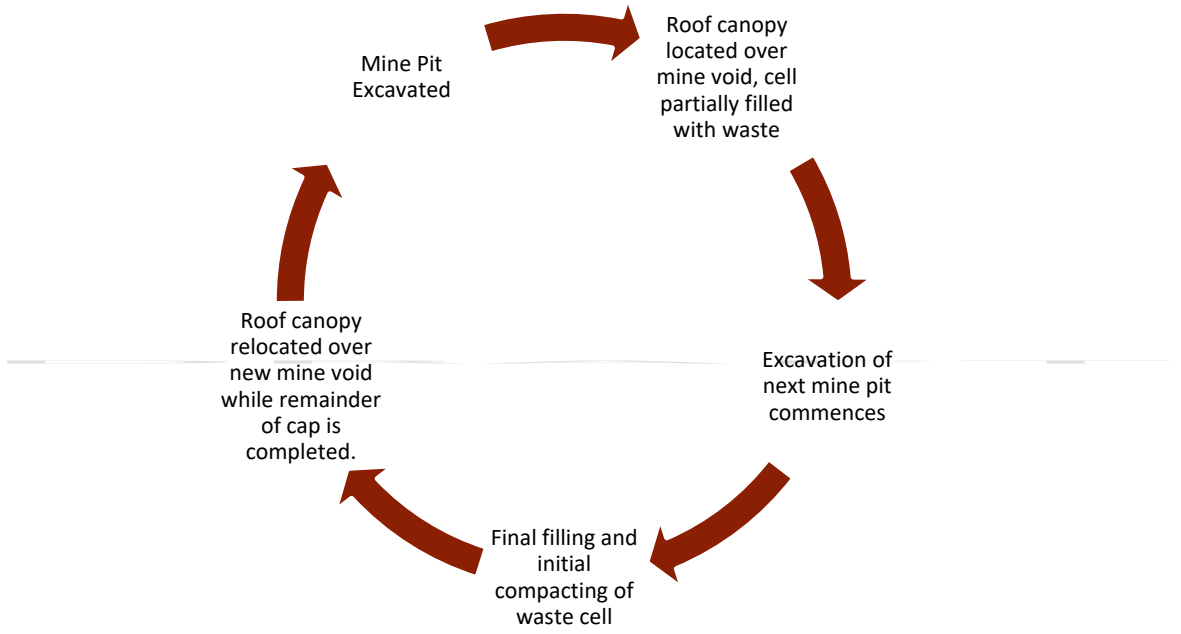
The elevation of the base of the pits varies depending on the location of the mineral resource and the elevation of the top of the saprock. Mine-planning activity would ensure that at least 5 m of kaolinised material remains in-situ between the bottom of the pit and above the top of the unweathered granite. This would be achieved through mine planning and grade control drilling. The location of each drill-hole would be surveyed so that any hole penetrations within the mining pit areas would be known, and any locations where ‘over-drilling’ below the pit floor elevation has taken place would be carefully backfilled with compacted kaolinitic material. This process would ensure that the drilling activities do not provide preferential pathways in the unweathered granite if in the unlikely event that a contaminated plume was ever generated from cells.

2.6.5 Transition from mine pit into waste cell

During mining, the excavation is termed a 'pit' but once it is completed and ready for use in waste isolation activities, it is termed a cell.

In a typical cycle, one new mining pit would be excavated with the mining activities being scheduled to finish just prior to the previous pit (now a waste cell) being completely filled (Figure 2–8). This would minimise the time that a completely mined pit would remain open to the weather. All surfaces within the pit will be graded to manage any precipitation which would run-off to a sump. The sump would be maintained in a dry state by a diesel powered portable pump, discharging to a pond at surface level.

Figure 2–8 Normal sequence of mining and waste storage

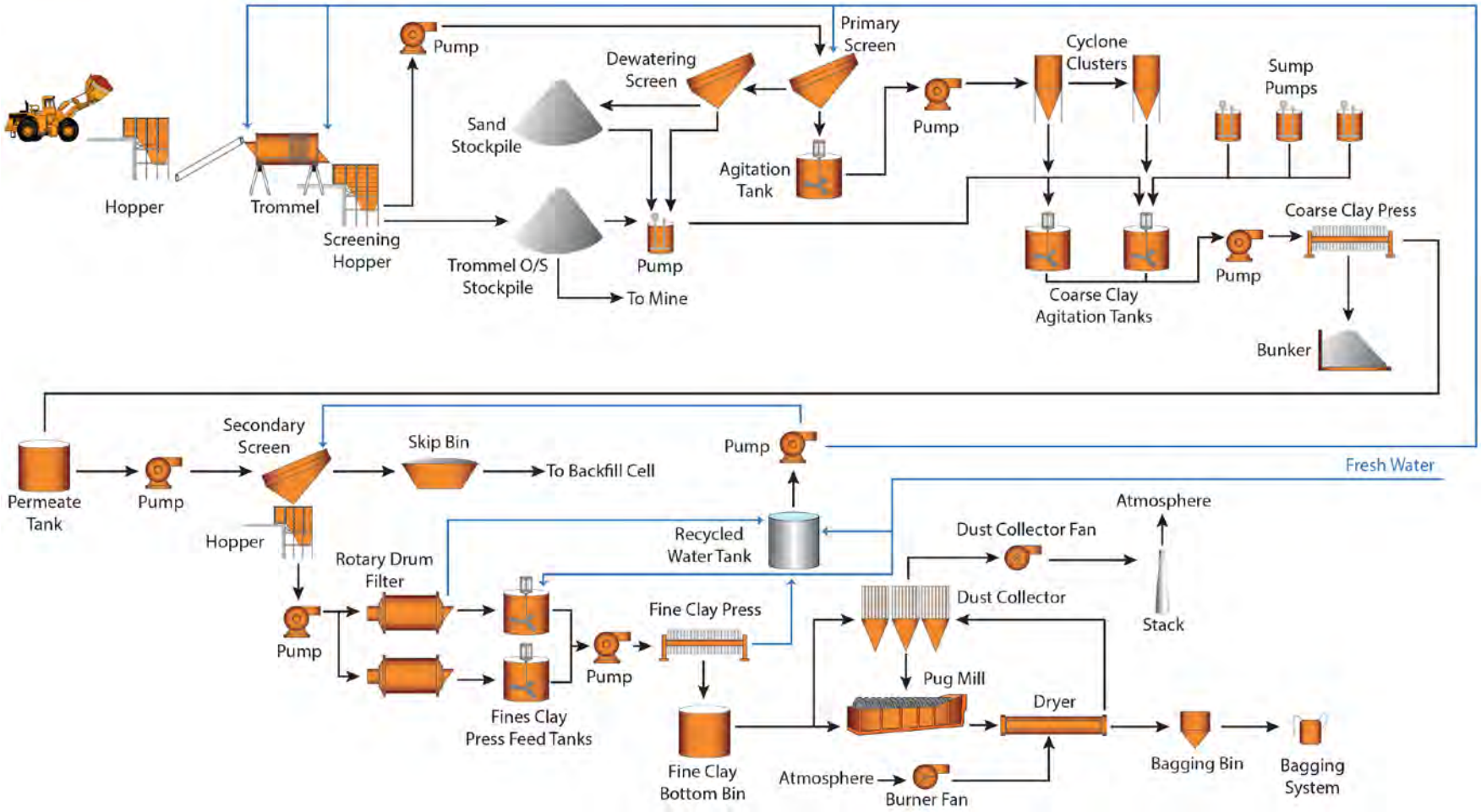


As soon as the first waste placement has taken place in a mine void/cell, Tellus considers the mining activities complete.

2.6.6 Kaolin processing description

A wet mineral processing circuit, as described further below, would be implemented to refine the kaolin product from the ore. A typical kaolin plant process flow diagram is provided in Figure 2–9 which illustrates the process

Figure 2–9 Conceptual process flow diagram



Run of mine (ROM) feed material is recovered from the ore stockpile by front end loader and placed into a hopper from which it is conveyed into a drum-scrubber. Water is added at this point to produce a slurry which then undergoes a process of washing and hydro-cycloning to reject all quartz sand particles and recover the fine (<45 micron) kaolin clay particles. Varying portions of coarser kaolin particles are rejected in the hydro-cyclone stage to control the product properties depending upon the grade of product being produced at that time. The refined kaolin slurry is dewatered by filter press for drying in a gas-fired kiln before being packaged in bulk-bags or paper sacks on pallets. Some kaolin products may be further dried and pulverised into a dry powder before bagging.

Bagged product would be stored onsite in a warehouse pending quality assurance checks and to facilitate optimal transport arrangement. The on-site storage also provides buffer capacity between production and dispatch in the event of interruptions to either activity.

Forklifts would handle the bags from the filling stations in the plant to the warehouse, and for loading of stored bags onto trucks or into sea containers.

Waste streams from the kaolin processing plant consist of ROM oversize, waste quartz sand and de-watered coarse kaolin and very fine sand. All of these materials are used for backfill in the waste cell. The washed quartz sand is stockpiled on a drainage pad to recover and recycle process water and to ensure that the sand's moisture content is optimal for compaction. Some sand and screen oversize would be used for maintaining internal haul roads. To meet waste storage scheduling requirements some of these materials would need to be stockpiled close to the active waste cell for some portion of the year.

The only chemical which might be required for mineral processing is a small quantity of Sodium Hydroxide, to counter the natural acidity of the kaolin ore. Only fresh water is used in the circuit. The fuel for the dryer is likely to be Liquefied Petroleum Gas (LPG), as this is clean burning and would not produce soot or sulphur oxides which might affect the quality of the kaolin.

Imported bentonite clay may be added in small quantities to improve some end-use properties of the kaolin.

2.6.7 Transport of kaolin products from Sandy Ridge

Kaolin products would be transported from Sandy Ridge to markets both domestically and internationally. International exports are likely to depart in sea-container lots via Fremantle Port. The route departing the site would commence along the IWDF access road to the intersection with Great Eastern Highway. Transport options are still being evaluated, but trucking is the most likely mode of transport. Export kaolin trucks then continue west along Great Eastern Highway to the outskirts of Perth. The route within Perth and to the port for full containers would depend upon which company is selected to provide intermediate warehousing and container services. If not already packed into containers at Sandy Ridge, transported bagged kaolin is packed into containers for export through the Fremantle Inner Harbour container terminals. The total distance of the journey from Sandy Ridge to Fremantle Port is approximately 750 km. It is proposed an average of

eight trucks would carry kaolin per week, and based on 50 weeks of truck movements, 400 trips per year would operate along the route.

2.7 Closure domains

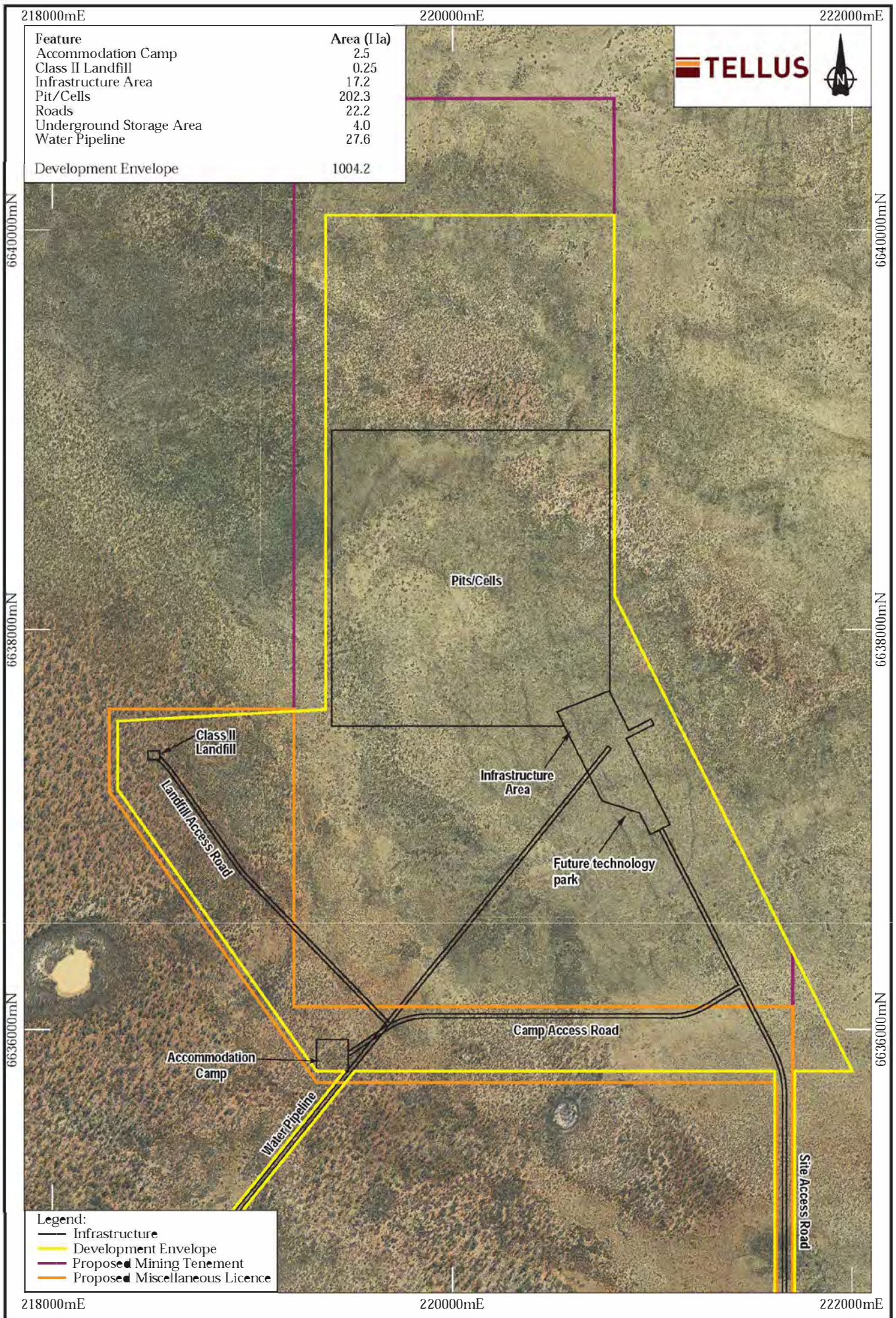
A closure domain is defined as a group of landform(s) or infrastructure that has similar rehabilitation and closure requirements and objectives. The domains for the Sandy Ridge Project are identified on Figure 2–10 and listed in Table 2–1 along with the disturbance types and areas.

Table 2–1 Domains, disturbance areas and activity types

Tenement	Domain	Disturbance area[1] (ha)	Activity type[2]
M16/540	Pits	202.3	Mining void (depth greater than 5m – above groundwater)
			Overburden stockpile (class 2)
			Topsoil stockpile
			Surface water diversion bund
	Infrastructure Area	17.2	Two saline water ponds
			Plant site (with a maximum processing capacity of at least 10 tonnes per hour)
			Mine site infrastructure – fuel storage
			Mine site infrastructure – offices
			Mine site infrastructure – workshop
			Mine site infrastructure – magazine
			Laydown or hardstand area
			Other buildings
			Run–of–mine pad
	Access Roads	3.49	Haulage roads
	Water Pipeline	2.99	Pipelines – other than fresh water
Land Not Disturbed		605.02	
TOTAL TENEMENT AREA		**831**	
Miscellaneous Licence XX/XX (pending)	Class II Landfill	0.25	Landfill site
	Accommodation Camp	2.5	Mine site infrastructure – camp site
	Access Roads	18.76	Access road
	Water Pipeline	0.80	Pipelines – other than fresh water
Land Not Disturbed		208.07	
TOTAL TENEMENT AREA		**230.38**	
Miscellaneous Licence XX/XX (pending)	Water Pipeline	23.27	Pipelines – other than fresh water
Land Not Disturbed		143.42	

[1] where the water pipeline overlaps with other features only the disturbance against the other feature is included, that is, when the water pipeline crosses the road, the disturbance is against the road only, to avoid doubling up on the disturbance area.
[2] as defined in Schedule 1 of the *Mining Rehabilitation Fund Regulations 2013*

Tenement	Domain	Disturbance area[1] (ha)	Activity type[2]
TOTAL TENEMENT AREA		**166.69**	
Miscellaneous Licence XX/XX (pending)	IWDF access road	958.50	Access road
TOTAL TENEMENT AREA		**958.50**	
Miscellaneous Licence XX/XX (pending)	IWDF access road	947.21	Access road
TOTAL TENEMENT AREA		**947.21**	



Feature	Area (Ha)
Accommodation Camp	2.5
Class II Landfill	0.25
Infrastructure Area	17.2
Pit/Cells	202.3
Roads	22.2
Underground Storage Area	4.0
Water Pipeline	27.6
Development Envelope	1004.2

0 400m
Scale 1:25,000
MGA94 (Zone 51)
CAD Ref: g2294_PER_01_02.dgn
Date: November 2016 | Rev: G | A4

Author: C. Dorrington | AE Ref: TI IO2014-003
Drawn: CAD Resources - www.cadresources.com.au
Tel: (08) 9246 3242 ~ Fax: (08) 9246 3202

Sandy Ridge Facility

Proposed development envelope

Public Environmental Review

Figure:

2-10

3 CLOSURE OBLIGATIONS AND COMMITMENTS

3.1 Legal obligations register

All legal obligations relevant to rehabilitation and closure at Sandy Ridge are identified in the Legal Obligations Register (Table 3–1). Note: this register will be updated following receipt of environmental approvals.

Table 3–1 Legal obligations register

Relevant DMP tenement conditions		
Tenement No	**Condition No**	**Closure Conditions**
Ministerial statement (No and Date)		
Condition No	**Condition**	
Works approval (No and Date) Relates to Tenement No: XX		
Condition	**Aspect Related to Closure**	
***Environmental Protection Act 1986* Licence No: Category:**		
Condition	**Aspect Related to Closure**	

4 STAKEHOLDER ENGAGEMENT

Tellus recognise the importance of engaging with stakeholders for mine closure planning, to achieve acceptable environmental outcomes, manage stakeholder expectations and eliminate or avoid potential risks associated with closure. The key to effective stakeholder engagement follows the five principles outlined in the Strategic Framework for Mine Closure (ANZMEC/MCA, 2000), which are:

1. Identification of stakeholders and interested parties.
2. Effective engagement is an inclusive process which encompasses all parties and should occur throughout the life of the mine.
3. A targeted communication strategy should reflect the needs of the stakeholder groups and interested parties.
4. Adequate resources should be allocated to ensure the effectiveness of the engagement process.
5. Wherever practical, work with communities to manage the potential impacts of mine closure.

A description of how Tellus will implement these principles is described in the following sections.

4.1 Stakeholder identification

'Stakeholders' are defined by the guidelines (DMP & EPA, 2015) as both internal and external parties who are likely to affect, to be affected by or to have an interest in mine closure planning and outcomes. The stakeholders for mine closure are:

Internal

- The Tellus Board and Corporate Executive.
- Project Leader – Michael Ingram.
- Mine Manager – To be confirmed.
- Environment & Approvals Manager – Richard Phillips

External

- Post–mining land owner / manager –To be confirmed.
- Environmental Regulators – WA Department of Mines and Petroleum, currently represented by Environmental Branch – Team Leader Minerals Kalgoorlie.
- Other interested government agencies – Department of Water, Department of Health (Environmental Health Branch).
- Local Government – Shire of Coolgardie, represented by the Chief Executive Officer.
- Local community members or groups.

- Interested non–government organisations.
- Adjacent Landholders – Department of Finance, Building Management and Works Branch – proponent for the IWDF Mount Walton East and IWDF access road.
- Adjacent Landholders – Department of Lands (for vacant crown land) and Department of Parks and Wildlife for lands vested in them (e.g. former Jaurdi Pastoral lease).
- Mineral Resources – Operator of the Carina Iron Ore Mine.

4.2 Stakeholder engagement register

A summary of stakeholder engagement in relation to mine closure is listed in Table 4–1. As the MCP is developed, this engagement register will be updated with each review of the MCP (i.e. every three years).

Table 4–1 Stakeholder engagement register

Stakeholder	CONSULTATION DATE	CONSULTATION METHOD	STAKEHOLDER COMMENTS/ISSUE	TELLUS RESPONSE	STAKEHOLDER RESPONSE
DMP (Environmental Branch – Team Leader Minerals Kalgoorlie) and DER (Manager Waste North and Senior Environmental Officer)	19 November 2015	Meeting	• Consider if a 10 year subsidence monitoring is appropriate for the Sandy Ridge Project. • The Mine Closure Plan and Waste Facility Closure and Decommissioning Plan should both outline Tellus' position on revegetation of the surface of the domed clay cap. • Waste Facility Closure and Decommissioning Plan will include a commitment for review of the document every 3 years. • The Mine Closure Plan and Waste Facility Closure and Decommissioning Plan should both outline Tellus' position on fencing and how maintenance is ensured long-term.	These items have been considered in this MCP and the WFDCP.	To be confirmed following review of this document.
DMP Environmental Branch – Team Leader Minerals Kalgoorlie, and Resources Safety Branch Mines Inspector	18 April 2016	Meeting and presentation of Conceptual Mine Closure Plan.	• Consider adding risk assessment and closure activities relating to a landform left from a kaolin stockpile that had not been processed.	This risk has been assessed and added to Table 8–1. Note: it has not been included in the workshop register presented in Appendix A.2 as the	To be confirmed following review of this document.

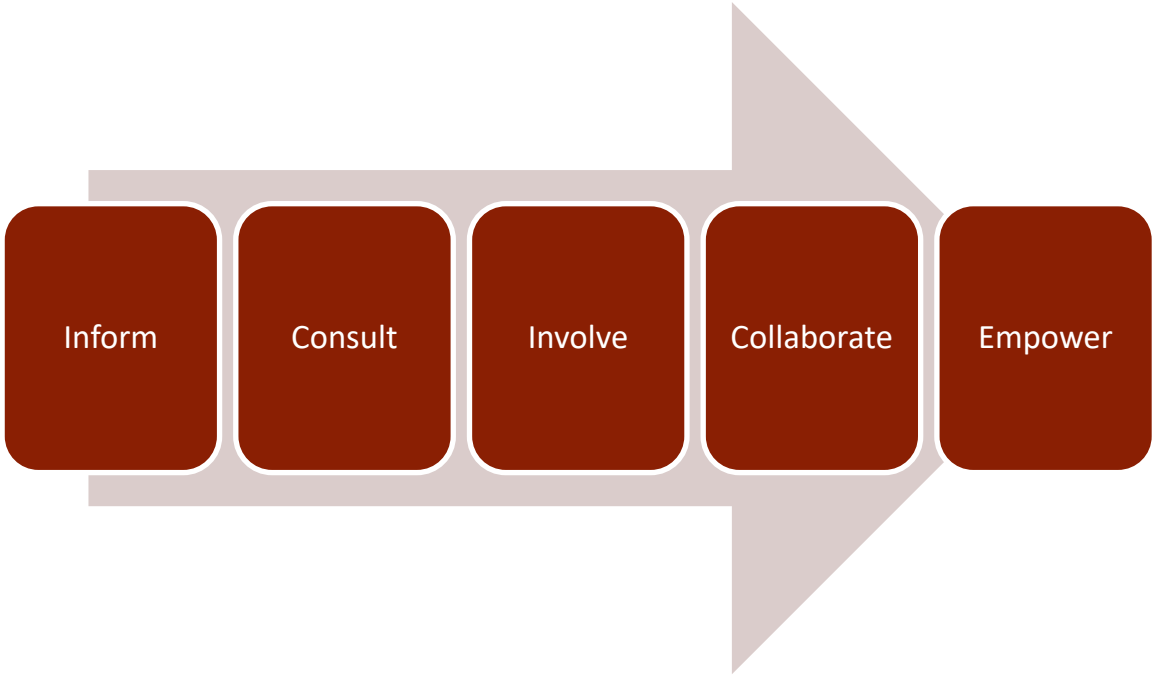
Stakeholder	CONSULTATION DATE	CONSULTATION METHOD	STAKEHOLDER COMMENTS/ISSUE	TELLUS RESPONSE	STAKEHOLDER RESPONSE
			• Consider amending the indicative completion criteria for 'safety and security' to clarify what is meant in terms of water in the pit.	workshop occurred prior to this meeting. Section 9.9 has been updated to include management of a kaolin stockpile during the care and maintenance phase. Table 6–1 has been amended to clarify the safety hazard to be avoided.	

4.2.1 Stakeholder engagement strategy

Purpose of Communication

For mine closure to be effective, engagement with stakeholders is required at every phase of the Sandy Ridge Project. The Community Engagement and Development Handbook (DITR, 2009) outlines two frameworks generally implemented by miners to engage with the community and stakeholders. Tellus considers the International Association of Public Participation (IAP2) process (illustrated in Figure 4–1) as the appropriate framework for the Sandy Ridge Project, as it allows for a continuum of consultation with stakeholders.

Figure 4–1 Continuum of Engagement



Tellus has interpreted the purpose of each type of engagement in Table 4–1 as described below:

Inform – providing information about the mine.

Consult – direct conversation on specific areas of risk and opportunity in relation to mine closure.

Involve – interactive mode between Tellus and the stakeholder to achieve a common closure outcome.

Collaborate – Stakeholder-driven consultation on aspects of closure.

Empower – participation in planning and decision-making, not only on issues related to operational impacts, but also on decisions regarding the community's future once the mine has closed.

In the initial stages of mine closure planning, Tellus will inform stakeholders of the plans for mine closure. As the mine develops and is operational, there will be a move towards the consult, involve

and collaborate forms of engagement. Nearing the end of the mine life, there may be opportunities to empower stakeholders. The purpose of communication and method chosen will be evaluated following each engagement event, and reflected upon during the three yearly review of this MCP.

Methods of Communication

Single or multiple methods may be used to communicate with stakeholders, depending on the purpose of the communication. Several methods are listed in Table 4–2.

Table 4–2 Communication methods

Purpose	Method
Inform	Information booths, media releases, newsletters, brochures, mail out programs, websites and hotlines.
Consult	Public meetings, discussion groups, polls, surveys and focus groups.
Involve and Collaborate	Workshops and discussion groups, learning circles, interviews, reference groups and community consultative committees.
Empowerment	Site visits, direct phone calls and electronic mail.

Targeted Communication

The consultation to be undertaken prior to the submission of the next revision of this MCP includes:

1. Discussions internally within Tellus to agree on any required changes to the post-mining land use and closure objectives (Section 5 of this MCP). If changes are proposed, these are to be assessed and a list of changes to the Completion Criteria (Section 6), Collection and Analysis of Closure Data (Section 7) and Closure Implementation (Section 9) and Closure Monitoring and Maintenance (Section 10) prepared.
2. The list of required changes will be discussed with all external stakeholders with the aim of achieving agreement.
3. Once agreed, Tellus will make the changes to the sections outlined above, and also recalculate and amend the Financial Provisioning for Closure (Section 11).

The revised MCP will be issued to all external stakeholders for comment, and where appropriate comments incorporated.

Adequate Resources for Engagement

Financial resources as documented in Section 11, have been allocated for expenses related to carrying out stakeholder engagement. In this conceptual MCP the Project Planner/Engineer and the Environment & Approvals Manager are responsible for stakeholder engagement, and have adequate time available as part of their current roles to engage with stakeholders.

Documentation

All stakeholder engagement, regardless of purpose or form, will be recorded in Table 4–1.

5 POST–MINING LAND USE AND CLOSURE OBJECTIVES

5.1 Pre-mining land use

The site is vacant Crown Land, with no current land use or occupation. Vegetation is in Excellent Condition (PGV Environmental, 2016) and relatively undisturbed (with the exception of exploration activities).

Given the remote location of the site, semi–arid climate and distance from the nearest town (75 km to Koolyanobbing), there is currently no proposed future land use.

5.2 Post–mining land use

The proposed post–mining land use is to reinstate the native vegetation (except for the pits) to be as similar as possible to the existing surrounding vegetation. The pits will be used for waste disposal (Class IV / V landfill) and regulated by the DER under the *Environmental Protection Act 1986*. Following decommissioning of the mine it will mostly be vacant, but the following infrastructure will remain:

- Water pipeline and associated equipment (Carina pit pumps, transfer water tanks, reverse osmosis (RO) plant, water tanks at the mine site). These will remain onsite to provide water to revegetated areas, to assist with access road maintenance, for dust suppression if required, and to assist in bushfire management.
- The administration building located adjacent to the front gate within the infrastructure area. This will remain as a facility to use (equipped with toilets and kitchen) for any visitors to the site, whilst the site is operating as a Class IV / V landfill.

It should be noted that the access roads into the mining lease will not be closed. This includes:

- 95 km road to the IWDF Mount Walton East (Access Reserve No. 44102) that extends northward from the Boorabbin Siding on Great Eastern Highway.
- 4.5 km westward section along an existing road that joins the IWDF access road; and
- 5.3 km northwards section of road north from the private existing road to Mount Dimer into the mining lease.
- The internal site road leading from the above roads, through the infrastructure area past the front administration building and to the pits/cells will also remain in place to allow access to the pits/cells for monitoring purposes.

The roads listed above will be closed, with the exception of the IWDF access road (Crown Reserve No. 44102), as part of the WFDCP. Figure 5–2 shows the proposed post–mine landscape with the infrastructure remaining at the relinquishment of the mining lease. The domains (except the pits)

will resemble the pre–disturbance topography (Figure 5–1) as shown in pre–mine surveys and will be vegetated.

Figure 5–1 Conceptual landform design diagram showing all domains rehabilitated to ground surface and vegetated (i.e. back to pre–mine disturbance condition)

Figure 5–2 Infrastructure remaining on site

5.3 Closure objectives and guiding principles

The DMP and EPA objectives for mine closure are:

'*rehabilitated mines to be (physically) safe to humans and animals, (geo-technically) stable, (geo–chemically) non-polluting / non-contaminating, and capable of sustaining an agreed post–mining land use'*

Tellus has assimilated these objectives into the mine planning process to in order to formulate the following closure objectives for the Sandy Ridge Project:

1. Each excavated pit is structurally stable.
2. Each excavated pit is free of ponded water (i.e. not a pit lake).
3. Vegetation in rehabilitated areas are comparable as reasonably practicable to the analogue site.
4. Mining related infrastructure (except for that infrastructure to be managed under the WFDCP) removed from the domain during the Decommissioning Phase.

6 COMPLETION CRITERIA

6.1 Basis for development

Whilst the Sandy Ridge Project is in the conceptual phase of mine closure planning, the completion criteria have been developed based on the technical environmental studies completed for the development envelope and an understanding of the basic criteria for successful closure.

Tellus understand that completion criteria should be:

- Specific enough to reflect a unique set of environmental, social and economic circumstances;
- Measurable to demonstrate that rehabilitation is trending towards analogue indices;
- Achievable or realistic so that the criteria being measured is attainable;
- Relevant to the objectives that are being measured and flexible enough to adapt to changing circumstances without compromising objectives;
- Time-bound so that the criteria can be monitored over an appropriate time frame to ensure the results are robust for ultimate relinquishment.

6.2 Development of completion criteria

In developing completion criteria for the Sandy Ridge Project, specific importance was placed on the DMP and EPA objectives for mine closure:

'rehabilitated mines to be (physically) safe to humans and animals, (geo-technically) stable, (geo–chemically) non-polluting / non-contaminating, and capable of sustaining an agreed post–mining land use'

Specific targets (i.e. completion criteria) are developed for three reasons:

- To allow effective reporting and auditing during the life of the mine.
- On achievement, they represent an endpoint for closure activities where the site can be considered by internal and external stakeholders as 'rehabilitated[3]'.
- Once completion criteria have been met, and the site is considered rehabilitated, the process of tenement relinquishment can commence.

The preliminary completion criteria for the Sandy Ridge Project is presented in Table 6–1.

[3] Defined in the MCP guidelines (DMP & EPA, 2015) as 'the return of disturbed land to a safe, stable, non–polluting / non–contaminating landform in an ecologically sustainable manner that is productive and self–sustaining consistent with the agreed post–mining land use'.

Table 6–1 Indicative completion criteria

Subject	Closure Objective	Indicative Completion Criteria[4]	Measurement Tools
Landform Stability	Each excavated pit is structurally stable.	At closure pit walls do not collapse inwards.	Geotechnical assessment.
Safety and Security	Each excavated pit is free of ponded water (i.e. not a pit lake).	At closure the mine void does not pose a safety hazard, that persons or vehicles could accidently fall into. The mine void will not contain water of sufficient volume that could create a potential drowning hazard.	Visual inspection. Safety bunding around all open pits.
Vegetation development	Vegetation in rehabilitated areas is comparable as reasonably practicable to the analogue site.	At the completion of the 10 year rehabilitation monitoring period vegetation composition is comparable to the species diversity/richness and structure of the analogue site. All plants used in rehabilitation to be of local provenance. No declared pests[5] to be introduced into the area.	Revegetation monitoring (see Section 10.1) results provided in Annual Environmental Report. Flora and Vegetation Survey report at the end of the 10 year monitoring period.
Decommissioning	Mining related infrastructure (except for that infrastructure to be closed under the WFDCP) removed from site during the Decommissioning Phase.	At mine closure no mining related infrastructure is left on the tenement.	Visual inspection.

[4] As described in Appendix K of the MCP guidelines (DMP & EPA, 2015), indicative completion criteria is used in the early stages of closure planning, and may be qualitative or semi–quantitative. As the closure planning progresses the completion criteria will become quantitative.
[5] Declared pests are defined under the Biosecurity and Agriculture Management Act 2007 and have the meaning (a) a prohibited organism; or (b) an organism for which a declaration under section 22(2) is in force.

7 COLLECTION AND ANALYSIS OF CLOSURE DATA

The Sandy Ridge Project is currently in the design/planning stages therefore baseline data collected has been specifically to inform the environmental impact assessment. A summary of the reports completed to date and the data available for the mining lease and miscellaneous licences is provided in Table 7–1. Further details on each aspect are described in Sections 7.1 to 7.9.

Table 7–1 Baseline data collected to date

Aspect	Report Title and Author	Data available
Climate and weather observations	A weather station has been installed at the site and is operational. Daily and monthly data summaries are available to download from: www.weathermation.net.au.	Weather observation data on: Wind speed (maximum and average). Average wind direction. Maximum peak wind gust. Relative humidity (maximum, minimum and average). Air temperature (maximum, minimum and average). Rainfall (total and maximum). Data collected from 8 May 2015 to present on a daily basis.
Flora and Vegetation	Sandy Ridge Project, Exploration Tenement E16/440 Level 1 Flora and Vegetation Survey (PGV Environmental, 2015)	Level 1 Flora and Vegetation Survey (desktop review).
	Sandy Ridge Project, Exploration Tenement E16/440 Flora and Vegetation Survey (PGV Environmental, 2016)	Level 2 Flora and Vegetation Survey (desktop review and field survey). Sampling of 25 non–permanent 20 m by 20 m quadrats and several traverses through proposed road and water pipeline alignments.
Fauna	Level 1 Fauna Survey (Terrestrial Ecosystems, 2015)	Level 1 Fauna Study (desktop review and reconnaissance survey).
	Targeted Malleefowl Survey (BCE, 2016)	Historical malleefowl mound locations.
Soils	Sandy Ridge Project Soil Assessment (Landloch, 2015a)	Characterisation of soil types Soil chemical and physical analysis results

Aspect	Report Title and Author	Data available
		Available topsoil and subsoil resource Soil management techniques
Hydrogeology	Hydrogeological Studies for the Sandy Ridge Project Drilling, Permeability Testing and Potential Water Sources Report (Rockwater, 2015)	Desktop review of previous hydrogeological investigations. Drilling and Monitoring Bore Construction methodology. Monitoring bore permeability tests. Description of hydrogeology Water Supply Assessment
Hydrology	Sandy Ridge Kaolinite Project Surface Water Assessment and Management Plan (Rockwater, 2016a) Sandy Ridge Kaolinite Project Surface Water Assessment and Management Plan: Addendum (Rockwater, 2016b)	Surface Catchment Hydrology Surface Catchment Runoff Hydraulics Water Management Requirements
Geotechnical Assessment of Cell Design	Report on Geotechnical Assessment Sandy Ridge Project Goldfields, WA (Douglas Partners, 2015)	Permeability of Compacted Iron Stained Kaolinised Granite and Kaolin Stream Waste Compaction of Backfilling Materials and Backfilling Methodology Capping Layer Compaction and Methodology
Aboriginal Heritage	Report on an Aboriginal Heritage Survey of Tellus Sandy Ridge Project (John Cecchi Heritage Management Consultancy, 2015)	Ethnographic background. Archaeological background. Survey methodology and results.
Characterisation of the clay capping material	Characterisation of the clay capping material from the Sandy Ridge Mine Site (Landloch, 2015b)	Chemical and physical analysis of kaolin capping material.

7.1 Climate and Weather Observations

The Proposal falls within the bioclimatic category defined in Beard (1990) as 'semi desert Mediterranean' and averages approximately 250 mm of rainfall per annum. The proposed development envelope lies just to the south of one of the driest regions in Western Australia and does not receive enough rainfall to allow the regular production of crops. The closest Bureau of Meteorology weather station to the proposed development envelope is located at Menzies,

approximately 110 km to the northeast. Table 7–2 summarises the Bureau of Meteorology's data for Menzies from around the last 100 years (BoM, 2015).

Table 7–2 Menzies climate data

Statistics	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Maximum Temperature													
Mean maximum temperature (°C)	35.1	33.9	31.1	26.2	21.3	17.7	17	19	23.1	26.8	30.7	33.9	26.3
Highest maximum temperature (°C)	46.2	45.6	45	39.4	33.9	28.3	28.3	31.1	36.4	40.8	42.9	45.2	46.2
Lowest maximum temperature (°C)	16.8	17.8	14.9	12.8	10.9	9.4	7.2	9.4	10.2	11.8	15.1	15	7.2
Minimum Temperature													
Mean minimum temperature (°C)	19.7	19.4	17.2	13.4	9.3	6.7	5.3	6.1	8.6	11.7	15.5	18.2	12.6
Highest minimum temperature (°C)	31	28.9	30.3	24	20.2	18.9	14.5	17.9	23.3	25	27.2	29.4	31
Lowest minimum temperature (°C)	11.7	10	7.6	1.1	-1.4	-4.8	-4	-3	-0.6	0.6	3.4	6.8	-4.8
Rainfall													
Mean rainfall (mm)	22.3	32.1	26.3	21.5	25.7	27.7	22.7	19.6	10.5	11.3	14.8	15.5	250

Source: BoM (2015)

An Automated Weather Station (AWS) was setup within the proposed development envelope in May 2015. It has been recording hourly average data on; wind speed and direction, total rainfall, relative humidity and air temperatures since 8 May 2015. Table 7–3 summarises the data collected to date (March 2016).

Table 7–3 Sandy Ridge weather station data

Data	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	Annual
Maximum Temperature													
Mean maximum temperature (°C)	20.7	20.2	18.7	19.8	31.2	31.6	32.4	34.1	34.1	33.0	30.0		
Highest maximum temperature (°C)	24	25.5	22.8	28.7	32.7	39.2	40.8	41.6	41.9	42.8	39.5		
Lowest maximum temperature (°C)	16	13.2	13.8	9.6	15.9	21.2	22.2	25.8	25.9	23.6	18.0		
Minimum Temperature													
Mean minimum temperature (°C)	4.1	4.6	3.1	5.3	5.8	12.1	14.5	15.3	18.4	15.8	16.4		
Highest minimum temperature (°C)	12	11.8	11.9	13.7	14.7	20.4	20.0	21.0	24.4	23.7	23.2		
Lowest minimum temperature (°C)	0	0	0	0.03	0.03	4.2	4.5	5.46	12.1	9.5	8.1		
Rainfall													
Total rainfall (mm)	0.6	21.8	23.2	31.2	0	3.6	22.2	26.4	70.8	35	35.2		

7.2 Flora and Vegetation

Key findings:

- 50 Threatened and Priority species located within 20 km radius of the mining lease.
- Desktop review indicated 25 Priority species possible occur in the mining lease. None of these species are listed as Threatened under the EPBC Act or WC Act.
- 97 species from 27 Families and 50 Genera were recorded. The most common Families were the Myrtaceae (21 species), Fabaceae (13 species), Proteaceae (8 species) and Asteraceae (8 species). The Genera with the most species were Acacia (11), Eucalyptus (8), Grevillea (7) and Melaleuca (5).
- No introduced species (declared pests under the *Biosecurity and Agricultural Management Act 2007*) were recorded.
- No Threatened (Declared Rare) species listed under the WC Act 1950 or EPBC Act 1999 were recorded.
- One Priority 3 species, *Calytrix creswellii*, was recorded at one location in *Acacia resinimarginea* Open Heath on loamy sand in the middle of the pits/cells area. Numerous plants were recorded in the quadrat and nearby.
- One Priority 3 species, *Lepidosperma lyonsii*, was recorded on the proposed pipeline route between the Mount Dimer Road and the tenement. Several plants were recorded in *Eucalyptus pileata*/*Acacia resinimarginea* Shrub Mallee/Open Heath vegetation.
- Five populations of the undescribed sedge species, *Lepidosperma sp*., were recorded in *Acacia resinimarginea* dominated vegetation on the site. The species is likely to be more widespread on the site than the populations recorded. The species was not able to be identified to specific level but was not considered to be any of the three Priority species previously recorded in the vicinity of the site. The taxonomy of Lepidosperma is being reviewed by the Western Australian Herbarium staff (R. Barrett) and until those results are published the Lepidosperma recorded on the site should be treated as potentially having some conservation value.
- Most of the vegetation in the survey area belongs to Beard vegetation association 437 'Shrublands; mixed acacia thicket on sandplain' with the southwestern area belonging to association 141 'Medium woodland; York gum, salmon gum and gimlet'.
- The vegetation condition was assessed as 'Excellent' using the Bush Forever condition scale.

7.3 Fauna

Key findings:

- Two fauna habitats were mapped within the mining lease and miscellaneous licences; open eucalypt woodland and shrublands.

- Most of the mining lease and miscellaneous licences are in 'Very Good' to 'Excellent' condition with the exception of vehicle tracks in the proposed pits/cells and infrastructure disturbance areas.
- Potential for 22 fauna species of conservation significance to occur within the mining lease and miscellaneous licence.
- Four of these species are listed as Threatened and two as Migratory under the EPBC Act. None of these species have previously been recorded within the mining lease and miscellaneous licence.
- No malleefowl or active mounds were observed during the targeted survey. Old mounds were evident, with 63 identified during the survey of various ages and in varying states of degradation. Most were little more than circular raised areas of gravel, potentially unused for decades or centuries.
- Two rainbow bee-eaters were observed during the survey; however, as the nesting period had finished for the season it was assumed the birds were just passing through (M. Bamford, pers. comm).

7.4 Soils

Key findings:

- The field assessment identified two soil types; Deep Yellow Sand and Red Sandy Duplexes.
- The Deep Yellow Sand is associated with the higher relief areas of low sandy dune systems. The pH of the Deep Yellow Sand is strongly acidic.
- The Red Sandy Duplex is associated with the lower-lying areas of the exploration lease, potentially broad areas of through going drainage, and consequently are areas of net erosion. The Red Sandy Duplexes were found at shallow depths (<0.3m BGL) over a tightly packed laterite ferricrete. The pH of the Red Sandy Duplex was neutral at surface to alkaline at depth.
- A description of each soil type is listed in Table 7–4 and Table 7–5, and the physical and chemical laboratory test results are provided in Table 7–6.

Table 7–4 Characteristics of the Red Sandy Duplexes

Property	Inspection Site Description
Brief description	Shallow dark red/brown sand over sandy clay loam
Soil samples	Pit 1, Pit 2
Gradients	Gently undulating
Soil Landscape	Norseman
Soil classification	Petroferric Kandosol
Surface coarse fragments	0-20% abundance sub-angular pebbles to small rocks
Surface condition	Soft to moderate
Permeability	Moderate (surface), slow (subsurface)
Water repellent	No
Drainage	Sheet wash and low relief drainage lines

Soil depth (cm)	Soil Profile Description
0-5	A_1 Dark red-brown (2.5YR-2.5/4), weakly structured, sand, <5% coarse pebble fragments, pH 7 (field)
5-20	A_2 Dark red-brown (2.5YR-3/6), weakly structured, loamy sand, <2% coarse pebble fragments, pH 7 (field)
20-30	A_2 Dark red-brown (10R-3/6), weakly structured, sandy clay loam, <2% coarse pebble fragments, pH 8 (field)
>30	Very hard pale laterite/ferricrete of unknown depth

Table 7–5 Characteristics of the Deep Yellow Sands

Property	Inspection Site Description
Brief description	Deep yellow acidic sand
Soil samples	Pit 3, Pit 4
Gradients	Flat to gently undulating
Soil Landscape	Norseman
Soil classification	Yellow Orthic Tenosol
Surface coarse fragments	<2%
Surface condition	Soft
Permeability	Moderate to high
Water repellent	No
Drainage	Surface sheet
Soil depth (cm)	**Soil Profile Description**
0-5	A_1 yellow red (7.5YR-6/6), massive, sand, few coarse fragments, pH ~4.5 (field)
>15	B_2 Dark red (7.5YR-7/6), massive, loamy sand, few coarse fragments, pH ~4.5 (field)

Table 7–6 Chemical and physical soil test results

Analyses		Unit	Sample ID					
			Red Sandy Duplexes			*Deep Yellow Sands*		
			Pit 2-1	**Pit 2-2**	**Pit 2-3**	**Pit 4-1**	**Pit 4-2**	**Pit 4-3**
			5cm	**20cm**	**30cm**	**5cm**	**20cm**	**50cm**
$pH_{1:5}$		pH units	7	7.06	8.89	4.92	4.37	4.21
Electrical conductivity ($EC_{1:5}$)		dS/cm	0.02	0.02	0.17	0.03	0.02	0.02
Total nitrogen		mg/kg	205	104	249	232	206	470
Total phosphorus		mg/kg	<75	<75	<75	<75	<75	<75
Organic carbon		%	0.47	0.20	0.28	0.73	0.41	0.17
Plant Available Nutrients	Phosphorus - Colwell	mg/kg	13.8	5.4	5.1	5.9	3.6	3.5
	Potassium – Colwell	mg/kg	218	28.2	208	44.3	22.6	46.7
	Sulphur – KCl	mg/kg	4.1	3.8	8.3	8.5	11.8	26.0
	Copper – DTPA	mg/kg	0.34	Not detected	Not detected	0.32	Not detected	Not detected
	Iron – DTPA	mg/kg	7.3	Not detected	Not detected	25.1	Not detected	Not detected
	Manganese – DTPA	mg/kg	2.3	Not detected	Not detected	0.9	Not detected	Not detected
	Zinc - DTPA	mg/kg	0.2	Not detected	Not detected	0.2	Not detected	Not detected

Analyses		Unit	Sample ID					
Exchangeable Cations	Calcium	meq/100g	2.49	2.18	9.52	0.92	0.62	0.51
	Magnesium	meq/100g	0.46	0.71	3.38	0.25	0.15	0.13
	Potassium	meq/100g	0.33	0.36	1.75	0.31	0.34	0.26
	Sodium	meq/100g	0.14	0.10	1.2	0.14	0.13	0.09
	Aluminium	meq/100g	0.04	0.01	0.02	0.006	0.36	0.37
	Effective Cation Exchange Capacity	meq/100g	3.5	3.4	15.9	1.7	1.6	1.4
	Exchangeable Sodium Percentage	%	4.1	2.9	7.6	8.4	7.9	6.4
Particle Size Distribution of Fine Fraction	Coarse Sand 0.2-2.0mm	%	70.4	67.3	49.2	70.3	68.9	57.7
	Fine sand 0.02-0.2mm	%	26.5	29.6	29.1	23.8	22.5	33.8
	Silt 0.002-0.02mm	%	0.4	0.4	0.4	2.2	0.4	2.2
	Clay <0.002mm	%	2.7	2.7	21.3	3.6	8.2	6.3
Dispersion Index		Class	3	3	2	7	6	6

7.5 Hydrogeology

Key findings:

- The Sandy Ridge project is in an area underlain by granitic rocks where there is a thick weathering profile. Little or no groundwater has been intersected within the mining lease, in either the mineral exploration drilling or the 2015 investigation programme.
- Six holes located in areas of greater depth to fresh granite, in the west and south-western parts of the pits/cells area, intersected small quantities of moderately saline groundwater (2,000 to 11,000 mg/L TDS). Airlift water yields ranged from zero to about 0.03 L/s, and permeabilities of the water-bearing zones were low, showing they do not constitute an aquifer.
- The kaolinite and weathered granite are indicated to be of low permeability (1.17 to 4.35 m per year, or 3.7 x 10^{-8} to 13.8 x 10^{-8} m per second). These values are based upon whole core permeability tests. Initial in-situ permeability tests in dry holes were discounted due to a lack of saturation of the surrounding ground and hence were more likely to be measuring capillary and wetting effects.
- The most practical source of water for the project is probably the Carina iron ore mine, located 13 km south-west of Sandy Ridge in the Yendilberin Hills, where there is abundant water available from the pit and/or dewatering bores (up to 3,000 kL/d). The water has a salinity of about 33,000 mg/L TDS. It is highly unlikely that accessing water from Carina mine will have any additional impact at Carina because the volume sought is small and will replace water that is currently lost by evaporation and seepage. Also, the mine is remote (at least 10 km) from other groundwater users (except Mineral Resources).

7.6 Hydrology

Key findings:

- The planned mining area is unaffected by any major flow paths, and surface water management is only required for short–term flows during rare high rainfall events. These flows are generally from small local catchments which drain residual runoff after infiltration losses to low-lying depressions. Generally water will only be retained for very short periods in the depressions due to continuing infiltration loss. Water could pond for longer periods if the depressions are clay pans. Evaporation will contribute to the loss of ponded water.
- The development envelope has predominantly sandy soil; with some small claypans where infiltration rates could be between 24 and 120 mm/day. With sandy loam soil the highest recorded rainfalls should infiltrate within 12 hours, or if not, soon after.

7.7 Aboriginal heritage

Key finding:

- No sites of aboriginal heritage were identified during the survey.

7.8 Geotechnical assessment of cell design

Key findings:

- The results of the tests indicate a permeability of between 5.7 x 10^{-8} m per second and 6.4 x 10^{-8} m per second (approximately 5 mm per day to 5.5 mm per day) for the iron stained kaolinised granite and between 1.6 x 10^{-8} m per second and 3.0 x 10^{-8} m per second (approximately 1.4 mm per day to 2.5 mm per day) for the kaolin stream waste.
- Granular filling to be placed within 2% of optimum moisture and compacted to 90% of maximum modified dry density (MMDD).
- Compaction testing carried out using a nuclear density gauge in accordance with *AS 1289.5.8.1*.
- The capping layer should be compacted to an average of 98% standard maximum dry density (SMDD), and the minimum compaction should be 95% MMDD.

7.9 Characteristics of the kaolin

Key findings:

- Kaolin is relatively benign in terms of its chemical characteristics. Some samples were slightly acidic and saline, but most trended towards neutral to non–saline.
- All metals analysis were below EILs (DEC, 2010) and therefore no pre–existing contamination was present in the samples analysed.
- The material is fine textured, has low permeability (0.26 – 1.2 mm/hr), and may potentially be hardsetting, indicating it may potentially erode.

- The physical and chemical characteristics of kaolin is listed in Table 7–7.

Table 7–7 Kaolin physical and chemical characteristics

Property		Unit	TC1	TC2	TC3	TC4	TC5	TC6
pH		pH units	6.72	6.91	6.59	6.51	5.75	6.59
Electrical conductivity		dS/cm	0.48	0.40	0.74	1.17	0.19	0.60
Exchangeable Cations	Calcium	meq/100g	0.69	0.74	0.72	0.55	0.49	0.71
	Magnesium	meq/100g	1.43	1.64	1.29	0.77	1.28	1.03
	Potassium	meq/100g	0.23	0.30	0.14	0.08	0.11	0.08
	Sodium	meq/100g	0.50	1.39	0.31	0.13	0.91	0.13
	Aluminium	meq/100g	0.01	0.01	0.01	0.01	0.01	0.01
	Effective Cation Exchange Capacity	meq/100g	2.8	4.1	2.5	1.5	2.8	2.0
	Exchangeable Sodium Percentage	%	17.4	34.1	12.5	8.4	32.4	6.49
Particle Size Distribution of Fine Fraction	Coarse Sand 0.2-2.0mm	%	50.3	33.2	49.1	39.0	46.3	39.4
	Fine sand 0.02-0.2mm	%	32.6	37.4	22.3	38.3	24.9	38.8
	Silt 0.002-0.02mm	%	13.8	28.1	10.8	16.4	14.5	18.4
	Clay <0.002mm	%	3.2	1.3	17.7	6.3	14.3	3.4
Plant Available Water		%	14	18	7	12	10	16
Dispersion Index		Class	6	6	6	6	6	6
Saturated Hydraulic Conductivity		mm/hr	0.46	0.26	1.20	0.29	0.50	0.45
Arsenic		mg/kg	<5	<5	<5	<5	<5	<5
Barium		mg/kg	<10	<10	<10	<10	<10	<10
Beryllium		mg/kg	<1	<1	<1	<1	<1	<1
Boron		mg/kg	<50	<50	<50	<50	<50	<50
Cadmium		mg/kg	<1	<1	<1	<1	<1	<1
Chromium		mg/kg	7	4	3	5	<2	<2
Cobalt		mg/kg	<2	<2	<2	<2	<2	<2
Copper		mg/kg	<5	<5	<5	<5	<5	<5
Lead		mg/kg	<5	<5	<5	<5	<5	<5
Manganese		mg/kg	<5	<5	<5	<5	<5	<5
Nickel		mg/kg	3	2	<2	2	<2	<2
Selenium		mg/kg	<5	<5	<5	<5	<5	<5
Vanadium		mg/kg	<5	10	<5	<5	<5	<5
Zinc		mg/kg	<5	<5	8	20	<5	7
Mercury		mg/kg	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1

7.10 Data gaps

A program for additional data collection is provided in Table 7–8.

Table 7–8 Future data collection

Aspect	Data to be Collected	Timeframe for Collection
Climate and weather observations	Weather observation data on: Wind speed (maximum and average). Average wind direction. Maximum peak wind gust. Relative humidity (maximum, minimum and average). Air temperature (maximum, minimum and average). Rainfall (total and maximum).	Daily until mining is completed.
Topography	Site survey.	Pre-mine construction
Baseline soil radioactivity	Baseline survey of background radionuclides in soils.	Pre-mine construction
Vegetation	Research described in Section 9.8.2.	Prior to revegetation.

8 IDENTIFICATION AND MANAGEMENT OF CLOSURE ISSUES

A risk assessment has been undertaken for all aspects of the mine closure, in accordance with the procedures outlined in the Australian and New Zealand Standards *AS/NZS ISO 31000:2009 Risk Management–Principles and Guidelines* (SAI Global, 2009) and *HB 203:2012 (Managing Environment-Related Risk)* (SAI Global, 2012), using Tellus' Risk Assessment Matrix (contained in the PER).

The sources of risks, environmental aspects and potential environmental impacts, as defined by *HB 203:2012* were identified in a workshop attended by the Sandy Ridge Project Leader and Aurora Environmental representatives. The identified environmental aspects were categorised into 'planned' that is those aspects which Tellus know will occur during closure, and those that are 'unplanned' and may credibly occur during closure, but which Tellus has no control over the frequency of occurrence. The identified potential environmental impact is based on the 'worst–case' credible impact.

Qualitative risk analysis was then undertaken, based on the likelihood of the potential environmental impact occurring. Analysis of the inherent risk was undertaken assuming no management/mitigation controls were in place. The group then discussed appropriate management and mitigation measures that would be implemented to reduce the likelihood or consequence, and then analysed the final residual risk.

The outcome of the risk assessment included the identification of 3 planned and 8 unplanned credible risks. This included:

- 2 – High residual risks.
- 9 – Low residual risks.

These risks are summarised in Table 8–1, with the full risk assessment provided in Appendix A.2. The high risks were evaluated following the workshop by the Sandy Ridge Project Leader, whom concluded that the occurrence of bushfires were outside of Tellus' control due to them being naturally occurring events. For this risk no treatment was considered necessary, other than preventative measures and response measures being implemented as per the Emergency Response and Management Plan.

Failure of rehabilitation was evaluated to be a risk that required treatment, and the further treatment proposed is to conduct research and trials prior to commencing revegetation to fill knowledge gaps. The outcomes or research and trials will enhance the proposed controls. The post-treatment consequence cannot be reduced as this relates to the cost of redoing revegetation, which is likely to be in the order of millions. Therefore once the research and trials are completed, Tellus consider this risk to be reduced to as low as reasonably practical.

Table 8–1 Closure risk register

Environmental Aspect	Sources of Risk (Hazard)	Potential Environmental Impact (Worst case)	Pre-treatment risk	Management and Mitigation Measures	Post-treatment Risk		Residual risk
					Consequence	Likelihood	
Revegetation of all domains (except pits/cells)	Topsoil degraded - no seed bank. Soils still compacted and plant roots cannot penetrate soils (i.e. no ripping occurred). Erosion of topsoil before seeds could establish. Seeds pre-treatment not undertaken and seeds remain dormant. No tubestock available. Fire, earthquake, cyclone, fauna predation, weed invasion.	Failure of revegetation.	High	Revegetation establishment procedure. Revegetation monitoring. Research and trials to grow vegetation prior to rehabilitation attempts. Collect seed from undisturbed areas of the mining lease.	Rare	Major	High
Naturally occurring events.	Bushfire at year 26	Injury or death of Threatened/Priority fauna. Damage or death of revegetation.	High	Firebreak, drying climate, low fuel load.	Likely	Minor	High
Decommissioning of the site	Movement of plant and collision with fauna.	Injury or death of Threatened/Priority fauna.	Low	Speed limit <20km/hr.	Rare	Insignificant	Low
Decommissioning of the site	Overturned truck/removal of tanks, forget to drain hydrocarbon lines.	Hydrocarbon spill and soil contamination.	Low	Front end loader onsite, cleanup procedures, extent is limited by absorptive nature of the clay, presence of silcrete layer. Adequate planning of demolition. Education of contractors.	Unlikely	Insignificant	Low

Environmental Aspect	Sources of Risk (Hazard)	Potential Environmental Impact (Worst case)	Pre-treatment risk	Management and Mitigation Measures	Post-treatment Risk		Residual risk
					Consequence	Likelihood	
Monitoring of the site	People accessing the site to complete monitoring.	Accidental fire (e.g. cigarette butt) leading to loss of vegetation.	Low	Education of contractors on fire prevention methods, vegetation is sparse and unlikely to be high fuel load.	Rare	Minor	Low
Decommissioning of the site	Footprint of removed infrastructure not rehabilitated	Generation of dust (potentially contaminated) which affects sensitive receptors.	Low	Contribution to MRF, Tellus insurances.	Rare	Insignificant	Low
Naturally occurring events.	Cyclones.	Erosion of soils, and sedimentation on revegetation.	Low	Establishment of vegetation outside of cyclone season as far as practicable.	Rare	Insignificant	Low
Unplanned explosion during decommissioning	LNG Facility, storage and use of gas. Diesel fuel tank and piping reticulation.	Degradation of air quality (localised). Death/injury of fauna within the vicinity of the blast zone or in the path of the fire.	Low	Adequate planning of demolition. Education of contractors.	Rare	Insignificant	Low
Introduction of weeds	Incoming vehicles to monitor the site.	Establishment of weeds on the site and competition for resources (e.g. water) with native vegetation.	Low	Inspection/brushdown of exterior of car before entering site. Brushdown of car between revegetation areas. Weed removal where they become established.	Rare	Insignificant	Low
Handling and storage of chemicals	Chemical spill during operations that was not remediated.	Soil contamination	Low	Contaminated sites assessment at closure. Remediation of affected soils.	Rare	Insignificant	Low
Unprocessed kaolin stockpile	Unstable stockpile	Erosion of the stockpile, dust generation, unstable landform, landform	Low	Unprocessed kaolin stockpiles comprising approximately 60 to 100 t	Rare	Insignificant	Low

Environmental Aspect	Sources of Risk (Hazard)	Potential Environmental Impact (Worst case)	Pre-treatment risk	Management and Mitigation Measures	Post-treatment Risk		Residual risk
					Consequence	Likelihood	
		with no vegetation growth.		would be dealt with by one of the following options: 1. stockpile backfilled into the final mine pit. 2. stockpile spread over a larger area and levelled to less than 10° to minimise erosion. Topsoil respread and vegetation established. 3. stockpile processed and kaolin products removed from site.			

9 CLOSURE IMPLEMENTATION

9.1 Closure domains

Five domains have been developed for the purpose of mine closure planning:

- Pits
- Infrastructure area
- Accommodation camp
- Class II Putrescible Landfill
- Access Roads

These domains are shown on Figure 4. Note: the water pipeline and associated infrastructure, the access roads into the mining lease, underground storage area and the cells will not be closed under this MCP; rather they will be closed under the WFDCP.

9.2 Timeline for closure

To estimate a timeline for closure, Tellus has assumed the following:

- a start date of 1 January 2018.
- that 25 mine pits will be created.
- that 10 years of vegetation monitoring of all domains will occur.
- completion criteria will be met at year 37 of the project.

Based on these assumptions the timeline is shown in Table 9–1.

Table 9–1 Closure timeline

Year of Project	Year 1 – 25	Year 26	Year 36	Year 37
Current estimated year	2018 – 2042	2043	2052	2053
Pits created, ore excavated				
Deep ripping/establishment of vegetation				
Vegetation monitoring				
Completion criteria met				
Mining tenement relinquished				

9.3 Pits domain closure work program

The pits domain will be considered closed when each pit has been excavated and the first waste is placed in the mine void. At mine closure there will be no residual stockpiles. All overburden, ore, and topsoil stockpile footprints adjacent to the pits will be rehabilitated.

Any surface water diversion bunds will also act as a safety bund (typically nominal 1m high) and will remain in place.

Sumps and V drains around the pits will require clay liners to be removed, the voids backfilled, ripped, topsoil spread and vegetation established.

A description of the closure work program for the pit domain is outlined in Table 9–2.

Table 9–2 Closure task register – pits domain

Pits domain	
Disturbance Area	202.3 ha
Activity Types in this Domain[6]	Mining void (depth greater than 5m – above groundwater)
Current Status of Rehabilitation	Not commenced
Estimated Closure Date	Last pit Year 25
Applicable Closure Objectives	1. Excavation is structurally stable. 2. Each excavated pit is free of ponded water (i.e. not a pit lake). 4. Mining related infrastructure (except for that infrastructure to be closed under the WFDCP) removed from the domain during the Decommissioning Phase.
Applicable Landform Design	Detailed engineered design of the pits.
Applicable Indicative Completion Criteria	• At closure pit walls do not collapse inwards. • At closure minimal water is present at the base of the excavation. • At mine closure no mining related infrastructure is left on the tenement.
Applicable General Implementation Strategies	1. Collection of Baseline Data 3. Materials Handling and Utilisation
Key Considerations for Closure	• Access to the pits must remain for monitoring purposes. • Progressive rehabilitation of disused sumps and V drains. • Progressive rehabilitation of overburden, ore, and topsoil stockpile footprints.
Key tasks for premature closure	• Rehabilitation of disused sumps and V drains. • Rehabilitation of overburden, ore, and topsoil stockpile footprints.

[6] as defined in Schedule 1 of the *Mining Rehabilitation Fund Regulations 2013*

9.4 Infrastructure area closure work program

All infrastructure associated with the mine will be decommissioned and removed from site, and their footprints ripped, vegetated and fertilised (if applicable) and then monitored for a period of 10 years. The exceptions to this are:

- Water pipeline and associated equipment (Carina pit pumps, transfer water tanks, RO plant, water tanks at the mine site). These will remain onsite to provide water to revegetated areas, to assist with access road maintenance, for dust suppression if required, and to assist in bushfire management.
- The administration building located adjacent to the front gate. This will remain as a facility to use (equipped with toilets and kitchen) for any visitors to the site, whilst the site is operating as a Class IV / V landfill. Some accommodation modules may be retained to house people coming to the site to conduct monitoring.

A description of the closure work program for the infrastructure area domain is outlined in Table 9–3.

Table 9–3 Closure task register – infrastructure area domain

Infrastructure area domain	
Disturbance Area	17.2 ha
Activity Types in this Domain[7]	Two saline water ponds (retention pond and raw water pond) Plant site (with a maximum processing capacity of at least 10 tonnes per hour) (kaolin processing plant) Mine site infrastructure – fuel storage (diesel fuel tank, piping reticulation and bowser) Mine site infrastructure – workshop Laydown or hardstand area Other buildings (kaolin products storage warehouse, waste laboratory, kaolin laboratory, contractor offices, explosive ordinance building) ROM pad
Current Status of Rehabilitation	Not commenced
Estimated Closure Date	Year 37
Applicable Closure Objectives	4. Vegetation in rehabilitated areas are comparable as reasonably practicable to the analogue site. 5. Mining related infrastructure (except for that infrastructure to be closed under the WFDCP) removed from site during the Decommissioning Phase.
Applicable Landform Design	None

[7] as defined in Schedule 1 of the *Mining Rehabilitation Fund Regulations 2013*

Infrastructure area domain	
Applicable Completion Criteria	• At the completion of the 10 year rehabilitation monitoring period vegetation composition is comparable to the species diversity/richness and structure. • All plants used in rehabilitation to be of local provenance. • No declared pests to be introduced into the area. • At mine closure no mining related infrastructure is left on the tenement.
Applicable General Implementation Strategies	1. Collection of Baseline Data 2. Research Investigation and Trials 3. Materials Handling and Utilisation 4. Identification of Potential Contamination 5. Progressive Rehabilitation
Key Considerations for Closure	• Obtaining volumes of fill, needed to fill any excavations back to natural soil surface level. • How and where to disposal of contaminated material, such as sediments from ponds. • Where broken concrete and asphalt will be disposed of. • Sale of plant equipment.
Key tasks for premature closure	All operating equipment and plant is made safe and secure. Decommissioning and removal of infrastructure no longer in use.
Performance monitoring	Vegetation monitoring as per Section 10.1.

A rehabilitation schedule for the infrastructure area is presented in Table 9–4.

Table 9–4 Infrastructure area domain rehabilitation schedule

Task	Year
Last Pit Completed	Year 25
Last Ore Stockpile Processed	Year 25
Removal of buildings, equipment, concrete pads and footings	Year 26
Ripping of soil surface	Year 26
Spread of topsoil	Year 26
Establishment of vegetation	Year 26
Monitoring of vegetation (10 years)	Year 26 – Year 36
Completion Criteria Met	Year 37

9.5 Accommodation camp closure work program

The accommodation camp will consist of; 4 person accommodation units, kitchen/dry mess, recreation and wet mess, office and first aid, toilet block, laundry block, gymnasium and carparking areas. All infrastructure associated with the accommodation camp will be decommissioned and removed from site, and their footprints ripped, vegetated and fertilised (if applicable) and then monitored for a period of 10 years.

A description of the closure work program for the accommodation camp domain is outlined in Table 9–5.

Table 9–5 Closure task register – accommodation camp domain

Accommodation camp domain	
Disturbance Area	2.5 ha
Activity Types in this Domain[8]	Accommodation camp
Current Status of Rehabilitation	Not commenced
Estimated Closure Date	Year 37
Applicable Closure Objectives	4. Vegetation in rehabilitated areas are comparable as reasonably practicable to the analogue site. 5. Mining related infrastructure (except for that infrastructure to be closed under the WFDCP) removed from site during the Decommissioning Phase.
Applicable Landform Design	None
Applicable Completion Criteria	• At the completion of the 10 year rehabilitation monitoring period vegetation composition is comparable to the species diversity/richness and structure. • All plants used in rehabilitation to be of local provenance. • No declared pests to be introduced into the area. • At mine closure no mining related infrastructure is left on the tenement.
Applicable General Implementation Strategies	1. Collection of Baseline Data 2. Research Investigation and Trials 3. Materials Handling and Utilisation 4. Identification of Potential Contamination 5. Progressive Rehabilitation
Key Considerations for Closure	• Removal of buildings and structures. • Disconnection of power, water and fuel. • Removal of concrete and imported fill.

[8] as defined in Schedule 1 of the *Mining Rehabilitation Fund Regulations 2013*

Accommodation camp domain	
	• Removal of fences. • Cleanup of general wastes. • Obtaining volumes of fill, needed to fill any excavations back to natural soil surface.
Key tasks for premature closure	The accommodation camp will be secured and any power, water and fuel supplies shut off.
Performance monitoring	Vegetation monitoring as per Section 10.1.

A rehabilitation schedule for the accommodation camp domain is presented in Table 9–6.

Table 9–6 Accommodation camp domain rehabilitation schedule

Task	Year
Last use of all camp facilities	Year 25
Decommissioning of the majority of the camp	Year 26
Ripping of soil surface	Year 26
Spread of growth medium	Year 26
Establishment of vegetation	Year 26
Monitoring of vegetation (10 years)	Year 26 – Year 36
Completion Criteria Met	Year 37

9.6 Class II landfill closure work program

An area of 0.25 ha has been allocated for a putrescible (Class II) landfill. This area will comprise a series of trenches each with the dimensions of 20 m long, 3 m wide and 3 m deep. Progressive closure of the landfill will occur, as one trench is filled, it will be capped with kaolin clay and the topsoil respread across it. Each successive trench will be capped and rehabilitated in this manner.

The existing site is relatively flat and the final landfill profile will be flush with the ground surface. Due to the low rainfall in the region, leachate migration is not likely to be a high risk; however the capping of the landfill site will isolate the waste long–term from variables such as wind disturbance and water infiltration.

Waste settlement is most rapid in the first few years of waste placement. Due to the small scale of this landfill, it is not expected that settlement will be a large problem. Should uneven settlement or erosion be detected, reinstatement of this area will be undertaken to minimise the risk of water infiltration into the landfill trenches.

Due to the small size of this landfill site, collection of landfill gases is not considered feasible or necessary.

A fence will be erected and maintained to exclude fauna from accessing the waste whilst the trench is open. Once the trench is capped the fence may be removed.

A description of the closure work program for the class II landfill domain is outlined in Table 9–7.

Table 9–7 Closure task register – class II landfill domain

Class II landfill domain	
Disturbance Area	0.25 ha
Activity Types in this Domain[9]	landfill
Current Status of Rehabilitation	Not commenced
Estimated Closure Date	Year 26
Applicable Closure Objectives	4. Vegetation in rehabilitated areas are comparable as reasonably practicable to the analogue site. 5. Mining related infrastructure (except for that infrastructure to be closed under the WFDCP) removed from site during the Decommissioning Phase.
Applicable Landform Design	Detailed engineering design
Applicable Completion Criteria	• At the completion of the 10 year rehabilitation monitoring period vegetation composition is comparable to the species diversity/richness and structure. • All plants used in rehabilitation to be of local provenance. • No declared pests to be introduced into the area. • At mine closure no mining related infrastructure is left on the tenement.
Applicable General Implementation Strategies	1. Collection of Baseline Data 2. Research Investigation and Trials 3. Materials Handling and Utilisation 4. Identification of Potential Contamination 5. Progressive Rehabilitation
Key Considerations for Closure	• Thickness of capping material. • Fence removal once last trench is capped. • Remove any equipment (e.g. loader) located at the landfill. • Obtaining volumes of fill, needed to fill any excavations back to natural soil surface.
Key tasks for premature closure	Cover any open trenches, compaction and respread growth medium.
Performance monitoring	Vegetation monitoring as per Section 10.1.

A rehabilitation schedule for the Class II landfill domain is presented in Table 9–8.

[9] as defined in Schedule 1 of the *Mining Rehabilitation Fund Regulations 2013*

Table 9–8 Class II landfill domain rehabilitation schedule

Task	Year
Cover last open trench	Year 25
Removal of fence	Year 25
Spread of growth medium	Year 26
Ripping of soil surface	Year 26
Establishment of vegetation	Year 26
Monitoring of vegetation (10 years)	Year 26 – Year 36
Completion Criteria Met	Year 37

9.7 Access roads closure work program

Three access roads have been identified for closure; Class II landfill road, accommodation camp road and internal site roads and parking areas. Prior to closing these roads, discussions will be held with external stakeholders to determine if any roads will be required for future access. Any roads that are not required will be rehabilitated.

It should be noted that the access roads into the mining lease will not be closed. This includes:

- 100 km road to the IWDF (Crown Reserve No. 44102) that extends northward from the Boorabbin Siding on Great Eastern Highway.
- 4.5 km westward section along an existing road that joins the IWDF access road; and
- 5.3 km northwards section of road north from the private existing road to Mount Dimer into the mining lease.
- The internal site road leading from the above roads, through the infrastructure area past the front administration building and to the pits/cells will also remain in place to allow access to the pits/cells for monitoring purposes.

The roads listed above will be closed as part of the WFDCP, with the exception of the IWDF access road (Crown Reserve No. 44102).

A description of the closure work program for the access roads domain is outlined in Table 9–9.

Table 9–9 Closure task register – access roads domain

Access Roads Domain	
Disturbance Area	Up to 22.2 ha.
Activity Types in this Domain[10]	roads
Current Status of Rehabilitation	Not commenced
Estimated Closure Date	Year 26
Applicable Closure Objectives	4. Vegetation in rehabilitated areas are comparable as reasonably practicable to the analogue site. 5. Mining related infrastructure (except for that infrastructure to be closed under the WFDCP) removed from site during the Decommissioning Phase.
Applicable Landform Design	Detailed engineering design
Applicable Completion Criteria	• At the completion of the 10 year rehabilitation monitoring period vegetation composition is comparable to the species diversity/richness and structure. • All plants used in rehabilitation to be of local provenance. • No declared pests to be introduced into the area. • At mine closure no mining related infrastructure is left on the tenement.
Applicable General Implementation Strategies	1. Collection of Baseline Data 2. Research Investigation and Trials 3. Materials Handling and Utilisation 4. Identification of Potential Contamination 5. Progressive Rehabilitation
Key Considerations for Closure	• Gradients for ripping (those on steep slopes will not be ripped as this encourages gully formation and erosion). • Remove traffic signs. • Remove traffic barriers (unless unsafe to do so).
Key tasks for premature closure	Close site access roads with bollards and signage.
Performance monitoring	Vegetation monitoring as per Section 10.1.

A rehabilitation schedule for the access roads domain is presented in Table 9–10.

[10] as defined in Schedule 1 of the *Mining Rehabilitation Fund Regulations 2013*

Table 9–10 Access roads domain rehabilitation schedule

Task	Year
Ripping of soil surface	Year 26
Spread of growth medium	Year 26
Establishment of vegetation	Year 26
Monitoring of vegetation (10 years)	Year 26 – Year 36
Completion Criteria Met	Year 37

9.8 General closure strategies

The general closure strategies are:

1. Collection of Baseline Data
2. Research Investigation and Trials
3. Materials Handling and Utilisation
4. Identification of Potential Contamination
5. Progressive Rehabilitation

The applicable domains, the purpose and key activities of each strategy, and a description of the strategy to be implemented is described further below.

9.8.1 Strategy 1 collection of baseline data

Applicable Domains: All

Purpose of Strategy: Baseline data is required to provide a benchmark on the status of the environment pre-mining, to allow comparison of the rehabilitated environment post-mining. Baseline data is very important for quantifying impacts to the environment from the mining operation.

Key activities:

- Data listed in Table 7–8 will be collected in the timeframes indicated.
- Collation of the collected data into this MCP every three years as the MCP is reviewed/revised.
- Review of collected data to ensure the data is verifiable, collected in line with best practice, the method used is appropriate for the task at hand and any gaps in knowledge are identified.
- Recommendations or gaps identified in baseline data will be documented in Table 7–8 for future reference and investigation.

Description of strategy:

At the time of preparation of this MCP rainfall data has been collected for a one year period, however the collection of data over the life of mine will provide Tellus with a better understanding of the expected rainfall at closure. A dataset of 25 years of rainfall data will:

- Identify which months receive the most rainfall, and which months are generally dry.
- Enable evaluation of the effects of cyclone events.
- Identify long-term trends and whether a drying climate is occurring.
- Be useful in comparing data against modelling predictions.

Knowledge gained from the dataset will allow Tellus to identify the best month of the year for revegetating topsoils to ensure they receive the most rainfall just after planting when vegetation is establishing itself. It will also enable Tellus to apply irrigation in known dryer months to ensure successful growth of revegetation.

The continued collection of baseline data for other environmental aspects will be beneficial at mine closure.

9.8.2 Strategy 2 – research, investigation and trials

Applicable Domains: All except pits domain.

Purpose: Research and onsite rehabilitation trials are important to collect data that will assist in the refinement of closure objectives and completion criteria.

Key activities:

- Research and investigation of successful techniques/methods for revegetation of land in arid climates.
- Research on the species listed to determine:
    - environmental cues to break dormancy.
    - flowering times.
    - seed collection methods.
    - viability of seed before or after storage.
    - optimum timing of sowing.
    - potential germination rates in the field.
    - germination enhancement technologies.
    - whether irrigation and fertilising would assist growth or be detrimental to overall survival.
    - probable survival rates of the seedlings.

- Revegetation trials on Deep Yellow Sand topsoils, which will be used in the infrastructure area, and on some access roads.
- Revegetation trials on Red Sandy Duplex topsoils, which will be used in the following domains: accommodation camp, Class II landfill, and access roads.
- Setup up analogue sites in the deep yellow sands and red sandy duplexes.
- Research on amendments to the soils, specifically looking at:
    - Reducing the dispersion risk of the Red Sandy Duplex subsoils;
    - Increasing the pH of the Deep Yellow Sands; and
    - Increasing the fertility of both soil types.

Description of strategy:

Prior to commencing rehabilitation it would be useful to trial different variables to see how vegetation responds and which variable stimulates the quickest growth. Selected areas of the site will be spread with Deep Yellow Sand topsoil and Red Sandy Duplex topsoils and seeded/planted to re–establish vegetation. Each type of topsoil will then be experimented with using different variables (fertiliser rates, water rates, tubestock versus seeds, etc). The results will be used to inform rehabilitation across the site.

9.8.3 Strategy 3 – material handling and utilisation

Applicable Domains: All

Purpose: Subsoils and topsoils will be stripped and handled to maintain their ecological value as a growth medium for rehabilitation. Placement of these materials onto rehabilitation areas should be carried out in accordance with best practice to optimise the ability for vegetation to establish.

Key activities:

- Soil Management Plan to be developed as part of this MCP and implemented. This plan should incorporate research on the current best practice for handling and utilising these materials.
- The surface of all rehabilitated areas would be ripped to alleviate compaction, prior to replacement of topsoil.

Description of strategy:

Soils are the primary nutrient medium for plants and must provide physical support and adequate inorganic nutrients at all times. The chemical and physical properties of soils are critical for rehabilitation. Plants require 17 inorganic nutrients for normal growth, with carbon, hydrogen and oxygen derived from air and water, and the rest derived from the plant's soil. A plant's roots adsorbs ions from the soils. These ions include; molybdenum, nickel, copper, zinc, manganese, boron, iron, chlorine, sulfur, phosphorus, magnesium, calcium, potassium and nitrogen. Phosphorus, potassium and nitrogen generally limit plant growth, hence the application of fertilisers will improve growth rates (Raven et al, 2003).

Best practice techniques for storage and handling of soils will be researched as part of preparing the Soil Management Plan. Landloch (2015a) proposed the following initial soil management strategies:

- Topsoils should be stripped to a depth of 10 cm so as to selectively harvest the soil containing the highest amounts of seed, biological activity and fertility.
- Subsoil should be stripped to a depth of 20 cm.
- Both soil types are poorly structured and have a high percentage of sand. This means they will be susceptible to erosion and may not be stable if placed on sloping land surfaces.
- Stripping of the hard laterite layer below the 30 cm depth from the Red Sandy Duplex soils, given the lack of competent rock available on the site, to be used as a resource to prevent erosion in high risk areas.
- Preservation of tree or scrub debris pushed over before soil stripping, to assist in rehabilitation areas with preventing surface water concentration, reducing wind erosion and it provided organic material, seed trapping areas and fauna habitat.
- Where possible stripped soils should be directly respread rather than stockpiled. This is because stockpiling of soils can lead to compaction, nutrient depletion, and loss of seed stock and soil microfauna.
- Stripping of soil should be undertaken after the wettest months, when the soil seed bank is highest. However soil should not be handled when wet.
- It is generally considered that stockpiling topsoils deeper than 1m tends to kill the topsoil seed bank and, to a lesser extent degrade the structure of soil at the bottom of the stockpile. Topsoil stockpiles should be flat-topped or domed.
- If soils are stockpiled for longer than 12 months they should be actively fertilised and seeded to:
    - Reduce erosion risk;
    - Maintain and accumulate soil organic matter levels; and
    - Increase soil seed banks.
- Subsoil and topsoil stockpile placement will be located to avoid possible contamination by wastes, radiation, hydrocarbons etc.
- Stabilise stockpiles to minimise erosion.
- Deep Yellow Sands can be stockpiled up to 4.0m high, however due to the high clay content of Red Sandy Duplex soils they should only be stockpiled 1.0m high.
- Due to the dispersion risk of the Red Sandy Duplex soils, Landloch (2015a) recommend adding gypsum to the soils. Indicative rates would be approximately 2–5t/ha and assumes the gypsum is incorporated into a soil depth of 30cm. Topsoil amendments are not required.
- Complete stockpile monitoring every 12 months to record; surface condition and erosion, nutrient status, pH, EC and seed germination rates.

9.8.4 Strategy 4 – identification of potential contamination

Applicable Domains: Infrastructure area, access roads, accommodation camp and class II landfill.

Purpose: Soils could be impacted by normal operations or unplanned events during the life of the mine. At mine closure no residual contamination relating to the operation should remain (with the exception of the waste stored in cells).

Key activities:

- Conduct a contamination assessment of the mine in accordance with *Assessment and Management of Contaminated Sites* (DER, 2014) or the appropriate regulatory guideline.
- Remediate affected areas in accordance with current best practice on advice from a contaminated sites specialist.
- Remove contaminated road base material to the appropriate class of landfill for burial.

Description of strategy:

Any potentially contaminated soil at the site will be investigated as per DER (2014) or the appropriate regulatory guideline. An example of how potentially contaminated soil would be identified is outlined below.

A section of the site has been impacted by a diesel spill to soil. A detailed site investigation in accordance with DER (2014) is undertaken and identifies that the extent of the spill affected 200 m^3 of soil. Laboratory analysis of the soil indicates the soil is impacted by hydrocarbons and the concentrations are less than the limits for disposal at a Class II landfill. The impacted material is excavated and placed in the onsite Class II landfill. Remediation and validation of the excavation void is conducted and a report provided confirming no residual contamination remains on the site.

9.8.5 Strategy 5 – progressive rehabilitation

Applicable Domains: All except pits domain.

Purpose: Progressive rehabilitation provides opportunities for testing rehabilitation practices, and for the gradual development and improvement of rehabilitation methods (DITR, 2006). It also assists financially to reduce the site's rehabilitation liability estimate (RLE).

Key Activities:

- Preparation and implementation of a revegetation establishment procedure which documents how and when vegetation is established, and the monitoring requirements to assess growth and success over time. This procedure will include information on:
    - Re-seeding/planting tubestock topsoil with species of local provenance. The species list of appropriate native species will be based on the best information available at the time of planting.

- Weed management during revegetation, including mitigation measure for regrowth and competition of weeds with native revegetated species.
- Irrigation of vegetation in a semi–arid climate.
- Fertilising vegetation during the establishment phase.

- Establish analogue vegetation sites in both vegetation communities present on the mining tenement. An analogue site is an unmined feature against which a mined feature may be compared (DITR, 2006).

Description of strategy:

Several areas of the site may be progressively rehabilitated if they are no longer needed. These are currently envisioned to be initial trenches of the Class II landfill, sumps and V drains around pit/cells and stockpile footprints. An example of how progressive rehabilitation would be undertaken is described for the Class II landfill.

The Class II landfill will be constructed in a series of trenches. Once a trench is filled with waste and covered, progressive rehabilitation of the trench will commence. This will involve removing the fence surrounding the trench, covering the surface with topsoil/subsoil, ripping the surface, planting tubestock or seeding the topsoil, irrigating and fertilising (if appropriate) and then monitoring the vegetation growth for 10 year. By year 25 most of the trenches will have been rehabilitated, with only those used near to the end of closure requiring rehabilitation.

9.9 Unexpected closure – care and maintenance

Care and maintenance of the mining operation would prevail under the following three scenarios:

1. Waste disposal continues and kaolin mining stops.
2. Kaolin mining continues and waste disposal stops.
3. Both activities stop indefinitely.

As kaolin mining will occur on a campaign basis, the first scenario is likely to occur every year. However care and maintenance phase would be triggered if an oversupply of kaolin was stockpiled and waiting for export, and an oversupply of kaolin waste material existed for backfilling cells.

In the scenario of waste disposal stopping, any partially open waste cell would be finished to completion (i.e. backfilled and capped) and active mining would cease. On-site stockpiles of overburden will be placed in the final mine pit prior to backfilling. No new mine pits would be opened during this phase.

Unprocessed kaolin stockpiles, comprising approximately 60 to 100 t, would be dealt with by one of (or a combination of) the following options:

1. stockpile backfilled into the final mine pit.
2. stockpile spread over a larger area and levelled to less than 10° to minimise erosion. Topsoil respread and vegetation established.
3. stockpile processed and kaolin products removed from site.

If both activities are stopped indefinitely due to market conditions, than Tellus would implement key tasks for premature closure for each domain as outlined in Section 9.

10 CLOSURE MONITORING AND MAINTENANCE

10.1 Vegetation monitoring

10.1.1 Methodology

The methodology appropriate for monitoring vegetation from year 26 to 36 will be based on the considered industry practice at the time. Currently the methodologies used by the industry include:

- **Point / Line intercept** — Uses a large number of observations to estimate cover values with high precision.
- **Quadrat monitoring** – Square or rectangle areas in the vegetation are examined and information regarding cover, frequency and diversity are collected.
- **Landscape Function Analysis** — measures the patchiness and quality of patch zones along a transect.
- **Plotless– vegetation monitoring** — the Point Centered Quarter method estimates density.A set of points (usually positioned along a transect to traverse the area) is initially selected. The area around each point is divided into four 90° quadrants, and the plant closest to the point in each quadrant is identified. The distance between the central point and selected plant in each quadrant is measured, and then averaged across the four to represent the distance at each sample point. At the conclusion of data collection, the average distance for all sample points is calculated (University of Arizona, 2016).
- **Photo–point monitoring** – photos are taken at fixed locations every monitoring event to visually see the change in vegetation.
- **Remote sensing** – a drone or similar may be used to look at the rehabilitation from a 'birds eye view'. GIS data can be collected and compared between monitoring events to see the change in vegetation cover.
- **Relevés method** – a list of plants in a delimited plot of vegetation, with information on species cover and a substrate and other abiotic features of the plot (Minnesota Department of Natural Resources, 2013).
- **Diameter at breast (DBH) height** – used as a measure of tree maturity, involves measuring the breast and height of a tree.

The method chosen will be part of an integrated approach designed for the specific climate of the site. The method or combination of methods will be repeatable (and auditable) and supported by studies and scientific literature. The methodology will also be discussed with the regulator prior to implementation.

10.1.2 Quality control

An analogue site is an unmined feature against which a mined feature may be compared (DITR, 2006). Two analogue sites, one in Deep Yellow Sand and one in Red Sandy Duplex soil types will be setup and monitored, as per the same methodology as the rehabilitation sites. The purpose of the analogue sites will be to act as a control site, and used for comparison of monitored parameters.

10.1.3 Monitoring frequency

Monitoring of all revegetated areas will be conducted on an annual basis for the first three to five years to determine initial establishment, then on a reduced frequency until completion criteria are achieved. Ideally, monitoring should be conducted at the same time each year following rains.

10.1.4 Reporting of results

Results will be graphed against historical monitoring results. Graphs and raw data will be included in Annual Environmental Reports to the DMP. An assessment of the results of the monitoring in relation to achieving the completion criteria will be discussed in Annual Environmental Reports for each revegetated area.

10.1.5 Remedial strategy

Targeted remediation of poor–performing rehabilitation areas may be necessary. Tellus will consult a botanist to determine the appropriate remedial strategy for rehabilitation should the results of the monitoring not be trending towards the completion criteria. Remedial strategies may include; amendments to the soil, more seed broadcasting, weed management and feral animal controls.

11 FINANCIAL PROVISIONING FOR CLOSURE

Financial provisioning information for closure of the Sandy Ridge Project is provided in Table 11–1. Closure cost estimates were calculated in an MS® Excel spreadsheet as part of Tellus' overall financial planning of the project, and the final estimates are provided in Table 11–1. The costings provided are based on the size of areas within each domain to be closed (as defined during the pre–feasibility phase of the project development) and 2016 rates. Rates account for; supply, labour, construction equipment and freight. The rate multiplied by the size of the area (quantity) provides a cost estimate. This cost estimate is then considered in terms of growth over the project life (i.e. growth of the quantity) to account for any change to the size of areas to be closed. The outcome is a total estimated direct cost for each domain and subtotal for elements within each domain. Tellus recognise the importance of updating the financial provisioning cost estimates with each revision of the MCP, to ensure closure is included in Tellus annual financial budgets.

Tellus will provide appropriate financial assurance for the expected closure costs of the Sandy Ridge project. Tellus intends on this financial assurance being via appropriate contributions to the WA Mining Rehabilitation Fund, consistent with the DMP's standard policy for mining projects in WA. Tellus will agree the final legal structure of the financial assurances to be put in place following detailed legal, tax and accounting advice and following consultation with relevant government agencies. Such financial assurance package will also be considered on a holistic basis with other financial assurances to be provided for the Project (ie for institutional control period).

12 MANAGEMENT OF INFORMATION AND DATA

All closure information and data, including previous versions of this MCP will be stored in Tellus' Environmental Management System (EMS) which is located on the Q drive of the Sydney server. The Tellus EMS is accredited to ISO 14001 standard and is regularly audited internally, and annually audited by an external party.

Each mine closure record, including monitoring reports and raw data will be saved electronically in the EMS with a unique reference number. Technical studies as outlined in Section 7 are saved electronically in the EMS.

Appropriate data management policies (including off site data back up and security) are in place.

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Drinking Water Quality Management Plan

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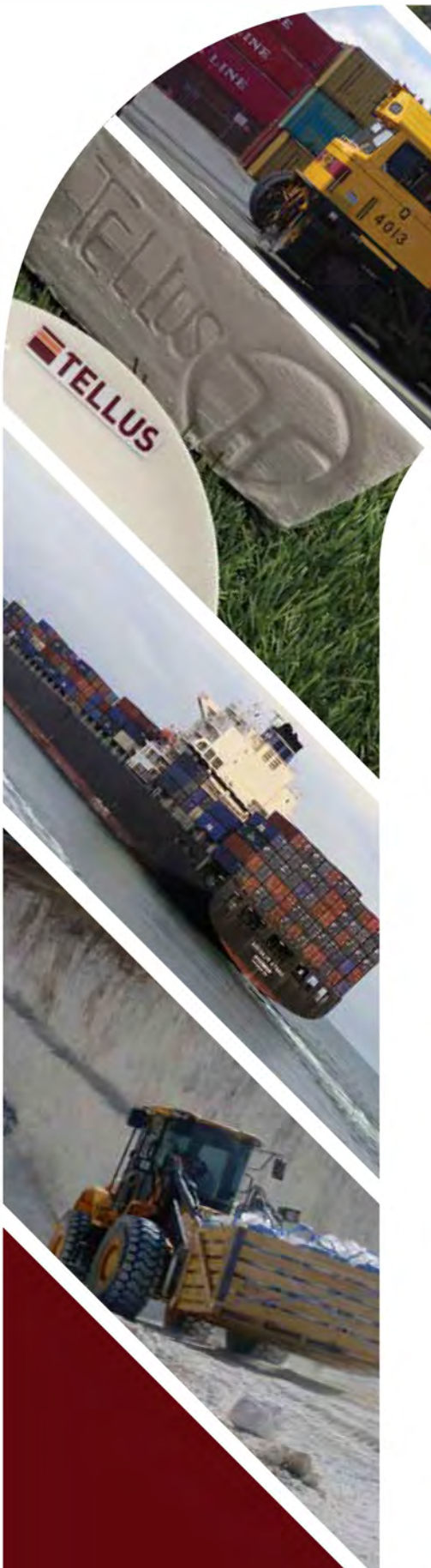

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Sandy Ridge Facility Draft Water Quality Management Plan

April 2016

SANDY RIDGE PROJECT DRINKING WATER QUALITY MANAGEMENT PLAN

Draft Report | April 2016

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DISTRIBUTION

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Drinking Water Quality Management Plan – V0.1	V0.1 (Draft)	Aurora Environmental	21 April 2016	Tellus Holdings Ltd.

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ABBREVIATIONS

DoH	Department of Health
kL	Kilolitre
km	Kilometre
mg/L	Milligrams per litre
RO	Reverse Osmosis

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1 GENERAL INFORMATION

1.1 Purpose and scope

The purpose of this Drinking Water Quality Management Plan (the Plan) is to specify the requirements for potable water management for the Sandy Ridge Project (the Site) operated by Tellus Holdings Pty Ltd (Tellus) and to ensure drinking water quality complies with relevant drinking water standards.

As Tellus will utilise self–managed water abstraction and collection systems for the reticulation, distribution and consumption of potable water for the Site, this Plan has been prepared to meet the requirements detailed in *Minesites and Exploration Camps Drinking Water Quality Monitoring Requirements* (Department of Health (DoH), 2009a) which specifies the following:

- Establish a Drinking Water Quality Management Plan in accordance with *Model Drinking Water Quality Management Plan* (DoH, 2009b).
- Establish a monitoring program as per *Small Community Sampling Grid.*
- Reporting in accordance with *Systems Compliance and Routine Reporting Requirements for Minesites and Exploration Camps* (DoH, 2011).

1.2 System layout

The Site is located approximately 75 kilometres (km) north–east of Koolyanobbing, in the Shire of Coolgardie, within the Goldfields Region of Western Australia (Figure 1).

The potable water system layout is shown on Figure 2, with the system schematic shown on Figure 3.

1.3 Duty of care holder

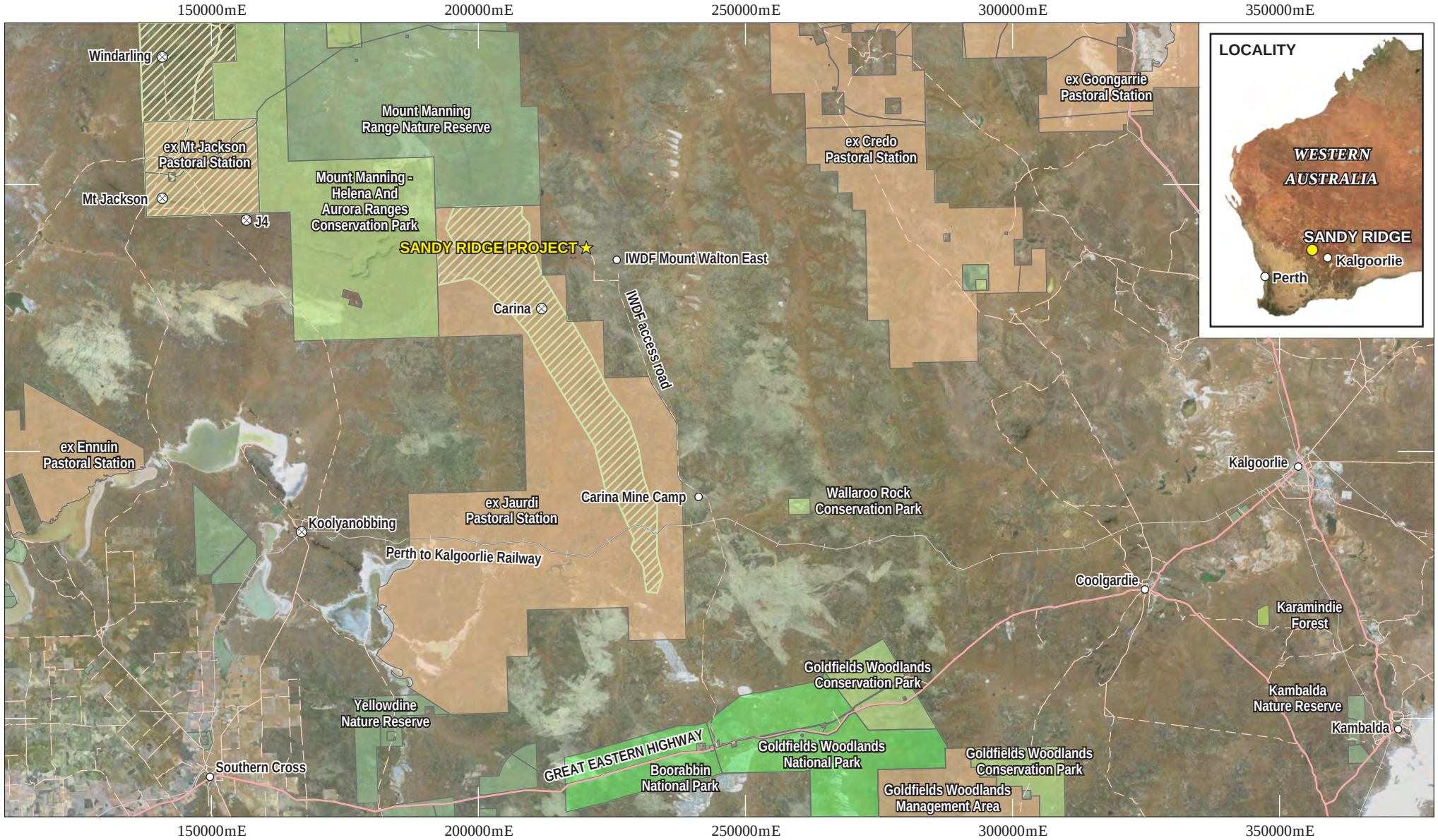
The duty of care holder for the Site is currently the Project Leader for the Sandy Ridge Project.

Mr Michael Ingram

Level 34, Exchange Tower

2 The Esplanade, Perth, WA 6000

E-mail: mike.ingram@tellusholdings.com



Legend:
- Iron Ore Mine
- Rail
- Major Road
- Minor Road

DPaW Managed Lands:
- Conservation Park
- Former Leasehold
- National Park
- Nature Reserve
- Proposed Conservation and Mining Reserve
- State Forest

Client: TELLUS

0 20km
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MGA94 (Zone 51)
CAD Ref: g2294_WMP_01_01.dgn
Date: Apr 2016 | Rev: A | A4

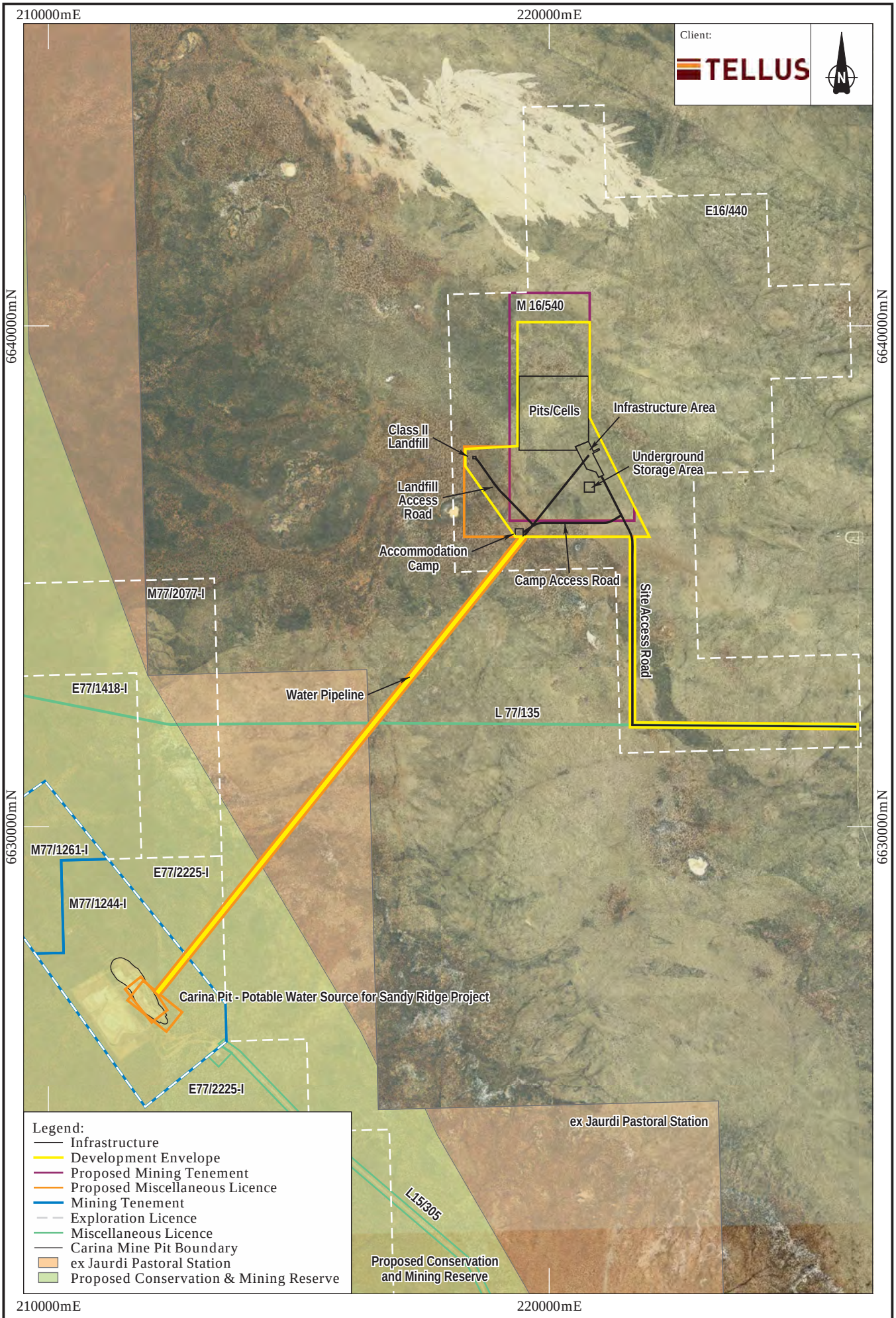
Aurora environmental
Author: D. Bourke | AE Ref: THO2014-003
Drawn: CAD Resources ~ www.cadresources.com.au
Tel: (08) 9246 3242 ~ Fax: (08) 9246 3202

Sandy Ridge Project

Regional Location

Drinking Water Quality Management Plan

Figure: **1**



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Date: April 2016 | Rev: A | A4

Aurora environmental

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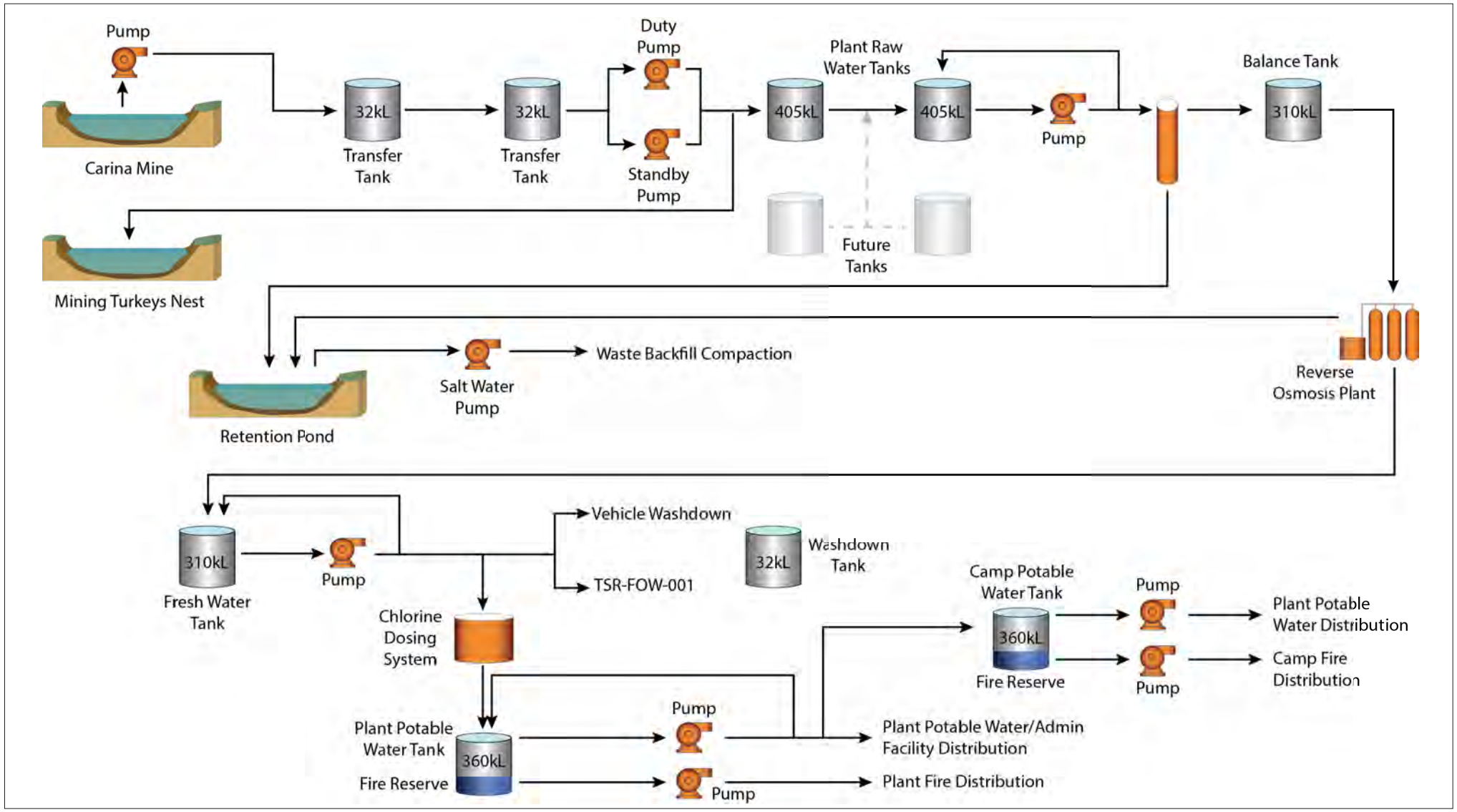
Sandy Ridge Project

Potable Water Source Location

Drinking Water Quality Management Plan

Figure: **2**



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Tel: (08) 9246 3242 ~ Fax: (08) 9246 3202

Sandy Ridge Project

Potable Water Schematic

Drinking Water Quality Management Plan

Figure: **3**

1.4 Water users

The potable water system will have the capacity to service all potable water requirements at the mine and accommodation camp, expected to be approximately 40 people. It is anticipated that 2,044 kL of potable water will be required per annum (based on 140 litres per person per day).

2 DRINKING WATER SUPPLY SYSTEM INFORMATION

2.1 Water harvesting / abstraction sources and methods

Water will be sourced from Mineral Resources' Carina Iron Ore Mine Pit, located 15 km to the south-west of the Site (Figure 2), which currently has excess water disposed of in evaporation ponds. By the time the Sandy Ridge Project commences, the mine pit will have been closed. Mineral Resources' mine closure plan includes partially backfilling the mine pit and then leaving it to flood as the groundwater recovers following dewatering activities. The mine pit will be accessed via a dedicated water pipeline. Analytical water quality data for the source water is included as Appendix A.1.

2.2 Storage system

The water storage system for the Sandy Ridge Project is summarised in Table 2–1. All tanks will be constructed of steel and will be sealed to prevent animal/insect intrusion. All tanks will be structurally sound and compliant with relevant Australian Standards.

Table 2–1 Water storage system

Tank Details	Tank Capacity (kL)	Location	Pre/Post Treatment	Turnover Time
Transfer Tank 1	32	Mine	Pre-treatment	X
Transfer Tank 2	32	Mine	Pre-treatment	X
Plant Raw Water Tank 1	405	Mine	Pre-treatment	X
Plant Raw Water Tank 2	405	Mine	Pre-treatment	X
Balance Tank	310	Mine	Pre-treatment	X
Fresh Water Tank	310	Mine	Post-treatment	x
Washdown Tank	32	Mine	Post-treatment	x
Plant Potable Water Tank (inc fire reserve)	360	Mine	Post-treatment	x
Camp Potable Water Tank (inc fire reserve)	360	Accommodation Camp	Post-treatment	x

2.3 Treatment system

Water for potable use will be treated by a Novatron SWE 200 kL/day RO system. Specifications of this system are provided in Table 2–2.

Table 2–2 Specifications of RO system

Specifications	
Output	200,000 Litres per 24 Hours
RO HP Pump	316 Stainless Steel, Positive Displacement
RO HP Pump Motor	45 kW With Soft Start
Pr.Relief Valve	1000 PSI
Frame Material	Epoxy Coated Steel
Pressure Vessels	2 x 80S100
Membranes	14 x 8040, Thin Film Composite Polyamide
Cartridge Filtration	5 & 1 Micron

The RO system will be serviced and cleaned quarterly by a Novatron service technician.

Water required for drinking (i.e. at the administration facility and the accommodation camp) will be treated with a chlorine dosing system. Dosing will take place on water pumped from the fresh water tank, prior to it entering the potable water tank (see Figure 3).

2.4 Reticulation network

Following treatment with RO, potable water is distributed via an above ground reticulation pipeline network which distributes water to the following storage tank locations (i.e. distribution points):

- Freshwater tank.
- Washdown tank.
- Plant potable water tank (via chlorine dosing).
- Camp potable water tank (via chlorine dosing).

Water from the plant potable water tank and camp potable water tanks are then distributed to the relevant consumption points.

2.5 Systems operation

The proposed operation of the potable water system for the Sandy Ridge Project commences with the transfer of up to 495 kL/day of raw water from Mineral Resources' Carina Iron Ore Mine Pit to two onsite 32 kL transfer tanks connected in series. Water from the transfer tanks is then pumped into either two 405 kL plant raw water tanks connected in series or to the mining turkeys nest for use as dust suppression. Water from the two raw water tanks is then pumped to a single 310 kL balance tank with any excess water being either diverted to a retention pond for use in waste backfill compaction or recirculated back into the plant raw water tanks.

Water then flows via gravity and is treated by Reverse Osmosis (RO) prior to entering a single 310 kL freshwater tank. Brine water removed as part of the RO treatment process is diverted to the retention pond. Some water from the freshwater tank is pumped to a single 32 kL washdown tank (used for vehicle washing etc.), while the remainder of the water is pumped via a chlorine dosing system to a single 360 kL plant potable water tank. Water from the plant potable water tank is then transferred by pump to the plant/administration facility for potable uses (i.e. drinking, washing etc.) or the 360 kL camp potable water tank. Any excess water is recirculated back into the plant potable

water tank. Some water from the plant potable water tank is also reserved for plant fire distribution. Water from the camp potable water tank is distributed to the camp for potable water uses (i.e. drinking, showering, washing etc.). A schematic of the potable water system is shown in Figure 3.

2.6 Operational monitoring and maintenance

Operational monitoring and maintenance systems will be in place to ensure the provision of safe potable water throughout the life of the mine, as outlined in Table 2–3.

Table 2–3 Monitoring and maintenance summary

Monitoring/Maintenance	Frequency	Responsibility
Visual inspection of source water pipeline, storage tanks and reticulation pipeline network	Weekly	Maintenance Department
RO system	Quarterly	Maintenance Department
Chlorine dosing system	Monthly	Maintenance Department
Water Quality	See Section 4	Environmental Department

2.7 System operators competency

All personnel operating the potable water supply system will have the appropriate qualifications and training to do so.

3 CATCHMENT

3.1 Map of catchment area

Potable water will be harvested from the Carina Iron Ore Mine Pit which is located in the upper portion of the regional Swan Avon Yilgarn catchment area (Figure 4).The Carina Iron Ore Mine Pit intersects a goethite–hematite orebody that constitutes the main aquifer. The ore is known to be highly vuggy and locally cavernous with a correspondingly high permeability. The adjoining mafic rocks appear to be relatively unfractured and excluding the contact zones between the Banded Iron Formation and country rock which are often permeable groundwater conduits, only minor aquifers exist outside of the major ore body aquifer. Water within this aquifer has a salinity of approximately 33,000 mg/L and a pH of approximately 7.5 – 8.0. As the annual recharge rate from rainfall is very small in the area, groundwater resources are considered in terms of groundwater in storage.

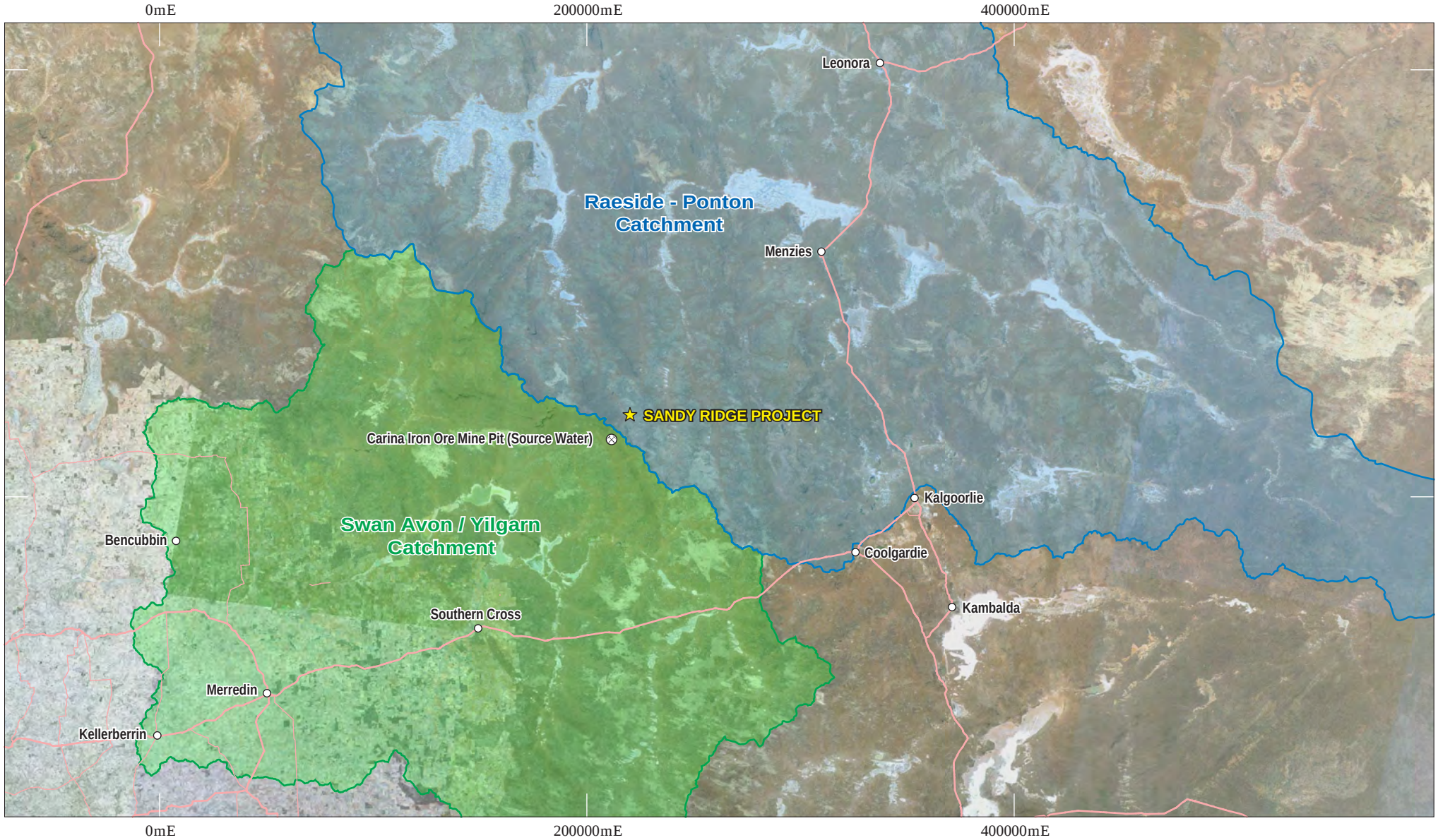
3.2 Risk assessment of catchment area

Given the location of the Carina Iron Ore Mine Pit (source water) in the upper portion of the Swan Avon Yilgarn catchment as well as the low rainfall, high evaporation rates, lack of major surface water flow paths and the significant depth to groundwater in the catchment area, risks of contamination to the aquifer (water source) are considered to be very low. The main risks will likely be associated with historic mining activities and facilities by Mineral Resources in the vicinity of the mine pit.

A risk assessment of the catchment area is summarised in Table 3–1.

Table 3–1 Catchment area risk assessment

Risks	Hazards	Management	Management Priority
Historic Effluent Ponds	Nutrients, micro-organisms (i.e. Thermotolerant coliforms *and E. Coli*)	Managed under Mineral Resources Mine Closure Plan	Low
Historic Evaporation Ponds	Metals Sulfides	Regular visual inspection of remaining infrastructure as required	Low
Historic Fuel Storage	Hydrocarbons		Low
Historic Chemical Storage	Nutrients Acids/Alkali		Low
Acid Mine Drainage	Acidification of groundwater Increased metals	Review of water quality data	Low



Legend:
- Site Location
- Carina Mine (Source Water)
- Raeside - Ponton Catchment
- Swan Avon / Yilgarn Catchment
- Major Road
- Minor Road

Client: TELLUS

0 50km
Scale 1:2,500,000
MGA94 (Zone 51)
CAD Ref: g2294_WMP_04_01.dgn
Date: Apr 2016 | Rev: A | A4

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Sandy Ridge Project

Regional Catchment Area

Drinking Water Quality Management Plan

Figure: 4

3.4 Catchment monitoring and maintenance

Due to the lack of catchment contamination pathways, formalised catchment monitoring is not considered necessary for this potable water source. Opportunistic sightings of potentially contaminating activities in the catchment area will be addressed and any contaminating activities that occur with potential to impact on the potable supply source will be managed accordingly.

4 MONITORING REQUIREMENTS

The water quality monitoring plan is outlined in Table 4–1 and has been prepared in accordance with the DoH's *Small Community Model Assessable Sampling Grid*. Disinfection will be through RO filtration and Chlorination.

Sample points are defined as follows:

- Source Water – Carine Iron Ore Mine Pit.
- Treated Water – A sample taken from the chlorination dosing system immediately after treatment.
- Distribution Point – Samples taken from the pump following the storage tanks at each storage tank location (i.e. potable water tank and camp potable water tank).
- Consumer Sample Point – A sample will be taken at all distribution areas (i.e. the kitchen, accommodation camp and administration/production facilities).

Table 4–1 Water quality monitoring plan

Category	Characteristic	Sampling Frequency			
		Source Water	Treated Water	Distribution Point	Consumer Sample Point
Micro-organisms	Thermo-tolerant coliforms (or *E. coli*)	Monthly	-		Monthly
	Amoeba (*Naegleria fowleri*)	-	-		Monthly
Physical Characteristics	Dissolved Oxygen	-	-	6 Monthly	
	Hardness	-	6 Monthly		
	pH	-		6 Monthly	
	Taste and odour	-			Annually
	Temperature	-			6 Monthly
	Total Dissolved Solids	-	6 Monthly		
	True Colour	-		6 Monthly	
	Turbidity	-		6 Monthly	
1. Inorganic Chemicals Disinfection Agents and Inorganic By-products of Disinfection	Chlorine (free)	-			Monthly
	Trihalomethanes	-			6 monthly
Organic Chemicals Disinfection By-products A	Chloroacetic Acid	-			6 monthly
	Dichloroacetic Acid	-			6 monthly
	Trichloroacetic Acid	-			6 monthly
	2-chlorophenol	-			6 monthly
	2,4-dichlorophenol	-			6 monthly
	2,4,6-trichlorophenol	-	-	-	6 monthly
	Trichloroacetaldehyde	-	-	-	6 monthly

Category	Characteristic	Sampling Frequency			
		Source Water	Treated Water	Distribution Point	Consumer Sample Point
	(chloral hydrate)				
2. Other Inorganic Chemicals	Aluminium (acid-soluble)	-	-	Annually	-
	Ammonia (as NH4)	-	-	Annually	-
	Antimony	-	-	-	Annually
	Arsenic	-	Annually	-	-
	Asbestos	-	-	2 Yearly	-
	Barium	Annually	-	-	-
	Beryllium	2 Yearly	-	-	-
	Boron	Annually	-	-	-
	Cadmium	-	-	-	Annually
	Chloride	-	Annually	-	-
	Chromium (as Cr(VI))	-	-	Annually	-
	Copper	-	-	-	Annually
	Cyanide	-	-	Annually	-
	Fluoride	Annually	-	-	-
	Hydrogen Sulfide		-	Annually	-
	Iodide	2 Yearly	-	-	-
	Iron	-	Annually	-	-
	Lead	-	-	-	Annually
	Manganese	-	Annually	-	-
	Mercury	Annually	-	-	-
	Molybdenum	Annually	-	-	-
	Nickel	-	-	-	Annually
	Nitrate	-	-	Annually	-
	Nitrite	-	-	Annually	-
	Selenium	Annually	-	-	-
	Silver	2 Yearly	-	-	-
	Sodium	-	Annually	-	-
	Sulfate	-	Annually	-	-
	Tin	2 Yearly	-	-	-
	Uranium	2 Yearly	-	-	-
	Zinc	-	-	-	Annually
Organic Compounds Treatment Organics (other than Disinfection By-products)	Acrylamide	-	Annually	-	-
	Carbon tetrachloride	-	Annually	-	-
Organic Compounds Industrial Hydrocarbons 1 (other than Disinfection By-products)	Benzene	2 Yearly	-	-	-
	Chlorobenzene	2 Yearly	-	-	-
	Dichlorobenzenes 1,2-dichlorobenzene (1,2-DCB)	2 Yearly	-	-	-
	Dichlorobenzenes 1,3-dichlorobenzene (1,3-DCB)	2 Yearly	-	-	-
	Dichlorobenzenes 1,4-dichlorobenzene (1,4-	2 Yearly	-	-	-

Category	Characteristic	Sampling Frequency			
		Source Water	Treated Water	Distribution Point	Consumer Sample Point
	DCB)				
	Dichloroethanes 1, 1-dichloroethane	2 Yearly	-	-	-
	Dichloroethanes 1, 2-dichloroethane	2 Yearly	-	-	-
	Dichloroethenes 1, 1-dichloroethene (1,1-DCE)	2 Yearly	-	-	-
	Dichloroethenes 1, 2-dichloroethene (1,2-DCE)	2 Yearly	-	-	-
	Dichloromethane (methylene chloride)	2 Yearly	-	-	-
	Epichlorohydrin	2 Yearly	-	-	-
	Ethylbenzene	2 Yearly	-	-	-
	Ethylenediamine tetraacetic acid (EDTA)	2 Yearly	-	-	-
	Hexachlorobutadiene	2 Yearly	-	-	-
	Nitrilotriacetic acid (NTA)	2 Yearly	-	-	-
	Styrene (vinylbenzene)	2 Yearly	-	-	-
	Trichlorobenzenes (total)	2 Yearly	-	-	-
	1,1,1-Trichloroethane	2 Yearly	-	-	-
	Vinyl chloride	2 Yearly	-	-	-
Organic Compounds Industrial Hydrocarbons 2 (other than Disinfection By-products)	Organotins dialkyltins	2 Yearly	-	-	-
	Organotins tributyltin oxide	2 Yearly	-	-	-
	Plasticisers di(2-ethylhexyl) phthalate (DEHP)	-	-	-	2 Yearly
	Plasticisers di(2-ethylhexyl) adipate (DEHA)	-	-	-	2 Yearly
	Polycyclic aromatic hydrocarbons (PAHs) Benzo-(a)-pyrene	-	-	-	2 Yearly
	Toluene	-	-	2 Yearly	-
	Xylene	-	-	2 Yearly	-
Organic Compounds (other than Disinfection By-products)	Tetrachloroethene	2 Yearly	-	-	-
	Trichloroethylene (TCE)	2 Yearly	-	-	-
Pesticides	Aldrin (and Dieldrin)	On startup	-	-	-
	Amitrole	On startup	-	-	-
	Atrazine	On startup	-	-	-
	Chlordane	On startup	-	-	-
	Chlorfenvinphos	On startup	-	-	-
	Clopyralid	On startup	-	-	-

Category	Characteristic	Sampling Frequency			
		Source Water	Treated Water	Distribution Point	Consumer Sample Point
	2,4-D	On startup	-	-	-
	DDT	On startup	-	-	-
	Dieldrin (and Aldrin)	On startup	-	-	-
	Diquat	On startup	-	-	-
	Diuron	On startup	-	-	-
	Endosulfan	On startup	-	-	-
	Fosamine	On startup	-	-	-
	Glyphosate	On startup	-	-	-
	Heptachlor	On startup	-	-	-
	Hexachlorobenzene	On startup	-	-	-
	Hexazinone	On startup	-	-	-
	Lindane	On startup	-	-	-
	Molinate	On startup	-	-	-
	Organophosphates	On startup	-	-	-
	Paraquat	On startup	-	-	-
	Pentachlorophenol	On startup	-	-	-
	Picloram	On startup	-	-	-
	Propiconazole	On startup	-	-	-
	Simazine	On startup	-	-	-
	Temephos	On startup	-	-	-
	Triclopyr	On startup	-	-	-
Radiological Characteristics	Gross Alpha	2 Yearly	-	-	-
	Gross Beta	2 Yearly	-	-	-

5 INCIDENCE RESPONSE PROCEDURE

A risk assessment for the potable water system is provided in Table 5–1.

Table 5–1 Potable water system risk assessment

Source of Risk (Hazard)	Possible Causes	Likelihood	Consequence	Risk	Response Action/Reporting Protocol	Preventative Measures
Failure of RO System	• Poor maintenance • Electrical faults • Pump failure	Unlikely	Moderate	Moderate	• Cease using potable water immediately. • Service immediately. • Ensure water quality is acceptable at the treated water, distribution points and consumption points. • Truck potable water to site if required. • Report to Environmental and Service Departments	Regular maintenance and monitoring of RO system
Failure of Chlorine Dosing System	Poor maintenance	Unlikely	Moderate	Moderate	• Cease using potable water immediately. • Service immediately • Manually treat water with chlorine	Regular maintenance

Source of Risk (Hazard)	Possible Causes	Likelihood	Consequence	Risk	Response Action/Reporting Protocol	Preventative Measures
					• Ensure water quality is acceptable at the treated water, distribution points and consumption points. • Truck potable water to site if required. • Report to Environmental and Service Departments.	
Hydrocarbon spill when refuelling pumps	• Over filling • Spillage • Fuel pump failure	Unlikely	Minor	Moderate	• Immediate clean-up of spill area • Ensure water quality is acceptable at distribution points and consumption points. • Report to Environmental Department	• Refuelling procedure in place • Competently trained operators • Spill kits available when refuelling • Refuelling on-site is within a separate catchment area and will not impact source water
Leakage of tanks and/or pipes	• Vehicle impacts with pipelines • Poor sealing of pipes and	Possible	Moderate	High	• Determine location of leak or break in the system.	Regular inspections of potable water infrastructure

Source of Risk (Hazard)	Possible Causes	Likelihood	Consequence	Risk	Response Action/Reporting Protocol	Preventative Measures
	fittings				• Repair immediately. • Determine available potable water remaining on-site. • Truck potable water to site if required. • Report to Service Department	

6 REPORTING REQUIREMENTS

All reporting (emergency and routine) will be conducted in accordance with *Systems Compliance and Routine Reporting Requirements for Minesites And Exploration Camps* (DoH, 2011). Appendix A.2 provides a model reporting format to be used for submission to the DoH.

7 REFERENCES

Department of Health, 2009a, *Minesites and Exploration Camps Drinking Water Quality Monitoring Requirements.*

Department of Health, 2009b, *Model Drinking Water Quality Management Plan.*

Department of Health, 2011, *Systems Compliance and Routine Reporting Requirements for Minesites and Exploration Camps*.

DoH see Department of Health.

APPENDICES

A.1 Analytical water quality data

ANALYTICAL REPORT

Accreditation No. 2562

CLIENT DETAILS

Contact	Steven Kinsey
Client	POLARIS_METALS
Address	1 Sleat Road Applecross WA 6153
Telephone	9329 3719
Facsimile	(Not specified)
Email	steven.kinsey@mineralresources.com.au
Project	**Carina Iron Ore Mine**
Order Number	**5498**
Samples	3
Date Started	26 Mar 2015

LABORATORY DETAILS

Manager	Ros Ma
Laboratory	SGS Perth Environmental
Address	28 Reid Rd Perth Airport WA 6105
Telephone	(08) 9373 3500
Facsimile	(08) 9373 3556
Email	au.environmental.perth@sgs.com
SGS Reference	**PE097555 R0**
Report Number	0000104701
Date Reported	01 Apr 2015
Date Received	25 Mar 2015

COMMENTS

Accredited for compliance with ISO/IEC 17025. NATA accredited laboratory 2562(898/20210).

Metals: LORs raised due to high conductivity.

SIGNATORIES

Hue Thanh Ly
Metals Team Leader

Mary Ann Ola-A
Inorganics Team Leader

Michael McKay
Inorganics and ARD Supervisor

Ohmar David
Metals Chemist

Ros Ma
Laboratory Manager

Parameter	Units	LOR	PE097555.001	PE097555.002	PE097555.003
Sample Number			PE097555.001	PE097555.002	PE097555.003
Sample Matrix			Water	Water	Water
Sample Date			24/3/15 15:15	24/3/15 15:40	24/3/15 16:10
Sample Name			WRD1	WRD2	WRD3
pH in water Method: AN101 Tested: 25/3/2015					
pH**	pH Units	-	7.2	7.5	7.4
Conductivity and TDS by Calculation - Water Method: AN106 Tested: 25/3/2015					
Conductivity @ 25 C	µS/cm	2	45000	52000	53000
Total Dissolved Solids (TDS) in water Method: AN113 Tested: 30/3/2015					
Total Dissolved Solids Dried at 175-185°C	mg/L	10	31000	36000	37000
Alkalinity Method: ME-AU-ENVAN135 Tested: 25/3/2015					
Total Alkalinity as CaCO3	mg/L	5	420	710	540
Carbonate Alkalinity as CO3	mg/L	1	<1	<1	<1
Bicarbonate Alkalinity as HCO3	mg/L	5	520	870	650
Acidity and Free CO2 Method: AN140 Tested: 25/3/2015					
Acidity to pH 8.3	mg CaCO3/L	5	85	100	89
Nitrate Nitrogen and Nitrite Nitrogen (NOx) by FIA Method: AN258 Tested: 30/3/2015					
Nitrate, NO_3 as NO_3	mg/L	0.2	0.5	<0.2	<0.2
Chloride by Discrete Analyser in Water Method: AN274 Tested: 27/3/2015					
Chloride, Cl	mg/L	1	16000	18000	19000
Sulphate in water Method: AN275 Tested: 27/3/2015					
Sulphate, SO4	mg/L	1	3100	3600	3700
Metals in Water (Dissolved) by ICPOES Method: AN320/AN321 Tested: 27/3/2015					
Aluminium, Al	mg/L	0.02	<0.10↑	<0.10↑	<0.10↑
Arsenic, As	mg/L	0.02	<0.10↑	<0.10↑	<0.10↑
Cadmium, Cd	mg/L	0.001	<0.005↑	<0.005↑	<0.005↑
Chromium, Cr	mg/L	0.005	<0.025↑	<0.025↑	<0.025↑
Copper, Cu	mg/L	0.005	<0.025↑	0.043	<0.025↑
Iron, Fe	mg/L	0.02	<0.10↑	<0.10↑	<0.10↑
Lead, Pb	mg/L	0.02	<0.10↑	<0.10↑	<0.10↑
Magnesium, Mg	mg/L	0.1	1400	1600	1600
Manganese, Mn	mg/L	0.005	0.11	0.43	0.33
Nickel, Ni	mg/L	0.005	0.063	0.073	0.11
Potassium, K	mg/L	0.1	150	180	160
Selenium, Se	mg/L	0.05	<0.25↑	<0.25↑	<0.25↑
Silver, Ag	mg/L	0.005	<0.025↑	<0.025↑	<0.025↑
Sodium, Na	mg/L	0.5	8700	10000	11000
Zinc, Zn	mg/L	0.01	0.07	<0.05↑	<0.05↑

Parameter	Units	LOR	Sample Number Sample Matrix Sample Date Sample Name	PE097555.001 Water 24/3/15 15:15 WRD1	PE097555.002 Water 24/3/15 15:40 WRD2	PE097555.003 Water 24/3/15 16:10 WRD3
Mercury (dissolved) in Water Method: AN311/AN312 Tested: 31/3/2015						
Mercury	mg/L	0.00005	<0.00005	<0.00005	<0.00005	

QC SUMMARY

MB blank results are compared to the Limit of Reporting
LCS and MS spike recoveries are measured as the percentage of analyte recovered from the sample compared the the amount of analyte spiked into the sample.
DUP and MSD relative percent differences are measured against their original counterpart samples according to the formula : *the absolute difference of the two results divided by the average of the two results as a percentage*. Where the DUP RPD is 'NA' , the results are less than the LOR and thus the RPD is not applicable.

Acidity and Free CO2 Method: ME-(AU)-[ENV]AN140

Parameter	QC Reference	Units	LOR	MB	DUP %RPD	LCS %Recovery
Acidity to pH 8.3	LB000477	mg CaCO3/L	5	<5	4%	NA

Alkalinity Method: ME-AU-ENVAN135

Parameter	QC Reference	Units	LOR	MB	DUP %RPD	LCS %Recovery
Total Alkalinity as CaCO3	LB000476	mg/L	5	<5	0 - 1%	100%
Carbonate Alkalinity as CO3	LB000476	mg/L	1	<1		
Bicarbonate Alkalinity as HCO3	LB000476	mg/L	5	<5		

Chloride by Discrete Analyser in Water Method: ME-(AU)-[ENV]AN274

Parameter	QC Reference	Units	LOR	MB	DUP %RPD	LCS %Recovery	MS %Recovery
Chloride, Cl	LB000512	mg/L	1	<1	1%	99%	79 - 94%

Conductivity and TDS by Calculation - Water Method: ME-(AU)-[ENV]AN106

Parameter	QC Reference	Units	LOR	MB	DUP %RPD	LCS %Recovery
Conductivity @ 25 C	LB000547	µS/cm	2	<2	0 - 2%	99%

Mercury (dissolved) in Water Method: ME-(AU)-[ENV]AN311/AN312

Parameter	QC Reference	Units	LOR	MB	DUP %RPD	LCS %Recovery	MS %Recovery
Mercury	LB000662	mg/L	0.00005	<0.00005	0%	97%	87%

Metals in Water (Dissolved) by ICPOES Method: ME-(AU)-[ENV]AN320/AN321

Parameter	QC Reference	Units	LOR	MB	DUP %RPD	LCS %Recovery	MS %Recovery
Aluminium, Al	LB000492	mg/L	0.02	<0.02		101%	
Arsenic, As	LB000492	mg/L	0.02	<0.020		107%	
Cadmium, Cd	LB000492	mg/L	0.001	<0.001		93%	
Chromium, Cr	LB000492	mg/L	0.005	<0.005		98%	
Copper, Cu	LB000492	mg/L	0.005	<0.005		103%	
Iron, Fe	LB000492	mg/L	0.02	<0.02		94%	
Lead, Pb	LB000492	mg/L	0.02	<0.02		99%	
Magnesium, Mg	LB000492	mg/L	0.1	<0.1	3%	96%	93%
Manganese, Mn	LB000492	mg/L	0.005	<0.005		101%	
Nickel, Ni	LB000492	mg/L	0.005	<0.005		100%	
Potassium, K	LB000492	mg/L	0.1	<0.1	2%	106%	103%
Selenium, Se	LB000492	mg/L	0.05	<0.05		100%	
Silver, Ag	LB000492	mg/L	0.005	<0.005			
Sodium, Na	LB000492	mg/L	0.5	<0.5	3%	97%	92%
Zinc, Zn	LB000492	mg/L	0.01	<0.01		96%	

QC SUMMARY

MB blank results are compared to the Limit of Reporting
LCS and MS spike recoveries are measured as the percentage of analyte recovered from the sample compared the the amount of analyte spiked into the sample.
DUP and MSD relative percent differences are measured against their original counterpart samples according to the formula : *the absolute difference of the two results divided by the average of the two results as a percentage.* Where the DUP RPD is 'NA' , the results are less than the LOR and thus the RPD is not applicable.

pH in water Method: ME-(AU)-[ENV]AN101

Parameter	QC Reference	Units	LOR	MB	DUP %RPD	LCS %Recovery
pH**	LB000547	pH Units	-	5.7 - 6.3	2%	100%

Sulphate in water Method: ME-(AU)-[ENV]AN275

Parameter	QC Reference	Units	LOR	MB	DUP %RPD	LCS %Recovery	MS %Recovery
Sulphate, SO4	LB000512	mg/L	1	<1	0 - 2%	101%	73 - 92%

Total Dissolved Solids (TDS) in water Method: ME-(AU)-[ENV]AN113

Parameter	QC Reference	Units	LOR	MB	DUP %RPD	LCS %Recovery	MS %Recovery	MSD %RPD
Total Dissolved Solids Dried at 175-185°C	LB000631	mg/L	10	<10	2 - 3%	94 - 99%	100%	0%

METHOD SUMMARY

METHOD	METHODOLOGY SUMMARY
	Nitrate and Nitrite by FIA: In an acidic medium, nitrate is reduced quantitatively to nitrite by cadmium metal. This nitrite plus any original nitrite is determined as an intense red-pink azo dye at 540 nm following diazotisation with sulphanilamide and subsequent coupling with N-(1-naphthyl) ethylenediamine dihydrochloride. Without the cadmium reduction only the original nitrite is determined. Reference APHA 4500-NO3- F.
AN101	pH in Soil Sludge Sediment and Water: pH is measured electrometrically using a combination electrode (glass plus reference electrode) and is calibrated against 3 buffers purchased commercially. For soils, an extract with water is made at a ratio of 1:5 and the pH determined and reported on the extract. Reference APHA 4500-H+.
AN106	Conductivity and TDS by Calculation: Conductivity is measured by meter with temperature compensation and is calibrated against a standard solution of potassium chloride. Conductivity is generally reported as µmhos/cm or µS/cm @ 25°C. For soils, an extract with water is made at a ratio of 1:5 and the EC determined and reported on the extract, or calculated back to the as-received sample. Total Dissolved Salts can be estimated from conductivity using a conversion factor, which for natural waters, is in the range 0.55 to 0.75. SGS use 0.6. Reference APHA 2520 B.
AN113	Total Dissolved Solids: A well-mixed filtered sample of known volume is evaporated to dryness at 180°C and the residue weighed. Approximate methods for correlating chemical analysis with dissolved solids are available. Reference APHA 2540 C.
AN135	Alkalinity (and forms of) by Titration: The sample is titrated with standard acid to pH 8.3 (P titre) and pH 4.5 (T titre) and permanent and/or total alkalinity calculated. The results are expressed as equivalents of calcium carbonate or recalculated as bicarbonate, carbonate and hydroxide. Reference APHA 2320. Internal Reference AN135
AN135	Free and Total Carbon Dioxide may be calculated using alkalinity forms only when the samples TDS is <500mg/L. If TDS is >500mg/L free or total carbon dioxide cannot be reported. APHA4500CO2 D.
AN140	Acidity by Tritration: The water sample is titrated with sodium hydroxide to designated pH end point. In a sample containing only carbon dioxide, bicarbonates and carbonates, titration to pH 8.3 at 25°C corresponds to stoichiometric neutralisation of carbonic acid to bicarbonate. Method reference APHA 2310 B.
AN274	Chloride by Aquakem DA: Chloride reacts with mercuric thiocyanate forming a mercuric chloride complex. In the presence of ferric iron, highly coloured ferric thiocyanate is formed which is proportional to the chloride concentration. Reference APHA 4500Cl-
AN275	Sulphate by Aquakem DA: Sulphate is precipitated in an acidic medium with barium chloride. The resulting turbidity is measured photometrically at 405nm and compared with standard calibration solutions to determine the sulphate concentration in the sample. Reference APHA 4500-SO42-. Internal reference AN275.
AN311/AN312	Mercury by Cold Vapour AAS in Waters: Mercury ions are reduced by stannous chloride reagent in acidic solution to elemental mercury. This mercury vapour is purged by nitrogen into a cold cell in an atomic absorption spectrometer or mercury analyser. Quantification is made by comparing absorbances to those of the calibration standards. Reference APHA 3112/3500.
AN320/AN321	Metals by ICP-OES: Samples are preserved with 10% nitric acid for a wide range of metals and some non-metals. This solution is measured by Inductively Coupled Plasma. Solutions are aspirated into an argon plasma at 8000-10000K and emit characteristic energy or light as a result of electron transitions through unique energy levels. The emitted light is focused onto a diffraction grating where it is separated into components .
AN320/AN321	Photomultipliers or CCDs are used to measure the light intensity at specific wavelengths. This intensity is directly proportional to concentration. Corrections are required to compensate for spectral overlap between elements. Reference APHA 3120 B.

FOOTNOTES

IS	Insufficient sample for analysis.	LOR	Limit of Reporting
LNR	Sample listed, but not received.	↑↓	Raised or Lowered Limit of Reporting
*	This analysis is not covered by the scope of accreditation.	QFH	QC result is above the upper tolerance
**	Indicative data, theoretical holding time exceeded.	QFL	QC result is below the lower tolerance
^	Performed by outside laboratory.	-	The sample was not analysed for this analyte
		NVL	Not Validated

Samples analysed as received.
Solid samples expressed on a dry weight basis.

Some totals may not appear to add up because the total is rounded after adding up the raw values.

The QC criteria are subject to internal review according to the SGS QAQC plan and may be provided on request or alternatively can be found here:
http://www.sgs.com.au/~/media/Local/Australia/Documents/ Technical%20Documents/MP-AU-ENV-QU-022%20QA%20QC%20Plan.pdf

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A.2 Systems Compliance and Routine Reporting Requirements for Minesites And Exploration Camps

System compliance and routine reporting requirements for minesites and exploration camps

This factsheet outlines the Department of Health's reporting requirements for minesites and exploration camp drinking water providers.

Emergency Reporting Protocol

Minesites and exploration camp drinking water providers are expected to notify the Department of Health in accordance with the following table:

Emergency Reporting Event	Report Due	Report To
■ Any thermotolerant coliform (or E.coli) result that exceeds 5 cfu/100ml. ■ Any thermophilic *Naegleria* tolerant to 42ºC including repeats. ■ Any pesticide result that exceeds the health value; ■ Any benzo[a]pyrene concentration greater than 50% of the WHO Guidelines Value but less than of equal to 100% of the WHO Guideline Value. ■ Any barrier breach such as a disinfection system failure or physical intrusion into or breach of the supply and distribution system. ■ Any change or event within the water catchment area that may have an imminent effect upon water quality. ■ Any other drinking water quality incident that the Water Provider considers could represent a public health risk.	Level 1 Immediate notification by fax, phone or electronic mail.	Water Unit 9388 4999 (if not available during working hours, to the Emergency Duty Officer 9328 0553)
■ Any thermotolerant coliform count greater than 0 cfu/100mL ■ Any health related chemical result that exceeds the health guideline value; ■ Any microbiological result that brings a locality into non-compliance with the rolling annual assessment criteria as set out in the agreed quality management system. ■ Any repeat sample showing the presence of thermotolerant coliforms. ■ Any pesticide result that is greater than or equal to 50% of the health value. ■ Any benzo[a]pyrene concentration greater than the ADWG Health Value but less than of equal to 50% of the WHO Guideline Value ■ Where the estimated annual radiation dose from radionuclide analysis of radium-226 and radium-228 exceeds 0.5 mSv ■ Any turbidity result that is greater than 5 NTU, where there is no filtration or clarification and no alternative source.	Level 2 To be reported within 24 hours by fax or electronic mail	Electronic mail to DWAlert@health.wa.gov.au Or Fax to: Water Unit 9388 4910

Routine Reporting Format

The 2004 Australian Drinking Water Guidelines provide the basis for the reporting protocol to the Department of Health. Model reporting formats (Appendix 1) should be read in conjunction with the summary of reporting requirements.

Summary of Reporting Requirements

Report No.	Report Title	Page Number	Quarterly	Annually
Administration				
1	Sample Cover Page	i	✓	✓
2	Water Provider Information	1	✓	✓
3	System Information	1	✗	✓
4	Performance Summary	2	✓	✓
Microbial Performance - (Rolling 12 Months Ending)				
5	Microbiological - Exception Notifications	3	✓	✗
6	Microbiological - Compliance By Region/Scheme/Zone/Service Provider (Summary)	4	✓(1)	✓(2)
7	Microbiological - Performance Community Specific	4	✓	✓
8	Microbiological - Charts By Region/Scheme/Zone/Service Provider	5	✓(1)	✓(2)
9	Microbiological Incident Specific Information	6	✓	✗
Chemical - Health Related Performance				
10	Chemical - Health Related - Exception Notifications	7	✓	✗
11	Chemical - Health Related	7	✓	✓ (3)
Chemical - Aesthetic Performance				
12	Chemical - Aesthetic - Charts	8	✓	✓
13	Chemical - Aesthetic - Incident Specific Information	8	✓	✗
Radiological Performance				
14	Radiological - Exception Notifications	9	✓	✗
15	Radiological Performance	9	✓	✓
Sampling				
16	Planned Sample Report	(5)	✗	✓(5)
17	Planned Sample Summary	10	✗	✓
18	Planned Sample Exceptions	10	✓	✓
19	General Notes/Other News	11	✓	✓(4)

Notes:

(1) Rolling twelve month.
(2) Calender Year.
(3) Compilation of quarterly.
(4) Overall trends and performance statements.
(5) Contact DoH for further details.

Sections may be subdivided as required. You may include any explanatory text, graphical or tabular representations in addition to those attached that you feel are required to assist the presentation of your report.

Routine Reporting Periods

Quarterly Reports to the Department of Health

Quarterly reports are based upon the quarterly planned sample program cycle. The reports are required within 4 weeks following the designated date for the quarterly planned samples.

Annual Reports to the Department of Health

Annual reports are based upon a calendar year. Annual reports should be provided to the Department of Health within 8 weeks following the designated date for the annually planned samples.

Reporting To

All reports should be sent to either:

Manager
Water Unit
Department of Health
PO Box 8172
PERTH BUSINESS CENTRE WA 6849

Or electronically to:

DWReports@health.wa.gov.au

More information

Water Unit
Environmental Health Directorate
Department of Health
PO Box 8172
PERTH BUSINESS CENTRE WA 6849

Telephone: (08) 9388 4999
Fax: (08) 9388 4910

Produced by Environmental Health Directorate
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Logo

Report to the Department of Health
by the
Insert Name of Water Authority
for the period
Day Month Year to *Day Month Year*

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1.0 Water Provider Information

Water Provider Contact Details			
Name of Company			
Company Address			
Company Phone		Fax	
Company Email			
Chief Executive Officer			
CEO Email			
DoH Liaison Officer			
DoH Liason Officer Email			

1.1 System Information (Annual Report Only)

Locality						
Zone Name	Number of Consumers	Average amount of Water Supplied (l/day)	Sources of Water (% Bore/ Surface catchment)	Treatment Systems	Length of Mains	Number of Sample points

Notes:

(1) Table may be expanded or collapsed according to the number of zones or subdivided to show regions, schemes or service providers

Catchment Details

Distribution System

2.0 Performance Summary

Water Quality Meeting the Drinking Water Guidelines/Minister of Health's Directions						
	Zone 1 (1)			Zone 2		
Microbiological Quality	No Assessed (2)	No Within Guidelines	Variance (3)	No Assessed	No Within Guidelines	Variance
Thermotolerant Coliforms / *E.coli*						
Amoeba (Thermophilic Naegleria)						
Chemical Quality(4)						
Chemical – Health related(5)						
Chemical – Aesthetic(6)						
Radiological						

Notes:

(1)Table may be expanded or collapsed according to the number of zones

(2) Number of samples taken for the quarter/year

(3) Number of samples that do not comply with the drinking water guidelines.

(4) Chemical performance is based on the results of the quarter.

(5) Chemicals tested with a health guideline value – Refer to Small Community Sampling Grid

(6) Chemicals without health guideline values

3.0 Microbial Performance - (Rolling 12 Months ending)

3.1 Microbiological - Exception Notifications

Microbiological Water Quality Exceptions							
Region/Scheme/Zone/ Service Provider	Population served	Date	Microbiological Characteristic	Alert Level	Remedial Action	DoH Notified	Close Out Date

Note:

Include all exceptions for the previous 12 months to the end of the reporting quarter.

3.2 Microbiological - Compliance by Zone (Summary).

Zone	No. of Bacteria samples	Thermotolerant Coliforms		Thermotolerant Coliforms 12 Mths Roll. Avg. (%)			No. of Amoeba Samples	Naegleria to >= 42C	Naegleria Fowleri	Thermophillic Naegleria 12 Mths Rolling Avg (%)		
		Non Comply	% Comply	Month -2	Month -1	Month				Month -2	Month -1	Month

Note:

Rolling 12 months average is calculated in the following manner:

$$\frac{\text{Number of assessable samples complying for the past 12 months}}{\text{Number of assessable samples taken in the past 12 months}} \times 100$$

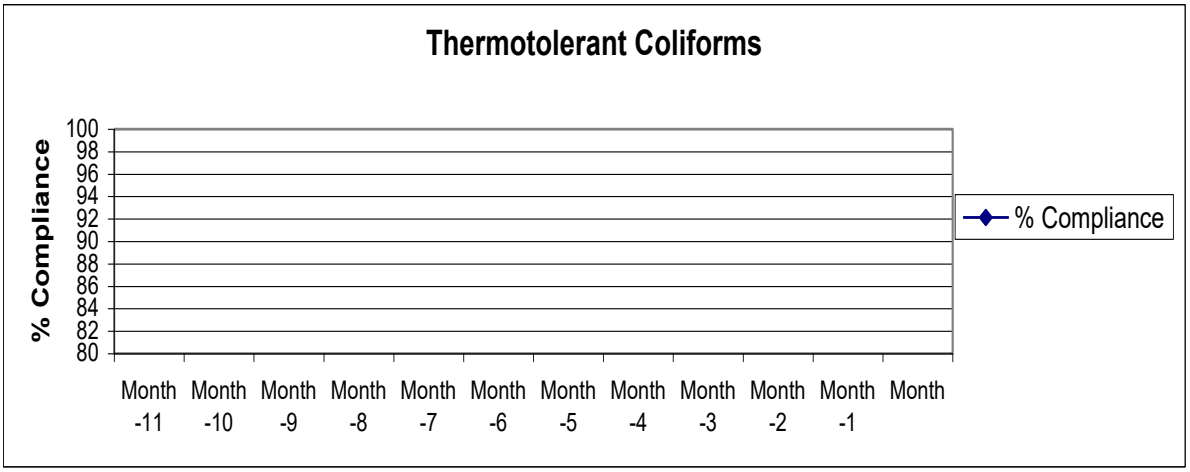
Example: 12 Months Rolling Average for the month of February 2011

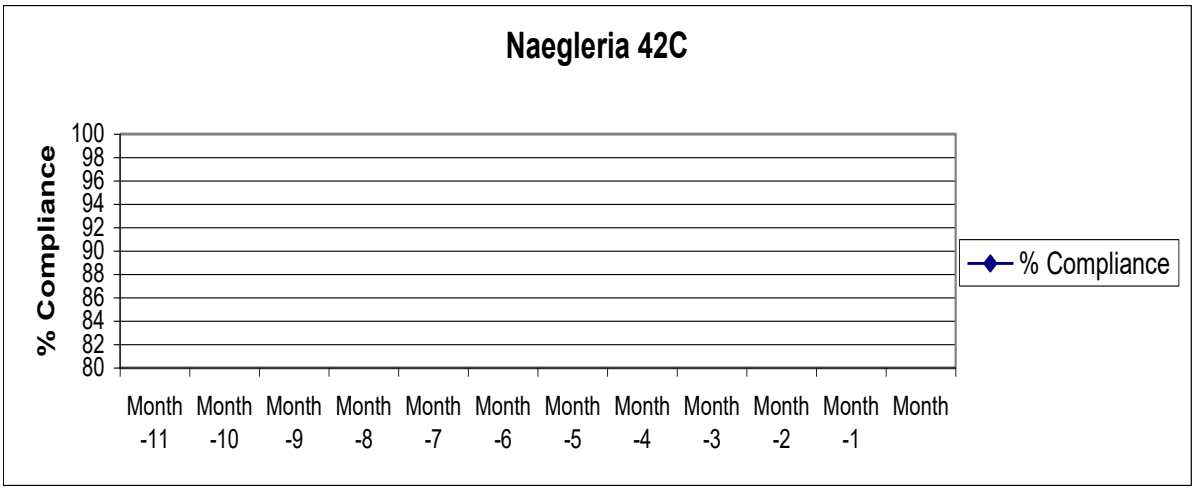
Number of assessable samples taken from 1 March 2010 to 28 February 2011 = **24**

Number of assessable samples complying from 1 March 2010 to 28 February 2011 = **20**

12 Months Rolling Average = **20 ÷ 24 x 100 = 83%**

3.3 Microbiological - Charts by Zone





Notes for all charts

(1) All results displayed are to be on a rolling twelve (12) month basis to the end of each respective month.

(2) Compliance target must be shown

3.5 Microbiological Incident Specific Information

3.5.1 Zone A

(Insert text)

3.5.2 Zone B

(Insert text)

4.0 Chemical - Health Related Performance

4.1 Chemical - Health Related - Exception Notifications

Health Related Chemical Water Quality Exceptions							
Region/Scheme/Zone/ Service Provider	Population served	Date	Health Related Chemical Characteristic	MoU Alert Level	Remedial Action	DoH Notified	Close Out Date

4.2 Chemical - Health Related

Text interpretation by Zone of results presented.

5.0 Chemical - Aesthetic Performance

Text interpretation by Zone of results presented on

5.1 Chemical - Aesthetic – Chart

Zone			
Aesthetic Characteristic	No of Analyses	No of Analyses Complying	% Compliance
Aluminium 0.2 mg/L			
Ammonia 0.5 mg/L			
Chloride 250/L			
Colour 15 HU			
Hardness 200 mg/L			
Iron 0.3 mg/L			
Manganese 0.1 mg/L			
pH <6.5			
pH >8.5			
Sodium 180 mg/L			
Sulphate 250 mg/L			
TDS 500 mg/L			
Turbidity 5 NTU			
Total samples taken			

Notes:

(1) Repeat table according to the number of zones.

(2) Record analyses for the reporting quarter.

5.2 Chemical - Aesthetic - Incident Specific Information

5.2.1 Zone A

(Insert text)

5.2.2 Zone B

(Insert text)

6.0 Radiological Performance

6.1 Radiological - Exception Notifications

Radiological Water Quality Exceptions							
Zone	Population served	Date	Radiological Characteristic	Alert Level	Remedial Action	DoH Notified	Close Out Date

6.2 Radiological Performance

Scheme/Service Provider	
Zone	% samples within range

7.0 Planned Sample Summary

Zone	Microbiological			Chemical			Radiological			Fluoride (if fluoridating)		
	Planned	Taken	% Taken	Planned	Taken	% Taken	Planned	Taken	% Taken	Planned	Taken	% Taken

7.1 Planned Sample Exceptions

Planned Sample Exceptions				
Zone	Sampling Point	Date Due	Characteristic (Microbiological/Chemical/Radiological)	Reason for missed sample

8.0 General Notes/Other News

This section can include reference to specific programs for maintenance, new additions to the scheme supply or report format or discussion on ongoing problems.

International Peer Review Terms of Reference

TELLUS

Review of the Design of the Sandy Ridge Disposal Facility

Reference: ENE-218A

Issue 1

for Tellus Holdings

Submitted by A Baker, Eden NE

Eden Nuclear and Environment

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1. INTRODUCTION

In this document, we report a review of proposed co-disposal of hazardous and radioactive wastes at a new near-surface disposal facility, the Sandy Ridge Facility. The review was undertaken on behalf of Tellus Holdings Ltd.

The proposal involves mining of kaolin clay for export and storage and disposal of hazardous, radioactive and intractable waste in mine voids. It is proposed that up to 100,000 tpa of waste will be disposed in the mine voids ('cells') over a 25 year period (i.e. disposal of 2,500,000 tonnes of waste in total).

Cells would be filled in layers with multiple sections in each layer. Each layer would be divided into sections containing wastes of similar characteristics. Each section will be backfilled, compacted and all air pockets/voids excluded. Each layer will be compacted, until approximately 7m below the ground surface, where a thick capping layer of low permeability clay will be installed to prevent water ingress into the cell. Following this, more backfilling and a clay domed cap would be situated on the top of the cell, to shed any rainfall. During the waste disposal process, a roof canopy is positioned over the cell to exclude rainfall prior to the thick capping layer being installed. After 10 years of monitoring a further un-compacted cap of yellow clayey sands is placed over the compacted clay dome to allow revegetation.

The hazardous wastes are toxic wastes from the mining, oil and gas and heavy industries, from agriculture and generated from man-made or natural disasters. The radioactive wastes are Very Short Lived Waste, Very Low Level Waste or Low Level Waste (LLW) [1].

Waste Acceptance Criteria (WAC) have been developed. It is intended that the WAC would ensure that no person is exposed above the appropriate dose limits. A zoning procedure has been developed to avoid adverse interactions between wastes of different types.

The radioactive wastes are generally the bye-product of medical research and industry, operation of research facilities (e.g. laboratory coats, overshoes, gloves), Naturally Occurring Radioactive Material (NORM), NORM occurring on pipework and scale from industry, oil spills containing NORM and orphan sources (i.e. gauges and instrumentation). Wastes that will not be disposed include: infectious materials, nuclear material, uncertified waste, putrescible waste and gases.

A multi-barrier system is used to provide long-term containment and isolation of the waste. After the placement of waste in the cell has been completed, the following protection measures will be implemented.

- An all-weather cover will be maintained over the cell until it is backfilled and capped to allow for protection from all weather conditions, preventing the possibility of creating leachates or contaminated surface water.
- Any airspace surrounding the placed waste will be backfilled with kaolin processing plant waste product (low value kaolin and quartz sand) to fill all void space and provide stability.
- The cell will then be backfilled with compacted clay, silcrete, laterite and yellow sand.
- The surface of the cell will be covered with a domed clay cap to exclude rainfall.

After a period of subsidence monitoring to confirm the stability and integrity of the clay capping, topsoil will be placed over the cap and the area re-vegetated with species of local

provenance. Local species would be selected based on their root system penetration (depth), ensuring that the capping design is not compromised.

The site will be managed for an extended period following closure before returning ownership to the State, a period termed institutional control. It is intended that the institutional control period (ICP) will ensure the wastes stored and disposed of in the repository are undisturbed for a period of time until they no longer pose a risk to human health and the local environment.

Details of the proposal are contained in reference [1].

The objective of this review is to undertake an independent peer review of the engineering design of waste cells to confirm best practice design has been met.

The required scope of the review includes:

- '*... consideration of the engineering design of waste cells to show best practice design for containment of wastes. This will draw on international best practice and expertise in encapsulating similar wastes around the world';*
- *' ... consideration of the waste material types intended for emplacement in the waste cells, to ensure long term encapsulation of wastes that reduces any risks to human health, the environment and environmental values to an acceptable level*.'

Any offsite activities are not within the scope of the review.

The review was based on the following Tellus documents and drawings:

- *Sandy Ridge Proposal, Draft Public Environmental Review for Adequacy*, 7th June 2016 (the 'PER' [1]).
- *Disposal of Radioactive Waste-Sealed Sources*, final, 1st July 2016.
- *Sandy Ridge Facility Waste Acceptance Criteria*, Draft V7, June 2016.
- *Sandy Ridge Facility Waste Acceptance Policy*, Draft V2, July 2016.
- *Sandy Ridge Facility Waste Acceptance Procedure*, Draft V2, July 2016.
- *Sandy Ridge Facility Waste Storage and Permanent Isolation Zoning Guide*, Draft V2, July 2016,
- *Sandy Ridge Pre-feasibility Study, Waste Isolation Shaft in a Cell, Backfill General Arrangement,* Drawing No C5409-6310-CE-004/B, September 2015.
- *Sandy Ridge Pre-feasibility Study, Waste Isolation Cell, Overall Layout Arrangement,* Drawing No C5409-6310-CE-005/A, August 2015.
- *Sandy Ridge Pre-feasibility Study, Waste Isolation Cell, 23m BGL Cell General Arrangement,* Drawing No C5409-6310-CE-006/A, September 2015.
- *Sandy Ridge Pre-feasibility Study, Waste Isolation Cell, 23m BGL Cell Sections and Details,* Drawing No C5409-6310-CE-007/A, September 2015.
- *Sandy Ridge Pre-feasibility Study, Waste Isolation Cell, 23m BGL Cell Co-Disposal Typical for NORM and Radioactive Materials,* Drawing No C5409-6310-CE-011/B, March 2016.
- *Sandy Ridge Waste Arrangement 160715,* Excel file.

- *The Assessment of Long-term Recharge to Encapsulated Waste Isolation Cells - Sandy Ridge Project,* (pdf file CyModHydrologyV3.R2-2), March 2016.
- *Radiation Risk Assessment-Post Closure-Sandy Ridge Facility,* Draft dated 15th May 2016.

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2. APPROACH

We have assessed the PER and other documents on the basis of the following.

- Our general knowledge of the design and underpinning approaches in other near-surface repositories for the disposal of LLW.
- The recommendations of the IAEA as covered by the Requirements set out in the IAEA document ' *IAEA Safety Standards, Disposal of Radioactive Waste, Specific Safety Requirements SSR-5, 2011'* [2]. We have presented the review against those requirements that we consider to be most relevant.
- We have reviewed Subsection A4 of the ARPANSA document '*Protecting People and the Environment from the Harmful Effects of Radiation, Licensing of Radioactive Waste Storage and Disposal Facilities', March 2013* [3]. As a result, we have identified one additional requirement relating to co-disposal.

The review has been undertaken and led by Andy Baker, an expert in the disposal of radioactive wastes. Until 2007, Andy managed the Environment Agency's Nuclear Waste Assessment Team[1], providing the technical lead on radioactive waste management and disposal issues within the UK's Environment Agency. Earlier in his career, Andy worked as a technical consultant on a wide range of radioactive waste management and disposal issues. He contributed to and managed a number of repository safety cases, including many key assessments (Nirex 95 and Nirex 97[2]) within the UK deep geological disposal programme and assessments of overseas repositories, including the Australian National Repository. He currently has a role as a consultant at the UK's Low Level Waste Repository[3] where he is responsible for the technical integration of the repository's Environmental Safety Case.

Andy was supported by Sandy Anderson, a senior manager with extensive experience of peer review. Sandy is a mechanical engineer having wide experience of structural mechanics and the preparation and review of Nuclear Safety Cases. He has a wide understanding of radioactive waste management. Over the past few years, he has become more involved with major projects and plan facilities. This included dealing with siting and facility design, planning applications and environmental permitting, site investigations, foundation design and justification, and plant commissioning from a regulatory perspective.

It is important to note that our review is at a strategic level so we have not evaluated every calculation and report in detail.

---

1 The Environment Agency is responsible for regulating the disposal of radioactive waste in England (and previously in England and Wales).

2 Nirex was the UK body set up to examine safe, environmental and economic aspects of deep geological disposal of intermediate and low level radioactive waste. The role previously filled by Nirex is currently undertaken by the UK Radioactive Waste Management Ltd. (RWM).

3 The UK national repository for the disposal of low level waste.

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3. REVIEW

As noted above, the review has been performed against a set of IAEA criteria, which are addressed in turn below.

3.1 General Comments

On the basis of knowledge of other disposal facilities for the disposal of LLW worldwide, we consider that the design of the Sandy Ridge Facility is excellent. It is a multi-barrier system comprising the following components.

- Metal and concrete filled containers for spent sealed sources.
- The use of impermeable fill within the cells to separate wastes of different characteristics or wastes disposed at different times.
- The construction of a thick clay cap that will encourage runoff and prevent infiltration.
- The presence of an extensive and thick natural clay liner.
- A generally dry environment where evaporation considerably exceeds precipitation.

The Sandy Ridge Facility is centrally located within a large expanse of State land in South-Western Australia. The local environment is arid with low annual rain flow, geologically stable with low seismic activity and remote from large centres of population. Based on our judgment, the design is likely to perform well during the longer term and it appears from the assessments performed that radiation doses will be very low during operations.

A comprehensive technical programme has been undertaken to underpin the disposal approach and demonstrate that the Tellus proposal for a combined purpose mining and waste facility is well founded, safe and geologically stable well into the future. This includes suitable site characterisation and consideration of safety issues; including an upper estimate of radiological dose uptake to workers on-site and members of the public both during normal operation and during the transport of waste materials to the site by road. A transport risk assessment of accidents occurring during transit has been provided to establish that these risks are tolerable (although assessment of off-site transport is outside the scope of this review).

At the current stage of development, some documents lack detail and insufficient argument and evidence is provided to underpin the safety arguments and hence the suitability of the design. However as part of the safety case process, it is the intention to carry-out hazard identification studies (HazOp, Hazan or SWIFT) and an Engineering Schedule developed that will contain the performance requirements for any required engineered key safety systems.

An indication of the timescale over which the facility will operate is provided, together with an estimate of the total volume of waste. We understand that 2.2% of this waste is planned to be radioactive waste. The quantity of radioactive waste is important context, which it would be helpful to make more prominent.

It is noted also that the proposal is generally favourable from an environmental perspective in that it involves the reuse of an opening created by mining activities.

We have presented the remainder of this section against certain specific requirements set out by the IAEA in SSR-5 [2].

3.2 Optimisation and the Role of Safety in Design

IAEA SSR-5 Requirement 4: Importance of safety in the process of development and operation of a disposal facility

Throughout the process of development and operation of a disposal facility for radioactive waste, an understanding of the relevance and the implications for safety of the available options for the facility shall be developed by the operator. This is for the purpose of providing an optimized level of safety in the operational stage and after closure.

It is clear that the design of the disposal facility has been developed with safety issues in mind.

The multiple barrier approach compares very well with current practice and regulatory requirements for repositories (and indeed power reactors and other nuclear facilities) across the World. This approach ensures Defence-in-Depth against challenge from both known natural hazards and, more importantly, from unrevealed faults.

The proposed design incorporates best practice in respect of characterizing and segregating the wastes. The design concept is a development of a nearby mixed waste facility at Mount Walton, where non-radioactive waste packages were entombed in a clay void created by mining, and this latter facility has operated without incident for over 20 years. The proposed design improvement added to cater for radioactive waste is to build isolated shafts within the cells as the layers of non-radioactive waste are completed and backfill levelled. Once the cell has been filled with non-radioactive waste, the shafts are then loaded with waste packages. In a separate store for higher activity wastes, the material will be transferred into double skinned steel waste containers (a 60 litre container within a 200 litre container) and the internal void filled with an annulus of concrete shielding. Higher activity waste packages would be disposed at the bottom of each shaft, with lower activity packages stored at higher levels. This in itself represents good practice as all three major factors affecting the control of radiation dose are addressed, i.e. time, distance and shielding.

Details of the position of all non-radioactive and radioactive wastes within each cell will be in accordance with and recorded in a Waste Management Plan for each cell. The Waste Management Plan will be developed once the exact nature of the received wastes is known. However, the wastes will conform to the Waste Acceptance Criteria (WAC) developed by Tellus.

It is clear that alternative options have been considered in developing the design and that some options assessments have been carried out.

It is noted that the full benefits of optimisation have yet been realised by the design concept. For example, it is not clear that different options for waste treatment, handling and emplacement have yet been considered, noting that such consideration might offer the potential of reducing double handling and consequent worker doses. We recognise that consideration could occur during the detailed design phase.

Although there is not a clear link in the documentation between the design and the safety case, which would be considered best practice, it is not considered necessary at this stage. However, the detailed safety case covering Reference Design and seeking regulatory permission to proceed with construction will need to demonstrate compliance with over-arching design safety principles in addition to meeting specific safety functional requirements identified through hazard identification studies. Evidence of design alternatives, optimisation and elements of Human Factors involvement, regular maintenance and the maintenance of any safety important/ safety related systems (including radiation monitoring systems) to

continue to perform their required safety function over the 25-year operational period before the site is locked down into a safe, passive state will be required. Using such an approach, the end result will be a safety informed design of the Sandy Ridge facility and the minimum requirement for regulatory oversight.

The proposal assumes that optimisation requirements can be addressed by working to criteria that are half of the appropriate regulatory criteria. This is not consistent with the spirit of optimisation, which requires that reduction in impacts be considered until the point at which such reductions are disproportionate in terms of cost or some other aspect of the system[4].

3.3 Passive Safety

IAEA SSR-5 Requirement 5: Passive means for the safety of the disposal facility

The operator shall evaluate the site and shall design, construct, operate and close the disposal facility in such a way that safety is ensured by passive means to the fullest extent possible and the need for actions to be taken after closure of the facility is minimized.

An acceptable approach is pursued during the operational period. Our view is that subject to further development of the safety case (which would be required for licensing), the design is capable of providing passive safety after the end of management control.

3.4 Understanding and Confidence

IAEA SSR-5 Requirement 6: Understanding of a disposal facility and confidence in safety

The operator of a disposal facility shall develop an adequate understanding of the features of the facility and its host environment and of the factors that influence its safety after closure over suitably long time periods, so that a sufficient level of confidence in safety can be achieved.

We consider that a sensible programme of work has been undertaken to understand the site covering surface characteristics, landform evolution, hydrology, hydrogeology and other aspects. We think this is a suitable basis for developing a safety case and a facility design.

We are not sure that consideration of all aspects of climate change (impacts on rainfall and infiltration, changed potential for flooding, changes to the characteristics of the surface environment and influences on the rate of erosive processes) have been fully documented. As documented below, with respect to human intrusion, we think that further work is needed to justify appropriate cases and calculations to determine appropriate limitations on the sources that could be disposed to the facility.

3.5 Multiple Safety Functions

IAEA SSR-5 Requirement 7: Multiple safety functions

The host environment shall be selected, the engineered barriers of the disposal facility shall

[4] In the UK the requirement is to reduce impacts until the costs (including time and effort) of doing so are “grossly disproportionate”. Part of the intent is to ensure that relatively minor adjustments are not precluded on an overly simplistic cost-benefit model. However, recognising that decreasing benefit will accrue at very low doses, a “threshold of optimisation” is also adopted below which it is necessary only to demonstrate that Best Available Techniques have been applied.

be designed and the facility shall be operated to ensure that safety is provided by means of multiple safety functions.

Containment and isolation of the waste shall be provided by means of a number of physical barriers of the disposal system. The performance of these physical barriers shall be achieved by means of diverse physical and chemical processes together with various operational controls. The capability of the individual barriers and controls together with that of the overall disposal system to perform as assumed in the safety case shall be demonstrated. The overall performance of the disposal system shall not be unduly dependent on a single safety function.

As noted in subsection 3.1, the facility is an excellent multi-barrier system.

3.6 Containment

IAEA SSR-5 Requirement 8: Containment of radioactive waste

The engineered barriers, including the waste form and packaging, shall be designed, and the host environment shall be selected, so as to provide containment of the radionuclides associated with the waste.

Containment shall be provided until radioactive decay has significantly reduced the hazard posed by the waste. In addition, in the case of heat generating waste, containment shall be provided while the waste is still producing heat energy in amounts that could adversely affect the performance of the disposal system.

The design conforms very well with the requirement to provide containment (see subsection 3.1).

3.7 Isolation

IAEA SSR-5 Requirement 9: Isolation of radioactive waste

The disposal facility shall be sited, designed and operated to provide features that are aimed at isolation of the radioactive waste from people and from the accessible biosphere. The features shall aim to provide isolation for several hundreds of years for short lived waste and at least several thousand years for intermediate and high level waste. In so doing, consideration shall be given to both the natural evolution of the disposal system and events causing disturbance of the facility.

The design provides good isolation from the perspective of natural events.

Institutional control will ensure that no intrusion occurs for the period of that control. After that point, intrusion is possible, but unlikely given the location and environment of the facility.

Wastes are emplaced at a depth of at least 7m, which means that only a restricted set of human intrusion scenarios would require consideration.

3.8 Step by Step Evaluation

IAEA SSR-5 Requirement 11: Step by step development and evaluation of disposal facilities

Disposal facilities for radioactive waste shall be developed, operated and closed in a series of steps. Each of these steps shall be supported, as necessary, by iterative evaluations of the site, of the options for design, construction, operation and management, and of the performance and safety of the disposal system.

The proposal describes appropriate periods and their duration over the lifetime of the facility e.g. closure, operations and institutional control.

We are aware that further work will be done in certain areas e.g. in terms of the licensing process. However, there is no evidence of a clear plan for reviewing the design, safety and underpinning documents in a staged manner. Such staged reviews should be proportionate to the hazard and would be considered part of good practice. As a result of such reviews updates to design or operating procedures might be agreed, for example. Such a staged process may be part of or could be incorporated in the forward work plan.

3.9 Safety Case and Safety Assessment

IAEA SSR-5 Requirement 12: Preparation, approval and use of the safety case and safety assessment for a disposal facility

A safety case and supporting safety assessment shall be prepared and updated by the operator, as necessary, at each step in the development of a disposal facility, in operation and after closure. The safety case and supporting safety assessment shall be submitted to the regulatory body for approval. The safety case and supporting safety assessment shall be sufficiently detailed and comprehensive to provide the necessary technical input for informing the regulatory body and for informing the decisions necessary at each step.

A safety case is appended to the PER. It is not yet sufficiently well developed to confirm that both operational and long-term impacts are acceptable and hence whether the design will perform appropriately. We understand that the safety case will be further developed for licensing purposes. However, at this stage, the safety statements and the PER overall gives confidence that the facility location, transport route, and radiation exposure to workers, the public, wildlife and plants are well within acceptable limits (excepting the comments on human intrusion that are set out below). The use of self-healing clay as the main structural barrier also installs confidence that the release of contamination (toxic and radioactive) would be minimal and well within acceptable limits.

In the PER, information is presented to indicate that erosion of the facility is not of concern. Other information is presented to indicate that any releases as a result of any dissolution of radionuclides in pore water and subsequent transport would be very low owing to the excellent multi-barrier system. Some further quantification of these arguments would be desirable s the case is developed.

Human intrusion is likely to be a critical pathway in determining limits on the spent sources that should be disposed in the facility (operational safety will also require consideration in this respect). International guidance indicates that such human intrusion after the loss of knowledge about the site should be considered on the basis of dose criteria. The value adopted in the proposal for the dose criterion is 10 mSv yr^{-1}, which seems appropriate.

The approach followed to define activity limits for disposed sources is to use generic concentration limits that were derived by the National Health and Medical Research Council (NHMRC) and published in 1992 [4]. When setting limits on the size of individual sources, the activity has been diluted over the material within the container containing the source. We are concerned that this approach is not consistent with best practice in a number of respects.

- The original calculations were undertaken in 1992 and there have been many developments since that time both pertaining to best practice in assessing the impacts

of human intrusion and in recommended dose coefficients and other parameters used in such assessments.

- There may be specific aspects of the design of the Sandy Ridge Facility that may differ from the generic design assumed in the code of practice, e.g. the waste at Sandy Ridge may be at greater depth and different cases may be appropriate for evaluation. Both good practice and references [4,5] indicate that a site- and design-specific evaluation of the human intrusion pathway should be presented.
- The approach involves averaging the source activities over the waste package to derive an average specific activity. It is not clear that this is appropriate since there are potential cases that involve direct exposure to the source, e.g. following geotechnical borehole investigations and retrieval of and exposure to a source (such cases are routinely considered in many safety assessments internationally). For handling, skin doses might require consideration.
- The proposition, potential doses and safety arguments for a suitable set of cases are not clearly set out in the proposal and are not easily available for scrutiny as part of the site safety case.

We note that disposal of sources at a depth of at least 7m would rule out many sorts of human intrusion and human intrusion may be very unlikely at the site.

We have also received a draft Radiation Risk Assessment [6]. Estimates of radiation dose are provided in the report, but further limits on source activities are not set out. We have not evaluated the calculations in detail. However, we note the following.

- The chosen dose limits seem to be too low.
- Some of the calculations are very cautious in terms of residence times and some of the doses are unexpectedly high for the waste under consideration.
- The choice of scenarios is not justified and seems inappropriate (e.g. archaeological excavation or borehole drilling should at least be considered since these are conventional in many human intrusion assessments).
- The requirement is for a suitable test to determine the upper activity limits for sources that can be disposed in the waste facility - the chosen case (digging an excavation next to the shaft containing waste, coupled with long-term occupancy of that excavation) seems difficult to justify and rather unconventional.

The WAC for sources [8] appear currently to be based on a generic calculation, which is not best practice. However, we understand that work is progressing in this area.

It is not clear that a radiological assessment has been performed of a fire in the waste. The documentation indicates that some flammable wastes will be accepted for treatment and hence would be stored somewhere on the site for a period.

It is very good that an assessment of radiological impacts to non-human biota has been performed using the ERICA assessment tool. However, a very cautious approach has been used to infer action, based on doses to an individual in close proximity to the waste. The intent of the ERICA approach is not to protect such an individual, but to protect the wider population. Hence decisions should be reached based on radiological impacts to a representative member of a population in the general area of the site. Corresponding doses are likely to be very low.

3.10 Site Characterisation

IAEA SSR-5 Requirement 15: Site characterization for a disposal facility

The site for a disposal facility shall be characterized at a level of detail sufficient to support a general understanding of both the characteristics of the site and how the site will evolve over time. This shall include its present condition, its probable natural evolution and possible natural events, and also human plans and actions in the vicinity that may affect the safety of the facility over the period of interest. It shall also include a specific understanding of the impact on safety of features, events and processes associated with the site and the facility.

We believe that the approach to site characterisation is excellent and suitable to support the design and safety case.

We are not sure that all aspects of climate change have been considered. They appear to have been considered in terms of near-surface hydrology [7], but arguments do not appear to be presented in relation to other aspects.

3.11 Design

IAEA SSR-5 Requirement 16: Design of a disposal facility

The disposal facility and its engineered barriers shall be designed to contain the waste with its associated hazard, to be physically and chemically compatible with the host geological formation and/or surface environment, and to provide safety features after closure that complement those features afforded by the host environment. The facility and its engineered barriers shall be designed to provide safety during the operational period.

The design is based on the design of another facility that has been operating successfully. It generally seems appropriate and consistent with good practice. As noted elsewhere, for licensing purposes, it would be desirable to demonstrate performance of the design quantitatively.

3.12 Waste Acceptance

IAEA SSR-5 Requirement 20: Waste acceptance in a disposal facility

Waste packages and unpackaged waste accepted for emplacement in a disposal facility shall conform to criteria that are fully consistent with, and are derived from, the safety case for the disposal facility in operation and after closure.

WAC are documented both for hazardous and radioactive wastes and a broadly suitable process has been set out for waste acceptance [8,9]. This is necessary as it must be ensured that only wastes that are compatible with the design are disposed.

The general requirements on the sorts of materials that would be disposed seem appropriate. We note the need to consider the acceptability of wastes that might potentially generate gas, which we understand is addressed by Gate 11 of the WAC [8]. We note that voidage is considered in the WAC, although it might be appropriate to have some quantitative limit, given the potential impact on the stability of the cap.

We have commented above about the use of generic waste acceptance criteria with respect to human intrusion and commented that good practice would be to develop WAC that are specific to the site and design and consistent with the safety case. In reference [8] site specific criteria are quoted for NORM wastes based on calculations with the RESRAD program. It is stated that these calculations addressed post-closure and human intrusion

scenarios. However, the question arises as to whether any WAC are required to mitigate any impacts during the period of operations. It may be that this is not required, but setting out the arguments would be best practice. The use of a 'sum of fractions' approach is appropriate.

3.13 Management Systems

IAEA SSR-5 Requirement 25: Management systems

Management systems to provide for the assurance of quality shall be applied to all safety related activities, systems and components throughout all the steps of the development and operation of a disposal facility. The level of assurance for each element shall be commensurate with its importance to safety.

From reviewing the PER and contents of the appendices provided, it is evident that Tellus Holdings operate a responsible Safety Culture across all levels of operation and management.

3.14 Co-Disposal

ARPANSA Guidance for Near-surface Disposal facilities Subsection A4.2

Proposals for co-disposal of radioactive waste with other hazardous wastes (chemical or biological) in the one facility should be assessed for the potential long-term effects of co-location of such wastes.

The review team was explicitly asked to consider the issue of co-disposal of hazardous and radioactive wastes. Co-disposal of different sorts of waste is an issue that has received attention in many repository programmes. The following issues might arise.

- Complexants generated from the hazardous waste might enhance transport of radionuclides.
- During operations, workers might be exposed to radiological hazards and might incur doses that might be avoided.
- Gas production from the hazardous wastes might degrade barriers intended to contain the radioactive wastes.
- Heat generated from the radioactive wastes might have an impact on the containment of the hazardous wastes.
- Design requirements for radioactive and hazardous wastes might differ and different design solutions might be required.
- After closure, cross contamination might occur and this might complicate any retrieval options if retrieval were to be required.

We do not believe that any of the above represent an issue, apart from possibly the potential for gas production. Taking each issue in turn:

The disposal system should do an excellent job of preventing significant environmental impacts as a result of releases in groundwater. Hence complexants would not be a significant issue.

Radioactive wastes will either be emplaced in a layer that will be covered by kaolinised granite backfill or in separate shafts and hence workers are likely to be substantially protected from exposure to radiation while undertaking non-radwaste operations in the cells.

Gas production could cause damage to the barriers if significant gas producing wastes were disposed. However, the disposal of reactive wastes is prohibited and water content of the wastes is likely to be low. As noted above, we understand that gas producing wastes would be excluded by Gate 11 of the WAC [8], although it might be better to make this more explicit

LLW does not produce significant heat.

The design appears to be appropriate for radioactive and hazardous wastes.

Use of kaolinite and other barriers within the cells and low water contents should mitigate against cross contamination.

Hence we consider that co-disposal is a suitable solution.

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4. FINAL REMARKS

Our overall findings based on the stated scope and review of the listed documents is as follows.

We consider that the design of the disposal facility is excellent and that the proposed multi-barrier system offers very good prospects of excellent long-term performance that would be comparable or in excess of that for many other LLW disposal facilities in other countries. This is facilitated by the favourable hydrological and hydrogeological environment.

However, we are concerned that the radionuclide specific activity limits for the sources that are suitable for disposal in the facility have not yet been set out adequately with consideration of design- and site-specific issues. We are aware that this is an area that Tellus are considering further.

A detailed safety case (or Pre-Commencement Safety Case, PCSR) will need to be developed for in-cell activities. Of initial concern for non-radioactive wastes would be whether a diesel fire resulting from insufficient dump truck maintenance could result in a tyre fire and what affect this would have on the toxic waste containers. Also, vehicle impacts in general would need consideration.

On the radiological side, the key concerns would be the design of the waste store and mechanical handling accidents involving the placing of ILW within the storage shafts, i.e. dropped/snagged load events, dynamic loads in general and the structural integrity of a single load path.

We would expect the detailed safety case to provide both detailed argument and supporting engineering calculations to demonstrate that the design would perform appropriately.

Similarly, we think that the waste management plan is not yet sufficiently developed to provide assurance that all aspects of waste storage, handling and emplacement will be appropriately managed.

The facility involves the co-disposal of both radioactive and hazardous wastes. Although arguments have not been identified in the documents that we have reviewed, we do not believe this represents a problem.

We note that the proposal involves reuse of mining void and is therefore environmentally beneficial. There are strong advantages also in managing and disposing of radioactive waste in one location rather than leaving it distributed at a range of different sites where there may be varying degrees of control and monitoring.

Overall, we consider that the proposal is sound from a technical viewpoint and that it is appropriate to proceed, notwithstanding our reservations in certain areas, which could be addressed by the programme as it moves forward.

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5. REFERENCES

1 Tellus, *Sandy Ridge Proposal, Draft Public Environmental Review for Adequacy*, 7th June 2016.

2 IAEA, *IAEA Safety Standards, Disposal of Radioactive Waste, Specific Safety Requirements,* IAEA Safety Standard Series SSR-5, 2011.

3 Australia Radiation Protection and Nuclear Safety Agency, *Protecting People and the Environment from the Harmful Effects of Radiation, Licensing of Radioactive Waste Storage and Disposal Facilities,* March 2013.

4 National Health and Medical Research Council, *Code of Practice for the Near-surface Disposal of Radioactive Waste in Australia, 1992.*

5 Australia Radiation Protection and Nuclear Safety Agency, *Classification and Disposal of Radioactive Waste in Australia - Consideration of Criteria for Near Surface Burial in an Arid Area,* Technical report 152, 2010.

6 Hygiea Consulting, *Radiation Risk Assessment-Post Closure-Sandy Ridge Facility,* Draft report for Tellus Holdings Ltd, dated 15th May 2016.

7 *The Assessment of Long-term Recharge to Encapsulated Waste Isolation Cells - Sandy Ridge Project,* (pdf file CyModHydrologyV3.R2-2), March 2016.

8 Tellus, *Sandy Ridge Facility Waste Acceptance Criteria*, Draft V7, June 2016.

9 Tellus, *Sandy Ridge Facility Waste Acceptance Procedure*, Draft V2, July 2016.

Appendix A. Units and Prefixes

SI units of radiation and radioactivity

Quantity	SI unit and abbreviation
Absorbed dose	Gray (Gy)
Effective Dose	Sievert (Sv)
Radioactivity	Becquerel (Bq)

Multiples and sub-multiples of SI units

Factor	Prefix and abbreviation	Factor	Prefix and abbreviation
10^{18}	exa (E)	10^{-3}	milli (m)
10^{15}	peta (P)	10^{-6}	micro (µ)
10^{12}	tera (T)	10^{-9}	nano (n)
10^{9}	giga (G)	10^{-12}	pico (p)
10^{6}	mega (M)	10^{-15}	femto (f)
10^{3}	kilo (k)	10^{-18}	atto (a)

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Eden Conference Barn
Low Moor, Penrith, Cumbria
CA10 1XQ

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Certificate Number 12609
ISO 9001

Company No 6314579, registered in England and Wales

Emergency Response Flow Chart

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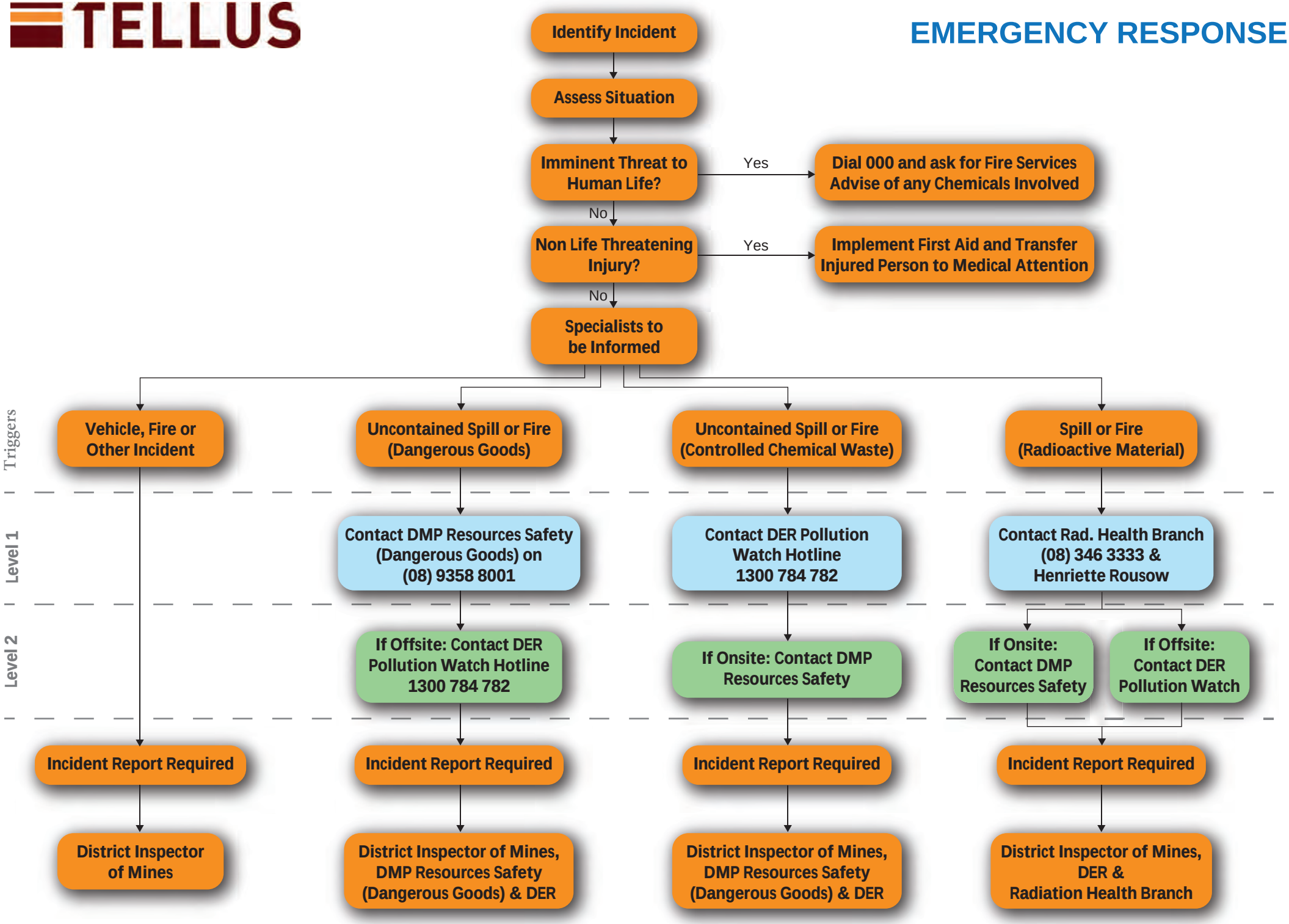
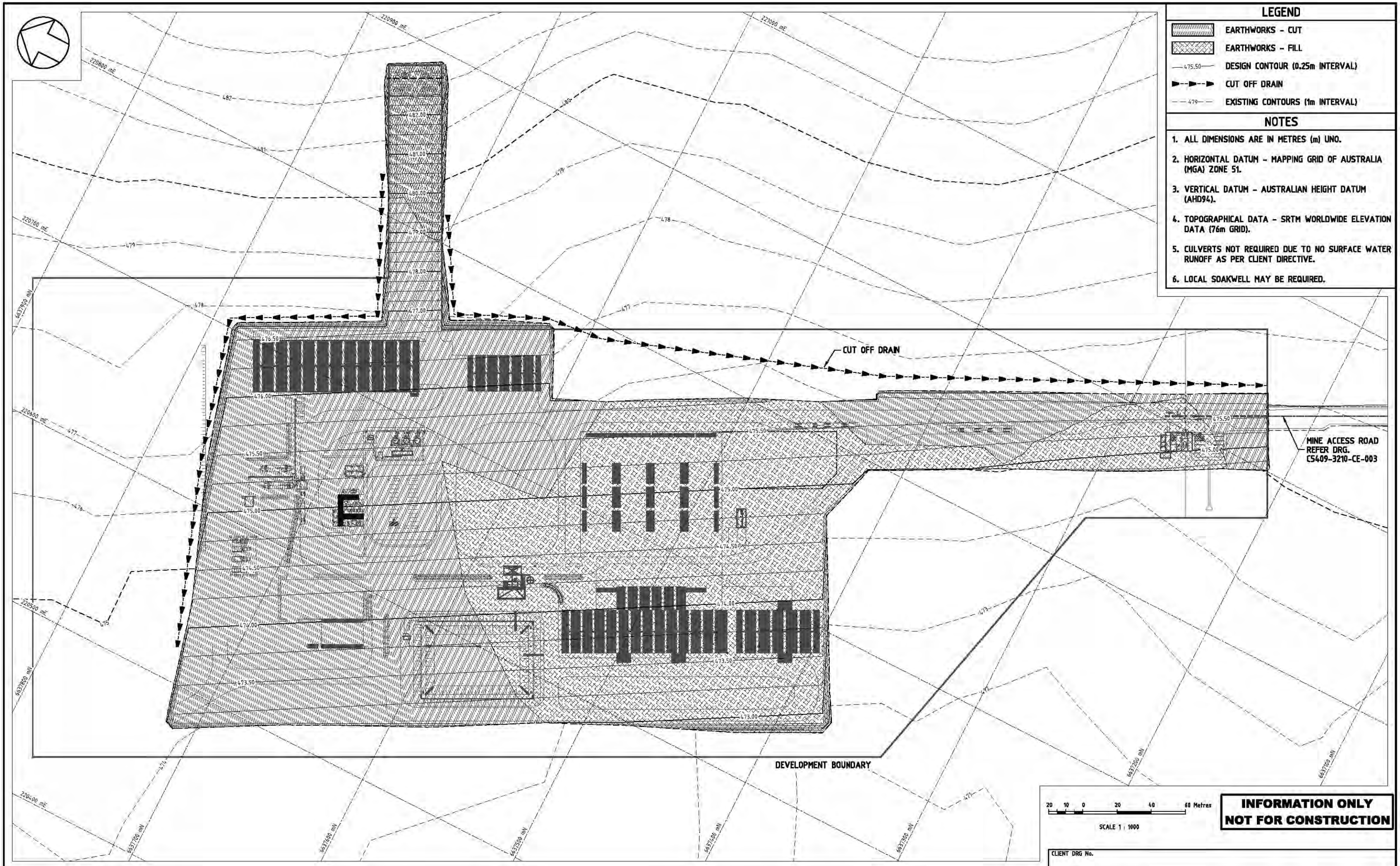
EMERGENCY RESPONSE



Engineering Designs of Waste Cells

TELLUS



LEGEND

- EARTHWORKS - CUT
- EARTHWORKS - FILL
- 475.50 DESIGN CONTOUR (0.25m INTERVAL)
- CUT OFF DRAIN
- 479 EXISTING CONTOURS (1m INTERVAL)

NOTES

1. ALL DIMENSIONS ARE IN METRES (m) UNO.
2. HORIZONTAL DATUM - MAPPING GRID OF AUSTRALIA (MGA) ZONE 51.
3. VERTICAL DATUM - AUSTRALIAN HEIGHT DATUM (AHD94).
4. TOPOGRAPHICAL DATA - SRTM WORLDWIDE ELEVATION DATA (76m GRID).
5. CULVERTS NOT REQUIRED DUE TO NO SURFACE WATER RUNOFF AS PER CLIENT DIRECTIVE.
6. LOCAL SOAKWELL MAY BE REQUIRED.

INFORMATION ONLY
NOT FOR CONSTRUCTION

CLIENT DRG No.

REF DRG No	TITLE	REV	BY	DATE	DESCRIPTION	CHKD	ENG
C5409-3210-CE-003	MINE ACCESS ROAD - GA SHEET 1	B	MB	27.08.15	ISSUED FOR PFS	JL	IB
C5409-0000-GE-001	KEY PLAN	A	JA	27.07.15	ISSUED FOR INTERNAL AND CLIENT REVIEW	DT	

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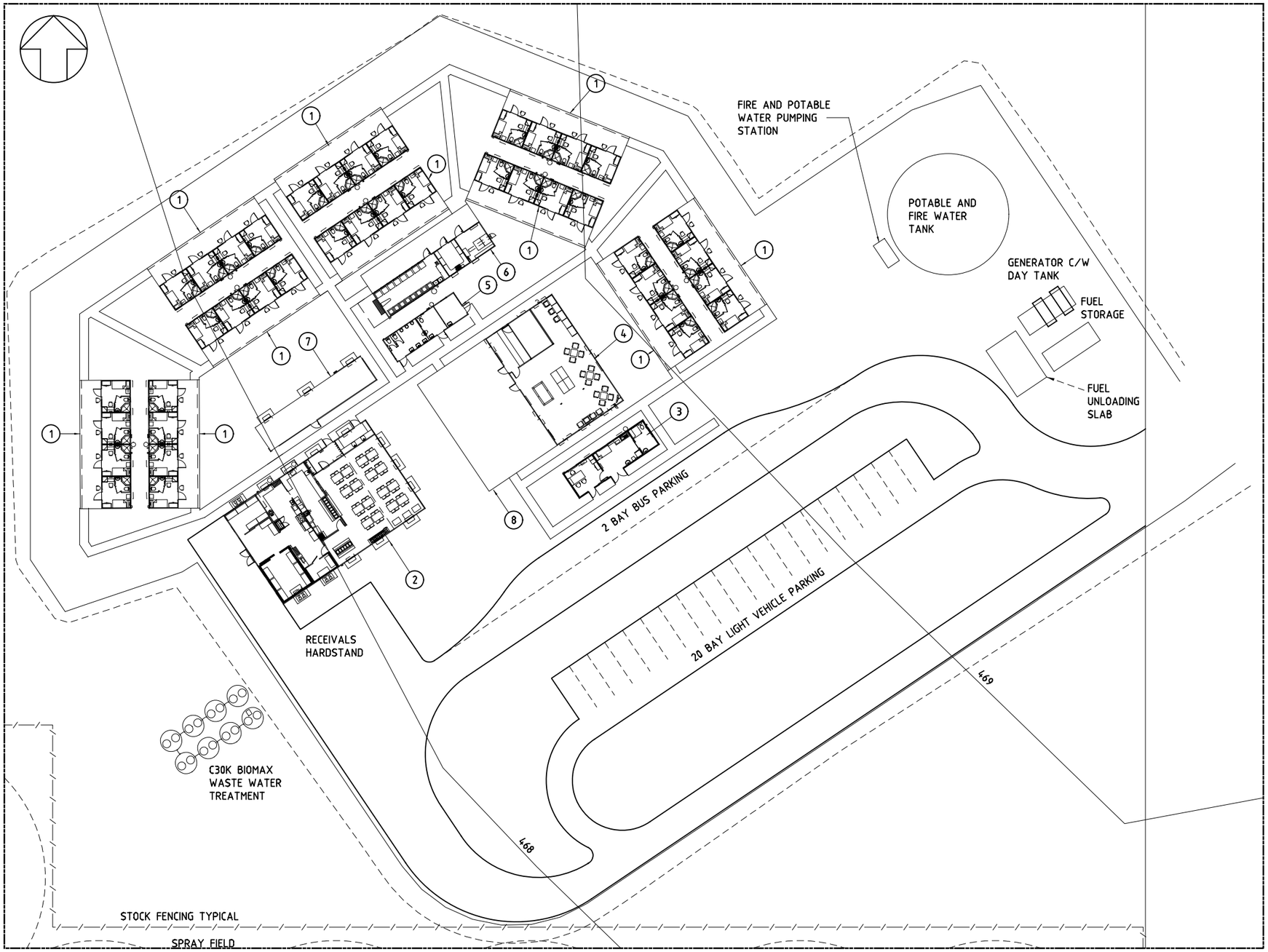
SGS

	BY	DATE
DRAWN	J.ANDERSON	23.07.15
CHKD		
DES ENG		
PROJ ENG		
CLIENT		

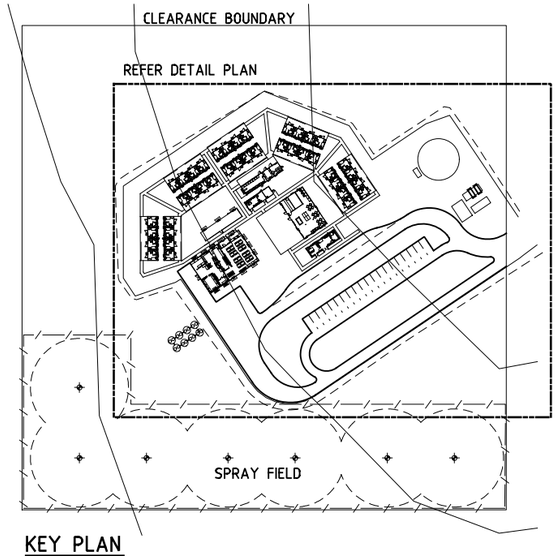
TITLE
TELLUS SANDY RIDGE
PRE-FEASIBILITY STUDY
INFRASTRUCTURE AREA BULK EARTHWORKS LAYOUT
GENERAL ARRANGEMENT

PROJECT No	SIZE	SCALE	DRG No	REV
C5409	A1	1:1000	C5409-3000-CE-001	B



DETAIL PLAN
SCALE 1:250

ITEM	DESCRIPTION
1	4 PERSON ACCOMMODATION UNIT C/W ENSUITE
2	KITCHEN DRY MESS
3	OFFICE AND FIRST AID
4	RECREATION AND WET MESS
5	TOILET BLOCK
6	LAUNDRY AND COMMUNICATIONS UNIT
7	GYMNASIUM
8	OUTDOOR UNDERCOVER AREA



KEY PLAN
SCALE 1:1000

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5 0 5 10 15 Metres
SCALE 1 : 250

REF DRG No	TITLE	REV	BY	DATE	DESCRIPTION	CHKD	ENG
		C	MB	27.08.15	ISSUED FOR PFS	MB	IB
		B	MF	07.08.15	REVISED FOR LARGER WWTP	JL	JL
C5409-0000-GE-001	KEY PLAN	A	MF	12.06.15	ISSUED FOR INTERNAL AND CLIENT REVIEW	JL	

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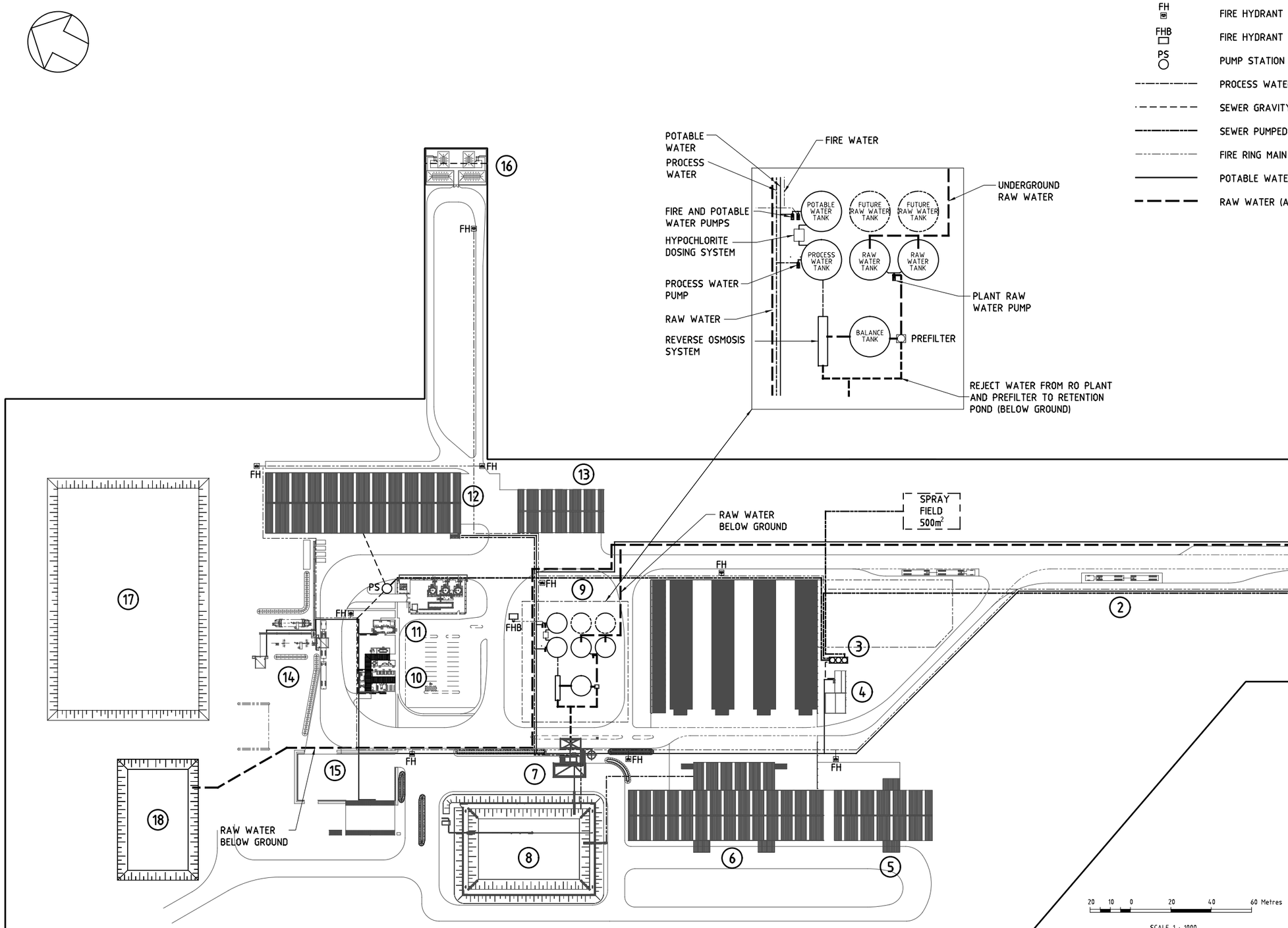
	BY	DATE
DRAWN	M.FISTONICH	16.06.15
CHKD		
DES ENG		
PROJ ENG		
CLIENT		

PROJECT No: C5409

CLIENT DRG No.

TITLE
TELLUS SANDY RIDGE
PRE-FEASIBILITY STUDY
ACCOMMODATION VILLAGE
GENERAL ARRANGEMENT

A1	SCALE 1:250	DRG No C5409-3000-GE-003	REV C



LEGEND

FH	FIRE HYDRANT
FHB	FIRE HYDRANT BOOSTER
PS	PUMP STATION
	PROCESS WATER (UNDERGOUND)
	SEWER GRAVITY (UNDERGOUND)
	SEWER PUMPED RISING MAIN
	FIRE RING MAIN (UNDERGOUND)
	POTABLE WATER (UNDERGOUND UNO)
	RAW WATER (ABOVE GROUND UNO)

ITEM	DESCRIPTION
1	OFFICE & AMENITIES
2	WEIGHBRIDGE
3	BIOMAX MODEL C30
4	WASTE LABORATORY
5	RADIOACTIVE WASTE STORAGE
6	KAOLIN PRODUCT STORAGE
7	WASHDOWN SLAB
8	RETENTION POND
9	RAW/POTABALE WATER TANKS
10	CONTRACTORS OFFICES
11	KAOLIN LABORATORY
12	KAOLIN PROCESS PLANT
13	KAOLIN PRODUCT STORAGE
14	DIESEL FUEL TANK & PIPING RETICULATION
15	CONTRACTORS WORKSHOP & YARD
16	EXPLOSIVE ORDINANCE BUILDING
17	KAOLIN ORE STOCKPILE
18	MINE TURKEY'S NEST - RAW WATER POND

INFORMATION ONLY
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REF DRG No	TITLE
C5409-0000-GE-002	OVERALL SITE LAYOUT

REV	BY	DATE	DESCRIPTION	CHKD	ENG
B	MB	27.08.15	ISSUED FOR PFS	JL	IB
A	MF	30.07.15	ISSUED FOR INTERNAL AND CLIENT REVIEW	JL	

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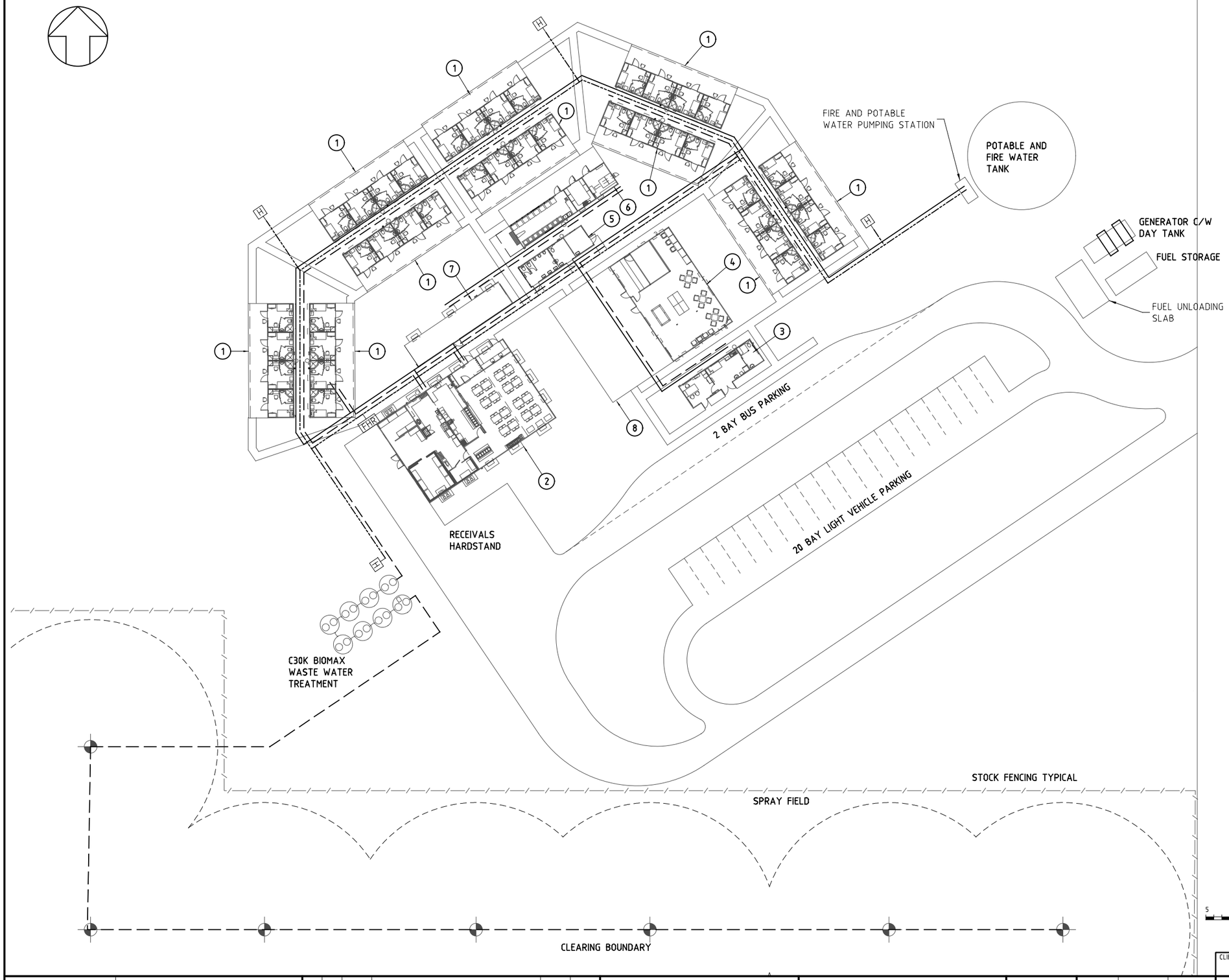
DRAWN	C.COETZEE	17/07/15
CHKD		
DES ENG		
PROJ ENG		
CLIENT		

CLIENT DRG No.

TITLE
TELLUS SANDY RIDGE
PRE-FEASIBILITY STUDY
SITE SERVICES
GENERAL ARRANGEMENT

PROJECT No		SCALE	DRG No	REV
C5409	A1	1:1000	C5409-3000-ME-001	B



ITEM	DESCRIPTION
1	4 PERSON ACCOMMODATION UNIT
2	KITCHEN DRY MESS
3	OFFICE AND FIRST AID
4	RECREATION AND WET MESS
5	TOILET BLOCK
6	LAUNDRY AND COMMUNICATIONS UNIT
7	GYMNASIUM
8	OUTDOOR UNDERCOVER AREA

LEGEND

- POTABLE WATER
- FIRE WATER
- SEWER
- HYDRANT
- FIRE HOSE REEL

5 0 5 10 15 Metres

SCALE 1 : 250

INFORMATION ONLY
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CLIENT DRG No.

REF DRG No	TITLE	REV	BY	DATE	DESCRIPTION	CHKD	ENG
		B	MB	27.08.15	ISSUED FOR PFS	JL	IB
C5409-0000-GE-001	KEY PLAN	A	MF	12.06.15	ISSUED FOR INTERNAL AND CLIENT REVIEW	JL	

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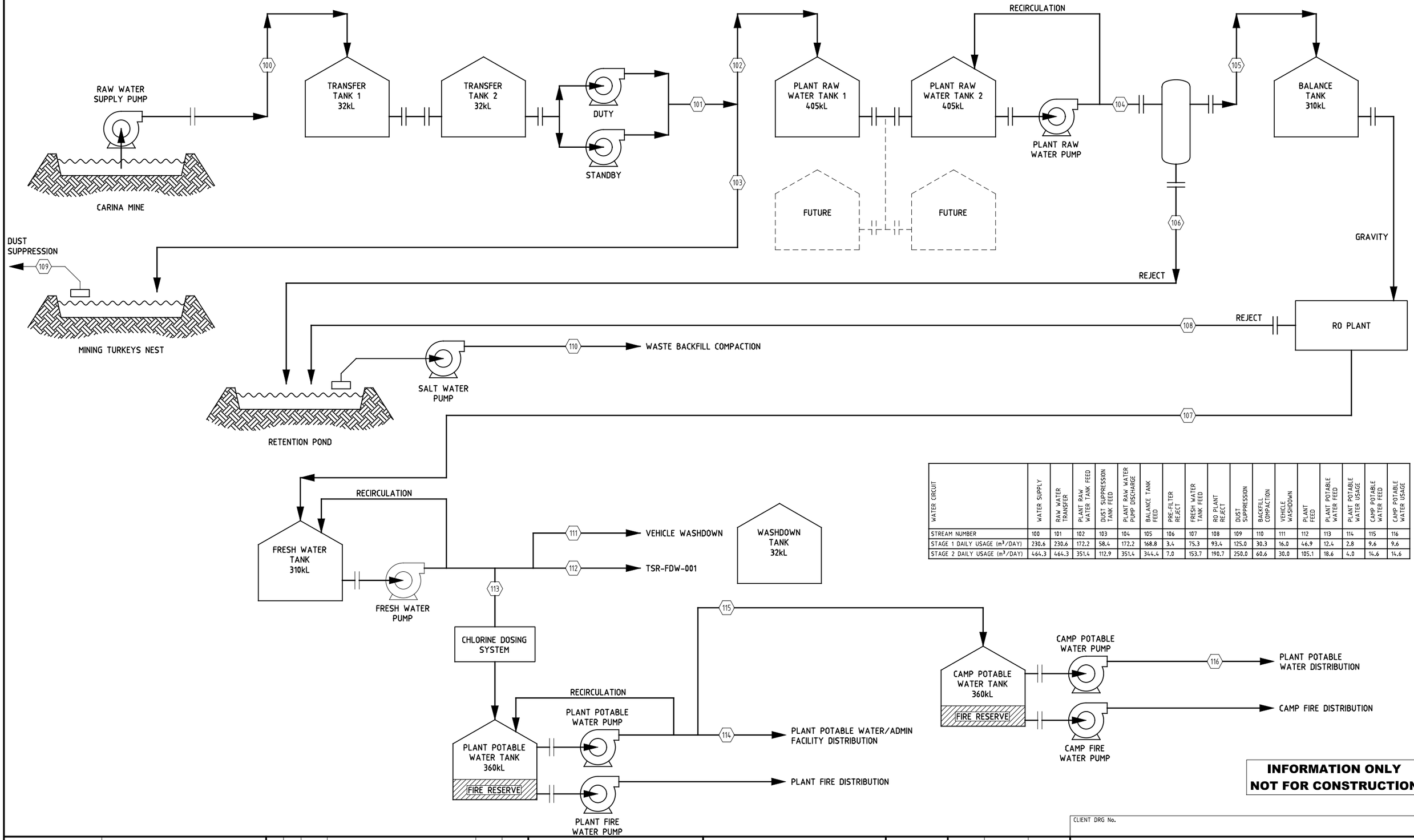
	BY	DATE
DRAWN	M.FISTONICH	16.06.15
CHKD		
DES ENG		
PROJ ENG		
CLIENT		

PROJECT No C5409

TITLE

TELLUS SANDY RIDGE
PRE-FEASIBILITY STUDY
ACCOMMODATION VILLAGE
SERVICES LAYOUT

A1 | SCALE 1:250 | DRG No C5409-3000-ME-004 | REV B



WATER CIRCUIT	WATER SUPPLY	RAW WATER TRANSFER	PLANT RAW WATER TANK FEED	DUST SUPPRESSION TANK FEED	PLANT RAW WATER PUMP DISCHARGE	BALANCE TANK FEED	PRE-FILTER REJECT	FRESH WATER TANK FEED	RO PLANT REJECT	DUST SUPPRESSION	BACKFILL COMPACTION	VEHICLE WASHDOWN	PLANT FEED	PLANT POTABLE WATER FEED	PLANT POTABLE WATER USAGE	CAMP POTABLE WATER FEED	CAMP POTABLE WATER USAGE
STREAM NUMBER	100	101	102	103	104	105	106	107	108	109	110	111	112	113	114	115	116
STAGE 1 DAILY USAGE (m^3/DAY)	230.6	230.6	172.2	58.4	172.2	168.8	3.4	75.3	93.4	125.0	30.3	16.0	46.9	12.4	2.8	9.6	9.6
STAGE 2 DAILY USAGE (m^3/DAY)	464.3	464.3	351.4	112.9	351.4	344.4	7.0	153.7	190.7	250.0	60.6	30.0	105.1	18.6	4.0	14.6	14.6

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REF DRG No	TITLE	REV	BY	DATE	DESCRIPTION	CHKD	ENG
C5409-4000-ME-001	CARINA MINE RAW WATER PUMP STATION GA	B	MB	21.08.15	ISSUED FOR PFS	JL	IB
C5409-3000-ME-001	SITE SERVICES GA	A	AL	03.07.15	ISSUED FOR INTERNAL AND CLIENT REVIEW	JL	

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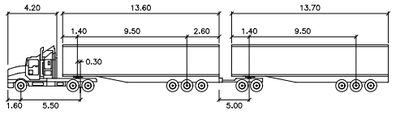
	BY	DATE
DRAWN	A LEE	26.06.15
CHKD		
DES ENG		
PROJ ENG		
CLIENT		

CLIENT DRG No.

TITLE
TELLUS SANDY RIDGE
PRE-FEASIBILITY STUDY
POTABLE WATER
SCHEMATIC

PROJECT No: C5409 | A1 | SCALE: NTS | DRG No: C5409-3000-PI-001 | REV: B



A–DOUBLE

	meters		
Tractor Width	: 2.50	Lock to Lock Time	: 6.0
Trailer Width	: 2.50	Steering Angle	: 23.4
Tractor Track	: 2.50	Articulating Angle	: 70.0
Trailer Track	: 2.50		

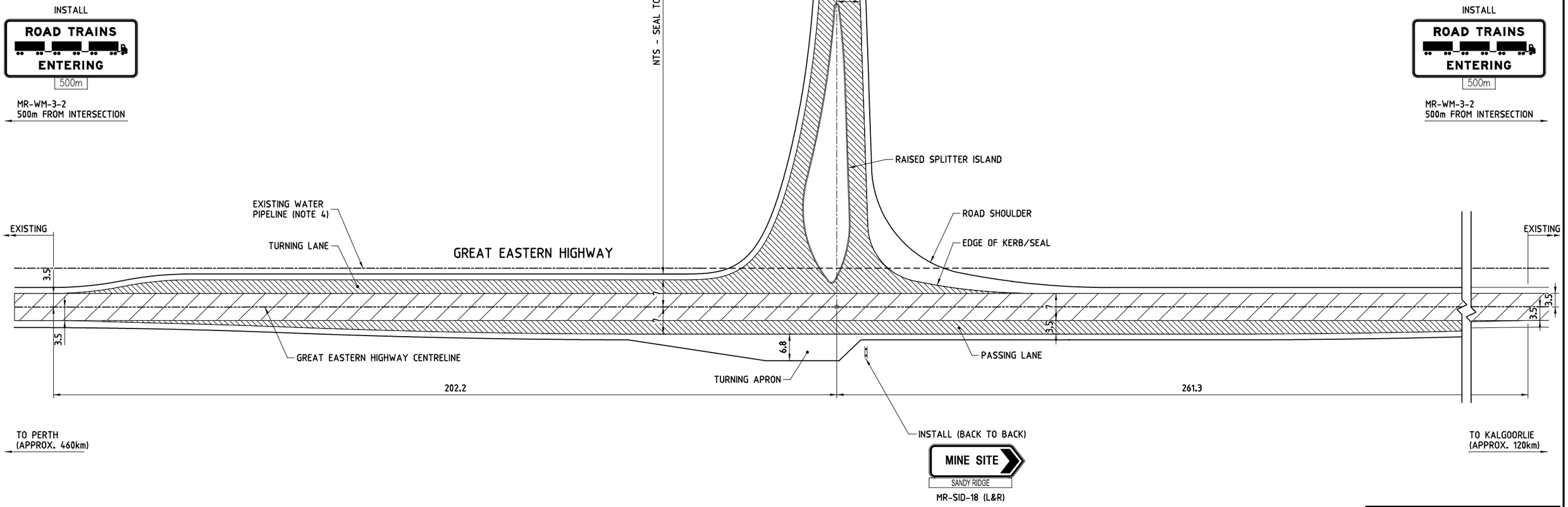
DESIGN VEHICLE

LEGEND

- EXISTING SEAL EXTENT
- NEW SEAL EXTENT

NOTES

1. ALL DIMENSIONS ARE IN METRES (m) UNLESS NOTED OTHERWISE.
2. ROAD DESIGNED TO SUIT STANDARD A-DOUBLE VEHICLE.
3. LINEMARKINGS AND SIGNAGE PLAN TO BE CREATED IN DETAILED DESIGN PHASE AND TO COMPLY WITH MRWA STANDARDS.
4. DRAINAGE SYSTEM AND INTERFACE WITH EXISTING WATER PIPELINE TO BE REVIEWED DURING DETAILED DESIGN.



10 0 10 20 30 Metres

SCALE 1 : 500

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CLIENT DRG No.

REF DRG No	TITLE	REV	BY	DATE	DESCRIPTION	CHKD	ENG
		C	MB	27.08.15	ISSUED FOR PFS	JL	IB
		B	JA	27.07.15	REVIEW COMMENTS INCORPORATED	DT	JL
C5409-0000-GE-001	KEY PLAN	A	JA	02.07.15	ISSUED FOR INTERNAL AND CLIENT REVIEW	DT	

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DRAWN	J.ANDERSON	02.07.15
CHKD		
DES ENG		
PROJ ENG		
CLIENT		

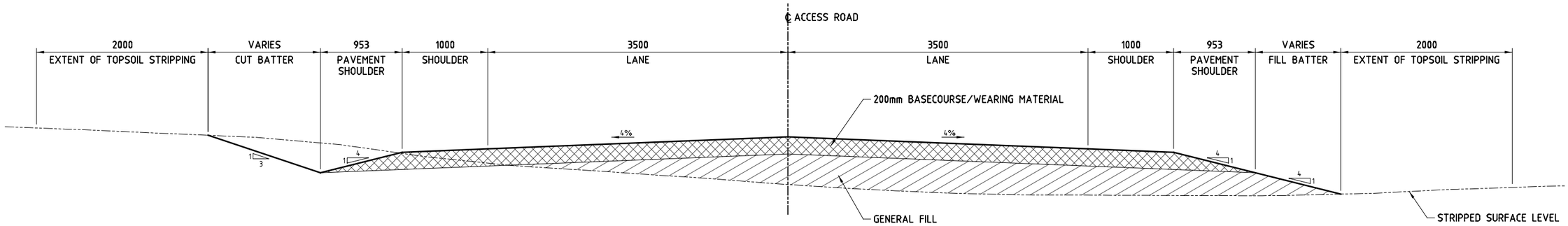
PROJECT No: C5409

TITLE
TELLUS SANDY RIDGE
PRE-FEASIBILITY STUDY
MT WALTON AND GREAT EASTERN HIGHWAY INTERSECTION
GENERAL ARRANGEMENT

A1	SCALE 1:500	DRG No C5409-3210-CE-001	REV C

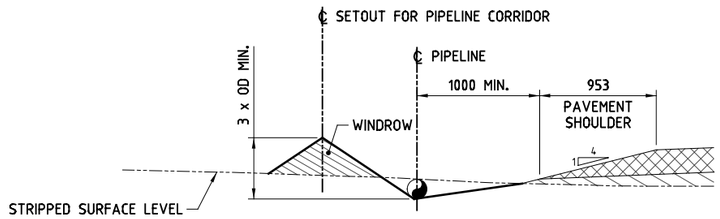
NOTES:

1. TOPSOIL REMOVAL 100mm TYP.
2. BASECOURSE THICKNESS BASED ON ESTIMATED SUBGRADE 15% CBR MIN.
3. LOCATION OF BORROW PITS FOR OBTAINING OF BASECOURSE MATERIAL SUBJECTED TO GEOTECHNICAL INVESTIGATION.



TYPICAL ROAD CROSS SECTION

SCALE 1:25



TYPICAL PIPELINE CORRIDOR SECTION

SCALE 1:25

0.5 0 0.5 1.0 1.5 Metres

SCALE 1 : 25

INFORMATION ONLY
NOT FOR CONSTRUCTION

REF DRG No	TITLE	REV	BY	DATE	DESCRIPTION	CHKD	ENG
C5409-3210-CE-005	VILLAGE & LANDFILL ACCESS ROADS - GA						
C5409-3210-CE-004	MINE ACCESS ROAD - GA - SHEET 2 OF 2						
C5409-3210-CE-003	MINE ACCESS ROAD - GA - SHEET 1 OF 2	C	MB	27.08.15	ISSUED FOR PFS	JL	IB
C5409-3210-CE-001	MT WALTON & GREAT EASTERN HWY INTERSECTION - GA	B	JA	27.07.15	REVIEW COMMENTS INCORPORATED	DT	JL
C5409-0000-GE-001	KEY PLAN	A	JA	02.07.15	ISSUED FOR INTERNAL AND CLIENT REVIEW	DT	

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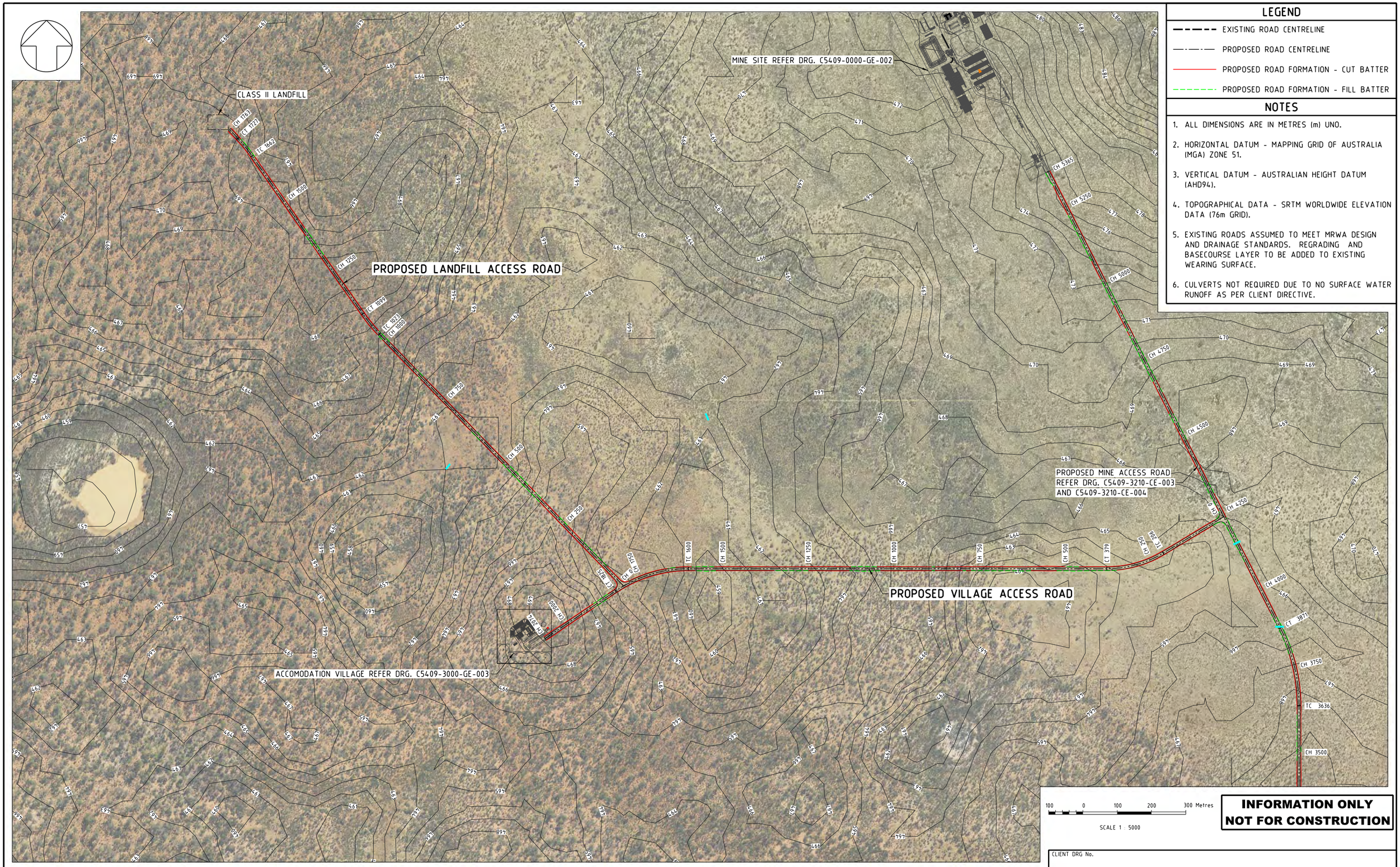
	BY	DATE
DRAWN	J.ANDERSON	02.07.15
CHKD		
DES ENG		
PROJ ENG		
CLIENT		

PROJECT No C5409

CLIENT DRG No.

TITLE
TELLUS SANDY RIDGE
PRE-FEASIBILITY STUDY
ACCESS ROAD AND RUNOFF DRAIN
TYPICAL SECTIONS AND DETAILS

A1 | SCALE 1:25 | DRG No C5409-3210-CE-002 | REV B



LEGEND

- EXISTING ROAD CENTRELINE
- PROPOSED ROAD CENTRELINE
- PROPOSED ROAD FORMATION - CUT BATTER
- PROPOSED ROAD FORMATION - FILL BATTER

NOTES

1. ALL DIMENSIONS ARE IN METRES (m) UNO.
2. HORIZONTAL DATUM - MAPPING GRID OF AUSTRALIA (MGA) ZONE 51.
3. VERTICAL DATUM - AUSTRALIAN HEIGHT DATUM (AHD94).
4. TOPOGRAPHICAL DATA - SRTM WORLDWIDE ELEVATION DATA (76m GRID).
5. EXISTING ROADS ASSUMED TO MEET MRWA DESIGN AND DRAINAGE STANDARDS. REGRADING AND BASECOURSE LAYER TO BE ADDED TO EXISTING WEARING SURFACE.
6. CULVERTS NOT REQUIRED DUE TO NO SURFACE WATER RUNOFF AS PER CLIENT DIRECTIVE.

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REF DRG No	TITLE	REV	BY	DATE	DESCRIPTION	CHKD	ENG
C5409-CE-3210-004	MINE ACCESS ROAD - GA SHEET 2						
C5409-CE-3210-003	MINE ACCESS ROAD - GA SHEET 1	C	MB	27.08.15	ISSUED FOR PFS	JL	IB
C5409-CE-3210-002	ACCESS ROAD AND RUNOFF DRAIN - TYPICAL DETAILS	B	JA	27.07.15	REVIEW COMMENTS INCORPORATED	DT	JL
C5409-GE-0000-001	KEY PLAN	A	JA	02.07.15	ISSUED FOR INTERNAL AND CLIENT REVIEW	DT	

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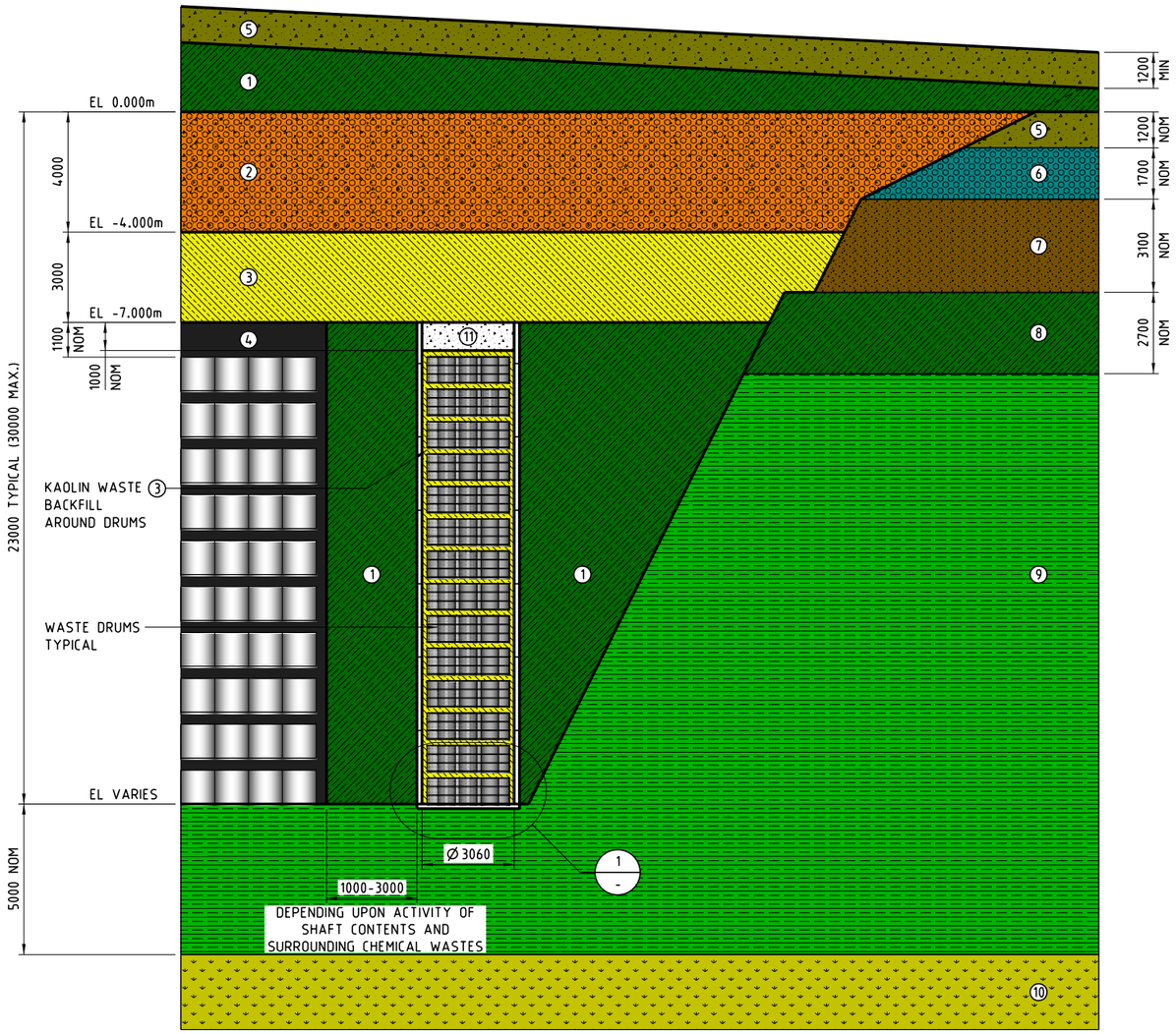
	BY	DATE
DRAWN	J.ANDERSON	02.07.15
CHKD		
DES ENG		
PROJ ENG		
CLIENT		

CLIENT DRG No.

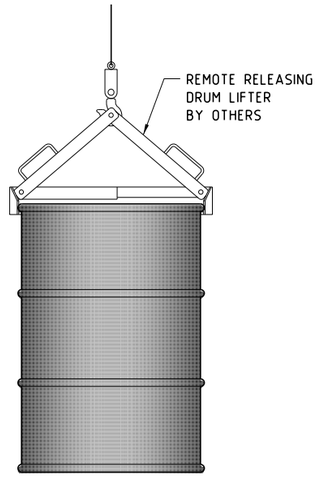
TITLE
TELLUS SANDY RIDGE
PRE-FEASIBILTY STUDY
VILLAGE AND LANDFILL ACCESS ROADS
GENERAL ARRANGEMENT

PROJECT No	SCALE	DRG No	REV
C5409	A1 1:5000	C5409-3210-CE-005	C

31/08/2015 1:35:49 PM FILE: M:_Projects\C5409\Civil Earthworks\Issues\C5409-3210-CE-005_C.dgn OWNER: michael.beaumont



TYPICAL SECTION

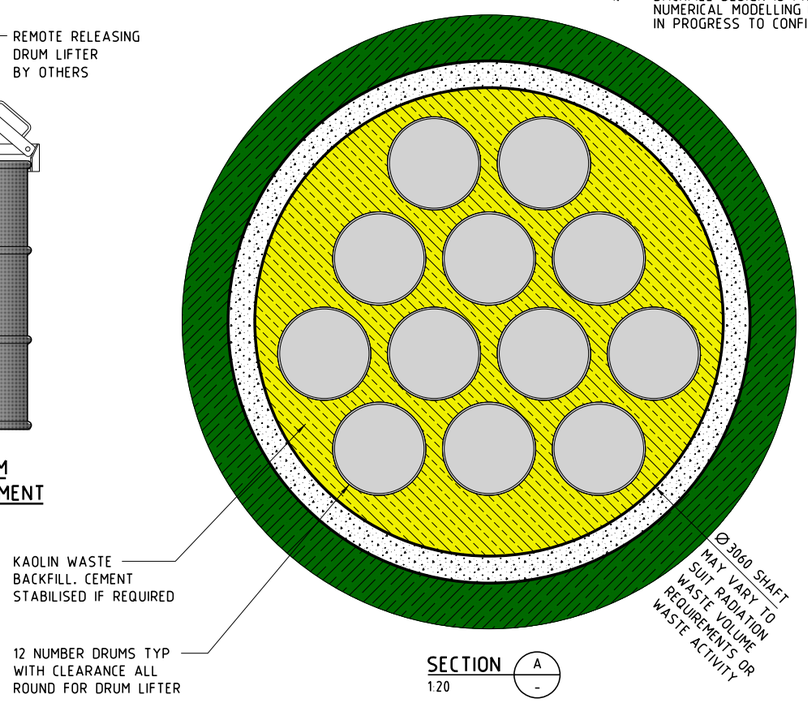


TYPICAL DRUM LIFTING ARRANGEMENT

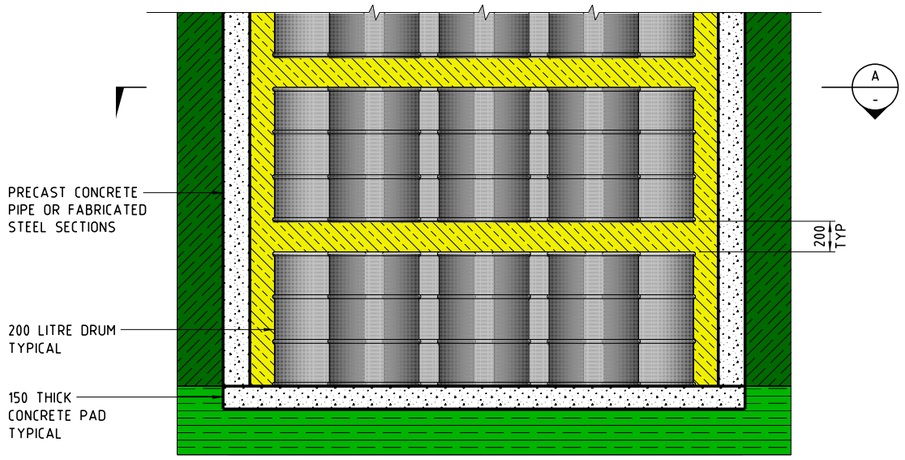
SCALE 1:10

NOTES

1. BACKFILL DESIGN IS PRELIMINARY ONLY. NUMERICAL MODELLING CALCULATION IS IN PROGRESS TO CONFIRM DESIGN.



SECTION A / -
1:20



DETAIL 1 / -
1:20

LAYER LEGEND - CELL AND SHAFT BACKFILL

- ① MOTTLED CLAYS COMPACTED TO 95%MMDD
- ② MIXED LATERITE AND SILCRETE AND CLAYEY SAND COMPACTED TO 95%MMDD, MAX. PARTICLE SIZE 40mm
- ③ KAOLIN WASTE COMPACTED TO 90%MMDD
- ④ WASTE SAND BACKFILLED AROUND DRUMS/BAGS COMPACTED TO 90%MMDD
- ⑪ CEMENT STABILISED COMPACTED KAOLINISED GRANITE

LAYER LEGEND - EXISTING GROUND

- ⑤ CLAYEY SAND
- ⑥ LATERITE
- ⑦ SILCRETE
- ⑧ MOTTLED CLAYS (IRON STAINED KAOLINISED GRANITE)
- ⑨ KAOLINISED GRANITE
- ⑩ UNWEATHERED GRANITE

LAYER LEGEND - SURFACE REHABILITATION

- ⑤ CLAYEY SAND

0.2 0.1 0 0.2 0.4 0.6 Metres
SCALE 1 : 10

0.4 0.2 0 0.4 0.8 1.2 Metres
SCALE 1 : 20

2 1 0 2 4 6 Metres
SCALE 1 : 100

INFORMATION ONLY
NOT FOR CONSTRUCTION

CLIENT DRG No.

REF DRG No	TITLE	REV	BY	DATE	DESCRIPTION	CHKD	ENG
		B	AL	27.11.15	FINAL REHABILITATION SURFACE ADDED	JL	
		A	BK	02.09.15	ISSUED FOR INTERNAL AND CLIENT REVIEW	JL	

CLIENT: TELLUS

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	BY	DATE
DRAWN	B KLEMICK	02.09.15
CHKD		
DES ENG		
PROJ ENG		
CLIENT		

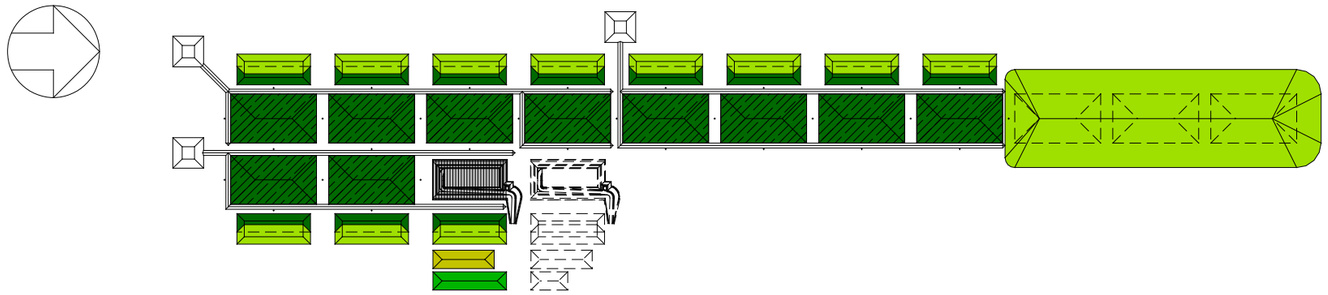
PROJECT No: C5409

TITLE: TELLUS SANDY RIDGE PRE-FEASIBILITY STUDY WASTE ISOLATION SHAFT IN CELL BACKFILL GENERAL ARRANGEMENT

A1 | SCALE 1:100 UNO | DRG No C5409-6310-CE-004 | REV B

NOTES

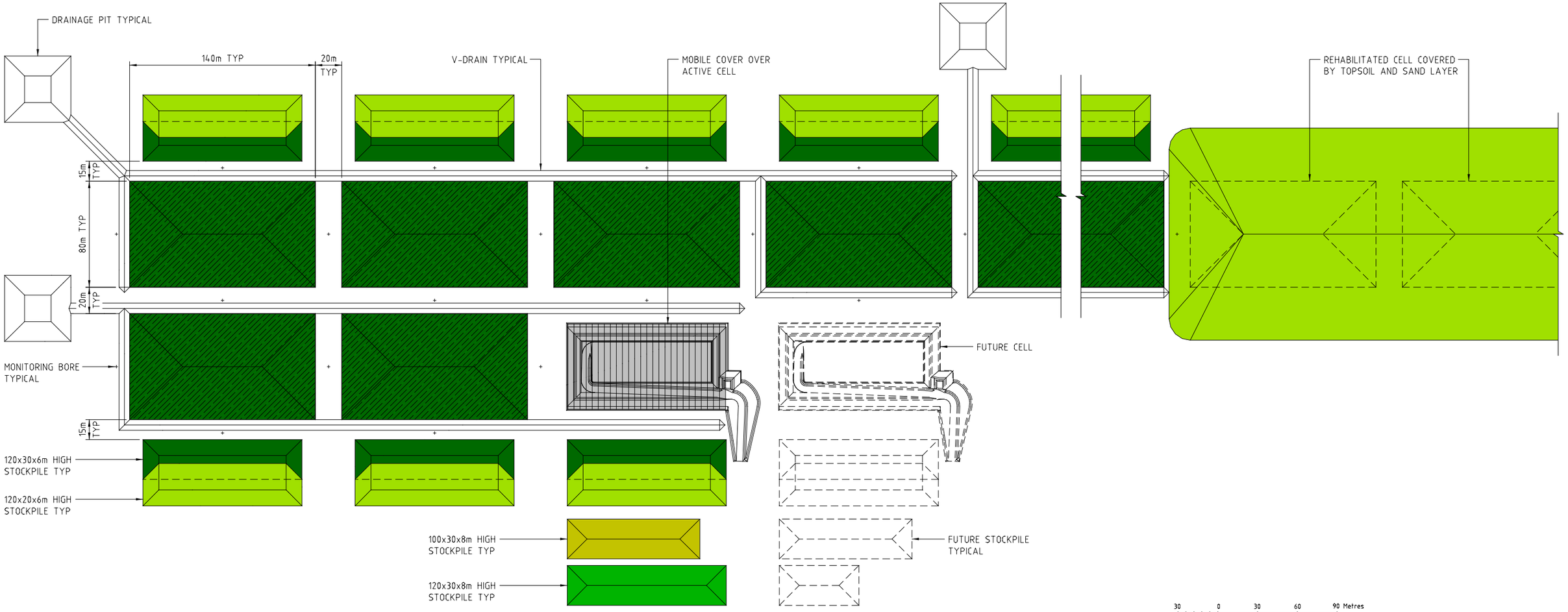
1. LAYOUT DESIGN IS PRELIMINARY ONLY.



OVERALL LAYOUT PLAN
SCALE 1:5000

LEGEND - STOCKPILES AND BACKFILL

- MOTTLED CLAYS
- YELLOW SAND AND TOPSOIL
- CRUSHED SILCRETE AND LATERITE
- KAOLINISED GRANITE
- MOTTLED CLAYS COMPACTED TO 95%MMDD BACKFILL



LAYOUT PLAN
SCALE 1:1500

30 0 30 60 90 Metres
SCALE 1 : 1500

100 0 100 200 300 Metres
SCALE 1 : 5000

INFORMATION ONLY
NOT FOR CONSTRUCTION

CLIENT DRG No.

REF DRG No	TITLE	REV	BY	DATE	DESCRIPTION	CHKD	ENG
		A	BK	15.09.15	ISSUED FOR INTERNAL AND CLIENT REVIEW	JL	IWB

CLIENT: TELLUS

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ISO 9001 SYSTEM CERTIFICATION SGS

	BY	DATE
DRAWN	B KLEMICK	08.09.15
CHKD		
DES ENG		
PROJ ENG		
CLIENT		

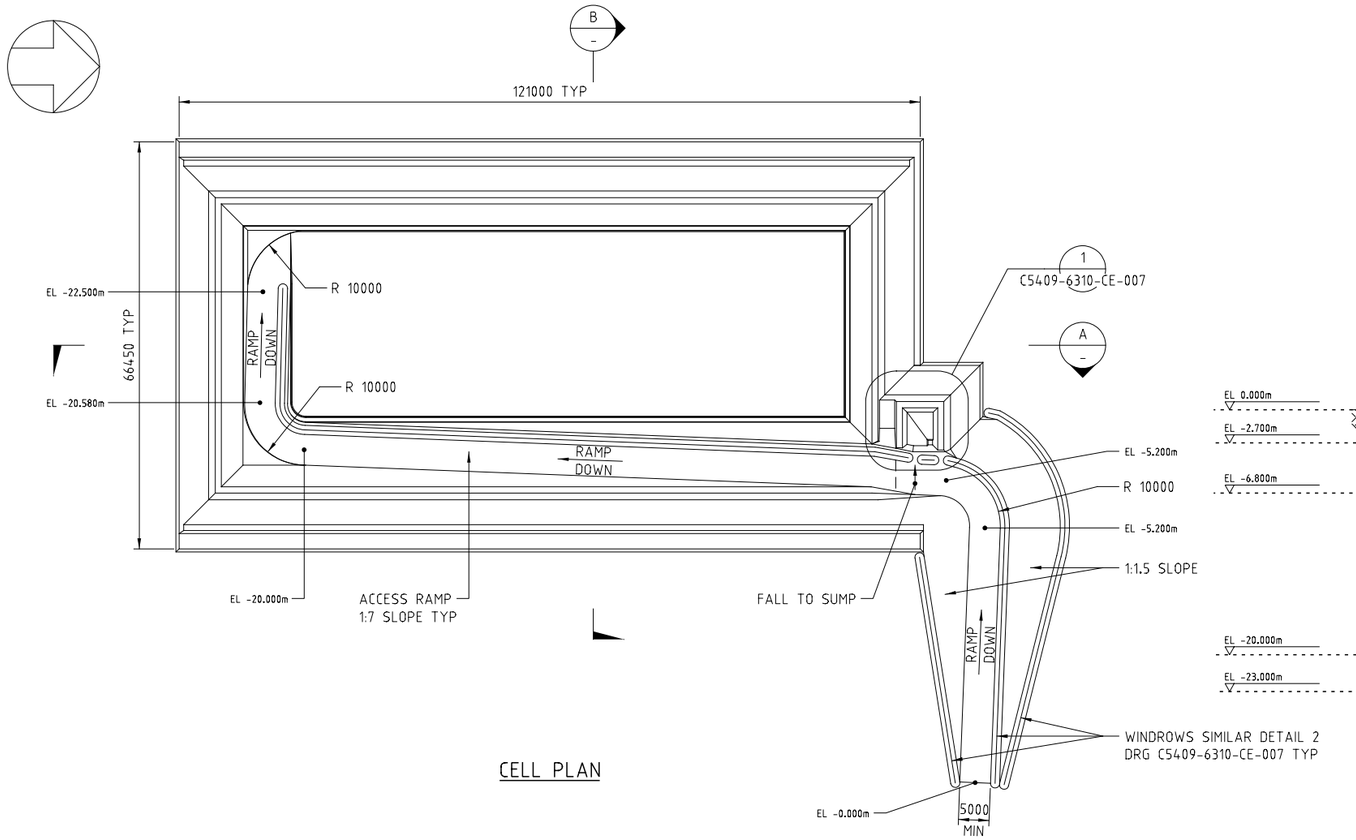
TITLE
TELLUS SANDY RIDGE
PRE-FEASIBILITY STUDY
WASTE ISOLATION CELL
OVERALL LAYOUT

PROJECT No		SCALE	DRG No	REV
C5409	A1	1:1500	C5409-6310-CE-005	A

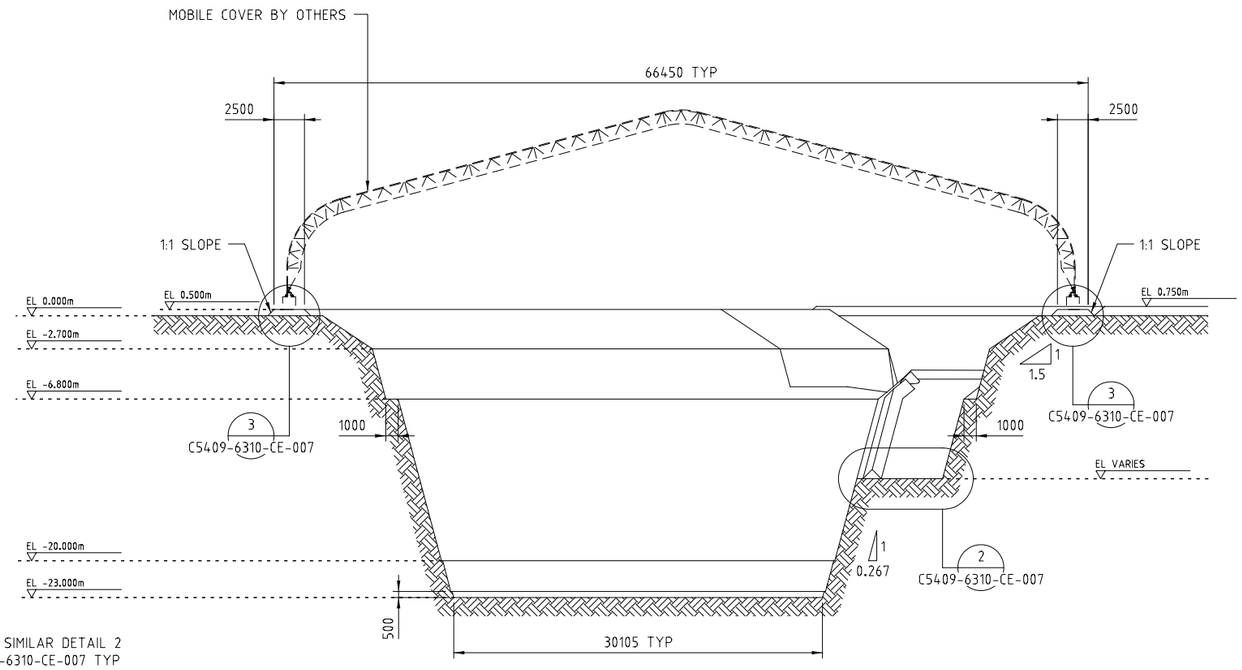
15/09/2015 10:22:14 AM

NOTES

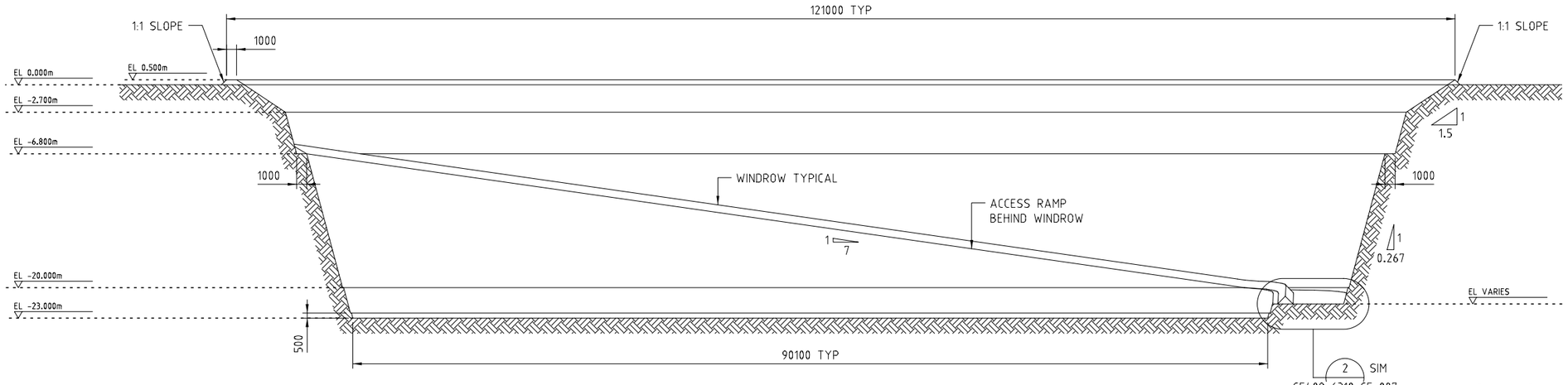
1. DESIGN IS PRELIMINARY ONLY.



CELL PLAN



SECTION B
1:250



SECTION A
1:250

5 0 5 10 15 Metres
SCALE 1 : 250

10 0 10 20 30 Metres
SCALE 1 : 500

INFORMATION ONLY
NOT FOR CONSTRUCTION

CLIENT DRG No.

REF DRG No	TITLE	REV	BY	DATE	DESCRIPTION	CHKD	ENG
C5409-6310-CE-007	WASTE ISOLATION CELL-23m BGL CELL SECT & DETAILS	A	BK	15.09.15	ISSUED FOR INTERNAL AND CLIENT REVIEW	JL	IWB

CLIENT: TELLUS

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ISO 9001 SGS

	BY	DATE
DRAWN	B KLEMICK	09.09.15
CHKD		
DES ENG		
PROJ ENG		
CLIENT		

PROJECT No: C5409

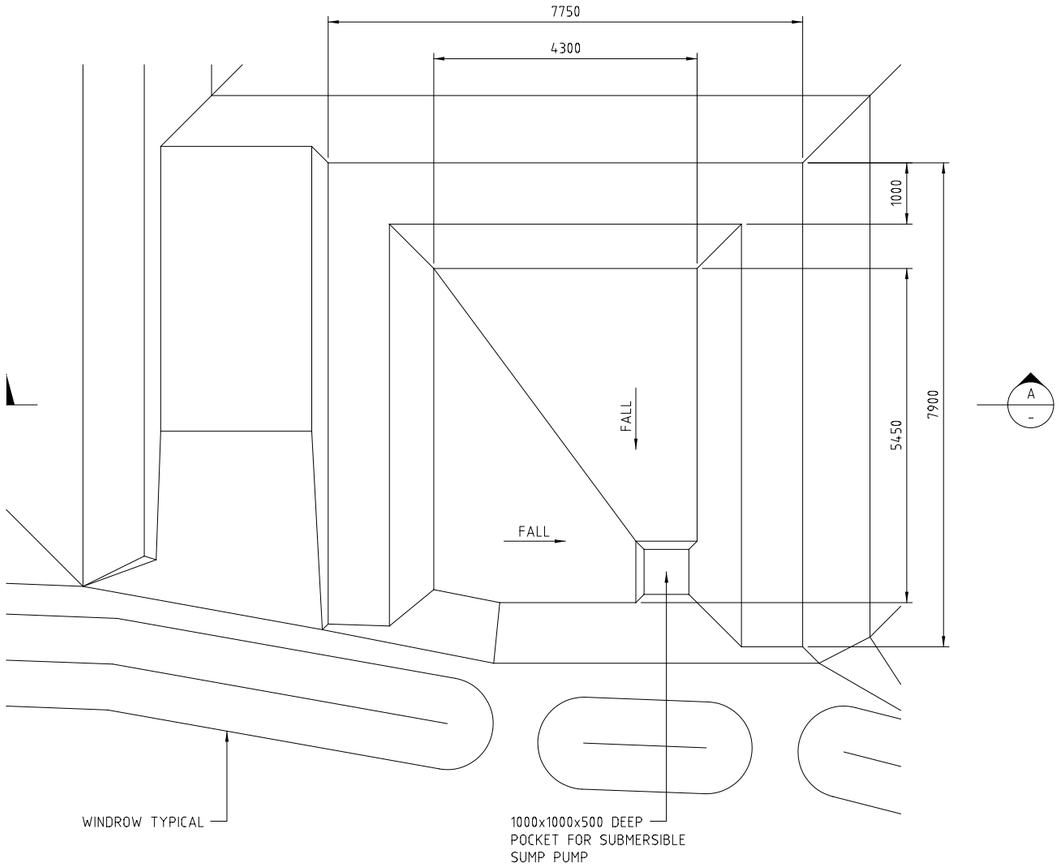
TITLE
TELLUS SANDY RIDGE
PRE-FEASIBILITY STUDY
WASTE ISOLATION CELL
23m BGL CELL GENERAL ARRANGEMENT

A1 | SCALE: 1:500 UNO | DRG No: C5409-6310-CE-006 | REV: A

15/09/2015 10:21:01 AM

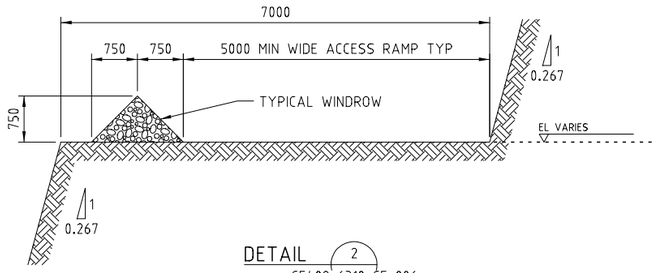
NOTES

1. DESIGN IS PRELIMINARY ONLY.

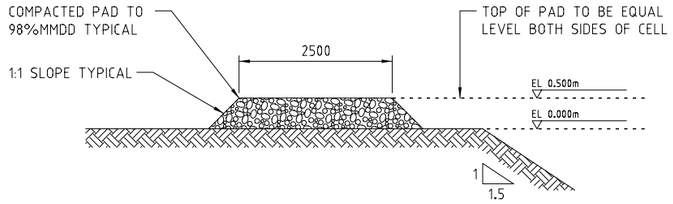


DETAIL 1
C5409-6310-CE-006

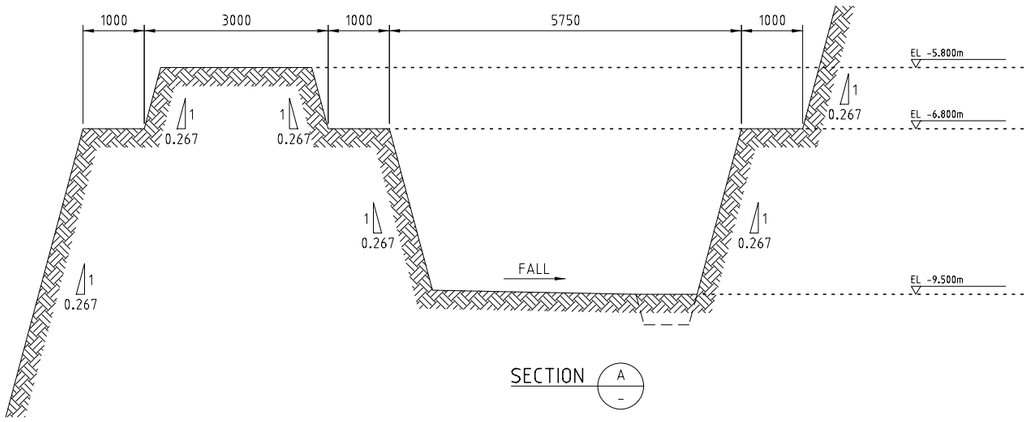
SUMP PLAN



DETAIL 2
C5409-6310-CE-006



DETAIL 3
C5409-6310-CE-006



SECTION A
-

1 0 1 2 3 Metres

SCALE 1 : 50

INFORMATION ONLY
NOT FOR CONSTRUCTION

CLIENT DRG No.

REF DRG No	TITLE	REV	BY	DATE	DESCRIPTION	CHKD	ENG
C5409-6310-CE-006	WASTE ISOLATION CELL-23m BGL CELL GA	A	BK	15.09.15	ISSUED FOR INTERNAL AND CLIENT REVIEW	JL	IWB

CLIENT: TELLUS

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ISO 9001 SGS

	BY	DATE
DRAWN	B KLEMICK	09.09.15
CHKD		
DES ENG		
PROJ ENG		
CLIENT		

PROJECT No: C5409

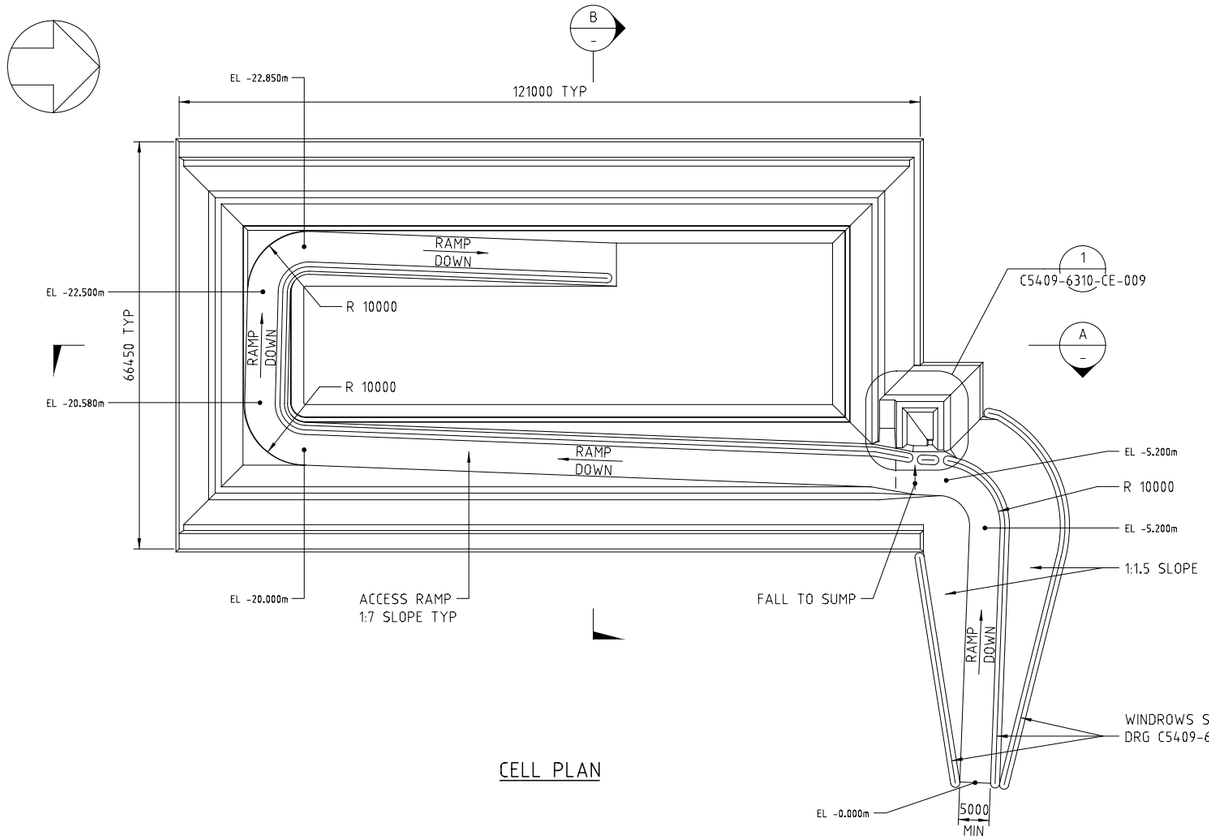
TITLE: TELLUS SANDY RIDGE
PRE-FEASIBILITY STUDY
WASTE ISOLATION CELL
23m BGL CELL SECTIONS AND DETAILS

A1 | SCALE 1:50 | DRG No C5409-6310-CE-007 | REV A

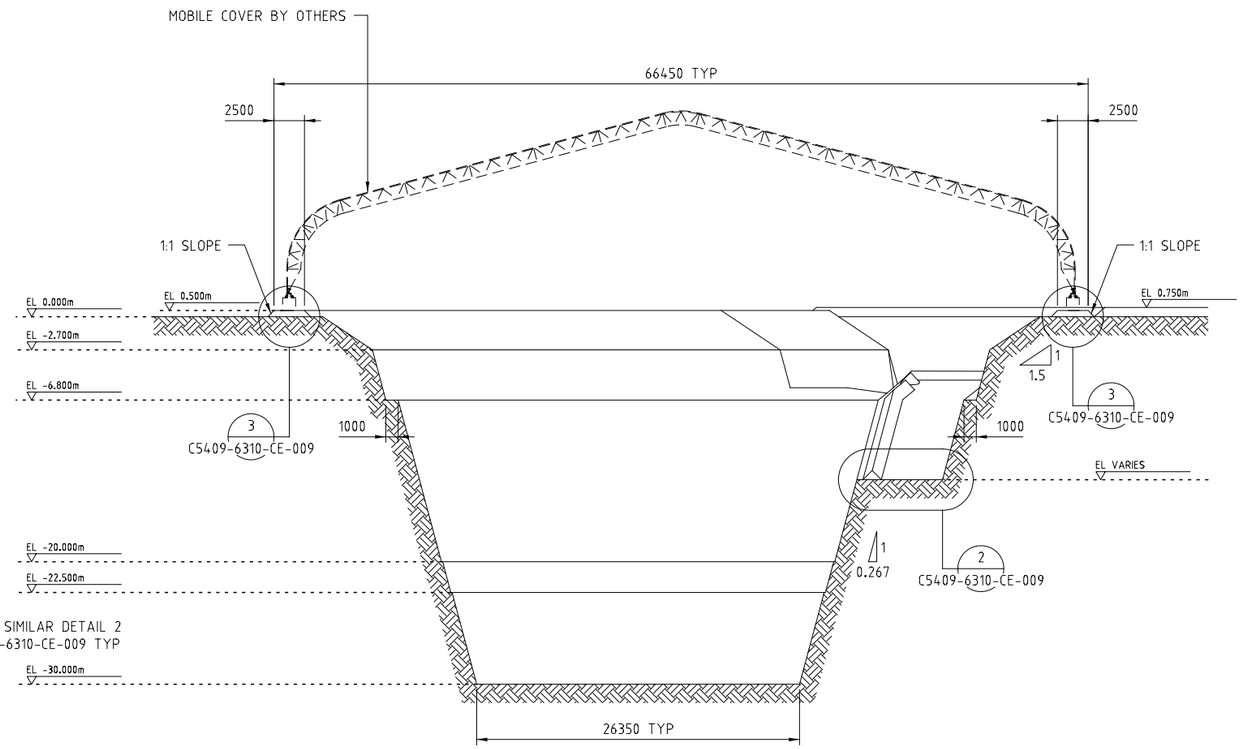
15/09/2015 10:19:47 AM

NOTES

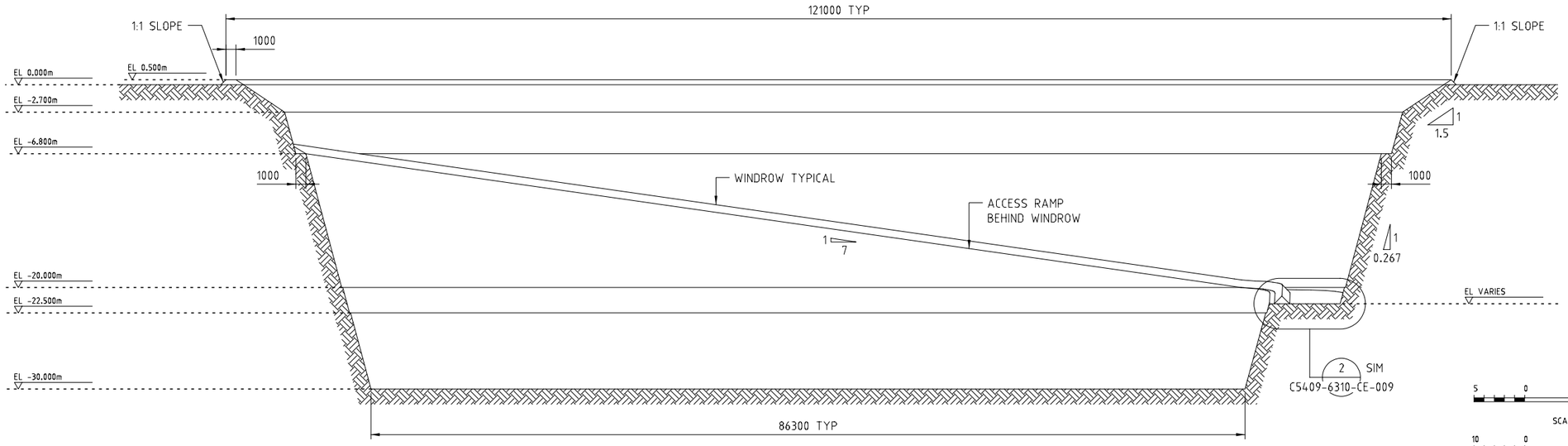
1. DESIGN IS PRELIMINARY ONLY.



CELL PLAN



SECTION B
1:250



SECTION A
1:250

5 0 5 10 15 Metres
SCALE 1 : 250
10 0 10 20 30 Metres
SCALE 1 : 500

INFORMATION ONLY
NOT FOR CONSTRUCTION

CLIENT DRG No.

REF DRG No	TITLE	REV	BY	DATE	DESCRIPTION	CHKD	ENG
C5409-6310-CE-009	WASTE ISOLATION CELL-30m BGL CELL SECT & DETAILS	A	BK	15.09.15	ISSUED FOR INTERNAL AND CLIENT REVIEW	JL	IWB

CLIENT: TELLUS

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SGS ISO 9001

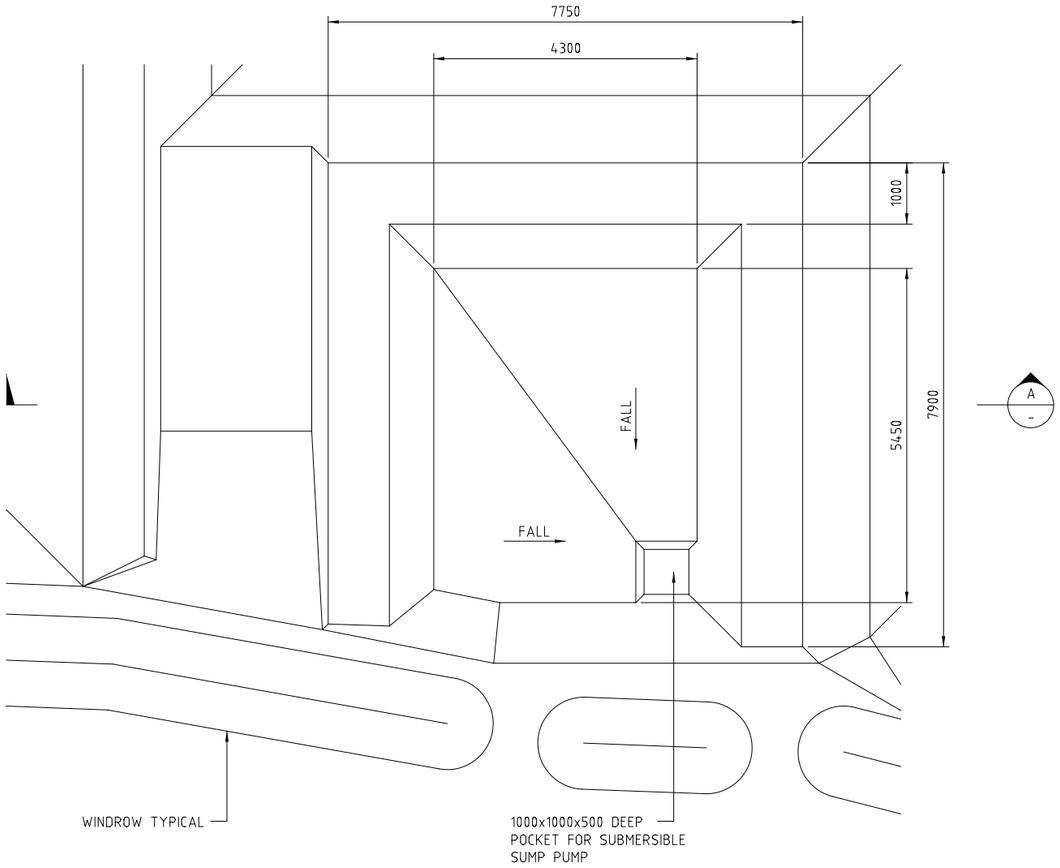
	BY	DATE
DRAWN	B KLEMICK	14.09.15
CHKD		
DES ENG		
PROJ ENG		
CLIENT		

PROJECT No: C5409

TITLE
TELLUS SANDY RIDGE
PRE-FEASIBILITY STUDY
WASTE ISOLATION CELL
30m BGL CELL GENERAL ARRANGEMENT

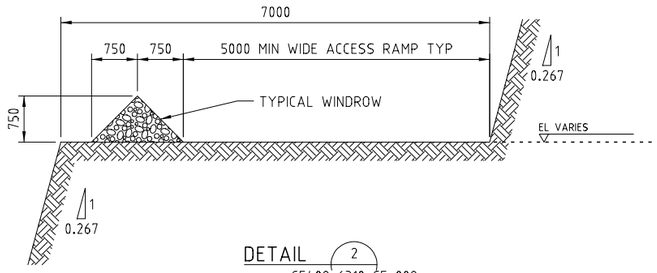
A1 | SCALE 1:500 UNO | DRG No C5409-6310-CE-008 | REV A

15/09/2015 10:18:06 AM

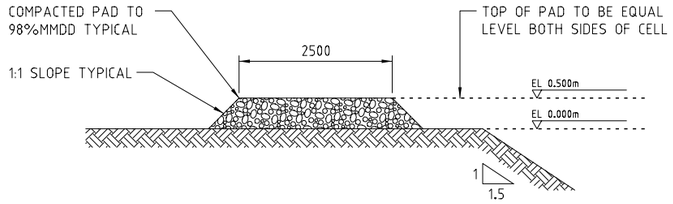


DETAIL 1
C5409-6310-CE-008

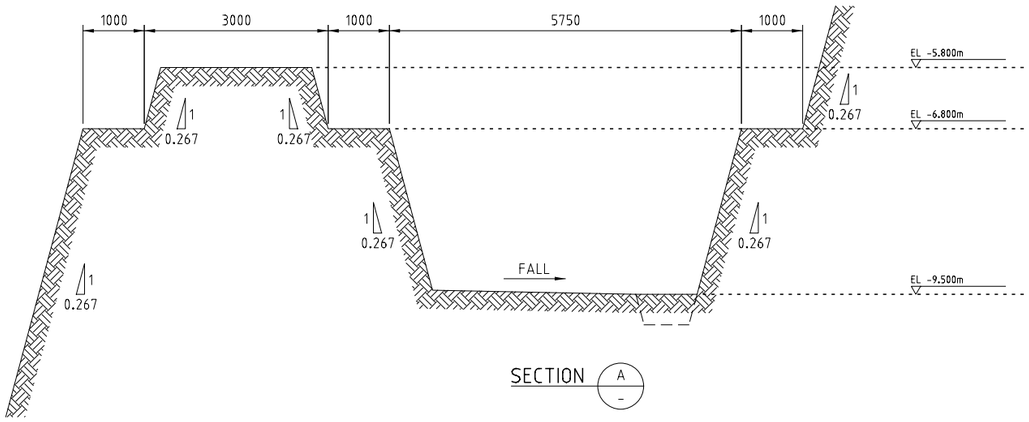
SUMP PLAN



DETAIL 2
C5409-6310-CE-008



DETAIL 3
C5409-6310-CE-008



SECTION A
-

NOTES

1. DESIGN IS PRELIMINARY ONLY.

1 0 1 2 3 Metres

SCALE 1 : 50

INFORMATION ONLY
NOT FOR CONSTRUCTION

CLIENT DRG No.

REF DRG No	TITLE	REV	BY	DATE	DESCRIPTION	CHKD	ENG
C5409-6310-CE-008	WASTE ISOLATION CELL-30m BGL CELL GA	A	BK	15.09.15	ISSUED FOR INTERNAL AND CLIENT REVIEW	JL	IWB

CLIENT: TELLUS

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ISO 9001 SGS

	BY	DATE
DRAWN	B KLEMICK	14.09.15
CHKD		
DES ENG		
PROJ ENG		
CLIENT		

PROJECT No: C5409

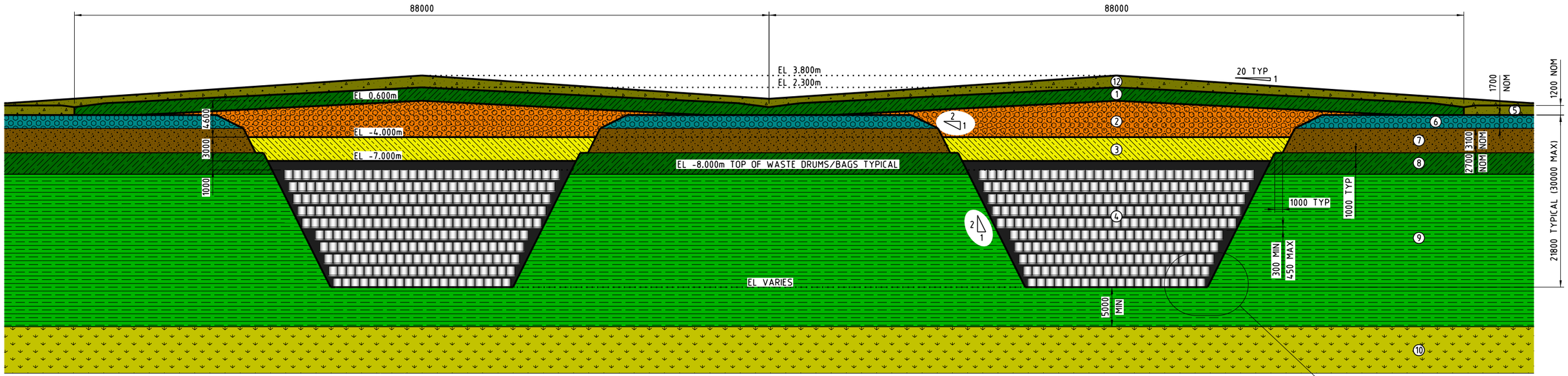
TITLE: TELLUS SANDY RIDGE
PRE-FEASIBILITY STUDY
WASTE ISOLATION CELL
30m BGL CELL SECTIONS AND DETAILS

A1 | SCALE 1:50 | DRG No C5409-6310-CE-009 | REV A

15/09/2015 10:16:11 AM

NOTES

1. MOTTLED CLAYS COMPACTED TO 90% MMDD MAY BE USED DEPENDING ON QUANTITIES OF MATERIAL AVAILABLE
2. BACKFILL DESIGN IS PRELIMINARY ONLY. NUMERICAL MODELLING CALCULATION IS IN PROGRESS TO CONFIRM DESIGN



SECTION B
1:250 6310-CE-001

LAYER LEGEND - CELL BACKFILL

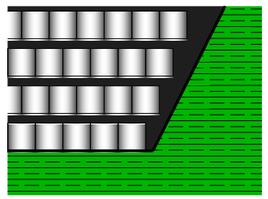
1. MOTTLED CLAYS COMPACTED TO 95%MMDD
2. MIXED LATERITE AND SILCRETE AND CLAYEY SAND COMPACTED TO 95%MMDD, MAX. PARTICLE SIZE 40mm
3. KAOLIN WASTE COMPACTED TO 90%MMDD
4. WASTE SAND BACKFILLED AROUND DRUMS/BAGS COMPACTED TO 90%MMDD
11. CEMENT STABILISED COMPACTED KAOLINISED GRANITE

LAYER LEGEND - EXISTING GROUND

5. CLAYEY SAND
6. LATERITE
7. SILCRETE
8. MOTTLED CLAYS (IRON STAINED KAOLINISED GRANITE)
9. KAOLINISED GRANITE
10. UNWEATHERED GRANITE

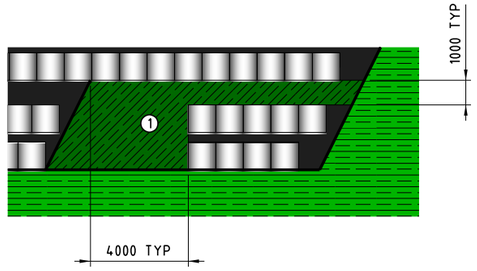
LAYER LEGEND - SURFACE REHABILITATION

12. CLAYEY SAND



DETAIL 1/-
1:125

NON-SEGREGATED WASTE



DETAIL 1/-
1:125

SEGREGATED WASTE

INFORMATION ONLY
NOT FOR CONSTRUCTION

5 0 5 10 15 Metres
SCALE 1 : 250

REF DRG No	TITLE	REV	BY	DATE	DESCRIPTION	CHKD	ENG
		C	AL	11.12.15	DIMENSIONS ON SEGREGATED WASTE DETAIL	JL	JL
		B	AL	10.12.15	SURFACE REHABILITATION LAYER REVISED	IB	IB
C5609-6310-CE-001	WASTE ISOLATION CELL-BACKFILL GENERAL ARRANGEMENT	A	AL	27.11.15	ISSUED FOR INTERNAL AND CLIENT REVIEW	JL	

CLIENT: TELLUS

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SGS ISO 9001

	BY	DATE
DRAWN	A LEE	26.11.2015
CHKD		
DES ENG		
PROJ ENG		
CLIENT		

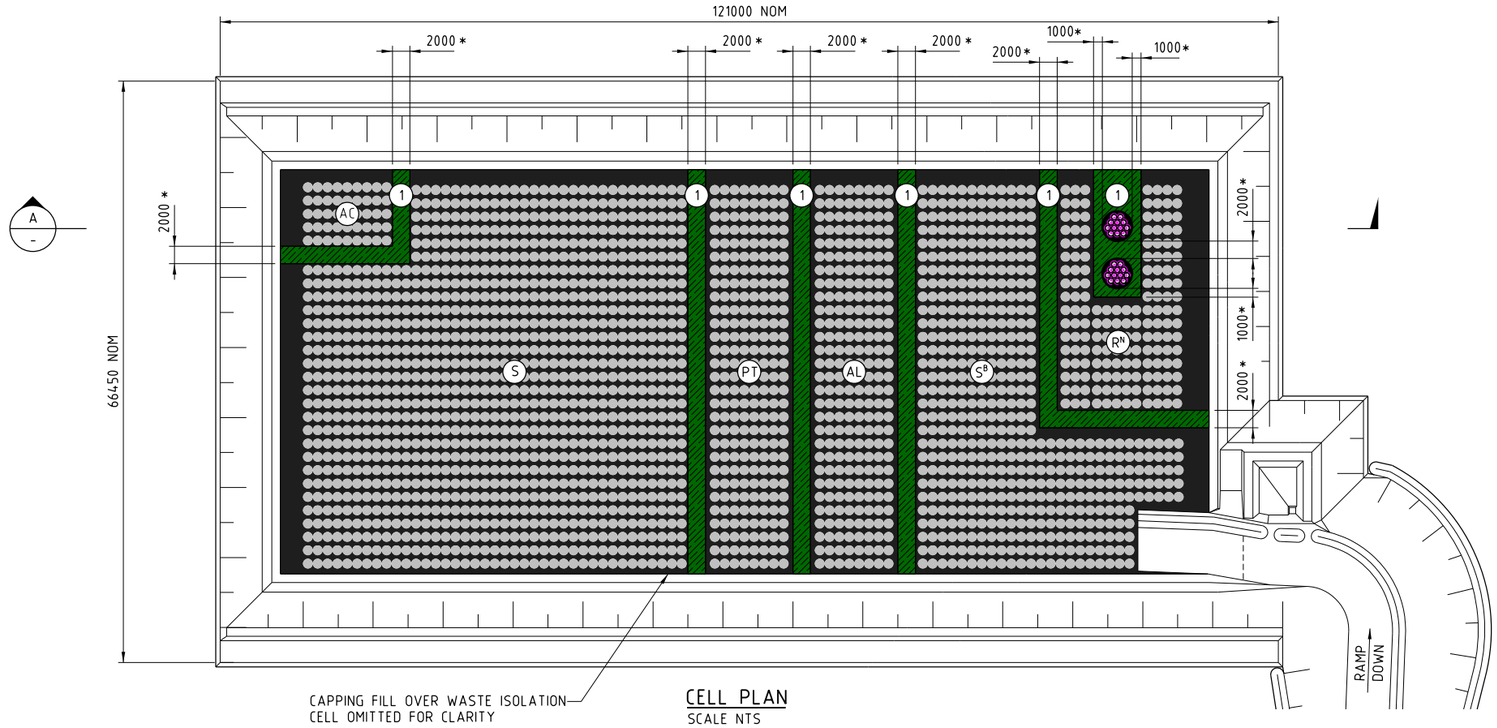
PROJECT No: C5409

CLIENT DRG No.

TITLE
TELLUS SANDY RIDGE
PRE-FEASIBILITY STUDY
WASTE ISOLATION CELL
TYPICAL BACKFILL CROSS SECTION - FINAL LANDFORM

A1 | SCALE 1:250 | DRG No C5409-6310-CE-010 | REV C

11/12/2015 1:46:55 PM FILE: M:_Projects\C5409\Civil Earthworks\Issues\C5409-6310-CE-010_C.dgn OWNER: adrian.lee



CELL PLAN

SCALE NTS

NOTES

1. QUANTITIES OF EACH TYPE OF WASTE AND NUMBER OF SHAFTS ARE INDICATIVELY SHOWN AND WILL VARY WITH WASTE MARKET EACH YEAR

* DENOTES TYPICAL BARRIER OF SEPARATION REQUIRED

LAYER LEGEND - CELL BACKFILL

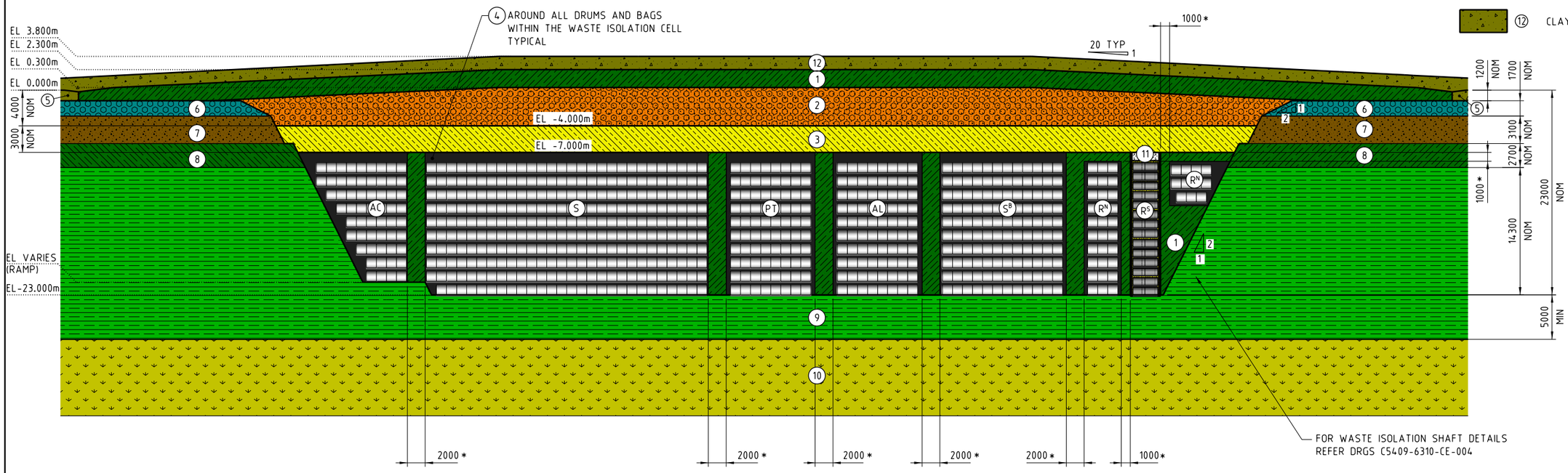
1. MOTTLED CLAYS COMPACTED TO 95%MMDD
2. MIXED LATERITE AND SILCRETE AND KAOLINISED GRANITE COMPACTED TO 95%MMDD, MAX. PARTICLE SIZE 40mm
3. KAOLIN WASTE COMPACTED TO 90%MMDD OR KAOLINISED GRANITE COMPACTED TO 95%MMDD
4. KAOLINISED GRANITE OR WASTE SAND BACKFILLED AROUND DRUMS/BAGS COMPACTED TO 90%MMDD
11. CEMENT OR CONCRETE STABILISED COMPACTED KAOLINISED GRANITE

LAYER LEGEND - EXISTING GROUND

5. CLAYEY SAND
6. LATERITE
7. SILCRETE
8. MOTTLED CLAYS (IRON STAINED KAOLINISED GRANITE)
9. KAOLINISED GRANITE
10. UNWEATHERED GRANITE

LAYER LEGEND - SURFACE REHABILITATION

12. CLAYEY SAND



SECTION A

1:250

WASTE ZONES	
PT	POISONOUS
AC	ACIDIC
AL	ALKALINE
S	ECOTOXIC
S^B	ECOTOXIC (BULK CONTAM SOILS)
R^S	SHAFT WASTE (REFER DRG 6310-CE-004)
R^N	NORM WASTE

REFER TO TELLUS WASTE STORAGE & DISPOSAL ZONING PROCEDURE TCO-5-05-004

INFORMATION ONLY
NOT FOR CONSTRUCTION

5 0 5 10 15 Metres

SCALE 1 : 250

REF DRG No	TITLE	REV	BY	DATE	DESCRIPTION	CHKD	ENG
		B	TS	05.08.16	WASTE STREAMS UPDATED	JL	
		A	SR	16.03.16	ISSUED FOR INTERNAL AND CLIENT REVIEW	JL	

CLIENT: TELLUS

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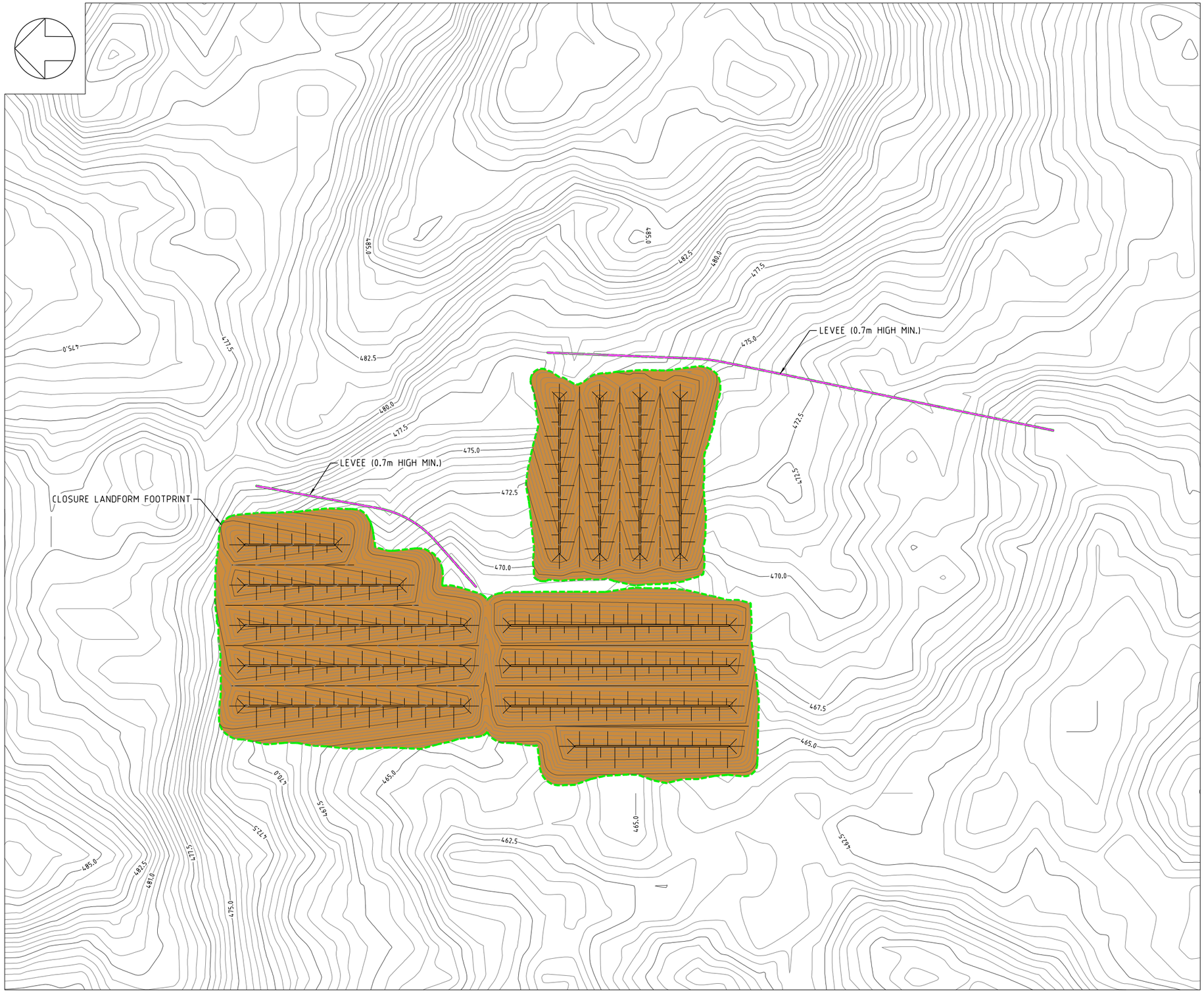
ISO 9001 SYSTEM CERTIFICATION SGS

	BY	DATE
DRAWN	S RUDDY	09.03.2016
CHKD		
DES ENG		
PROJ ENG		
CLIENT		
PROJECT No	C5409	

CLIENT DRG No.

TITLE
TELLUS SANDY RIDGE
PRE-FEASIBILITY STUDY
WASTE ISOLATION CELL - CO-DISPOSAL
INDICATIVE ZONING PLAN

A1 | SCALE 1:250 UNO | DRG No C5409-6310-CE-011 | REV B



LEGEND

- CONTOUR - MINOR (0.5m INTERVAL)
- CONTOUR - MAJOR (2.5m INTERVAL)
- CLOSURE LANDFORM FOOTPRINT
- LANDFORM INTERFACE TO NATURAL SURFACE
- LEVEE

INFORMATION ONLY
NOT FOR CONSTRUCTION

100 0 100 200 300 Metres

SCALE 1 5000

CLIENT DRG No.

REF DRG No	TITLE	REV	BY	DATE	DESCRIPTION	CHKD	ENG
		A	JA	28.09.15	ISSUED FOR INTERNAL/CLIENT REVIEW		

CLIENT

TELLUS

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ISO 9001 SYSTEM CERTIFICATION SGS

	BY	DATE
DRAWN	J.ANDERSON	28/09/15
CHKD		
DES ENG		
PROJ ENG		
CLIENT		

PROJECT No C5409

TITLE
TELLUS SANDY RIDGE
PRE-FEASIBILITY STUDY
CLOSURE PLAN
GENERAL ARRANGEMENT

A1 | SCALE 1:5000 | DRG No SK-C5409-CE-001 | REV A

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Waste Acceptance Criteria and Supporting Documents

TELLUS

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SANDY RIDGE FACILITY WASTE ACCEPTANCE POLICY

Final Report | August 2016

Version	Date	Description	Signatures		
			Originator	Checked	Approved
0	10/08/2016	For issue	S. Reece	J. Livesey R. Phillips	D van der Merwe

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ABBREVIATIONS

ARPANSA	Australian Radiation Protection and Nuclear Safety Agency
The Convention	The Basel Convention
The Council	The Radiological Council
DEC	Department of Environment and Conservation
EP	Environmental Protection
The Facility	The Sandy Ridge Facility
IAEA	International Atomic Energy Agency
IWDF	Intractable Waste Disposal Facility
km	Kilometres
NHRMC	National Health and Medical Research Council
RHC	Radiation Health Committee
Tellus	Tellus Holdings Ltd.
WAC	Waste Acceptance Criteria
WAP	Waste Acceptance Procedures
WCD	Waste Classification and Waste Definitions
WZG	Waste Zoning Guidelines

DEFINITIONS

Cell - an excavated area (pit) of kaolin which is below ground level which will be used for *in cell storage* or *permanent isolation* of waste.

Conditions of storage - The term "in the conditions of storage" is used to differentiate between the generic properties of a material and how those properties may be modified when that material is placed into "in cell storage" or "permanent isolation" within a cell.

Dangerous goods – the Dangerous Goods Safety (General) Regulations 2007 defines "dangerous goods" as any substance or article that is:

a) Found to be within any of the following classes or divisions under the Australian Dangerous Goods Code: Class 1, Class 2, Class 3, Class 4, Class 5, Division 6.1, Class 8, or Class 9; unless stated otherwise within the Code.

b) named or described in Schedule 1 of the Environmental Protection (Controlled Waste) Regulations 2004

Geological repository (in the context of Sandy Ridge) - The term geological repository is used to mean a landfill facility constructed and with the equivalent properties of a Class IV or Class V Landfill as defined in Landfill Waste Classification and Waste Definitions 1996 (As amended December 2009) Western Australia Department Of Environment And Conservation. In the context of Sandy Ridge this means an arid near-surface facility used to permanently isolate waste. Geological repositories provide the highest levels of containment through the use of carefully selected natural geological barriers rather than reliance on man-made liner systems and are increasingly recognised as a cost effective and preferred method of permanently isolating difficult to manage wastes. The geological barrier provides permanent isolation of wastes from the environment over the very long term and creates additional opportunities for the future recovery and recycling of valuable materials from the waste which can re-enter the circular economy.

Hazardous waste - Component of the waste stream which by its characteristics poses a threat or risk to public health, safety or the environment (includes substances which are toxic, infectious, mutagenic, carcinogenic, teratogenic, explosive, flammable, corrosive, oxidising and radioactive). As defined in Landfill Waste Classification and Waste Definitions 1996 (As amended December 2009) Western Australia Department of Environment And Conservation

In Cell Storage - medium to long term below ground storage of wastes inside a cell with ongoing opportunity to recover waste if required.

Intractable Waste- Waste which is a management problem by virtue of its toxicity or chemical or physical characteristics which make it difficult to dispose of or treat safely, and is not suitable for disposal in Class I, II, III and IV landfill facilities. As defined in Landfill Waste Classification and Waste

Definitions 1996 (As amended December 2009) Western Australia Department Of Environment And Conservation

Permanent Isolation - indefinite below ground storage of wastes determined suitable for acceptance.

Storage - the short term above ground storage of materials following delivery and includes the time awaiting sampling, analysis and management prior to movement for “in cell storage”.

Disclaimer:

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Tellus, as part of their continuous improvement activities will review and may update and amend this document from time to time.

1 INTRODUCTION

1.1 The Sandy Ridge Facility

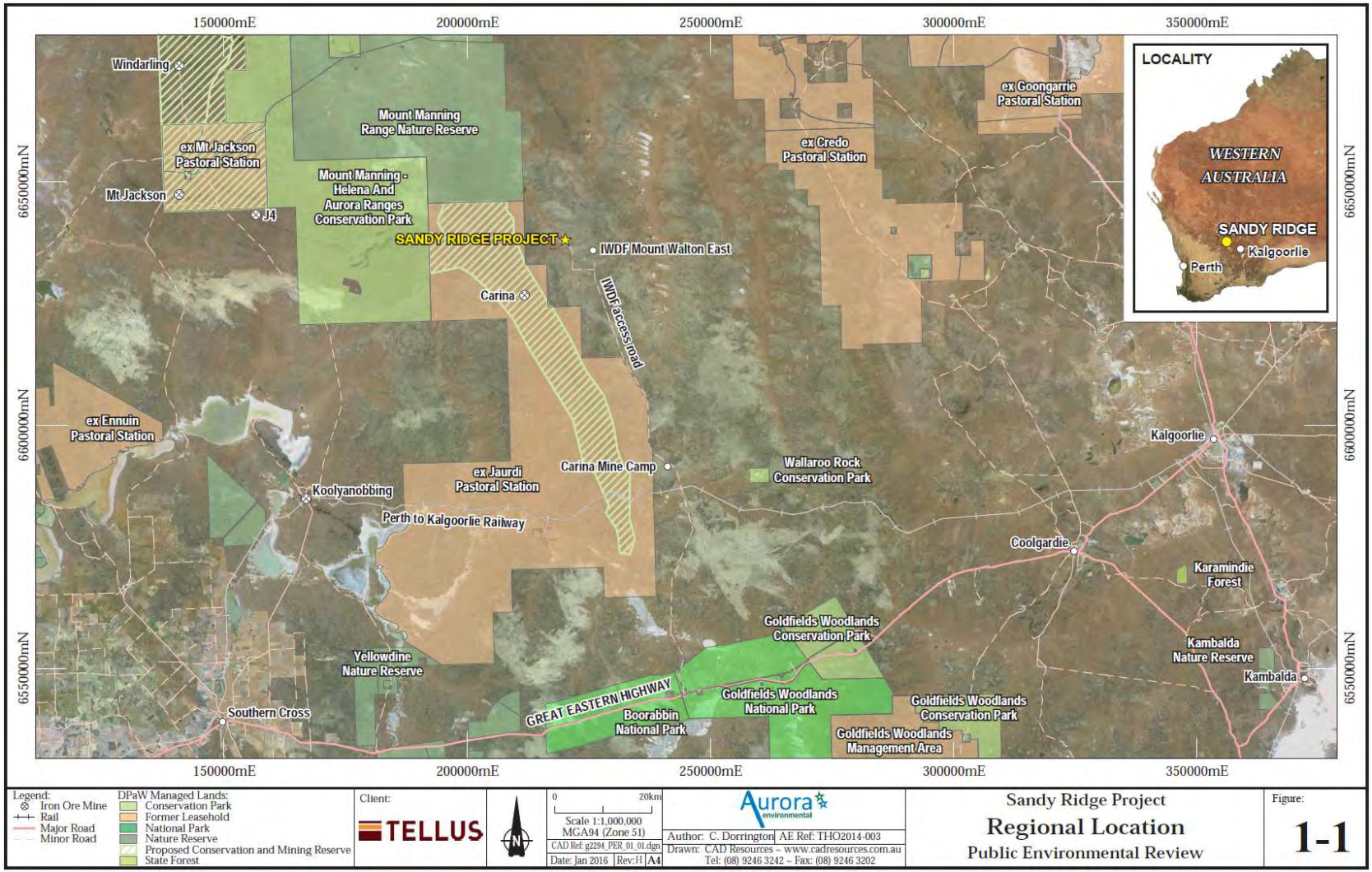
The proposed Sandy Ridge Facility (hereby referred to as the proposed "Facility") is a dual use kaolin mine with the voids created by mining used to store and permanently isolate hazardous and intractable wastes. The site is located approximately 75 km northeast of Koolyanobbing, in the Shire of Coolgardie, within the Goldfields Region of Western Australia (Figure 1-1).

The location for the Facility was specifically chosen as its principal characteristics; semi–arid climate, high rates of evaporation, geologically stable, natural geological barriers, no regional aquifer, no surface water receptors, no flooding, low erosion rates, no heritage values, topography etc. satisfy the requirements for a near surface geological repository for intractable and hazardous waste storage and isolation purposes.

There are no sensitive receptors within the immediate vicinity of the proposed Facility. The nearest operation is the Class V IWDF Mount Walton East Intractable Waste Disposal facility located approximately 6 km to the east, which operates on a campaign basis and does not have permanent residents. The nearest mining camp is the Carina Iron Ore Mine accommodation village located approximately 52 km to the south east of the proposed Facility.

The arid and remote nature of the location, absence of nearby population, coupled with the site characteristics make the site ideal for long-term storage and permanent isolation of hazardous and intractable waste.

Figure 1-1: Sandy Ridge site location



1.2 Document aims and objectives

Tellus have developed a suite of waste acceptance documents under which Tellus would operate their facilities; define the type of waste materials that would be accepted by Tellus; explain how waste material will be tested and then how the material would be stored and isolated during operations. The documents are in order of hierarchy:

- Waste Acceptance Policy.
- Waste Acceptance Criteria (WAC).
- Waste Acceptance Procedure (WAP).
- Waste Zoning Guide (WZG).

The aim of this Waste Acceptance Policy document is to set a policy framework for each of Tellus' proposed Facilities listed in Figure 1-2. This document applies to the proposed Sandy Ridge Facility.

The Waste Acceptance Policy is the Tier One document within Tellus' Waste Acceptance hierarchy, as shown in Figure 1-2. Lower tier documents provide additional detail and procedure relating to operational activities that include acceptance and zoning.

Figure 1-2: Waste Acceptance Criteria document hierarchy

1.3 Intended audience

This document is intended initially for use by regulators responsible for assessing the facility and issuing licences for the operation of the proposed Facility, and for the formation of procedures to control the process by which waste producers and Tellus staff will determine if the waste streams may be suitable for storage or permanent isolation.

The document will also be of interest to other stakeholders who wish to understand the approach being followed by Tellus for waste acceptance, including the safe storage and permanent isolation of wastes.

Finally, this document will be used by Tellus staff and their specialist advisors to establish the framework that incorporates more detailed operational procedures which underpin this document.

2 WASTE ACCEPTANCE POLICY

Before waste can be accepted for storage or permanent isolation at the proposed Sandy Ridge Facility, Tellus must be satisfied that waste meets:

- All environmental approvals and licences issued by regulators:
- The Sandy Ridge WAC.
- The Sandy Ridge WAP
- The Sandy Ridge WZG.

Together, these steps form the basis of Tellus' WAP for the proposed Sandy Ridge Facility. These are briefly summarised below and are detailed in separate standalone documents.

2.1 Waste Acceptance Criteria

WAC have been established for the proposed Facility to determine waste types which can and cannot be accepted in order to achieve safe operation. WAC were also established to ensure long term environmental protection through containment of potential pollutants present within the wastes. In some cases, the criteria used will lead to straightforward "go or no go" decisions based on compatibility with the site characteristics and WAC, and in other cases acceptance values and parameters will be used.

Whilst Tellus will ensure that waste generators are aware of the WAC for the proposed Facility, it is recognised that on some occasions particular wastes presented will not conform to set criteria and re-evaluation of appropriate management techniques will be required so as to achieve the objective of safe storage or permanent isolation so that the threat to the receiving environment is minimised or prevented.

2.2 Waste Acceptance Procedure

As part of the WAP it is necessary to first characterise the waste material. Tellus have adopted a three stage approach to waste characterisation[1] which is summarised below. The most detailed characterisation takes place to determine if waste meets the overarching criteria and licence conditions of the site, followed by further ongoing testing at levels 2 and 3 described below.

- **Level 1: Basic characterisation**. This is a thorough determination, according to standardised analysis and behaviour-testing methods, of the characteristic properties of the waste.

[1] *UK Environment Agency Waste acceptance at landfills - 2010*

- **Level 2: Compliance testing**. This is periodic testing of regularly arising wastes by simpler standardised analysis methods to determine whether a waste complies with licence conditions and whether a waste with known properties has changed significantly.

- **Level 3: On-site verification**. This constitutes rapid check methods to confirm that a waste is the same as that which has been subjected to compliance testing and that which is described in the accompanying documents.

2.3 Waste Zoning

After wastes have been accepted at the Facility it is important that they are both stored and permanently isolated in a safe manner. Within the Facility, waste materials would be grouped into compatible waste type groups that can be stored together, Dangerous Goods Segregation protocols will be adopted, in accordance with Australian Standard AS/NZ 3833.

When the waste is placed into a cell for permanent isolation, waste zoning protocols will be implemented, as presented in the WZG. The WZG have been developed to reflect the conditions of storage within the cell and how the various wastes can be stored or permanently isolated without adverse interaction. Adopting a zoning approach also increases the opportunity for potential future recovery of certain materials for beneficial use.

3 REGULATORY CONTEXT

3.1 Overview

In considering the development of the proposed Sandy Ridge Facility, Tellus has taken into account the requirements of both Commonwealth and State legislative provisions. As the proposed Facility is designed to accept hazardous and intractable wastes, and small quantities of radioactive wastes, the WAC have consequently considered a wide range of legislative requirements as guidance.

This section sets out applicable legislation, regulation and guidelines for the proposed Sandy Ridge Facility. It is to be noted that the volume of hazardous and intractable wastes received at the proposed Sandy Ridge Facility are likely to be significantly greater than proposed radioactive waste volumes.

3.2 Commonwealth legislation, regulation and guidelines

Licensing of Radioactive Waste Storage and Disposal Facilities March 2013

This Regulatory Guide is directed to proponents applying for a licence under the ARPANS Act (*Australian Radiation Protection and Nuclear Safety Act 1998*) to prepare a site for construction, operation, decommissioning and closure, if that site is intended to be a storage or disposal facility for radioactive waste.

Annex 4 in particular provides guidance on International Best Practice Guidance for the Licence Application for Near-Surface Disposal Facilities. Information is provided from Australian and international guidance documents for consideration in meeting the relevant requirements. It advises that waste acceptance should be undertaken in accordance with Section 2.6 of the *Code of practice for the near-surface disposal of radioactive waste in Australia (1992)*. Guidance on generic waste acceptance criteria for disposal of radioactive waste in Australia is provided in Annex G of *RPS No. 16 Safety Guide for the Predisposal Management of Radioactive Waste (2008)*. There is some additional guidance in *Classification of Radioactive Waste Radiation Protection Series Publication No. 20 (2010).*

Classification of Radioactive Waste Radiation Protection Series Publication No. 20 April 2010

Various methods have evolved for classifying radioactive waste according to the physical, chemical and radiological properties that are relevant to particular facilities, or circumstances, in which radioactive waste is generated and managed. Prior to 2010 Australia had never had a formal method for classifying radioactive waste. There was, however, a system of categorising radioactive waste relating to near surface disposal that was included in the *NHMRC Code of practice for the near surface disposal of radioactive waste in Australia (1992) (RHS35)*. At the time, there were three categories of waste recognised to be suitable for near surface disposal, Category A, Category B and Category C, which were pertinent to the IWDF and can be seen in the IWDF waste acceptance criteria (see below). Given more recent developments in guidance on classification of radioactive waste, in particular the *IAEA General Safety Guide Classification of Radioactive Waste (No. GSG-1)*

published in late 2009, Australia adopted a nationally uniform system of classification of radioactive waste which underpins a range of further guidance of radioactive waste management.

Radioactive waste arises from the industrial, medical and research use of radioactive materials. Some of this waste has such low activity concentrations that it falls below regulatory concern or within discharge limits that allow it to be disposed of to the atmosphere, sewer or landfill. More active radioactive waste can be stored for short periods until it has decayed to very low level radioactive waste or to levels below regulatory concern and disposed of with non-radioactive waste. Radioactive waste with higher activity concentrations need to be managed pending access to disposal facilities. It is important that all types of radioactive waste be correctly classified to ensure that appropriate disposal measures can be implemented.

Environment Protection and Biodiversity Conservation Act 1999

The *Environment Protection and Biodiversity Conservation Act 1999* is the principal environmental law administered by the Australian Government. The law regulates actions with regard to matters of national environmental significance. Under the Act, any proposed action that is likely to have a significant impact on a matter of national environmental significance must be referred to the Minister for the Environment. The proposed Sandy Ridge Facility was determined to be a 'controlled action' requiring environmental assessment by one of a number of means, including a Public Environmental Review.

A proposed nuclear action must also be referred to the Minister for the Environment and may be subject to the same environmental assessment processes.

If an environmental assessment is triggered by both the *Environment Protection and Biodiversity Conservation Act 1999* and State environmental law, a single environmental assessment was set as the agreed approval process for the proposal to address a bilateral agreement between the Australian Government and the Western Australian Government.

Australian Radiation Protection and Nuclear Safety Act 1998

The *Australian Radiation Protection and Nuclear Safety Act 1998* is the principal law regulating radioactive materials and activities. The objective of the law is to protect the health and safety of people, and to protect the environment, from the harmful effects of radiation.

The key provisions of the Act establish the Australian Radiation Protection and Nuclear Safety Agency (ARPANSA) and regulate controlled material, apparatus and facilities. ARPANSA is the regulatory body for Commonwealth agencies.

It is noted that the agency is not the regulatory body for activities that are not undertaken by the Commonwealth, instead, these responsibilities are deferred to other authorities that are established in each State or Territory. The agency produces guidance material on radioactive material and is informed by a range of advisory bodies including the Radiation Health and Safety Advisory Council, Radiation Health Committee, and the Nuclear Safety Committee.

National Environment Protection Measures (Implementation) Act 1998

The *National Environment Protection Measures (Implementation) Act 1998* gives force to the national environmental protection measures made by the National Environment Protection Council by requiring their implementation through State regulatory systems. The national environmental protection measures made by the council cover environmental matters including;

- Air Toxics.
- Ambient Air Quality.
- Assessment of Site Contamination.
- Diesel Vehicle Emissions.
- Movement of Controlled Waste between States and Territories.
- National Pollutant Inventory.
- Used Packaging Materials.

National Environment Protection (Movement of Controlled Waste between States and Territories) Measure 1998.

The National Environmental Protection (movement of controlled wastes between States and Territories) Measure provides a national framework for developing and integrating State and Territory systems for the management of the movement of controlled wastes between States and Territories originating from commercial, trade, industrial or business activities. These management systems include:

- Tracking systems which would provide information to assist agencies and emergency services, and would ensure that controlled wastes are directed to, and reach, appropriate facilities.
- Prior notification systems, which would provide participating States and Territories with access to information, to assess the appropriateness of proposed movements of controlled wastes in terms of transportation and facility selection.
- The licensing of transporters and regulation of producers and facilities so that tracking and notification functions are compatible with participating State and Territory requirements.

For the avoidance of doubt, it is noted that this Measure relates to the movement of wastes between States and Territories within Australia, and is not intended to have any direct or indirect bearing upon Australia's international rights or obligations with respect to the international movement of waste.

Code of practice for the near-surface disposal of radioactive waste in Australia (1992)

The regulatory guidelines for near surface disposal facilities *Code of practice for the near-surface disposal of radioactive waste in Australia (1992)* clearly outline the need to consider the possible

migration of contaminants, especially via leachate formation, over the life of a facility and in geological time frames. It must be safely demonstrated that the proposed Facility can effectively isolate the contaminants from the biosphere

Hazardous Waste (Regulation of Exports and Imports) Act 1989.

The *Hazardous Waste (Regulation of Exports and Imports) Act 1989* aims to regulate the export, import and transit of hazardous waste to ensure that exported, imported or transited waste is managed in an environmentally sound manner so that human beings and the environment, both within and outside Australia, are protected from the harmful effects of the waste.

This Act looks to:

- Give effect to the Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and their Disposal.
- Give effect to agreements and arrangements of the kind mentioned in Article 11 of the Basel Convention.

The Australian Code for the Transport of Dangerous Goods by Road and Rail (7th Edition)

The *Australian Code for the Transport of Dangerous Goods by Road & Rail* is developed by the National Transport Commission. The code provides classifications of dangerous goods as:

- Class 1 – Explosive.
- Class 2 – Gases.
- Class 3 – Flammable liquids.
- Class 4.1 – Flammable solids, self-reactive substances and solid desensitised explosives.
- Class 4.2 – Substances liable to spontaneous combustion.
- Class 4.3 – Substances which in contact with water emit flammable gases.
- Class 5.1 – Oxidising substances.
- Class 5.2 – Organic peroxides.
- Class 6.1 – Toxic substances.
- Class 6.2 – Infectious substances.
- Class 7 – Radioactive material.
- Class 8 – Corrosive substances.
- Class 9 – Miscellaneous dangerous substances.

The code includes a detailed list of dangerous goods by classification. The code also sets standards for storage and handling of dangerous goods including packaging, labelling, stowage and restraint, segregation and safety equipment. With regard to Class 7 – Radioactive material, the code refers to

the *Code of Practice for the Safe Transport of Radioactive Material*. Whilst the Sandy Ridge WAC does not deal with transport, there is clearly an interface between transport deliveries to site and the safe acceptance, storage, and disposal of wastes and, as such, due consideration of these regulations has been adopted in the WAC and its supportive documents.

Classification and Disposal, Radioactive Waste in Australia - Consideration of Criteria for Near Surface Burial in an Arid Area ARPANSA Technical Report No. 152

In 1986, the National Health and Medical Research Council requested its Radiation Health Standing Committee (RHC) to prepare a code of practice and guidelines on radioactive waste management in order to develop criteria for classifying radioactive waste for disposal and to provide guidance on the selection of sites for near-surface disposal of waste.

This document provides background on the development of the published NHMRC *Code of practice for the near-surface disposal of radioactive waste in Australia* (see above). Although effectively superseded by the *Classification of Radioactive Waste Radiation Protection Series Publication No. 20 April 2010* (see above), this classification is used by the IWDF and has therefore been left in this document as an important reference, and for completeness.

3.3 State legislation, regulation and guidelines

Disposal of Chemical wastes at the Intractable Waste Disposal Facility (Mount Walton East) – Waste Acceptance Guidelines April 2011

Tellus is currently seeking approval for the proposed Facility to be licenced as a Class V landfill. Subject to approval, it will be one of only two Class V landfill sites in Western Australia, the other being the Mount Walton East Intractable Waste Disposal Facility (IWDF), located approximately 6 km East South-East of the proposed Facility. Since first becoming operational in 1992, the IWDF has demonstrated the effective isolation of Class V wastes over many years.

Due to their close proximity, both sites possess very similar geology and environmental conditions, Tellus has carefully considered the WAC and procedures for the IWDF and applied them where appropriate to the proposed Sandy Ridge Facility.

It must be noted that Tellus wishes to have the ability to accept wastes that are excluded from the IWDF provided it can be demonstrated that safe storage or permanent isolation can occur. In order to achieve this, Tellus will formulate strategies for the treatment of certain waste items prior to acceptance.

The IWDF waste acceptance criteria details the generic properties and characteristics that are unsuitable for disposal at the IWDF.

- Liquids.
- Explosive materials.
- Highly flammable materials.

- Highly reactive materials.
- Gases.
- Materials that decompose.

Category S[2] radioactive material.

Department of Environment and Conservation (DEC) Landfill Waste Classification and Waste Definitions 1996 (As amended December 2009)

The Western Australia Department of Environment and Conservation (DEC) Landfill Waste Classification and Waste Definitions 1996 (As amended December 2009) (WCD) is one of the key government issued guidelines utilised to inform the development of the Facility's WAC. It provides detailed descriptions of the five different landfill classifications used in Western Australia, which are presented in Table 3-1

Waste Avoidance and Resource Recovery Regulations 2008

The Waste Avoidance and Resource Recovery Regulation 2008 outlines details of the landfill levy and appoints the landfill owner or licensee as the person liable for payment of the levy for all wastes received.

The Regulation also ensures the operator will record and maintain details of the wastes once received at the facility including:

- The time and date of the delivery.
- The name and licence number of the licensee.
- The volume of the waste disposed of to landfill on the premises and a description of the type of waste.
- Where appropriate and if necessary, the amount of levy payable in respect of the waste.
- Any other particulars relevant to the calculation or verification of the amount of the levy payable by the licensee.

Waste Avoidance and Resource Recovery Levy Regulations 2008

The *Waste Avoidance and Resource Recovery Levy Regulations 2008* sets the levy for waste disposal for all wastes collected within the Perth metropolitan region. Most wastes accepted by the proposed

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[2] *The Code of Practice for the Near Surface Disposal of Radioactive Waste in Australia (1992) states that Category S radioactive material is unacceptable for near-surface disposal. Category S – covers waste that does not meet the specifications of Categories A, B or C. Typically this category will comprise sealed sources, gauges or bulk waste which contains radionuclides at higher concentrations than are allowable under Categories A, B or C.*

Facility will be exempt from the levy by virtue of not being able to be reasonably reused, reprocessed, recycled or used in energy recovery.

Waste Avoidance and Resource Recovery Act 2007

The *Waste Avoidance and Resource Recovery Act 2007* outlines the requirements for the state to develop and maintain a waste strategy, the purpose of which is to provide for long term continuous improvement of waste services, waste avoidance and resource recovery, and set out targets for waste reduction, resource recovery and the diversion of wastes from landfill disposal.

Dangerous Goods Safety Act 2004

The *Dangerous Goods Safety Act 2004* outlines the responsibilities and penalties for persons responsible, directly or indirectly, for storing, handling, or transporting dangerous goods.

The responsibilities include the need to notify in certain instances and occurrences, and for those involved in the storage and handling of dangerous goods to have suitable safety management systems, and for licencing of persons and vehicles involved with the transport of dangerous goods.

The WAC and associated procedures will capture details of transporters and outline reporting requirements for items being stored above ground prior to relocation for In Cell Storage or permanent isolation.

Environmental Protection (Controlled Waste) Regulations 2004

Controlled wastes, by definition, include all liquid waste, and any wastes that cannot be disposed of at a Class I, II or III landfill site. Controlled wastes also include asbestos, clinical or related waste, tyres and waste that has been immobilised or encapsulated. The Department of Environment Regulation regulates the transportation of controlled wastes that may cause environmental or health risks. It does so through the application of the Environmental Protection (Controlled Waste) Regulations 2004. The Regulations provide for the licensing of carriers, drivers and vehicles involved in the transportation of controlled wastes on public roads.

Schedule 1 of the Regulations identifies the waste which is classified as controlled. The waste may also be dangerous goods. Regulations relating to transporting dangerous goods are separate from controlled waste.

Nuclear Waste Storage and Transportation (Prohibition) Act 1999

The *Nuclear Waste Storage and Transportation (Prohibition) Act 1999* prohibits the construction or operation of a nuclear waste storage facility in Western Australia or the use of any place in the State for the storage or disposal of nuclear waste. It also prohibits the transport of nuclear waste in the State. Nuclear waste in this case means material that is or contains a radioactive substance which has been derived from a nuclear reactor, a radioisotope enrichment plant involved in the enrichment of uranium or plutonium, a nuclear reprocessing plant or a nuclear weapons facility, or

from the testing, use or decommissioning of nuclear weapons. Tellus has clearly stated it will not store or dispose of such material.

Environmental Protection Act 1986 and Environmental Protection Regulations 1987

The Department of Environment Regulation (DER) has responsibility under Part V of *the Environmental Protection Act 1986* (EP Act) for the licensing and registration of prescribed premises, the issuing of works approvals and administration of a range of regulations. DER also monitors and audits compliance with works approvals, licence conditions and regulations, takes enforcement actions as appropriate, and implements Departmental licensing and industry regulation policy. DER is responsible for regulating industrial emissions and discharges to the environment through the works approval and licensing process.

The EP Act requires a works approval to be obtained before constructing a prescribed industrial premises and makes it an offence to cause an emission or discharge unless a licence or registration is held for the premises. Prescribed premises categories are outlined in Schedule 1 of the Environmental Protection Regulations 1987.

Table 3-1 Landfill classes and waste types in Western Australia

Landfill class	Common name	Waste types permitted for disposal
Class I (Prescribed Premises Category 63)	Inert landfill	• Clean fill. • Type 1 inert waste. • Contaminated solid wastes meeting waste acceptance criteria specified for Class I landfills (possibly with specific licence conditions). • Type 2 inert waste (with specific license conditions). • Type 3 inert waste (subject to DEC approval). • Type 1 special waste.
Class II (Prescribed Premises Category 64 or 89)	Putrescible landfill	• Clean fill. • Type 1 inert waste. • Putrescible wastes. • Contaminated solid waste meeting waste acceptance criteria specified for Class II landfills (possibly with specific license conditions). • Type 2 inert wastes (with specific license conditions). • Type 1 and Type 2 special wastes (for registered sites as approved under the Controlled Waste Regulations).
Class III (Prescribed Premises Category 64)	Putrescible landfill	• Clean fill. • Type 1 inert waste. • Putrescible wastes. • Contaminated solid waste meeting waste acceptance criteria specified for Class II or Class III landfills (possibly with specific license conditions). • Type 2 inert wastes (with specific license conditions). • Type 1 and Type 2 special wastes.
Class IV (Prescribed Premises Category 65)	Secure landfill	• Clean fill. • Type 1 inert waste. • Contaminated solid waste meeting criteria specified for Class II, Class III or Class IV landfills (possibly with specific license conditions). • Type 2 inert wastes (with specific license conditions). • Type 1 and Type 2 special wastes.
Class V (Prescribed Premises Category 66)	Intractable landfill	• Intractable and other wastes in accordance with the approvals for site.

The WCD provides explanation as to the steps that should be taken to classify waste in order to enable its assignment to the appropriate class of landfill. It provides clear examples of waste types and provides specific examples of hazardous and intractable wastes, which is of particular relevance to the Facility's WAC.

Additionally, contaminant thresholds, leachable concentrations, and concentration limits are stipulated for a wide range of contaminants for Class I to Class IV landfills. The Acceptance Criteria stipulated for Intractable Class V Landfills are to store or treat waste as appropriate.

Radiation Safety (General) Regulations 1983

Regulation 31A of the Radiation Safety (General) Regulations 1983 deals with the Near-surface disposal of radioactive waste. The regulations require a disposal facility, in this case the proposed Facility, to comply with the requirements of the *Code of practice for the near-surface disposal of radioactive waste in Australia (1992).*

Radiation Safety Act 1975

The Radiological Council (the Council) is an independent statutory authority appointed under the *Radiation Safety Act* in Western Australia to assist the Minister for Health to protect public health and to maintain safe practices in the use of radiation. The *Radiation Safety Act 1975* regulates the keeping and use of radioactive substances, irradiating apparatus (e.g. x-ray equipment) and certain electronic products (e.g. lasers, sun-tanning units, and UV transilluminators). The Act applies to both ionising and non-ionising radiation. Registration and licensing are the principal means by which the use of radiation is regulated. Daily administration of the Act is handled by personnel of the Radiation Health Branch.

Section 34 of the *Radiation Safety Act 1975* deals with the issuing of disposal permits by the Council. A disposal permit authorises the holder to deal with the substance, apparatus or product in a manner satisfactory to the Council in accordance with the provisions of, and within the period specified in, that permit.

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Waste Acceptance Criteria and Supporting Documents

TELLUS

SANDY RIDGE FACILITY
WASTE ACCEPTANCE CRITERIA

Final Report | August 2016

Version	Date	Description	Signatures		
			Originator	Checked	Approved
0	10/08/2016	For issue	S. Reece	J. Livesey R. Phillips	D van der Merwe

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ABBREVIATIONS

ARPANSA	Australian Radiation Protection and Nuclear Safety Agency
Bq	Bequerel
EW	Exempt Waste (Radioactive)
The Facility	The Sandy Ridge Facility
g	Gram
HLW	High Level Waste (Radioactive)
IAEA	International Atomic Energy Agency
TECDOC	Technical Document published by IAEA
IBC	Intermediate Bulk Container
ILW	Intermediate Level Waste (Radioactive)
ISO	International Organisation for Standardization
IWDF	Intractable Waste Disposal Facility
km	Kilometres
kPa	Kilopascals
L	Litre
LLW	Low Level Waste (Radioactive)
mSv/y	Milli-Sievert per year
NEPM	National Environmental Protection Measure
NHMRC	National Health and Medical Research Council
NORM	Naturally Occurring Radioactive Materials
PPE	Personal Protective Equipment
Tellus	Tellus Holdings Ltd.
VLLW	Very Low Level Waste (Radioactive)

VSLW	Very Short Lived Waste (Radioactive)
WAC	Waste Acceptance Criteria
WAP	Waste Acceptance Procedure
WZG	Waste Zoning Guidelines

DEFINITIONS

Cell - an excavated area (pit) of kaolin which is below ground level which will be used for *in cell storage* or *permanent isolation* of waste.

Conditions of storage – The term "in the conditions of storage" is used to differentiate between the generic properties of a material and how those properties may be modified when that material is placed into "in cell storage" or "permanent isolation" within a cell.

Dangerous goods – the Dangerous Goods Safety (General) Regulations 2007 defines "dangerous goods" as any substance or article that is:

a) Found to be within any of the following classes or divisions under the Australian Dangerous Goods Code: Class 1, Class 2, Class 3, Class 4, Class 5, Division 6.1, Class 8, or Class 9; unless stated otherwise within the Code.

b) named or described in Schedule 1 of the Environmental Protection (Controlled Waste) Regulations 2004

Geological repository (in the context of Sandy Ridge) - The term geological repository is used to mean a landfill facility constructed and with the equivalent properties of a Class IV or Class V Landfill as defined in Landfill Waste Classification and Waste Definitions 1996 (As amended December 2009) Western Australia Department Of Environment And Conservation. In the context of Sandy Ridge this means an arid near-surface facility used to permanently isolate waste. Geological repositories provide the highest levels of containment through the use of carefully selected natural geological barriers rather than reliance on man-made liner systems and are increasingly recognised as a cost effective and preferred method of permanently isolating difficult to manage wastes. The geological barrier provides permanent isolation of wastes from the environment over the very long term and creates additional opportunities for the future recovery and recycling of valuable materials from the waste which can re-enter the circular economy.

Hazardous waste - Component of the waste stream which by its characteristics poses a threat or risk to public health, safety or the environment (includes substances which are toxic, infectious, mutagenic, carcinogenic, teratogenic, explosive, flammable, corrosive, oxidising and radioactive). As defined in Landfill Waste Classification and Waste Definitions 1996 (As amended December 2009) Western Australia Department Of Environment And Conservation

In Cell Storage – medium to long term below ground storage of wastes inside a cell with ongoing opportunity to recover waste if required.

Intractable Waste - Waste which is a management problem by virtue of its toxicity or chemical or physical characteristics which make it difficult to dispose of or treat safely, and is not suitable for disposal in Class I, II, III and IV landfill facilities. As defined in Landfill Waste Classification and Waste

Notice and Certification Assurance program - Tellus' Notices and Certificates that include the following: Customer Dispatch, Arrival and Rejection Notices and Tellus-Acceptance©, Tellus-Storage©, Tellus-Recovery© Tellus-Solidification© and Tellus-Permanent Isolation Certificates©.

Permanent Isolation – indefinite below ground storage of wastes determined suitable for acceptance.

Storage – the short term above ground storage of materials following delivery and includes the time awaiting sampling, analysis and management prior to movement for "in cell storage".

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1 INTRODUCTION

1.1 The Sandy Ridge Facility

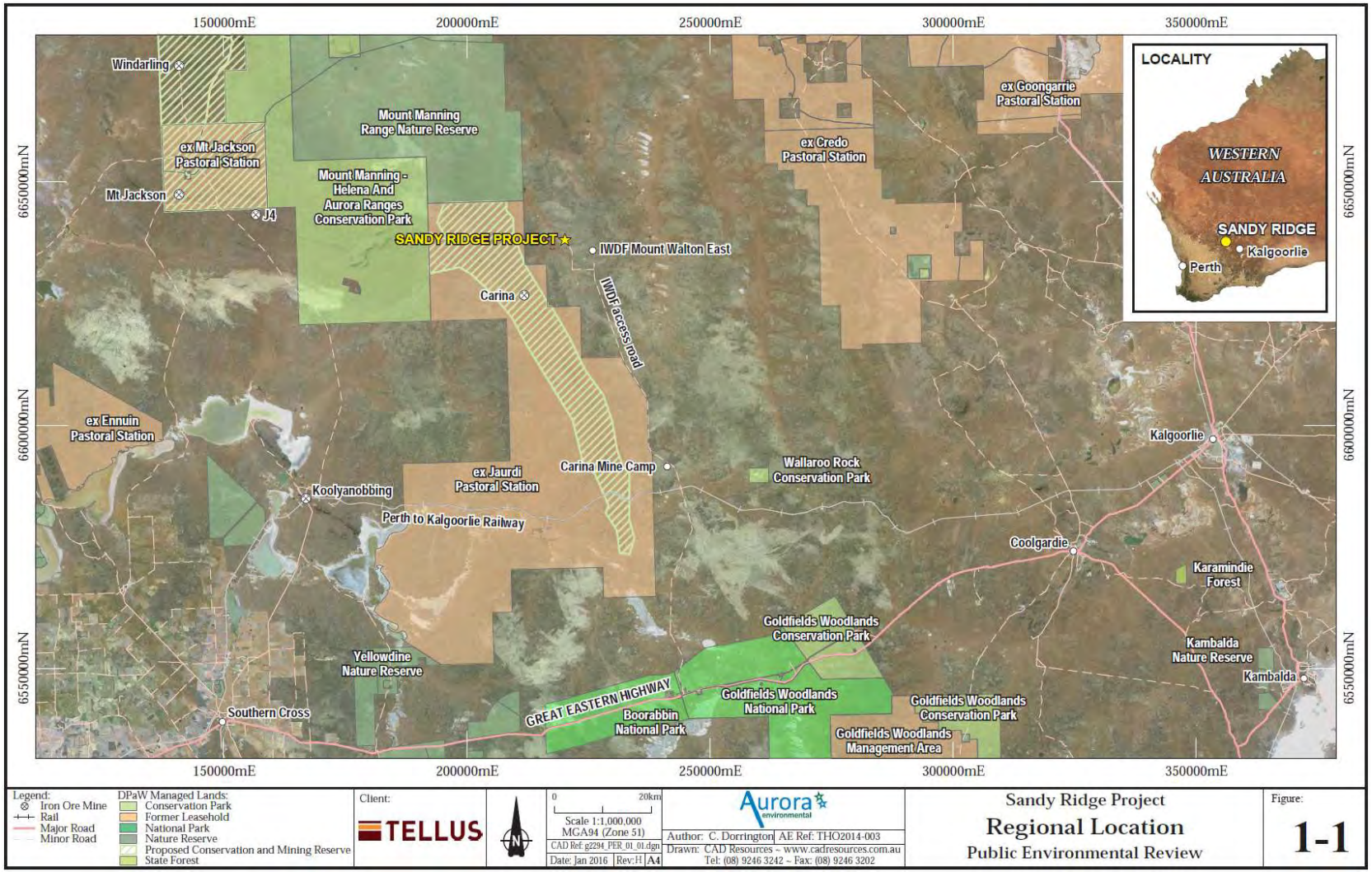
The proposed Sandy Ridge Facility (hereby referred to as the proposed "Facility") is a dual use kaolin mine with the voids created by mining used to store and permanently isolate hazardous and intractable wastes. The site is located approximately 75 km northeast of Koolyanobbing, in the Shire of Coolgardie, within the Goldfields Region of Western Australia (Figure 1-1).

The location for the Facility was specifically chosen as its principal characteristics; semi–arid climate, high rates of evaporation, geologically stable, natural geological barriers, no regional aquifer, no surface water receptors, no flooding, low erosion rates, no heritage values, topography etc. satisfy the requirements for a near surface geological repository for intractable and hazardous waste storage and isolation purposes.

There are no sensitive receptors within the immediate vicinity of the proposed Facility. The nearest operation is the Class V IWDF Mount Walton East Intractable Waste Disposal facility located approximately 6 km to the east, which operates on a campaign basis and does not have permanent residents. The nearest mining camp is the Carina Iron Ore Mine accommodation village located approximately 52 km to the south east of the proposed Facility.

The arid and remote nature of the location, absence of nearby population, coupled with the site characteristics make the site ideal for long-term storage and permanent isolation of hazardous and intractable waste.

Figure 1-1: Sandy Ridge site location



1.2 Document Aims and Objectives

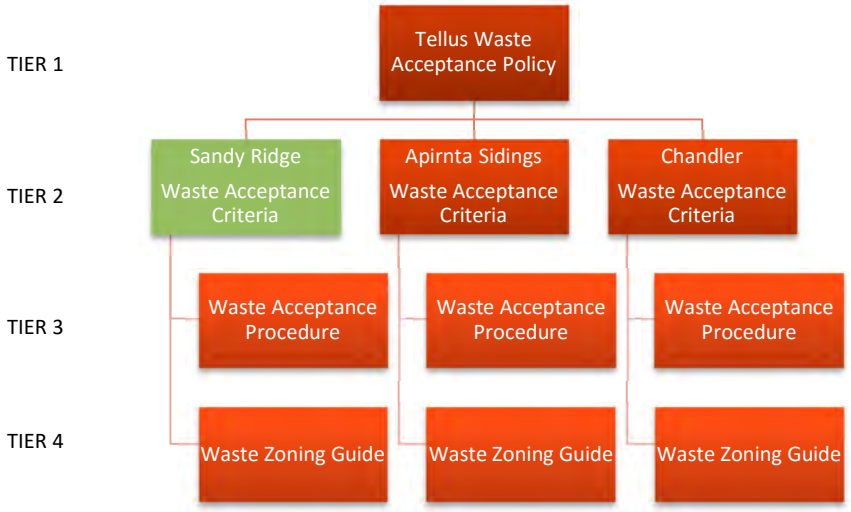
The aim of this document is to present the Waste Acceptance Criteria (WAC) that will be applied at the Facility. This document should be read in conjunction with the following:

- Waste Acceptance Policy.
- Waste Acceptance Procedure (WAP).
- Waste Zoning Guide (WZG).

This document is part of a hierarchy of documents and is the tier 2 document which covers the WAC. Lower tier documents provide greater detail on specific criteria and procedures.

The document hierarchy is presented in Figure 1-2, which includes an equivalent suite of documents for Tellus' Northern Territory Chandler Project.

Figure 1-2: Waste Acceptance Criteria Document Hierarchy



The objective of the Sandy Ridge WAC is to establish and explain to regulators, customers and other stakeholders;

- The criteria that will be applied for the exclusion of certain types of wastes.
- The criteria that will be applied to the acceptance of certain types of wastes.
- The requirement for suitable packaging and the criteria that will be applied for packaging acceptance.

1.3 Intended Audience

This document is intended initially for use by regulators responsible for assessing the facility and issuing licences for the operation of the proposed Facility, and for the formation of procedures to control the process by which waste producers and Tellus Staff will determine if the waste streams may be suitable for storage or permanent isolation.

The document will also be of interest to other stakeholders who wish to understand the approach being followed by Tellus for waste acceptance, including the safe storage and permanent isolation of wastes.

Finally, this document will be used by Tellus staff and their specialist advisors to establish the framework that incorporates more detailed operational procedures which underpin this document.

2 WASTE ACCEPTANCE CRITERIA

2.1 Introduction

Tellus is proposing to develop a world's best practice facility designed for the storage and permanent isolation of hazardous chemical waste. Tellus is also planning to accept waste arising from the power, electronics, ceramics, mining, metals and minerals processing, oil and gas, water and agricultural fertiliser industries that contains NORM. Tellus will apply for a Licence (Controlled Action under Commonwealth legislation) to accept non-nuclear low level radioactive waste (LLW) such as sealed sources. The Sandy Ridge Environmental Scoping Document and Draft Public Environmental Review state the wastes which will not be disposed of at the proposed Facility which include; infectious materials, nuclear material[1], intermediate and high level radioactive waste, uncertified waste, and putrescible waste. A summary of the wastes which are proposed to be accepted are presented in Table 2-1.

Table 2-1: Summary of waste acceptance classifications at Sandy Ridge

Waste classification	Accepted
Chemical waste (NEPM Schedule A List 1: Waste categories)	Yes
Naturally occurring radioactive waste ("NORM")	Yes
Low level radioactive waste (LLW)	Yes
Intermediate level radioactive waste (ILW)	No
High level radioactive waste (HLW)	No

2.2 Excluded waste criteria

It is normal when establishing waste acceptance criteria for storage and permeant isolation to first determine which wastes, under normal circumstances, will not be accepted i.e. will be excluded. In making this determination, and in keeping with best practice in similar facilities, including the Mount Walton East Intractable Waste Disposal Facility (IWDF), wastes that may undergo undesired physical, chemical or biological transformation after they have been deposited will not be accepted at Sandy Ridge.

Materials possessing the following characteristics, unless they pass the WAC tests outlined in the WAP, will normally be excluded from storage and permanent isolation at the Sandy Ridge Facility

[1] *Nuclear material as defined in the Nuclear Waste Storage and Transportation (Prohibition) Act 1999 - is waste of a nuclear plant; or results from the testing, use or decommissioning of nuclear weapons, whether or not that material has been conditioned or reprocessed*

unless they can be modified to a form that makes them suitable for storage or permanent isolation, and they subsequently pass the WAP tests.

2.2.1 Liquids

Unless they can undergo solidification/stabilisation processing to make them suitable for permanent isolation, liquid wastes are to be excluded from permanent isolation at the proposed Facility. It is assumed that containers containing liquids will eventually fail in the conditions of storage and allow the liquid to seep into the encapsulating clay.

Although the adsorbent properties of the surrounding kaolin formation will prevent movement of the wastes off-site, it is possible that the loss of volume could damage the cap and allow infiltration of water into the cell. Similarly, waste sludges are to be excluded from permanent isolation at the Facility unless treatment can be applied to remove any free liquid and create a waste form which is structurally sound and in keeping with maintaining the integrity of the cell capping.

2.2.2 Explosive materials

The following classes of materials, as defined by *The Australian Code for the Transport of Dangerous Goods by Road and Rail* (2016) **in the conditions of storage**[2] are not acceptable;

- Class 1.1 – substances and articles that have a mass explosion hazard (a mass explosion is one that affects almost the entire load virtually instantaneously).
- Class 1.2 – substances and articles that have a projection hazard but not a mass explosion hazard.
- Class 1.3 – substances and articles that have a fire hazard and either a minor blast hazard or a minor projection hazard or both, but not a mass explosion hazard. This includes substances and articles that give rise to considerable radiant heat, or that burn one after another, producing minor blast or projection effects or both.

Materials that are not themselves explosive but which have the potential to form or generate an explosive atmosphere of gas or vapour may not be suitable for permanent isolation at the Facility. This would depend on several factors such as the rapidity of vapour or gas generation and the reactions involved and should be assessed by a suitably qualified person prior to acceptance being confirmed.

[2] *The term in the conditions of storage is used to differentiate between the generic properties of a material and how those properties may be modified when that material is placed into storage or is permanently isolated within a disposal cell.*

2.2.3 Highly flammable materials

The following classes of materials, as defined in The Australian Code for the Transport of Dangerous Goods by Road and Rail (2016), **in the conditions of storage** will not be accepted;

- **Class 3 – Flammable liquids**. Liquids, or mixtures of liquids, or liquids containing solids in solution or suspension which give off a flammable vapour at temperatures of not more than 60 °C, closed cup test, or not more than 65.6 °C, open-cup test, normally referred to as the flash point.

- **Class 4.1 – Flammable solids**. Solids which, under conditions encountered in transport, are readily combustible or may cause or contribute to fire through friction; self-reactive substances which are liable to undergo a strongly exothermic reaction; solid desensitised explosives which may explode if not diluted sufficiently;

- **Class 4.2 – Substances liable to spontaneous combustion**. Substances which are liable to spontaneous heating under normal conditions encountered in transport, or to heating up in contact with air, and being then liable to catch fire;

- **Class 4.3 – Substances which in contact with water emit flammable gases**. Substances which, by interaction with water, are liable to become spontaneously flammable or to give off flammable gases in dangerous quantities.

Some substances that are flammable, such as wood and synthetic materials, may be acceptable for permanent isolation if they require an open flame and oxygen for combustion since in the conditions of storage they will be buried in an environment essentially devoid of both these characteristics. Class 4.3 may be suitable in the conditions of storage due to the absence of water at the Facility.

2.2.4 Highly reactive materials

The following classes of materials, as defined in *The Australian Code for the Transport of Dangerous Goods by Road and Rail* (2016), when **in the conditions of storage** will not be accepted:

- **Class 5 – Oxidising Substances**. Substances that, while in themselves not necessarily combustible, may, generally by yielding oxygen, cause, or contribute to, the combustion of other materials.

- **Class 8 – Corrosive substances**. Substances that, by chemical action, will cause severe damage when in contact with living tissue, or, in the case of leakage, will materially damage or even destroy, other goods or the means of transport; and may cause other hazards

Verification of the oxidising or corrosive nature of the material may be required, by a combination of chemical (pH) and other corrosivity testing.

2.2.5 Gases

Gases will not be accepted at the Facility, even if altered into a liquid or solid form (e.g. compressed, liquefied, dissolved, or adsorbed). Permanent isolation cannot be guaranteed, and gas migration could cause a loss of volume within the permanent isolation cell, resulting in subsequent damage to the capping system. This, in turn, leads to possible water infiltration into the cell, and uncontrolled escape of the gas to the atmosphere.

2.2.6 Infectious materials

Infectious wastes such as "Clinical wastes" as defined in the *Environmental Protection (Controlled Wastes) Regulation 2004* includes waste generated by medical, nursing, dental, veterinary, pharmaceutical or other related activity which is;

- Poisonous or infectious.
- Likely to cause injury to public health.
- Contains human tissue or body parts.

The "Clinical and Related Waste Management Policy" has been developed and adopted by the Government of Western Australia, Department of Health to control the permanent isolation of clinical wastes.

2.2.7 Biodegradable materials

The IWDF *Waste Acceptance Guidelines*[3] state that materials that are likely to decompose and produce combustible hazardous gases, or wastes that decompose and become compressible are not suitable for near-surface disposal, since any significant volume reduction could compromise the integrity of the capping system. In addition, gases generated within a waste cell have the potential to create subsurface pathways, which could provide a route for subsequent rainwater ingress to the cell. Such materials include organic, domestic wastes.

2.2.8 Nuclear material

The *Nuclear Waste Storage and Transportation (Prohibition) Act 1999,* defines nuclear waste as material that is, or contains, a radioactive substance, provided that the material in question is either waste from a nuclear plant, or waste resulting from the testing, use or decommissioning of nuclear weapons, whether that material has been reprocessed or not. Wastes classified as nuclear wastes will not be accepted at the proposed Sandy Ridge facility. For the avoidance of doubt the definition of nuclear waste does not include waste that results from the use of the products of a nuclear plant.

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[3] *Disposal Of Chemical Wastes At The Intractable Waste Disposal Facility, Mt Walton East Waste Acceptance Guidelines April 2011 Revision*

2.3 Chemical waste acceptance

2.3.1 Introduction

The types and forms of chemical waste that are likely to be managed at the proposed Facility would be generated from industry. Examples of these wastes and their NEPM code are listed in Table 2-2.

Table 2-2: Example chemical wastes likely to be suitable for permanent isolation at Sandy Ridge

NEPM code	Waste description
N205	Residues from industrial waste treatment/disposal operations
D110	Inorganic fluorine compounds excluding calcium fluoride
N120	Soils contaminated with a controlled waste
N220	Asbestos
J120	Waste oil/water, hydrocarbons/water mixtures or emulsions
D220	Lead; lead compounds
C100	Basic solutions or bases in solid form
D230	Zinc compounds
J100	Waste mineral oils unfit for their original intended use
D300	Non-toxic salts
B100	Acidic solutions or acids in solid form
N160	Encapsulated, chemically-fixed, solidified or polymerised wastes referred to in this list
F100	Waste from the production, formulation and use of inks, dyes, pigments, paints, lacquers and varnish
M100	Waste substances and articles containing or contaminated with polychlorinated biphenyls, polychlorinated napthalenes, polychlorinated terphenyls and/or polybrominated biphenyls
N100	Containers and drums that are contaminated with residues of substances referred to in this list
N190	Filter cake contaminated with residues of substances referred to in this list
G110	Organic solvents excluding halogenated solvents
M250	Surface active agents (surfactants), containing principally organic constituents and which may contain metals and inorganic materials
A100	Waste resulting from surface treatment of metals and plastics
N150	Fly ash, excluding fly ash generated from Australian coal fired power stations

2.4 Radioactive waste acceptance

2.4.1 Introduction

The types and forms of radioactive waste that are likely to be managed at the proposed Facility would be generated from:

- Mining and processing of mineral ores or other material containing NORM, such as phosphate minerals, mineral sands, coal, some gold bearing rocks and hydrocarbons. These generally contain long lived radionuclides at relatively low concentrations. NORM such as

scales arising in the oil and gas industry may have higher activity concentration levels but would still be categorised as low level wastes.

- Intervention actions, which are necessary after accidents or to remediate areas affected by past practices.
- Medicine, research and industry (use of radioisotopes and sealed radioactive sources which contains low activity concentrations).
- Permanent isolation of disused sealed radioactive sources (including orphan sources).

All wastes need to be characterised by means of collecting information about the waste in order to build up a picture of its properties. Data will be collected about the radiological, chemical and physical properties of the waste. This information helps to decide how the waste should be handled, packaged, stored and safely disposed of by the facility.

2.4.2 Classification of radioactive waste

Radioactive waste is defined as radioactive material in gaseous, liquid or solid form for which no further use is foreseen, and which is controlled as radioactive waste by a regulatory body.

In Australia there are two principal documents which discuss the classification of radioactive waste:

- The ARPANSA Safety Guide for the *Classification of Radioactive Waste* (2010) (RPS20).
- NHMRC *Code of practice for the near surface disposal of radioactive waste in Australia* (1992) (RHS35).

A system of categorising radioactive waste relating to near surface disposal is proposed in the NHMRC Code of practice. The classification was based on international recommendations for radioactive waste management adapted for the type of waste generated in Australia.

The categories suitable for near surface disposal are Category A, Category B and Category C. Category S is not suitable for near surface disposal. This classification summarised in Table 2-3. The classification is only used by regulatory authorities to classify waste destined for disposal, not as a general classification system.

Table 2-3: Code of practice for the near surface disposal of radioactive waste in Australia (1992) - waste classification summary

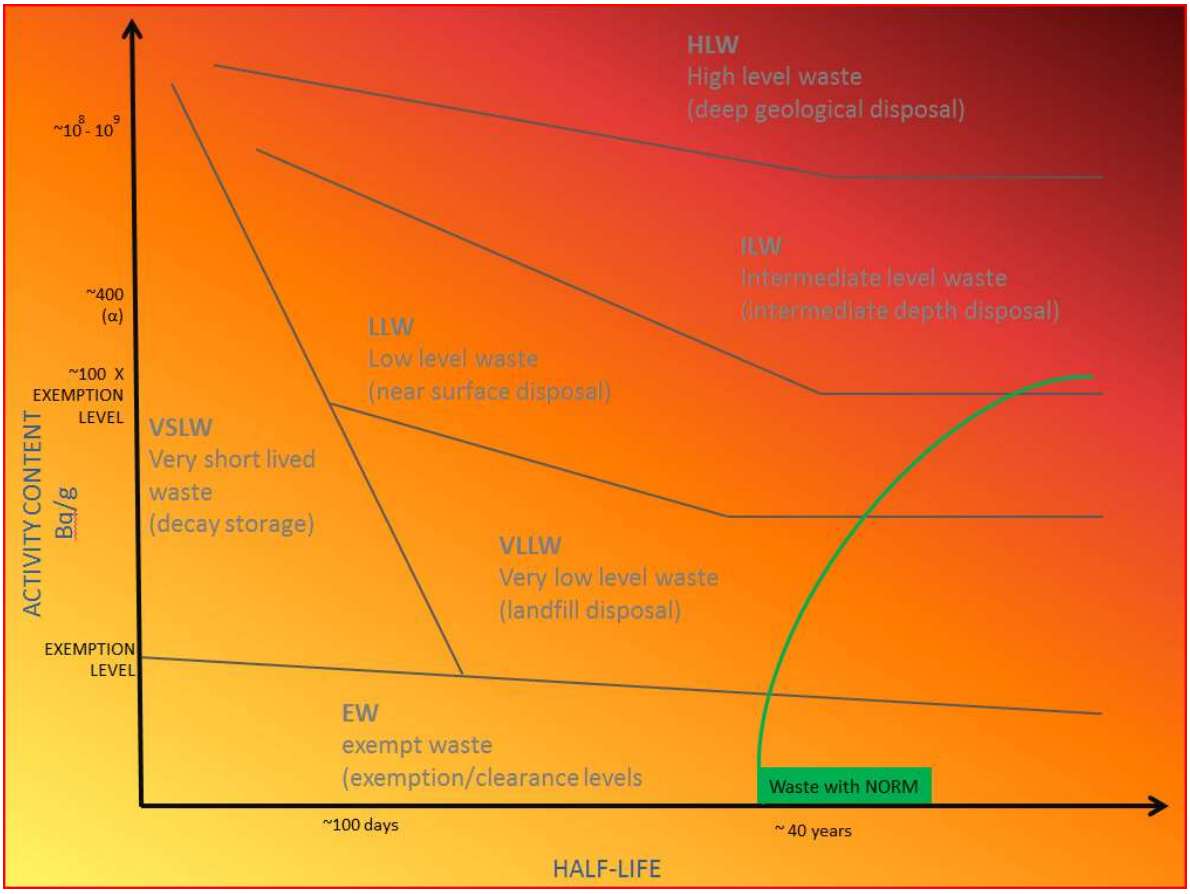
Waste category near surface code	Definition
Category A waste	Category A waste covers solid waste with radioactive constituents, mainly beta or gamma emitting radionuclides. Long-lived alpha-emitting radionuclides should only be present at very low concentrations. This category of waste will comprise, predominantly, lightly contaminated or activated items such as paper, cardboard, plastics, rags, protective clothing, glassware, laboratory trash or equipment, certain consumer products and industrial tools or equipment. It may also comprise lightly contaminated bulk waste from mineral processing or lightly contaminated soils.
Category B waste	Covers solid waste and shielded sources with considerably higher activities of beta- or gamma-emitting radionuclides than Category A waste. Long-lived alpha-emitting radionuclides should be at relatively low levels. This category of waste will comprise, typically, gauges and sealed sources used in industry, medical diagnostic and therapeutic sources or devices, and small items of contaminated equipment.
Category C waste	Covers solid waste containing alpha-, beta- or gamma-emitting radionuclides with activity concentrations similar to those for Category B. However, this waste typically will comp rise bulk materials, such as those arising from downstream processing of radioactive minerals, significantly contaminated soils, or large individual items of contaminated plant or equipment for which conditioning would prove to be impractical
Category S waste	Covers waste that does not meet the specifications of Categories A, B or C. Typically this category will comprise sealed sources, gauges or bulk waste which contains radionuclides at higher concentrations than are allowable under Categories A, B or C.

The classification of radioactive waste has been defined in international standards developed by the International Atomic Energy Agency (IAEA). The ARPANSA *Safety Guide for Classification of Radioactive Waste (2010)* largely reflects this international guidance. It does not include quantitative values of allowable activity content for each significant radionuclide.

Radioactive waste generated in Australia generally falls within the very short lived waste (VSLW), very low level waste (VLLW), low level waste (LLW) or intermediate level waste (ILW) classifications. Australia does not generate any electricity from nuclear power and therefore currently does not generate any used fuel that would be classified as high level waste (HLW).

Figure 2-1 presents a conceptual illustration of the waste classification system and potential permanent isolation options. Tellus is seeking approval to accept radioactive wastes that will fall into the EW, VSLW, SLW and LLW classifications.

Figure 2-1 Conceptual illustration of the waste classification system and potential permanent isolation options



2.4.3 Acceptance criteria

The effective management of EW, VSLW, VLLW and LLW depends on knowledge of the waste characteristics and the contained radioactivity.

The proposed Facility seeks approval for a wide variety of waste, ranging from lightly contaminated soil to sealed sources. The design of the Facility allows for a range of containers to be used for different types of waste, for example 200-litre drums and engineered concrete canisters or other modular containers or structures that meet containment and structural requirements

The property of radioactive waste varies, not only in terms of radioactive content and activity concentration but also in terms of physical and chemical properties. A common characteristic of all radioactive waste is its potential to present a hazard to people and to the environment, and it must be managed so as to reduce any associated risk to acceptable levels as defined by regulations which consider both the operational and post closure phases the Facility.

Predisposal management of radioactive waste

The overall objective of predisposal management of radioactive waste is to produce waste packages that can be handled, transported, stored and disposed securely and safely. In addition to compliance with individual dose limits, the practices that are adopted in waste conditioning, such as grouting, packaging and other containment, shall be carried out so that any potential exposure will be as low as reasonably achievable.

A brief summary of how Tellus proposes to manage radioactive waste accepted at the proposed Facility is presented below. More detail on exposure control and waste management practices is given in the Radioactive Waste Management Plan.

NORM containing pastes, sludges and liquids

Once delivered to site, NORM containing pastes, sludges or liquids will be stored in the radioactive waste warehouse or in sea containers on hardstand (dependent upon activity). In campaigns, waste will be unpacked, inspected and verified by laboratory testing. If required, the waste will then be treated with absorbent and pozzolanic materials to form slurry, which will solidify and stabilise the waste. The slurry can be poured into drums, moulds, or contained sections of the cell where it will set. This waste will then be covered with kaolin or other suitable material which will be compacted to maintain structural integrity of the cell.

Contaminated solid materials

Contaminated solid material such as pipes and valves will be stored in the radioactive waste warehouse or in sea containers on a hardstand (dependent upon activity) until suitable space is available in cell. Depending upon physical size and shape of materials, type and activity of radiation, these wastes will either be:

- Compacted into drums and filled with kaolin or cement grout prior to permanent isolation.
- Crushed or cut to remove void space and remaining voids filled in with cement grout or kaolin solids.
- Placed in a sea-container in the cell, holes cut in top of container and all void space filled with cement grout.

These actions are taken to remove void space in the materials which could cause structural instability within the cell with the potential to disturb the cell cap.

Contaminated soil or sands (bulk material)

Bulk contaminated soils or sands will be delivered to site in either bulk bags, shipping containers or other appropriate transport vehicles, depending on volume and physical characteristics of the material. Where possible, transport will be arranged to coincide with a campaign so it can be disposed of directly into a cell, but if not viable, the material will be stored in the radioactive waste warehouse. For large volumes of material, separate stockpile areas will be set up (ad hoc stockpiles),

and dust control measures introduced. These are discussed in the Radiation Management Plan and include a designated stockpile area with concrete slab and bunded walls, closing stockpile with tarp material, dust suppression agents and a monitoring program to confirm efficiency of controls implemented. The bulk material can be disposed of directly in the cell, diluted or mixed with other material, or set in concrete if required.

NORM and bulk wastes

In order to derive activity concentrations limits for individual radionuclides in NORM and bulk wastes, two criteria have been used:

- Dose rate to a human receptor post closure (with capping material in place) to not exceed a dose constraint of 0.3 mSv in a year. An occupancy of 3.5 days a year was assumed as per ARPANSA TRS No. 141 for an arid and remote site.
- Dose rate to a human receptor upon intrusion (no capping) corresponding to 10mSv/y. as per ICRP guidance on radiological criteria applied to human intrusion.

The RESRAD (Onsite) code was used, to determine radionuclide activity concentration levels in bulk NORM wastes which would give rise to conditions as specified above for post closure and intrusion scenarios. Details of assessment are presented in the Radiological Risk Assessment: Post Closure report. Table 2-4 summarises the radionuclide restrictions that will be applied at the Facility for the disposal of NORM bulk wastes.

For bulk NORM wastes having mixtures of radionuclides, an additional constraint should be adhered to so that the total dose from all radionuclides should not exceed relevant dose limits or constraints. This is referred to as the summation rule and requires the following constraint:

$$\sum_i Q_i / Q_{i,l} <= 1$$

Where Q_i (Bq) is the actual activity of radionuclide i to be disposed and $Q_{i,l}$ (Bq) is the activity limit for radionuclide if it were the only radionuclide to be disposed of.

Table 2-4: Waste Acceptance Criteria (WAC) for the Facility for bulk NORM waste

Radionuclides	Half Life	Individual Radionuclide Activity Concentration of Bulk NORM Waste (Bq/g)
		(Bq/g) to achieve 10 mSv/y upon Intrusion
U-238	4.468 billion years	1.0E+05
U-234	246,000 years	2.0E+06
Th-230	75,380 years	1.2E+04

U-235	703.8 million	2.2E+04
Pa-231	32,760 years	7.1E+03
Ra-226	1600 years	1.8E+03
Th-232	14.05 billion years	1.1E+03

Sealed sources

Sealed sources will, upon receipt, be stored in the radioactive waste warehouse, unpacked, inspected and verified. After verification, sources will be secured in a 60 L drum inside a 200 L drum. Cement slurry will be added to the 60 L drum to fill all the void spaces and to cover all the items. The cement filled 60 L drums will be placed in the centre of a 200 L drum, which will then be filled with concrete or equivalent materials. The 200 L drum will be marked with its identification number and labelled. These drums will be stored until the shaft is prepared for disposal. Drums will then be transferred to the cell, loaded into the shaft and covered with fill/grout.

WAC for the facility are based on the design of the facility, including, but not limited to, such items as the engineered barriers, duration of institutional control and site specific characteristics such as geology, low rainfall, lack of receptors, etc.

The activity of the radionuclides present in the radioactive waste packages will be limited in such a way that the radiological impact of the site remains within acceptable levels during the operational and post-closure phases of the site. In accordance with International Atomic Energy Agency (IAEA) waste are considered as a function of their half-life and activity concentration. Radiation doses to the public and workers as a consequence of waste management, storage and disposal activities are not to exceed the dose limits in Regulations 59 and 60 of the ARPANS Regulations. The effective dose limit for occupational exposure is 20 mSv annually, averaged over 5 consecutive calendar years. However, the effective dose for a person subject to occupational exposure must not, in a year, be greater than 50 mSv. The effective dose limit for public exposure is 1 mSv annually).

The ARPANSA *Licensing of Radioactive Waste Storage and Disposal Facilities March 2013* explains that waste acceptance should be undertaken in accordance with Section 2.6 of the Near-Surface Disposal Code, Specific criteria and requirements for waste acceptance and disposal. Guidance on determining waste activity limits for low level waste in near-surface disposal facilities is found in the IAEA TECDOC *Derivation of Activity Limits for the Disposal of Radioactive Waste in near Surface Disposal Facilities* (IAEA-TECDOC-1380, 2003).

The following generic limits will be adopted for the Sandy Ridge Facility (Category B levels as per NHMRC (1992) and ARPANSA (2010)). Waste packages with activity concentration greater than those specified in Table 2-5 will not be accepted for disposal without reassessing the safety case and seeking approval from the relevant regulatory bodies.

Waste acceptance criteria, and the specific limitations on activity, will follow the safety analysis, during operations and for the long term, taking into account the applicable radiological criteria. The

Sandy Ridge site meets the general criteria for a near surface geological repository set by the NHMRC (1992).

Table 2-5: Generic Concentration Limits for Sealed sources-LLW for 100 year Institutional Control Period (ICP) [Ref NHMRC (1992)]

LLW	Concentration limit (Bq/kg)	Concentration limit (Bq)[4]
	100 years	100 years ICP
Tritium	1.00E+11	2.00E+13
Carbon-14	5.00E+08	1.00E+11
Radium-226	5.00E+06	1.00E+09
Alpha (α) emitting radionuclides (Am-241,U-238,PU-239)	1.00E+08	2.00E+10
Beta (B) /gamma (γ)emitters with half-lives > 5y	1.00E+09	2.00E+11
Beta (B) /gamma (γ)emitters with half-lives ≤ 5y	no limit	no limit

Table 2-6 summarises the Waste Acceptance Criteria (WAC) proposed for the disposal of Sealed Sources. The activity of the radionuclides present in the radioactive waste packages will be limited in such a way that the radiological impact of the site is within the dose constraint limits under foreseeable circumstances. Sources at activity Concentration levels above those specified in the table will not be accepted for permanent isolation without re-assessing the safety case and seeking approval from the relevant regulatory bodies.

[4] *Assumes a bulk density of 1 kg/L. The concentration of a radionuclide in the waste package as presented for disposal is calculated by averaging the activity of the source over the weight of the whole conditioned package. For example, the activity of sealed sources, which have been conditioned by being embedded in a solid matrix, can be averaged over the weight of the solid waste matrix. However, to reduce the risks from any future inadvertent intrusion, only one sealed source should be incorporated in a single conditioned package. An industrial gauge source in its approved housing will most likely meet the requirements for disposal if embedded in concrete. In practice, a limit on the maximum activity per package for beta/gamma emitting radionuclides with half-lives of 5 years or less, including cobalt-60, will be imposed by occupational and transport considerations. ARPANSA (2010) Technical Report No. 152)*

Table 2-6: limits for common sources based on NHMRC near surface code (1992)

Radioisotope	Symbol	Half-life	Decay	Concentration limit (Bq)*
				100 years ICP
Americium-241	Am-241	432.17 y	α	2.00E+10
Barium-133	Ba-133	10.74 years	EC	no limit
Caesium-137	Cs-137	30.07 years	γ/β	2.00E+11
Californium-252	Cf-252	2.6 years	α	2.00E+10
Carbon-14	C-14	5 715 years	β	2.00E+11
Chlorine-36	Cl-36	301,000 years	β	2.00E+11
Chromium-51	Cr-51	2.7 days	EC	no limit
Cobalt 57	Co-57	271.8 days	EC	no limit
Cobalt-60	Co-60	5.27 years	γ	no limit
Gold-198	Au-198	2.7 days	β	no limit
Hydrogen-3 (tritium)	H-3	12.32 years	β	2.00E+11
Indium-111	In-111	2.80 days	EC	no limit
Iodine-129	I-129	15.7 million years	β	2.00E+10
Iridium-192	Ir-192	73.8 days	γ/B	2.00E+10
Krypton-85	Kr-85	10.5 years	β	2.00E+11
Iron-55	Fe-55	2.74years	EC	no limit
Lead-210	Pb-210	22.6 years	β	2.00E+11
Manganese-54	Mn-54	312.1 days	EC	no limit
Molybdenum-99	Mo-99	66 hours	β	no limit
Nickel-63	Ni-63	96 Years	β	2.00E+11
Polonium-210	Po-210	138 days	α	2.00E+10
Radium-226	Ra-226	1,600 years	α	1.00E+09
Selenium-75	Se-75	120 days	γ	no limit
Sodium-22	Na-22	2.6 years	γ	no limit
Strontium-90	Sr-90	28.8 years	β	2.00E+11
Technetium-99m	Tc-99m	6.01 days	γ	no limit
Thallium-204	Tl-204	3.78 years	β	no limit
Thulium-170	Tm-170	129 days	β	no limit
Ytterbium-169	Yb-169	32 days	EC	no limit
Zinc-65	Zn-65	243.87 days	EC	no limit

**(alpha (α), Beta (β), Gamma (γ) or Electro capturing (EC))*

3 WASTE PACKAGING CRITERIA

The Australian Code for the Transport of Dangerous Goods by Road and Rail (2016) details the requirements for safe packaging and transport of hazardous materials, based on the classification of the waste. Tellus requires that all customers adhere to the code to ensure packaging is appropriate to the hazardous characteristics of the waste in question. Containment systems should normally consist of one or more of the following packaging options;

- 20' ISO shipping containers or 20' ISO tank-container.
- Bulk bags in containers, on pallets or free standing.
- 215 Litre drums on pallets in containers.
- $1m^3$ IBCs in containers.
- Small palletised goods in containers (e.g. radioactive materials).
- Loose bulk in containers (e.g. contaminated soils).
- Liquid tanker truck (e.g. bulk liquids or pastes) which will undergo solidification or stabilization treatments.
- Pneumatic tanker truck (e.g. bulk dry powder solids).
- Solid materials on flatbed trucks (e.g. railway sleepers, O&G pipe, machinery).

Typical Packaging examples are presented in Appendix A.1

3.1 Packaging criteria

The original IWDF *Waste Acceptance Guidelines* 2011 provide clear criteria for the packaging of waste for delivery to the Mount Walton East site, which is presented below. Tellus have considered the IWDF packaging requirements to be consistent with industry best practices; therefore waste packaging delivered to the proposed Facility must fulfil the following criteria:

- Not have a total measured weight of more than the Safe Working Load.
- Be capable of being disposed of with the waste.
- Be filled so as to contain no significant voids.
- Be free of ruptures at the point of delivery.
- Be free of external contamination at the point of delivery.
- Not significantly deteriorate during the duration of storage, transport and handling when in contact with the waste.
- Remain intact during normal transport and handling procedures.
- Be strong enough to be walked on if required.

- Be clearly labelled with the waste owner's name and identification number and material description/name on opposite sides of the waste package.
- Allow no leakage during normal transport and handling operations.
- Be capable of containing all the waste whatever the orientation of the package.

3.2 Mitigating package failure

It can be anticipated that packaging containers have the potential to fail in the conditions of storage if no other consideration is given to the form of the packaging and wastes contained therein. To minimise the likelihood and potential impacts of packaging failure, the following measures are required to be undertaken:

- Void spaces inside containers are to be minimised – packages shall be grout filled or similar to remove voids inside any container that will be disposed with the waste.
- Low density wastes (PPE etc.) should be baled or similarly compacted to the highest density reasonably and practicably achieved (as close to 200 kPa as practical to be consistent with the available backfill materials). This compaction activity should be undertaken prior to any grout filling.
- Low density wastes should be identified so that, as far as practicable during the receival activity at site, be segregate for special attention in the development of the cell filling plan.
- Low density waste should be packaged in smaller vessels, or should be packaged and disposed as long shallow packages to reduce the scale of any settlement or failure.

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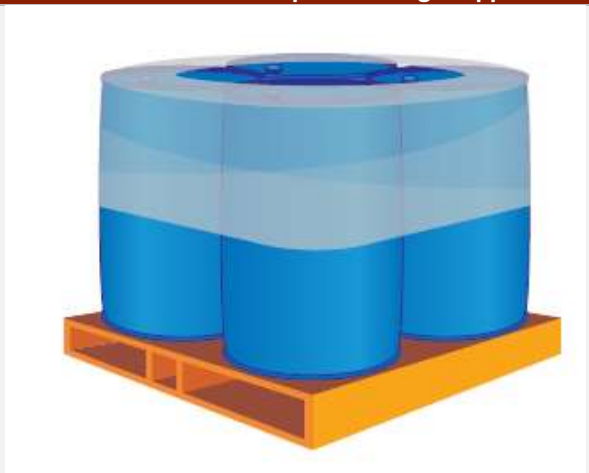
A.1 Potential waste category list

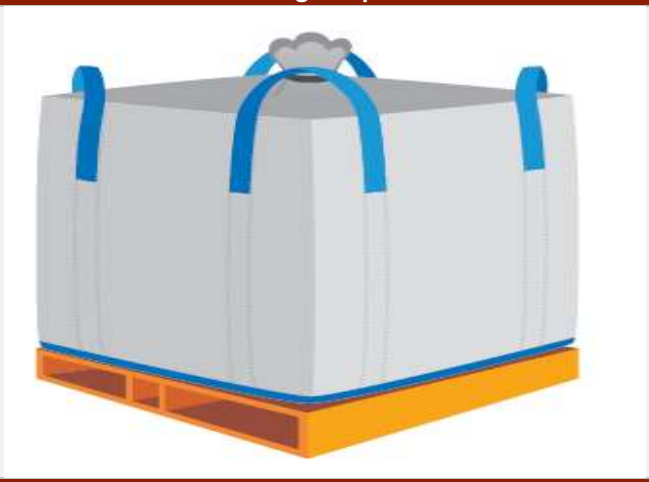
Common industrial hazardous waste (NEPM basis)	
Acidic solutions or acids in solid form	B100
Animal effluent and residues (abattoir effluent, poultry and fish processing wastes)	K100
Antimony; antimony compounds	D170
Arsenic; arsenic compounds	D130
Asbestos	N220
Barium compounds (excluding barium sulphate)	D290
Basic solutions or bases in solid form	C100
Beryllium; beryllium compounds	D160
Boron compounds	D310
Cadmium; cadmium compounds	D150
Ceramic-based fibres with physio-chemical characteristics similar to those of asbestos	N230
Chlorates	D350
Chromium compounds (hexavalent and trivalent)	D140
Clinical and related wastes	R100
Cobalt compounds	D200
Containers and drums that are contaminated with residues of substances referred to in this list	N100
Copper compounds	D190
Cyanides (inorganic)	A130
Cyanides (organic)	M210
Encapsulated, chemically-fixed, solidified or polymerised wastes referred to in this list	N160
Ethers	G100
Filter cake contaminated with residues of substances referred to in this list	N190
Fire debris and fire wash waters	N140
Fly ash, excluding fly ash generated from Australian coal fired power stations	N150
Grease trap waste	K110
Halogenated organic solvents	G150
Highly odorous organic chemicals (including mercaptans and acrylates)	M260
Inorganic fluorine compounds excluding calcium fluoride	D110
Inorganic sulfides	D330
Isocyanate compounds	M220
Lead; lead compounds	D220
Mercury; mercury compounds	D120
Metal carbonyls	D100
Nickel compounds	D210
Non-toxic salts	D300
Organic phosphorous compounds	H110
Organic solvents excluding halogenated solvents	G110
Organo halogen compounds—other than substances referred to in this Table.	M160
Perchlorates	D340
Phenols, phenol compounds including chlorophenols	M150

Common industrial hazardous waste (NEPM basis)	
Phosphorus compounds excluding mineral phosphates	D360
Polychlorinated dibenzo-furan (any congener)	M170
Polychlorinated dibenzo-p-dioxin (any congener)	M180
Residues from industrial waste treatment/disposal operations	N205
Selenium; selenium compounds	D240
Soils contaminated with a controlled waste	N120
Surface active agents (surfactants), containing principally organic constituents and which may contain metals and inorganic materials	M250
Tannery wastes (including leather dust, ash, sludge's and flours)	K140
Tellurium; tellurium compounds	D250
Thallium; thallium compounds	D180
Triethylamine catalysts for setting foundry sands	M230
Tyres	T140
Vanadium compounds	D270
Waste chemical substances arising from research and development or teaching activities, including those which are not identified and/or are new and whose effects on human health and/or the environment are not known	T100
Waste containing peroxides other than hydrogen peroxide	E100
Waste from heat treatment and tempering operations containing cyanides	A110
Waste from manufacture, formulation and use of wood-preserving chemicals	H170
Waste from the production and preparation of pharmaceutical products	R140
Waste from the production, formulation and use of biocides and phytopharmaceuticals	H100
Waste from the production, formulation and use of inks, dyes, pigments, paints, lacquers and varnish	F100
Waste from the production, formulation and use of organic solvents	G160
Waste from the production, formulation and use of photographic chemicals and processing materials	T120
Waste from the production, formulation and use of resins, latex, plasticisers, glues and adhesives	F110
Waste mineral oils unfit for their original intended use	J100
Waste of an explosive nature not subject to other legislation	T200
Waste oil/water, hydrocarbons/water mixtures or emulsions	J120
Waste pharmaceuticals, drugs and medicines	R120
Waste resulting from surface treatment of metals and plastics	A100
Waste substances and articles containing or contaminated with polychlorinated biphenyls, polychlorinated napthalenes, polychlorinated terphenyls and/or polybrominated biphenyls	M100
Waste tarry residues arising from refining, distillation, and any pyrolytic treatment	J160
Wool scouring wastes	K190
Zinc compounds	D230

A.2 Packaging examples

4 Plastic drums on a pallet
4 Plastic drums on a pallet - clingwrapped

4 Steel drums on a pallet

Bulk bags on pallets



Plastic drums in sea containers

Bulk bags in sea containers

Waste Acceptance Criteria and Supporting Documents

TELLUS

TELLUS

SANDY RIDGE FACILITY WASTE ACCEPTANCE PROCEDURE

Final Report | August 2016

Version	Date	Description	Signatures		
			Originator	Checked	Approved
0	10/08/2016	Issued for use	S. Reece	J.Livesey R.Phillips	D van der Merwe

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ABBREVIATIONS

AC	Acceptance Certificate
ASTM	American Society for Testing and Materials
ARPANSA	Australian Radiation Protection and Nuclear Safety Agency
Bq	Becquerel
The Facility	The Sandy Ridge Facility
IAEA	International Atomic Energy Agency
IAEA TECDOC	Technical Document published by IAEA
IBC	Intermediate Bulk Container
ISO	International Organisation for Standardization
IWDF	Intractable Waste Disposal Facility
kPa	Kilopascals
m	metre
MSDS	Material Safety Data Sheet
NEPM	National Environmental Protection Measure
NHRMC	National Health and Medical Research Council
NORM	Naturally Occurring Radioactive Materials
PIC	Permanent Isolation Certificate
PPE	Personal Protective Equipment
SC	Storage Certificate
Tellus	Tellus Holdings Ltd.
TOC	Total Organic Carbon
WAC	Waste Acceptance Criteria
WAP	Waste Acceptance Procedures

WCD	Waste Classification Definitions
WZG	Waste Zoning Guidelines

DEFINITIONS

Cell - an excavated area (pit) of kaolin which is below ground level which will be used for *in cell storage* or *permanent isolation* of waste.

Conditions of storage - The term "in the conditions of storage" is used to differentiate between the generic properties of a material and how those properties may be modified when that material is placed into "in cell storage" or "permanent isolation" within a cell.

Dangerous goods – the Dangerous Goods Safety (General) Regulations 2007 defines "dangerous goods" as any substance or article that is:

a) Found to be within any of the following classes or divisions under the Australian Dangerous Goods Code: Class 1, Class 2, Class 3, Class 4, Class 5, Division 6.1, Class 8, or Class 9; unless stated otherwise within the Code.

b) named or described in Schedule 1 of the Environmental Protection (Controlled Waste) Regulations 2004

Geological repository (in the context of Sandy Ridge) - The term geological repository is used to mean a landfill facility constructed and with the equivalent properties of a Class IV or Class V Landfill as defined in Landfill Waste Classification and Waste Definitions 1996 (As amended December 2009) Western Australia Department Of Environment And Conservation. In the context of Sandy Ridge this means an arid near-surface facility used to permanently isolate waste. Geological repositories provide the highest levels of containment through the use of carefully selected natural geological barriers rather than reliance on man-made liner systems and are increasingly recognised as a cost effective and preferred method of permanently isolating difficult to manage wastes. The geological barrier provides permanent isolation of wastes from the environment over the very long term and creates additional opportunities for the future recovery and recycling of valuable materials from the waste which can re-enter the circular economy.

Hazardous waste - Component of the waste stream which by its characteristics poses a threat or risk to public health, safety or the environment (includes substances which are toxic, infectious, mutagenic, carcinogenic, teratogenic, explosive, flammable, corrosive, oxidising and radioactive). As defined in Landfill Waste Classification and Waste Definitions 1996 (As amended December 2009) Western Australia Department Of Environment And Conservation

In Cell Storage - medium to long term below ground storage of wastes inside a cell with ongoing opportunity to recover waste if required.

Intractable Waste- Waste which is a management problem by virtue of its toxicity or chemical or physical characteristics which make it difficult to dispose of or treat safely, and is not suitable for disposal in Class I, II, III and IV landfill facilities. As defined in Landfill Waste Classification and Waste

Definitions 1996 (As amended December 2009) Western Australia Department Of Environment And Conservation

Permanent Isolation - indefinite below ground storage of wastes determined suitable for acceptance.

Storage - the short term above ground storage of materials following delivery and includes the time awaiting sampling, analysis and management prior to movement for “in cell storage”.

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1 INTRODUCTION

1.1 The Sandy Ridge Facility

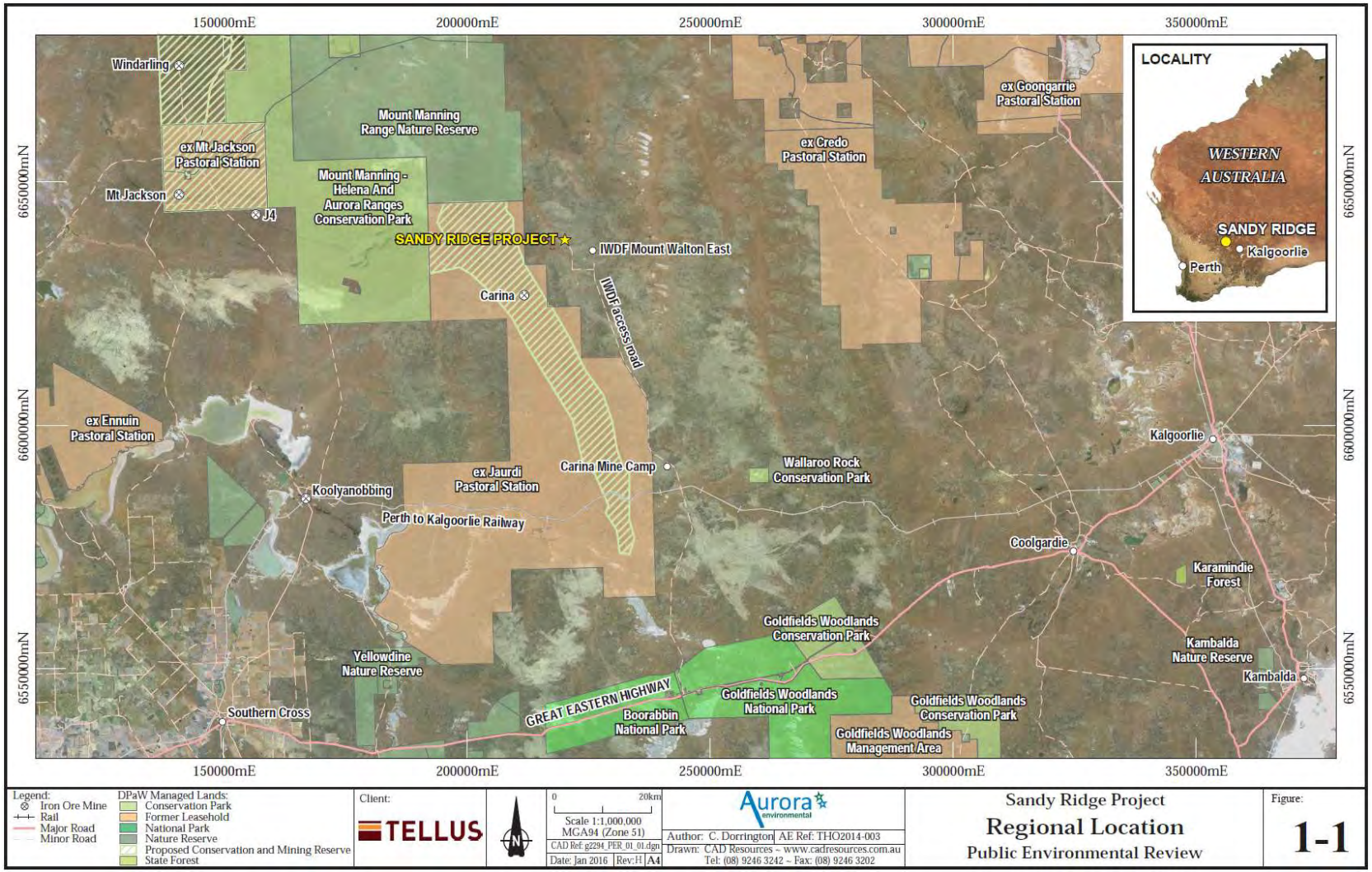
The proposed Sandy Ridge Facility (hereby referred to as the proposed "Facility") is a dual use kaolin mine with the voids created by mining used to store and permanently isolate hazardous and intractable wastes. The site is located approximately 75 km northeast of Koolyanobbing, in the Shire of Coolgardie, within the Goldfields Region of Western Australia (Figure 1-1).

The location for the Facility was specifically chosen as its principal characteristics; semi–arid climate, high rates of evaporation, geologically stable, natural geological barriers, no regional aquifer, no surface water receptors, no flooding, low erosion rates, no heritage values, topography etc. satisfy the requirements for a near surface geological repository for intractable and hazardous waste storage and isolation purposes.

There are no sensitive receptors within the immediate vicinity of the proposed Facility. The nearest operation is the Class V IWDF Mount Walton East Intractable Waste Disposal facility located approximately 6 km to the east, which operates on a campaign basis and does not have permanent residents. The nearest mining camp is the Carina Iron Ore Mine accommodation village located approximately 52 km to the south east of the proposed Facility.

The arid and remote nature of the location, absence of nearby population, coupled with the site characteristics make the site ideal for long-term storage and permanent isolation of hazardous and intractable waste.

Figure 1-1: Sandy Ridge site location



1.2 Document aims and objectives

The aim of this document is to present the Waste Acceptance Procedure (WAP) that will be used at the proposed Sandy Ridge Facility to determine if wastes meet all of the acceptance criteria. This document should be read in conjunction with the following:

- Tellus Waste Acceptance Policy.
- Sandy Ridge Waste Acceptance Criteria (WAC).
- Sandy Ridge Waste Zoning Guide (WZG).

This document is part of a hierarchy of documents and is a tier 3 document as highlighted in Figure 1-2 below. Tier 3 documents work together with tier 4 documents to provide details of specific operational procedures and include the development of an assumed inventory[1] for storage and permanent isolation. The assumed inventory will in turn inform the licence application submitted to the regulator.

The document hierarchy is presented in Figure 1-2, and includes an equivalent suite of documents for Tellus' Northern Territory Chandler Project which includes the Apirnta rail sidings where waste acceptance will be carried out..

Figure 1-2: Waste Acceptance Criteria Document Hierarchy

Having established the overarching waste exclusion criteria to be applied at the proposed Facility (refer to WAC), a gated WAP (this document), using specified test methods and criteria values will be

[1] *Due to the variability in the wastes that could be encountered at the proposed Facility, the assumed inventory is likely to be subject to change and should be considered as an initial guide for the acceptance of the various wastes listed. Changes to the inventory are to be controlled by a suitably qualified person(s) making decisions in accordance with the principles presented in this document.*

applied to determine if a waste can be accepted. The gated procedure is set out in Appendix A.1, with an explanation of each step and corresponding test method provided in Section 3.

In addition to considering the specific characteristics of the waste, consideration is also given to how the wastes will perform in the conditions of storage and permanent isolation. This assessment will be performed by a suitably qualified person who has the necessary skill in determining such matters.

Wastes will need to pass through each waste acceptance "criteria gate" to be accepted for in cell storage or permanent isolation at the Sandy Ridge facility.

1.3 Intended audience

This document is intended initially for use by regulators responsible for assessing the facility and issuing licences for the operation of the proposed Facility, and for the formation of procedures to control the process by which waste producers and Tellus Staff will determine if the waste streams may be suitable for storage or permanent isolation.

The document will also be of interest to other stakeholders who wish to understand the approach being followed by Tellus for waste acceptance, including the safe storage and permanent isolation of wastes.

Finally, this document will be used by Tellus staff and their specialist advisors to establish the framework that incorporates more detailed operational procedures which underpin this document.

2 CONTEXT

Tellus Waste Acceptance Policy establishes the context and importance of effective Waste Acceptance Procedures. The Policy states before waste can be accepted for storage or permanent isolation at the proposed Sandy Ridge Facility, Tellus must be satisfied that the waste meets agreed acceptance criteria, has been subject to the tests set out in the WAP and that the waste can be accepted in accordance with Approvals and Licences issued by regulators.

2.1 Waste Acceptance Criteria

WAC have been established to determine waste types which can and cannot be accepted when considering the characteristics and design of the site to achieve safe operation of the facility and to ensure long term environmental protection through containment of potential pollutants present within the wastes. In some cases the criteria used will lead to straightforward "go or no go" decisions based on compatibility with the site characteristics and WAC, and in other cases acceptance values and parameters will be used.

Whilst Tellus will ensure that waste generators are aware of the WAC for the Facility, it is recognised that on some occasions particular wastes presented will not conform to set criteria and re-evaluation of appropriate management techniques will be required so as to achieve the objective of safe storage or permanent isolation so that the threat to the receiving environment is minimised or prevented.

2.2 Waste Acceptance Procedure

As part of the WAP it is necessary to first characterise the waste material. Tellus have adopted a three stage approach to waste characterisation[2], which is summarised below. The most detailed characterisation takes place to determine if waste meets the overarching criteria and licence conditions of the site, followed by further ongoing testing at levels 2 and 3 described below.

- **Level 1: Basic characterisation**. This is a thorough determination, according to standardised analysis and behaviour-testing methods, of the characteristic properties of the waste.
- **Level 2: Compliance testing**. This is periodic testing of regularly arising wastes by simpler standardised analysis methods to determine whether a waste complies with licence conditions and whether a waste with known properties has changed significantly.
- **Level 3: On-site verification**. This constitutes rapid check methods to confirm that a waste is the same as that which has been subjected to compliance testing and that which is described in the accompanying documents.

For acceptance at the proposed Sandy Ridge Facility wastes need to continually meet the acceptance criteria laid down for the site in WAC document. Criteria compliance is therefore continually tested by using the three levels of basic characterisation, compliance testing and on-site verification, which is outlined in detail in this document.

2.3 Waste Zoning

After wastes have been accepted at the proposed Facility, it is important that they are both stored and disposed of in a safe manner. The wastes that Tellus are planning to accept, many of which are classified as Dangerous Goods, will be grouped into compatible waste type groups that can be stored and disposed of together. Whilst in transit and surface storage Dangerous Goods Segregation protocols will be adopted (AS/NZ 3833 Figure 6.1).

When the waste is placed into a cell for permanent isolation, waste zoning protocols will be implemented, as presented in the WZG. The WZG have been developed to reflect the conditions of storage within the cell and how the various wastes can be stored or permanently isolated without adverse interaction. Adopting a zoning approach also increases the opportunity for potential future recovery of certain materials for beneficial use.

3 WASTE CHARACTERISATION

As part of the WAP it is necessary to first characterise the waste material. Tellus have adopted a three stage approach to waste characterisation[3] which is summarised below. The most detailed characterisation takes place to determine if waste meets the overarching criteria and licence conditions of the site, followed by further ongoing testing at levels 2 and 3 described below.

- **Level 1: Basic characterisation**. This is a thorough determination, according to standardised analysis and behaviour-testing methods, of the characteristic properties of the waste.
- **Level 2: Compliance testing**. This is periodic testing of regularly arising wastes by simpler standardised analysis methods to determine whether a waste complies with licence conditions and whether a waste with known properties has changed significantly.
- **Level 3: On-site verification**. This constitutes rapid check methods to confirm that a waste is the same as that which has been subjected to compliance testing and that which is described in the accompanying documents.

3.1 Basic characterisation[4]

Basic characterisation is the first step in the acceptance procedure and constitutes a full characterisation of the waste by the waste producer by gathering all the necessary information for safe disposal of the waste in the long term. Basic characterisation is required for each waste stream and involves using test methods outlined in the gated acceptance procedure (see Section 4) to determine whether the wastes pass all of the acceptance criteria

3.1.1 Functions of basic characterisation

- Establish basic information on the waste (physical form, origin, composition, consistency, and, where necessary and available, other relevant characteristic properties).
- Provide basic information for understanding the behaviour of waste in the Facility conditions of storage and options for treatment.
- Detection of key variables (critical parameters) for compliance testing and options for simplification of compliance testing (leading to a significant decrease of constituents to be measured, but only after demonstration of relevant information). Characterisation may deliver relationships between basic characterisation and results of simplified test procedures as well as frequency for compliance testing.

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[3] *UK Environment Agency Waste acceptance at landfills - 2010*
[4] *(2003/33/EC) COUNCIL DECISION of 19 December 2002 establishing criteria and procedures for the acceptance of waste at landfills pursuant to Article 16 of and Annex II to Directive 1999/31/EC*

If the basic characterisation of waste shows that the waste fulfils the criteria for the Facility set out in the WAC, the waste will be deemed to be acceptable. If this is not the case, the waste is not acceptable. The producer of the waste or the person responsible for its management, is responsible for ensuring that the characterisation information is correct.

The content of the characterisation, the extent of laboratory testing required and the relationship between basic characterisation and compliance checking depends on the type of waste. A differentiation can be made between wastes that are regularly generated in the same process and wastes that are not regularly generated.

Wastes regularly generated in the same process

These are individual and consistent wastes regularly generated in the same process, where:

- The installation and the process generating the waste are well known and the input materials to the process, and the process itself, are well defined.
- The operator of the installation provides all necessary information and informs Tellus of changes to the process (especially changes to the input material).

The process will often be at a single installation; however, the waste may also be from different installations, if it can be identified as single stream with common characteristics within known boundaries (e.g. bottom ash from the incineration of municipal waste). For these wastes the basic characterisation will comprise the fundamental requirements listed in Gate 1 of section 4 of this document, and especially the following:

- Chemical composition range for the individual wastes.
- Range and variability of characteristic properties.

If the waste is produced in the same process but at different sites, information must be given on the scope of the evaluation. Consequently, a sufficient number of measurements must be taken to show the range and variability of the characteristic properties of the waste. The waste can then be considered characterised and shall subsequently be subject to compliance testing only, unless significant change in the generation processes occur.

For wastes generated from the same process at the same site, the results of the measurements may show only minor variations in the properties of the waste, in comparison with the relevant acceptance parameters. The waste can then be considered characterised, and shall subsequently be subject to compliance testing only, unless significant changes in the generation process occur.

Waste sourced from facilities for the bulking or mixing of waste, from waste transfer stations or mixed waste streams from waste collectors, can vary considerably in their properties. This must be taken into consideration in the basic characterisation. Such wastes may fall under the following case.

Wastes that are not regularly generated

These wastes are not regularly generated in the same process in the same installation and are hence not part of a well-characterised waste stream. Each batch produced of such waste will need to be characterised. The basic characterisation shall include the same fundamental requirements as for basic characterisation. As each batch produced has to be characterised, no compliance testing is needed in this case.

3.2 Compliance testing

When waste has been deemed acceptable on the basis of a basic characterisation it shall subsequently be subject to compliance testing to determine if it complies with the results of the basic characterisation and the relevant acceptance criteria as laid down in the WAC. Compliance testing, as with basic characterisation, will also normally be carried out at the waste producer site.

The function of compliance testing is to periodically check regularly arising waste streams are compliant with the WAC. The initial basic characterisation will have identified critical parameters (key waste properties) for each waste stream. Only a check on these critical parameters, as determined in the basic characterisation, is necessary. The check has to show that the waste meets the limits of acceptance for the identified critical parameters. The tests used for compliance testing shall be one or more of those used in the basic characterisation.

Compliance testing shall be carried out at a frequency to be agreed with Tellus and must, in any event, ensure that compliance testing is carried out in the scope and frequency determined by basic characterisation.

3.3 On-site verification

Each load of waste delivered to Sandy Ridge shall be visually inspected before and after unloading, and the required documentation shall be checked.

The waste may be accepted at the Facility, if it is the same as that which has been subjected to basic characterisation and compliance testing, and which is described in the accompanying documents. If this is not the case, the waste must not be accepted. Tellus will determine the testing requirements for on-site verification, including where appropriate rapid test methods.

Upon delivery, samples will be taken periodically. The samples taken will be kept after acceptance of the waste for a period that will be determined by Tellus.

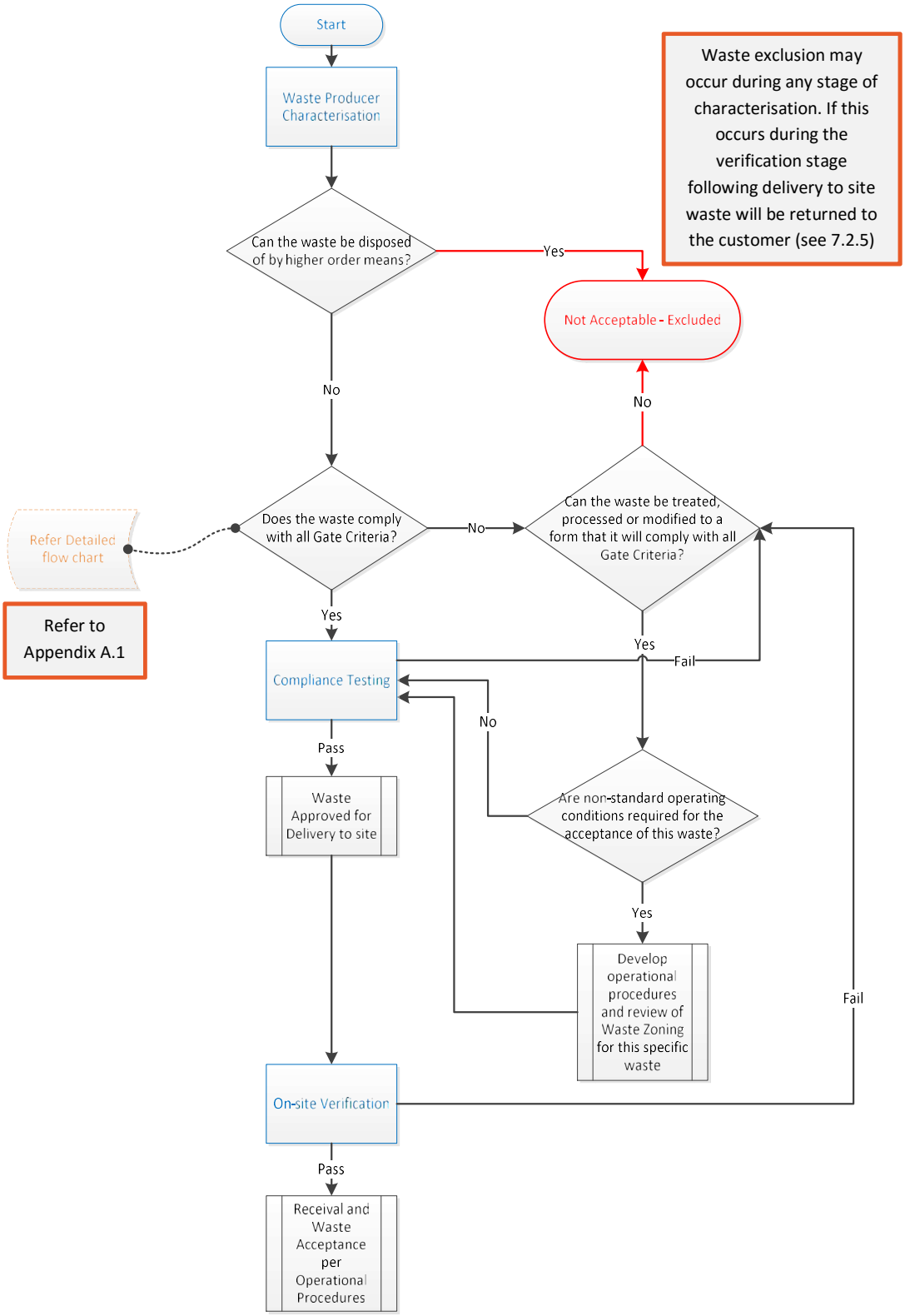
4 GATED WASTE ACCEPTANCE PROCEDURE

A gated WAP using specified test methods and criteria values will be applied to determine if a waste can be accepted. Detailed explanations of each gate, its associated criteria and an applicable test method(s) required to be used to confirm acceptance, are presented below, with a corresponding detailed flow chart included in Appendix A.1. A summary of the overall procedure for characterisation, compliance, acceptance and verification is set out in Figure 4-1 below.

In addition to considering the specific characteristics of the waste for the purpose of permanent isolation, consideration is also given to how the wastes will perform in the conditions of storage. This assessment will be performed by a suitably qualified person who has the necessary skill in determining such matters. Wastes will need to pass through all waste acceptance “criteria gates” to be accepted for storage or permanent isolation at the Sandy Ridge facility.

From the point of waste generation, the flow diagram highlights that characterisation is performed in accordance with the principles outlined above with the option to develop non-standard operating procedures for the management of non-conforming wastes prior to or following receipt at the proposed Facility.

Figure 4-1: Waste Acceptance Procedure summary – (Refer to Appendix A.1 for Detailed Flow Chart)



Gate 1 – Is the waste on the potential waste category list

The first stage of assessing the potential suitability of a waste for storage and permanent isolation is to determine whether the waste is on the facility's potential waste category list. The list has been developed by Tellus based on wastes that broadly have the physical and chemical properties that meet the criteria for storage and permanent isolation at the facility. The list aims, insofar as is possible at the outset, to exclude categories of wastes that would fail the site's acceptance criteria and are therefore considered unacceptable. In developing this list Tellus have referred to the National Environment Protection (Movement of Controlled Waste between States and Territories) Measure 1998 Schedule A and the Western Australia Environmental Protection (Controlled Waste) Regulations 2004 Schedule 1 Controlled waste list.

A waste producer will be requested to provide information on the waste, using the Level 1 - Basic Characterisation Form presented in Figure 4-2. The form contains the following elements of basic characterisation;

- Source and origin of the waste.
- Information on the process producing the waste (description and characteristics of raw materials and products).
- Appearance of the waste (smell, colour, physical form).
- Radiological assessment of the waste.
- Dangerous Goods Code
- Code according to the Basel Convention (Annex III) list of hazardous characteristics [Annex III of the Basel Convention is included as Appendix A.2 of this document for ease of reference].

If the waste is deemed to be on the Potential Waste Category List, the remaining elements of basic characterisation will be undertaken to provide the necessary information to allow the further steps in the site's acceptance procedure to be undertaken.

If the waste is deemed not to be on the Potential Waste Category List, Tellus may advise the regulator that after modification or treatment, a waste not on the list would be acceptable for storage and treatment. Advice would include a report from the suitably qualified person that demonstrates that hazards have been reduced or managed to make that waste suitable for in cell storage or permanent isolation.

The remaining elements of basic characterisation include;

- Description of any waste treatment applied or to be applied, or a statement of reasons why such treatment is not considered necessary.
- Data on the composition of the waste.
- Additional precautions to be taken when handling the material, particularly if classified as a dangerous good.

- An indication if the waste could be recycled or recovered now or in the future.

Figure 4-2: Basic Characterisation Form

TO BE COMPLETED IN BLOCK CAPITALS OR TYPED	No. of attached sheets:	Sheets of analysis:

Waste Producer's full name: …… **Address: ……** **……** **……** **Postcode: …… Tel No: ……**	**Place of collection (if different). Full name and address:** **……** **……** **……** **Postcode: …… Tel No: ……**
Quantity: **Method of Containment** **Collection Frequency:**	
Full chemical description:…… **……** **……**	Colour: **Approx. pH:** Physical form: **Approx. strength:**
Process from which waste/material is derived, including details of any pre-treatment: …… **……**	
Will the waste/material vary? YES/NO if YES, in what way? ……	
Does the waste/material smell? YES/NO if YES, give possible cause(s) ……	
CLIENT'S DECLARATION OF CONSTITUENTS OF THE WASTE/MATERIAL (Delete as appropriate) **Include and specify any know toxic, dangerous or objectionable contaminants either against the entry or in additional information box below**	**No. of samples taken**

CONSTITUENT	PRESENT		IF YES, PLEASE SPECIFY	CONSTITUENT	PRESENT		**IF YES, PLEASE SPECIFY**
Acids	YES	NO		Controlled drugs/POMs	YES	NO	
Alkalis	YES	NO		Oxidizing agents	YES	NO	
Flammable liquids/Solids	YES	NO		Reducing agents	YES	NO	
Spontaneously combustibles	YES	NO		Radioactive	YES	NO	
Water-reactive materials	YES	NO		Cyanides (free/complex)	YES	NO	
Oils, Fats, greases	YES	NO		Ammonia/amines	YES	NO	
Halogenated solvents	YES	NO		Nitrates/nitrites	YES	NO	
Phenols/halogenated phenols	YES	NO		Agrochemicals	YES	NO	
Sulphur compounds	YES	NO		PCBs/PCTs	YES	NO	
Explosives	YES	NO		Bio-hazardous materials	YES	NO	
Metals/metal compounds	YES	NO		**Hazardous Characteristics (Basel Convention Annex III)**			
Additional information;				**Dangerous Goods Code**			

Signed on behalf of the Waste Producer's Name: Job Title: Date:

…… …… …… ……

Test methods:

Review of waste information provided by customer and MSDS as supplied against the Potential Waste Category list presented in Appendix A.3

Limit of acceptance:

Identified on Potential Waste Category list.

Gate 2 – Has the waste been identified as likely for future recovery?

If a waste stream has the potential to be recycled or recovered in the future but there is currently no viable process available that will be noted and the viability/availability of that option will be periodically reviewed. The absence of a current viable route in accordance with the principles of "Environmentally Sound Management[5]" will enable the waste to be accepted at the Sandy Ridge site for storage.

Test methods:

Review of waste type, information supplied and MSDS against listed wastes.

Limit of acceptance:

Not applicable

Gate 3 – Gases, liquids and sludges

Gas and liquid are assumed to mean the physical state of the waste at 25°C and 1 atm (STP), with a sludge being a homogeneous mixture of solid and liquid materials which requires containment to prevent the material from flowing.

Gate 3.1 – Is the waste a gas?

Gases will not be accepted for permanent isolation, this includes wastes which could reasonably be expected to be gases in a free phase condition in the conditions of permanent isolation. This exclusion will include wastes received as aerosols, liquids, or solids which may change form during or following emplacement.

Test methods:

Review of MSDS.

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[5] *The Basel Convention on the Control of Transboundary Movement of Hazardous Waste and their Disposal, which came into force in 1992, defines "environmentally sound management" as "taking all practical steps to ensure that hazardous wastes or other wastes are managed in a manner which will protect human health and the environment against adverse effects, which might result from such wastes."*

Limit of acceptance:

The Australian Code for the Transport of Dangerous Goods by Road and Rail defines “gases” as substances that have a vapour pressure greater than 300 kPa at 50°C, or are completely gaseous at 20°C and standard pressure of 101.3 kPa (STP).

Gate 3.2 – Is the waste a liquid or sludge?

Liquid and sludge wastes will not be accepted directly for permanent isolation at the proposed Facility. This includes wastes received as liquids, or solids which may change form during or following emplacement (i.e. may return to liquid phase during long term storage). Should a suitable technology and process be available to permanently solidify the liquid to a suitable consistency then it may be possible to dispose of the waste at the proposed Facility.

Test methods:

MSDS Review

Liquids test ASTM D 4359-90:

Slump test (BS 1881: Part 102 or equivalent). A slump test involves the placing of a sample of material into an inverted cone of known height. This is then placed the correct way onto a flat surface. The surrounding cone is then slowly removed and the height of the resulting waste form will be measured. The slump is calculated as the original height minus the height of the resultant waste form and reported in mm.

Limit of acceptance:

The Australian Code for the Transport of Dangerous Goods by Road and Rail (2007) defines “liquids” as substances that have a vapour pressure of not more than 300 kPa at 50°C, are not completely gaseous at 20°C and standard pressure of 101.3 kPa, and have a melting point or initial melting point of 20°C or less at standard pressure of 101.3 kPa. The code continues to state that a viscous substance for which a specific melting point cannot be determined must be subjected to the ASTM D 4359-90 test; or to the test for determining fluidity (penetrometer test).

Slump Test: The waste will fail the test and be deemed unsuitable for the facility, if the height has dropped by 25% or more of the original height.

Gate 4 - Does the waste possess hazardous characteristics which, in the conditions of storage, are explosive, corrosive, oxidizing, or highly flammable?

Gate 4 sets out a number of generic exclusion properties of potential wastes, based on the reactivity of the wastes. Each property should be considered independently from the others through the gating process. A waste that fails in any one of these sub-gates will be deemed as failing Gate 4 and will not be accepted for permanent isolation at the proposed Facility. The hazardous characteristics

list is presented at Appendix . The conditions of storage will be considered when assessing these criteria.

Gate 4.1 – Is the waste Explosive (H1)?

Wastes which are explosive will not be accepted directly for permanent isolation at the proposed Facility. Should a suitable treatment or encapsulation method be identified to treat or manage the wastes such that it is no longer explosive in the conditions of storage, it may be possible to accept the waste material for permanent isolation or in cell storage. A suitably qualified person will be required to determine if and when such wastes may be received and disposed at the proposed Facility. Any treatment methodology for the stabilisation of the waste must be controlled and undertaken by suitably qualified persons. Detailed risk assessment will be undertaken to ensure the stabilisation and subsequent storage can be undertaken safely.

Test methods:

The United Nations *Recommendations On The Transport Of Dangerous Goods, Manual Of Tests And Criteria* (United Nations Test Manual) gives a series of laboratory tests to determine whether a substance is classified as explosive, and if so, what division falls into. As Tellus will not be accepting any explosive material, irrespective of which division it falls into, only test types 1 and 2 will be utilized at the proposed Facility.

The following Type 1 tests answer the question “is it an explosive substance?”

- Test 1 (a): UN Gap test – assess ability of substance to propagate a detonation;
- Test 1 (b): Koenen test – effects of intense heat under high confinement;
- Test 1 (c) (i): Time/Pressure test – effects of ignition under confinement;
- Test 1 (c) (ii): Internal ignition test – tendency to transition from deflagration to detonation.

If every test yields a negative result the waste is classified as non-explosive and can be considered for acceptance; however, if <u>any</u> of these tests give a positive result, the waste is then subjected to Type 2 testing to determine the sensitivity.

Type 2 tests answer the question “is it too insensitive for acceptance into Class 1?” These tests use the same basic apparatus and method but with minor variations, or less stringent criteria.

Limit of acceptance:

The substance is classified as "explosive" under the following conditions and will not be accepted:

- Type 1: if any of the tests yields a positive (+) result; and
- Type 2: if any of the tests yields a positive (+) result

Gate 4.2 – Is the waste Highly Corrosive (H8)?

Highly corrosive wastes will not be accepted for direct permanent isolation at Sandy Ridge. Should a suitable treatment or encapsulation method be identified to treat or manage the wastes such that they do not remain highly corrosive under the conditions of storage, it may be possible to accept the waste material for permanent isolation or in cell storage. Any stabilisation shall be undertaken under the instruction of the suitably qualified person.

Test methods:

The United Nations Test Manual recommends Test C.1 to determine the corrosive properties of liquids and solids that may become liquids during storage and/or transport.

A representative sample of the waste is placed in contact with a minimum of 3 metal plates (one test using steel, and another using aluminium) measuring 20 x 50 x 2 mm. One plate is submerged in the solution, another is half submerged, and the final plate is suspended in the gas phase. The test temperature is maintained at 55°C for at least one week before the metal plates are removed and analysed for mass loss.

Limit of acceptance:

The results are based on both localised, and uniform corrosion. The material will be classified as highly corrosive under the following conditions:

- Uniform corrosion: the mass loss of the most corroded sample exceeds the values given in Table 4-1; or

Table 4-1: Uniform corrosion mass loss criteria

Exposure time	Mass loss
7 days	13.5%
14 days	26.5%
21 days	39.2%
28 days	51.5%

- Localised corrosion: the depth of the deepest intrusion (to be determined metallographically) into the metal surface exceeds the values given in Table 4-2

Table 4-2: Localised corrosion intrusion criteria

Exposure time	Min. intrusion depth
7 days	120 µm
14 days	240 µm
21 days	360 µm
28 days	480 µm

Gate 4.3 – Does the waste have oxidising potential (H5.1)?

Oxidizing wastes will not normally be accepted directly for permanent isolation at the proposed Facility. Should a suitable treatment or encapsulation method be identified to treat or manage the wastes such that little or no oxidizing potential remains under the conditions of storage, it may be possible to accept the waste material. Any stabilisation shall be undertaken under the instruction of the suitably qualified person.

Test methods:

The United Nations Test Manual recommends using Test O.1 to classify oxidizing solids. This test is designed to measure the potential for the material to increase the burning rate or burning intensity of a combustible substance when they are thoroughly mixed, and to compare these characteristics with that of potassium bromate.

The *Recommendations On The Transport Of Dangerous Goods, Manual Of Tests And Criteria* also gives test methods for determining the oxidization potential of a liquid substance; however these materials will be excluded in Gate 3.2 and therefore the tests will not be utilized at the proposed facility

Limit of acceptance:

Substances that fail to ignite and burn under test conditions, or exhibits mean burning times greater than that of a 3:7 mixture (by mass) of potassium bromate and cellulose, will not to be classified as oxidising (H5.1).

Gate 4.4 – Is the waste a flammable liquids (H3)?

Flammable liquids will not be accepted directly for permanent isolation at the proposed Facility. Should a suitable treatment or encapsulation method be identified to treat or manage the wastes such that it is not flammable or liquid under the conditions of storage, it may be possible to accept the waste material for permanent isolation or in cell storage.

The processing of flammable liquid waste materials should be undertaken only if safe to do so, and if appropriate risk management and controls are in place. A suitably qualified person will be required to determine if and when any potentially flammable wastes may be received and disposed at the proposed Facility. Any treatment methodology for the stabilisation of the waste must be controlled and undertaken by suitably qualified persons. Detailed risk assessment will be undertaken to ensure the stabilisation and subsequent storage can be undertaken safely. Any treatment option must also address the state of the waste such that the stabilised waste will be solid in the conditions of storage.

Test methods:

Substances are classified as flammable liquids when their flash point is lower than 60°C in a closed-cup test, or lower than 65.6°C in an open-cup test. It is expected that flash point tests will be

completed for liquids suspected to be flammable as part of the initial characterisation testing via one or more of the following international standards:

- ISO 1516 Determination of flash/no flash – closed cup equilibrium method
- ISO 1523 Determination of flash point – Closed cup equilibrium method
- ISO 2719 Determination of flash point – Pensky-Martens closed cup method
- ISO 13736 Determination of flash point – Abel closed cup method
- ISO 3679 Determination of flash no flash and flash point – Rapid equilibrium closed cup method

Material that is found to be a flammable liquid must undergo treatment to ensure that it is unable to sustain combustion, and is no longer liquid. Test L.2 is designed to test the ability of a liquid to sustain combustion, by exposing a small portion to flame under controlled conditions. The full procedure and apparatus is given in *Recommendations On The Transport Of Dangerous Goods, Manual Of Tests And Criteria*.

Even if the waste is modified so that it passes Test L.2, it will not be accepted at the proposed Facility until Tellus is certain that it meets all other acceptance criteria.

Limit of acceptance:

The waste will be found to be capable of sustaining combustion if the following behavior is observed:

- The test sample ignites and sustains combustion when the test flame is off; or
- The test sample ignites while the test flame is applied for 15 seconds and maintains combustion for a minimum of 15 seconds after the flame has been turned off.

Intermittent flashing of the test sample material should not be interpreted as sustained combustion.

Gate 4.5 – Is the waste a flammable solid (H4.1)?

Highly flammable solid wastes will not normally be accepted directly for permanent isolation at the proposed Facility. Should a suitable treatment or encapsulation method be identified to treat or manage the wastes such that it is not flammable under the conditions of storage, it may be possible to accept the waste material for permanent isolation or in cell storage. The processing of flammable waste materials should be undertaken only if safe to do so, and if appropriate risk management and controls are in place. A suitably qualified person will be required to determine if and when any potentially flammable wastes may be received and disposed at the proposed Facility. Any treatment methodology for the stabilisation of the waste must be controlled and undertaken by suitably qualified persons.

Test methods:

Test N.1, taken from the *Recommendations On The Transport Of Dangerous Goods, Manual Of Tests And Criteria* published by the United Nations, assesses the ability of a substance to propagate combustion by igniting it and measuring the burning time.

Limit of acceptance:

Powdered, granular or pasty substances should be classified as Division 4.1 when the time of burning of one or more of the test runs, in accordance with the test method is less than 45 seconds or the rate of burning is more than 2.2 mm/s. Powders of metals or metal alloys should be classified when they can be ignited and the reaction spreads over the whole length of the sample in 10 minutes or less.

Gate 5 – Is the waste potentially self combustible and liable to Auto-Ignition?

Wastes which are self combustible and/or prone to self-ignition **in the conditions of storage** will not be accepted for in cell storage or permenant isolation at the proposed Facility. Such wastes may be reactive with soil moisture or incompatible with other waste types received at the facility for permanent isolation. If it can be demonstrated that the waste can be encapsulated or isolated, or transformed chemically and or physically to a form that is no longer combustible or prone to self-ignition, the waste may be able to be accepted for permanent isolation with controls in place.

The processing of self combustible and self-igniting waste materials should be undertaken only if safe to do so, and if appropriate risk management and controls are in place. A suitably qualified person will be required to determine if and when any potentially combustible and self-igniting wastes may be received and disposed at proposed Facility. Any treatment methodology for the stabilisation of the waste must be controlled and undertaken by suitably qualified persons. Detailed risk assessment will be undertaken to ensure the stabilisation and subsequent storage can be undertaken safely.

Test methods:

The *Recommendations On The Transport Of Dangerous Goods, Manual Of Tests And Criteria* outlines test methods to identify two different types of spontaneous combustion properties:

- Pyrophoric: Substances which ignite within five minutes of coming into contact with air. These are the most liable to spontaneous combustion.
- Self-heating: substances which, in contact with air and without an energy supply, are liable to self-heating. These substances will ignite only when in large quantities (kilograms) and after long periods of time (hours, days).

Solid pyrophoric substances are classified based on results from Test N.2. The test involves exposing the material to air for 5 minutes to determine whether the material ignites, and the time taken for ignition to occur.

Self-heating substances are classified based on the results from Test N.4. The test involves exposing samples of the material to air temperatures between 100°C and 140°C and measuring the temperature of the material compared to the air temperature.

Limit of acceptance:

Test N.2: if the material does not ignite within 5 minutes of air contact, the material is not pyrophoric.

Test N.4: a positive result is obtained if the material temperature exceeds that of the oven temperature by 60°C during the testing time. Otherwise it will be negative. The material will not be classified as self-heating if:

- A negative result is obtained in a test using 100mm cube sample at 140°C;
- A positive result is obtained in a test using a 100mm cube sample at 140°C and a negative result is obtained in a test using a 25mm cube sample at 140°C.

Gate 6 – Can the waste generate a gas-air mixture which is toxic or explosive?

Gate 3.1 prevents the acceptance of gases for permanent isolation. Wastes that can generate a gas air mixture that is toxic or explosive will also not be accepted at the proposed Facility for in cell storage or permanent isolation. Some wastes which may react with water or other wastes to release gases may be specifically excluded from permanent isolation. Alternatively, they may be managed through encapsulation, or physically and chemically transformed to a form which is no longer capable of releasing the toxic or explosive gases. In such cases, the method of management shall be developed specifically for that waste type, and managed and recorded by the supervising chemist or suitably qualified person.

Test methods:

The United Nations recommends Test N.5 to assess whether the substance will react with water to produce a flammable gas. A small sample of the material is brought into contact with water under controlled conditions.

A representative 500g sample of the waste will be reacted with concentrated hydrochloric acid (or sodium hydroxide to determine ammonia release from wastes with pH>10) for a period of 1 hour and absorption solutions used to absorb any toxic gases evolved. Appropriate analytical methods will then be used to quantify the gases present which values are then compared with thresholds based on concentrations required to create a toxic atmosphere at the bottom of the cell.

Limit of acceptance:

Based on the results from test N.5, the substance is classified as Class 4.3 if:

- Spontaneous ignition takes place in any step of the test procedure

- There is evolution of flammable gas at a rate greater than 1 Litre per Kilogram of the substance per hour

Gate 7 – Is the waste biodegradable?

Waste that is biodegrade, either by aerobic or anaerobic decomposition, are considered unacceptable for in cell storage or permeant isolation. Therefore such wastes are excluded from the facility. The wastes covered by this exclusion include:

- Vegetable matter (including food and garden waste).
- Animal matter (including food, animal parts, excreta, sanitary waste, animal fibre).
- Mixed household, commercial and industrial waste.
- Clinical waste (excluding pharmaceuticals).

Test methods:

Depending on the waste type, the total organic carbon (TOC) will be determined as part of the testing under basic characterisation. It is envisaged that, in general, TOC will be the parameter used as the organic content of any waste is of primary interest. The test method to be used will be based on BS EN 13137:2001 or equivalent.

Limit of acceptance:

If the TOC content of the waste is <6%[6] then it will be deemed acceptable for storage and permanent isolation at Sandy Ridge by this criterion. Certain wastes that contain organic carbon, for example railway sleepers impregnated with pesticides or certain hydrocarbon containing wastes, will be treated on a case by case basis to determine a suitable permanent isolation concept that in the conditions of storage will not compromise the integrity of the facility.

Gate 8 – Is the waste an infectious hospital or clinical waste (H6.2)?

Hospital waste or other clinical waste arising from medical or veterinary establishments which are infections as defined by property H6.2 in Annex III will not be accepted for permanent isolation at the proposed Facility. Alternative higher order methods of management are generally available for these wastes.

Test methods:

Material source identified. Visual inspection of waste.

[6] *the maximum TOC level permitted at a hazardous waste site - EC Waste Acceptance Criteria Section 2.4.2*

Limit of acceptance:

Zero hospital or clinical waste present in the waste load.

Gate 9 – Does the waste have the potential to be infectious to animals or humans (H6.2)?

Substances or wastes containing viable micro-organisms or their toxins which are known or suspected to cause disease in animals or humans will not be accepted for permanent isolation at the proposed Facility. Alternative higher order methods of management are generally available for these wastes.

Test methods:

Material source identified. Visual inspection of waste.

Limit of acceptance:

Zero infectious waste present in the waste load.

Gate 10 – Tyres

Used tyres are a controlled waste, as listed in Schedule 1 of the Environmental Protection (Controlled Waste) Regulations 2004.

Used tyres pose an environmental pollution risk mainly due the potential discharges and emissions from tyre fires. In certain circumstances tyres, or the products of tyre reprocessing may be accepted for permanent isolation at the Facility but only if it can be demonstrated that the waste can be encapsulated or isolated, or transformed chemically and or physically to a form that is no longer flammable (see Gate 4.1)

Test methods:

Visual Inspection

Limit of acceptance:

Compliance with all other criteria gates

Gate 11 – Conditions of Storage criteria. Can the waste and/or its container, release liquid, or react with the host clay in the facility which could affect either the operational and/or post closure safety of the facility?

Gate 11.1 – Can the waste release free liquid in the conditions of storage?

Wastes that possess the ability to release liquid, *self-transport* or move in the conditions of storage will be excluded from the Facility. Typical examples include hygroscopic materials, which have the ability to absorb water from the air, and wastes containing persistent organic pollutants that may separate into two phases, i.e. solid phase and liquid phase.

Test methods:

A pressure test will be used to determine if a waste will separate into two phases, with the pressure used being in excess of the maximum loading a waste could experience in the cell storage conditions (i.e. the pressure experienced by a the bottom bulk bag at the bottom of the cell). A further test will be carried out on wastes that pass the pressure test, but are considered to have the potential to separate into two phases. This would include wastes that have the potential to retain liquid in interstitial spaces, such as sand/water mixture and ion exchange resins.

A representative sample of the waste will be thoroughly mixed and subjected to a differential pressure of 1.5 bar for 15 minutes. This will be done by either applying pressure to the material on a filter or applying suction to the filter holding the material. Any displaced liquid will be measured as a volume and reported as a percentage of the whole.

A representative sample of the waste will be thoroughly mixed and be stood on a glass sinter for a period of 24 hours. If a liquid phase separates, the liquid will be measured as a volume and reported as a percentage of the whole.

Limit of acceptance:

The waste will fail the test and be deemed unsuitable for the facility if greater than 1% w/w of liquid is released.

Gate 11.2 – Does the waste possess the potential for an adverse reaction with the host clay?

Wastes may have the potential to react with the host Kaolin clay. If basic characterisation indicates the presence of any substance that is known to have the potential to react adversely with kaolin clay, the waste will be tested to determine if there is any reaction that may adversely affect the integrity of the clay barrier. Wastes exhibiting these properties that cannot be suitably modified or contained will be excluded.

Test methods:

A representative sample of the waste will be mixed with kaolin clay from the Sandy Ridge mine and left to stand for a period of 24 hours in a sealed container. The pressure and temperature within the container will be monitored to determine if a reaction has occurred.

Limit of acceptance:

Changes in pressure compared to ambient conditions indicates a reaction involving gas formation is occurring, while changes in temperature compared to ambient conditions indicates exothermic or endothermic reaction is occurring, even if no gas is generated. Any wastes which is found to react with kaolin will not be accepted for permanent isolation without stabilization treatment to make it unreactive.

Gate 11.3 – Does the waste have the potential to yield another hazardous substance (H13)?

Some wastes may change with time and produce intermediate products with differing properties to the initial disposed product. Wastes may also react with the containers to produce products with undesirable properties in the conditions of storage. Substances or wastes which, by interaction with air, water or other wastes that are liable to yield other hazardous substances in dangerous quantities need to be identified. Any waste which has the potential to yield other hazardous substances will not be accepted at the proposed Facility. Wastes exhibiting or expected to exhibit these properties that *cannot* be suitably modified or contained will be excluded.

Test methods:

To be determined on a case by case basis by competent person.

Limit of acceptance:

To be determined depending on waste streams considered.

Gate 12 – Is the waste radioactive?

Gate 12.1 – Generic waste acceptance criteria for radioactive waste

The following is a list of generic *waste acceptance criteria*[7] for radioactive waste that will be accepted at the proposed Facility. For waste to be acceptable for permanent isolation, the following physical and chemical characteristics shall apply to all categories of waste. These requirements are specified to minimise the potential hazard to personnel at the site, and to facilitate safe handling

[7] *Section 2.6 of the Near-Surface Disposal Code, Specific criteria and requirements for waste acceptance and disposal.*

during operations. The intention is to ensure the long-term stability of the waste and reduce the potential for dispersal of radionuclides from the site.

- Waste shall not contain corrosive materials; waste containing inorganic acids, alkalis and corrosive salts shall be treated to neutralise them and thereby to nullify the chemical effect of these materials.
- Where practicable, flammable or combustible materials, such as paper, plastics, cloth or resins, shall be separated from non-flammable solids and packaged, contained and labelled in a proper manner.
- Waste shall not contain or be capable of generating gaseous materials in quantities which might lead to the release of harmful vapours or fumes, or compromise the integrity of the facility.
- Waste shall not contain material which will readily detonate upon impact, decompose explosively, react violently with water or undergo vigorous exothermic reaction at normal temperatures and pressures.
- Waste containing pyrophoric material shall be treated, conditioned or packaged to render it non-flammable.
- Liquid waste shall be solidified to be acceptable for permanent isolation. The final package for permanent isolation shall comply with the stability requirements for the particular category of waste.
- As far as practicable, waste materials being disposed of should be free of biological materials.
- Radioactive waste contaminated with toxic, pathogenic or infectious material shall be treated or conditioned to minimise both the potential hazard to site personnel and the long-term health risks to members of the public. Any treatment should be carried out in accordance with relevant NHMRC guidelines such as National guidelines for the management of clinical and related wastes (Australian Government Publishing Service, Canberra, 1988) and Guidelines for laboratory personnel working with carcinogenic or highly toxic chemicals (Australian Government Publishing Service, Canberra, 1990).
- Waste which contains chelating agents shall be treated or conditioned to reduce the possible long-term effects of leaching by water, although water in the Sandy Ridge cells is not expected.

Gate 12.2 – Radiological acceptance criteria

Refer to Section 5 of this procedure for specific activity and half-life values for radioactive waste acceptance.

Gate 13 – Does the waste meet the packaging criteria?

The Australian Code for the Transport of Dangerous Goods by Road and Rail (2016) details the requirements for safe packaging and transport of hazardous materials, based on the classification of the waste. Tellus requires that all customers adhere to the code to ensure packaging is appropriate to the hazardous characteristics of the waste in question. Containment systems should normally consist of one or more of the following packaging options;

- 20' ISO shipping containers or 20' ISO tank containers
- Bulk bags in containers, on pallets or free standing
- 215 Litre drums on pallets in containers
- $1m^3$ IBCs in containers
- Small palletised goods in containers (e.g. radioactive materials)
- Loose bulk in containers (e.g. contaminated soils)
- Liquid tanker truck (e.g. bulk liquids or pastes) which will undergo solidification or stabilization treatments
- Pneumatic tanker truck (e.g. bulk dry powder solids)
- Solid materials on flatbed trucks (e.g. railway sleepers, O&G pipe, machinery).

The original IWDF *Waste Acceptance Guidelines* 2011 provide clear criteria for the packaging of waste for delivery to the Mount Walton East site, which is presented below. Tellus have considered the IWDF packaging requirements to be consistent with industry best practices; therefore waste packaging delivered to the proposed Facility should fulfil the following criteria;

- Not have a total measured weight of more than the Safe Working Load
- Be capable of being disposed of with the waste
- Be filled so as to contain no significant voids
- Be free of ruptures at the point of delivery
- Be free of external contamination at the point of delivery
- Not significantly deteriorate during the duration of storage, transport and handling when in contact with the waste
- Remain intact during normal transport and handling procedures
- Be strong enough to be walked on if required

- Be clearly labelled with the waste owner's name and identification number and material description/name on opposite sides of the waste package
- Allow no leakage during normal transport and handling operations
- Be capable of containing all the waste whatever the orientation of the package.

It should be anticipated that packaging containers have the potential to fail in the conditions of storage if no other consideration is given to the form of the packaging and wastes contained therein. To minimise the likelihood and potential impacts of packaging failure, the following measures are required to be undertaken:

- Void spaces inside containers are to be minimised – packages shall be grout filled or similar to remove voids inside any container that will be disposed with the waste.
- Low density wastes (PPE etc.) should be baled or similarly compacted to the highest density reasonably and practicably achieved (as close to 200kPa as practical to be consistent with the available backfill materials). This compaction activity should be undertaken prior to any grout filling.
- Low density wastes should be identified so that, as far as practicable during the receival activity at site, be segregate for special attention in the development of the filling plan.
- Low density waste should be packaged in smaller vessels, or should be packaged and disposed as long shallow packages to reduce the scale of any settlement or failure.

5 RADIOACTIVE WASTE

5.1 Waste Acceptance Procedure for radioactive waste

WAC for the facility are based on the design of the facility, including, but not limited to, such items as the engineered barriers, duration of institutional control and site specific characteristics such as geology, low rainfall, lack of receptors, etc.

The activity of the radionuclides present in the radioactive waste packages will be limited in such a way that the radiological impact of the site remains within acceptable levels during the operational and post-closure phases of the site. In accordance with international atomic energy agency (IAEA) waste are considered as a function of their half-life and activity concentration. Radiation doses to the public and workers as a consequence of waste management, storage and disposal activities are not to exceed the dose limits in Regulations 59 and 60 of the ARPANS Regulations. The effective dose limit for occupational exposure is 20 mSv annually, averaged over 5 consecutive calendar years. However, the effective dose for a person subject to occupational exposure must not, in a year, be greater than 50 mSv. The effective dose limit for public exposure is 1 mSv annually).

The ARPANSA *Licensing of Radioactive Waste Storage and Disposal Facilities March 2013* explains that waste acceptance should be undertaken in accordance with Section 2.6 of the Near-Surface Disposal Code, Specific criteria and requirements for waste acceptance and disposal. Guidance on determining waste activity limits for low level waste in near-surface disposal facilities is found in the IAEA TECDOC *Derivation of Activity Limits for the Disposal of Radioactive Waste in near Surface Disposal Facilities* (IAEA-TECDOC-1380, 2003).

The following sections provide details on how the regulatory guidance has been applied in establishing criteria for acceptance of NORM and bulk wastes and also for sealed sources.

5.2 Norm and bulk wastes

In order to derive activity concentrations limits for individual radionuclides in NORM and bulk wastes, two criteria have been used:

- Dose rate to a human receptor post closure (with capping material in place) to not exceed a dose constraint of 0.3 mSv in a year. Occupancy of 3.5 days a year was assumed as per ARPANSA TRS No. 141 for an arid and remote site.
- Dose rate to a human receptor upon intrusion (no capping) corresponding to 10mSv/y as per ICRP guidance on radiological criteria applied to human intrusion.

The RESRAD (Onsite) code was used, to determine radionuclide activity concentration levels in bulk NORM wastes which would give rise to conditions as specified above for post closure and intrusion scenarios. Details of assessment are presented in the Radiological Risk Assessment: Post Closure

report. Table 5-1 summaries the Radionuclide restrictions that should be applied in the Waste Acceptance Criteria (WAC) for the Facility for the disposal of NORM bulk wastes.

For bulk NORM wastes having mixtures of radionuclides, an additional constraint should be adhered to so that the total dose from all the radionuclides should not exceed relevant dose limits or constraints. This is referred to as the summation rule and requires the following constraint:

$$\sum_i Q_i / Q_{i,l} <= 1$$

Where Q_i (Bq) is the actual activity of radionuclide i to be disposed and $Q_{i,l}$ (Bq) is the activity limit for radionuclide i if it were the only radionuclide to be disposed of.

Table 5-1: Waste Acceptance Criteria (WAC) for the Facility for bulk NORM waste

Radionuclides	Half Life	Individual Radionuclide Activity Concentration of Bulk NORM Waste (Bq/g)
		(Bq/g) to achieve 10 mSv/y upon Intrusion
U-238	4.468 billion years	1.0E+05
U-234	246,000 years	2.0E+06
Th-230	75,380 years	1.2E+04
U-235	703.8 million	2.2E+04
Pa-231	32,760 years	7.1E+03
Ra-226	1600 years	1.8E+03
Th-232	14.05 billion years	1.1E+03

5.3 Sealed Sources

Table 5-2 summarises the Waste Acceptance Criteria (WAC) proposed for the disposal of Sealed Sources. The activity of the radionuclides present in the radioactive waste packages will be limited in such a way that the radiological impact of the site is within the dose constraint limits set by the facility, under any foreseeable set of circumstances. Sources at activity Concentration levels above those specified in the table will not be accepted for disposal without re-assessing the safety case and seeking approval from the relevant regulatory bodies.

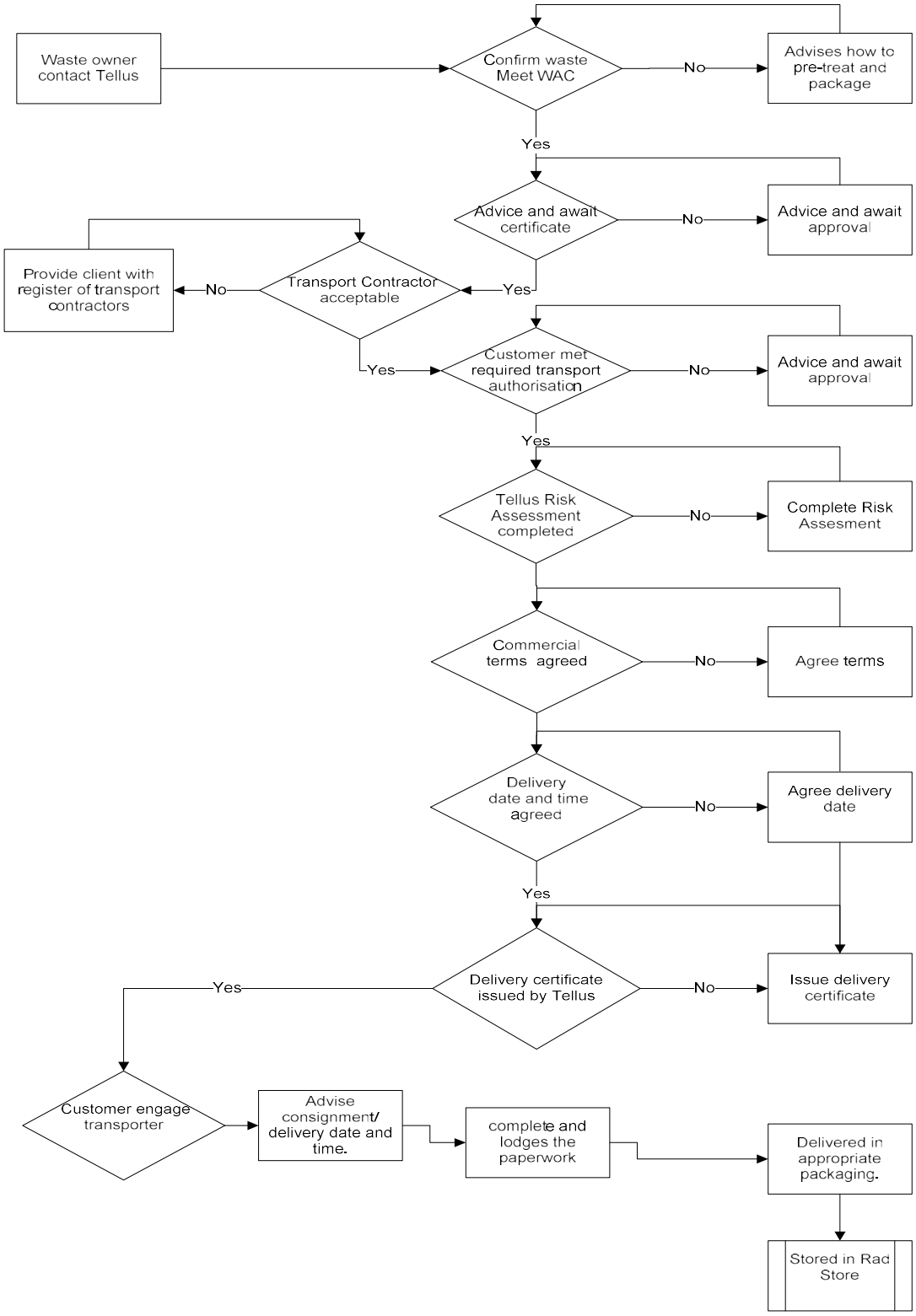
Table 5-2: Limits for common sources based on NHMRC near surface code (1992)

Radioisotope	Symbol	Half-life	Decay	Concentration limit (Bq)*
				100 years ICP
Americium-241	Am-241	432.17 y	α	2.00E+10
Barium-133	Ba-133	10.74 years	EC	no limit
Caesium-137	Cs-137	30.07 years	γ/β	2.00E+11
Californium-252	Cf-252	2.6 years	α	2.00E+10
Carbon-14	C-14	5 715 years	β	2.00E+11
Chlorine-36	Cl-36	301 000 years	β	2.00E+11
Chromium-51	Cr-51	2.7 days	EC	no limit
Cobalt 57	Co-57	271.8 days	EC	no limit
Cobalt-60	Co-60	5.27 years	γ	no limit
Gold-198	Au-198	2.7 days	β	no limit
Hydrogen-3 (tritium)	H-3	12.32 years	β	2.00E+11
Indium-111	In-111	2.80 days	EC	no limit
Iodine-129	I-129	15.7 million years	β	2.00E+10
Iridium-192	Ir-192	73.8 days	γ/B	2.00E+10
Krypton-85	Kr-85	10.5 years	β	2.00E+11
Iron-55	Fe-55	2.74years	EC	no limit
Lead-210	Pb-210	22.6 years	β	2.00E+11
Manganese-54	Mn-54	312.1 days	EC	no limit
molybdenum-99	Mo-99	66 hours	β	no limit
Nickel-63	Ni-63	96 Years	β	2.00E+11
Polonium-210	Po-210	138 days	α	2.00E+10
Radium-226	Ra-226	1,600 years	α	1.00E+09
Selenium-75	Se-75	120 days	γ	no limit
Sodium-22	Na-22	2.6 years	γ	no limit
Strontium-90	Sr-90	28.8 years	β	2.00E+11
Technetium-99m	Tc-99m	6.01 days	γ	no limit
Thallium-204	Tl-204	3.78 years	β	no limit
Thulium-170	Tm-170	129 days	β	no limit
Ytterbium-169	Yb-169	32 days	EC	no limit
Zinc-65	Zn-65	243.87 days	EC	no limit

**(alpha (α), Beta (β), Gamma (γ) or Electro capturing (EC))*

Before a radioactive waste can be accepted, Tellus must be satisfied that the waste meets its WAC (refer to WAC). The WAP for radioactive waste is summarised in Figure 5-1 below and discussed in more detail in the WAP document. It should be noted that the second step on the flow chart "Advice and await certificate" is a regulator step where a review of the permanent isolation application is carried out prior to the issuing of a disposal certificate.

Figure 5-1: Radioactive waste acceptance procedure



6 REJECTED WASTES

Wastes that do not meet the acceptance criteria may need to be rejected. This should not occur frequently due to the first two Levels, compliance and verification testing that will take place. Level 3 on-site verification may occasionally identify wastes that need to be rejected or some wastes may fail waste packaging criteria tests.

- **Level 1: Basic characterisation**. This is a thorough determination, according to standardised analysis and behaviour-testing methods, of the characteristic properties of the waste. This is the key decision step in determining whether a waste can or cannot be accepted. This stage takes place at the waste supplier site and only if the waste passes all of the WAC gates can Tellus agree to accept the waste at the Sandy Ridge Facility.

- **Level 2: Compliance testing**. After a waste stream has been accepted as meeting the Sandy Ridge WAC Level 2 compliance testing is then periodically performed on regularly arising wastes by simpler standardised analysis and behaviour-testing methods to determine whether a waste complies with licence conditions and whether a waste with known properties has changed significantly. The tests focus on key variables and behaviour identified by basic characterisation.

- **Level 3: On-site verification**. This constitutes rapid check methods to confirm that a waste is the same as that which has been subjected to compliance testing and that which is described in the accompanying documents.

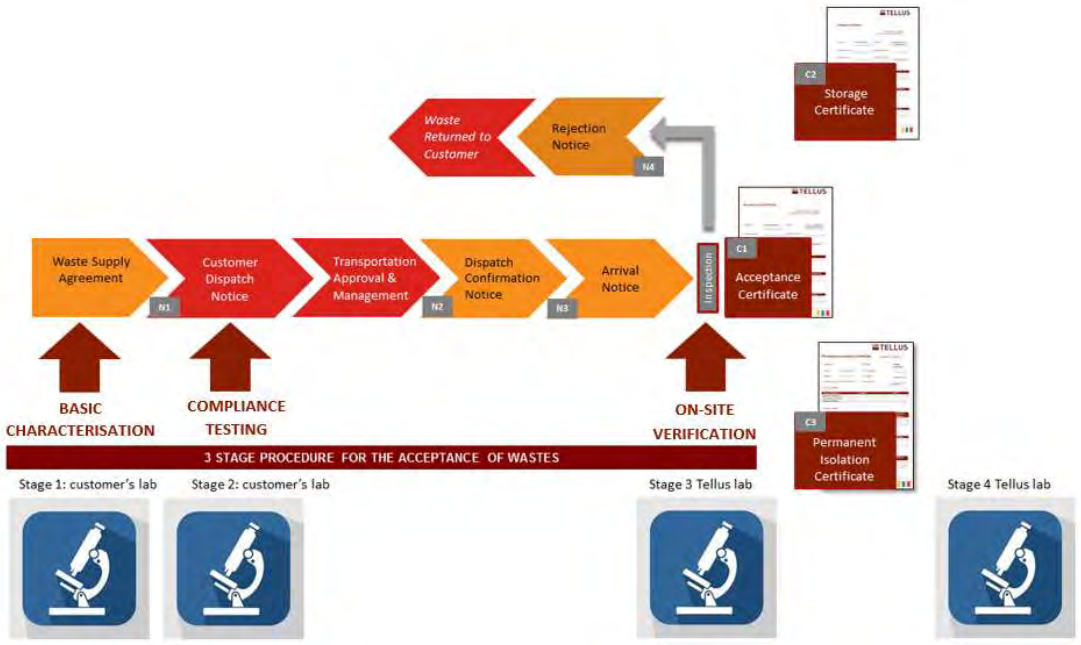
In the event that waste that cannot be accepted arrives at the site it will be placed into a specifically identified quarantine area until arrangements can be made to modify it into a waste form suitable for storage and disposal or to safely return it to the customer.

7 NOTIFICATION AND CERTIFICATION

7.1 Traceability, Approval System and Documents

At all of its facilities, Tellus will adopt a rigid Quality Assurance, Traceability, Notification and Certification System. This process is summarised in Figure 7-1 and is designed to complement tracking systems required by other legislation such as the *Australian Code for the Transport of Dangerous Goods by Road and Rail* and the *National Environmental Protection (movement of controlled wastes between States and Territories) Measure.*

Figure 7-1: Tellus' traceability process



7.2 Notification Service

Tellus will implement a notification service for management of the waste that is delivered to Sandy Ridge. This will include;

- N1 - Dispatch Notice issued by Customer
- N2 - Dispatch Confirmation issued by Tellus
- N3 - Arrival Notice issued by Tellus
- N4 - Rejection Notice issued by Tellus if necessary

7.2.1 N1 - Dispatch notice issued by Customer

Prior to dispatching waste to the Facility, the Customer must issue a Dispatch Notice to Tellus. The Dispatch Notices must be issued so that deliveries are in accordance with the Waste Delivery Plan. The Dispatch Notice will include information on the waste code, description, weight, volume, MSDS, proposed date of delivery and Transport Plan. It is anticipated that following the issue of a Dispatch Notice the Customer will secure all required approvals for transportation (e.g. NEPM approvals for movement of controlled substances and Dangerous Goods), arranging packing and accredited transporters.

7.2.2 N2 - Dispatch confirmation notice issued by Tellus

Tellus will issue a Dispatch Confirmation Notice to the Customer, either confirming that the dispatch may proceed; or may not proceed, including reasons (example: resources or space temporarily not available). This will normally be issued within 5 Business Days of Tellus receiving evidence from the Customer of all required approvals for transportation. Tellus is not required to accept waste at the Facility unless Tellus has issued a Dispatch Confirmation Notice.

7.2.3 N3 - Arrival notice issued by Tellus

All deliveries of waste must be booked in at least 48 hours prior to the arrival of the delivery. This is to ensure that sufficient segregated storage is available for any particular waste stream. Un-booked deliveries may be subject to delays in unloading and/or may incur additional charges. Tellus will issue an Arrival Notice to the customer confirming arrival of the delivery at the Nominated Facility (provided that Tellus has issued a Dispatch Confirmation Notice in relation to that delivery). The Arrival Notice will be generated at the weighbridge (in real time).

7.2.4 Inspection point

Following the issue of an Arrival Notice, at the Sandy Ridge Delivery Point, the waste will be subjected to weighing, visual inspection of containers, and sampling. On-site laboratory testing (Level 3, On-site verification checks) will be performed by qualified persons to analyse the waste streams to determine if the waste acceptance criteria are satisfied and to ensure compliance with any site licence Conditions of Acceptance. If the waste is accepted, this is the point of risk transfer and an Acceptance Certificate is issued. If the waste is rejected, there is no transfer of risk, and a Rejection Notice is issued. A representative sample will be taken from each delivery batch and waste type. Details of third party analysis and a Material Safety Data Sheet will assist in the correct identification.

The Conditions of Acceptance for the Nominated Facility will specify that the Customer must provide:

- Prior to unloading, documentation supporting that Waste was transported in accordance with all required Approvals;

- the weight card, which provides evidence of the gross weight of the delivery to be used as the basis for billing;
- documentation of Waste volume, and waste codes; and
- acceptable packaging;

The waste must not comprise any unlawful material. The delivery must be consistent with the Dispatch Notice from the Customer

7.2.5 N4 Rejection Notice N4 - Rejection Notice issued by Tellus (if necessary)

If an Acceptance Certificate is not issued, the Customer will be issued a Rejection Notice and will remain responsible for the delivery; and the rejected delivery will be managed in accordance with the Rejection Procedure. The Procedure will provide that, amongst other things, Tellus may procure the return of the delivery to the address in the Dispatch Notice (at the cost and risk of the Customer).

Tellus may (in its sole discretion) elect, by notice in writing, to accept the delivery in which case Tellus may treat and or repackage the waste at the cost of the Customer. If Tellus makes this election, the waste will be deemed to be Acceptable Waste and an Acceptance Certificate will be issued.

7.3 Documents - Certification Service

Tellus will implement a certification process post inspection for Acceptable Waste that is delivered to the delivery point within the proposed Facility. This will include;

- C1 - Acceptance Certificate.
- C2 - Storage Certificate.
- C3 - Permanent Isolation Certificate.

C1 - Acceptance certification (AC)

Assuming that the delivery of waste is compliant with the Conditions of Acceptance for the Nominated Facility and has been taken to have been accepted at the Nominated Facility by both the Inspection Manager and the Facility Manager then an Acceptance Certificate is issued

C2 - Storage certificate (SC)

Tellus must place Acceptable Waste in a Storage Location and issue a Storage Certificate to the Customer. This certificate will be issued within twenty business days of placement in the Storage Location

C3 - Permanent isolation certificate (PIC)

Tellus will isolate Acceptable Waste, and issue a PIC once that waste is in its final destination (underground room or cell in the geological repository part of the Nominated Facility). This certificate will be issued within twenty business days of placement in the final destination (refer to Annexure).

7.4 Waste Title and Management risk

Title to the waste and management risk of the waste varies depending on wether the waste is rejected, placed into storage or permanently isolated. This is summarised below;

Rejected waste:

Title to the waste and management risk remains with Customer and accordingly, neither title nor risk pass to Tellus at any time.

Storage service:

Title in the waste remains at all times with the Customer (whether short or long term storage) and the ***management risk*** in the waste passes to Tellus on issue of the Acceptance Certificate, for so long as the Waste continues to comply with the Conditions of Acceptance. Risk passes back to Customer at the end of the Storage Term.

Permanent isolation service:

Title and ***management risk*** in the waste passes to Tellus on the issue of an Acceptance Certificate until the site is handed back to government.

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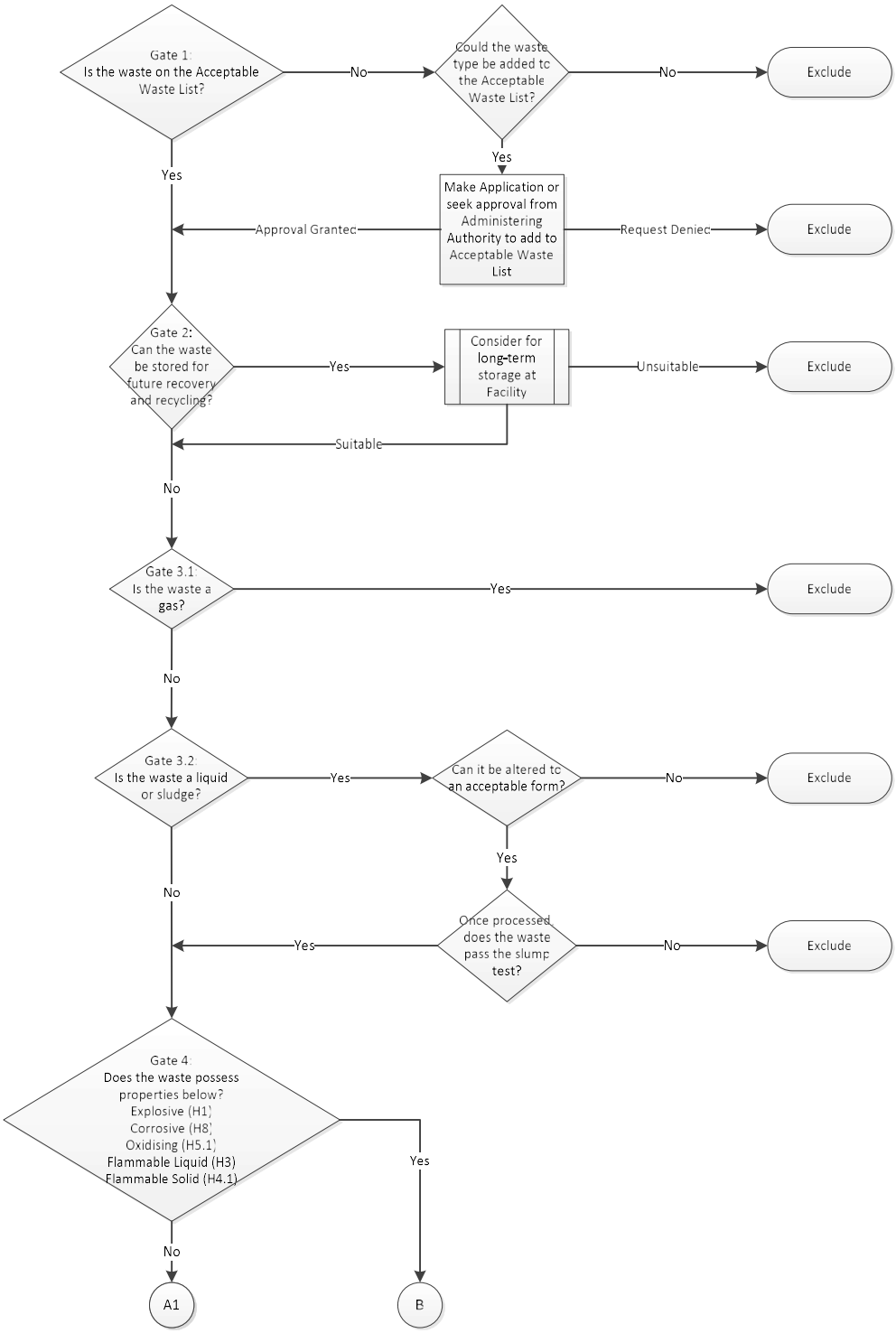
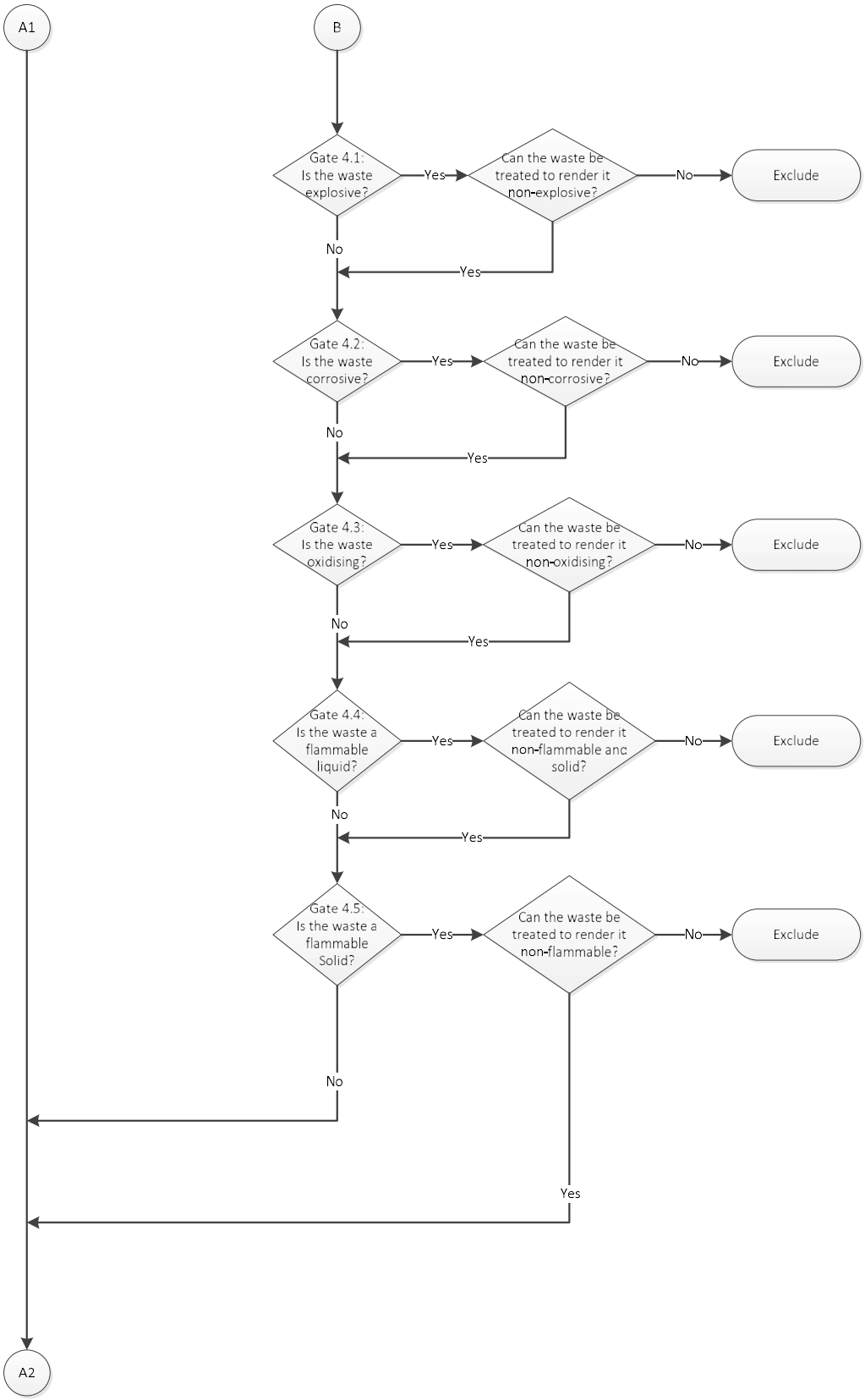
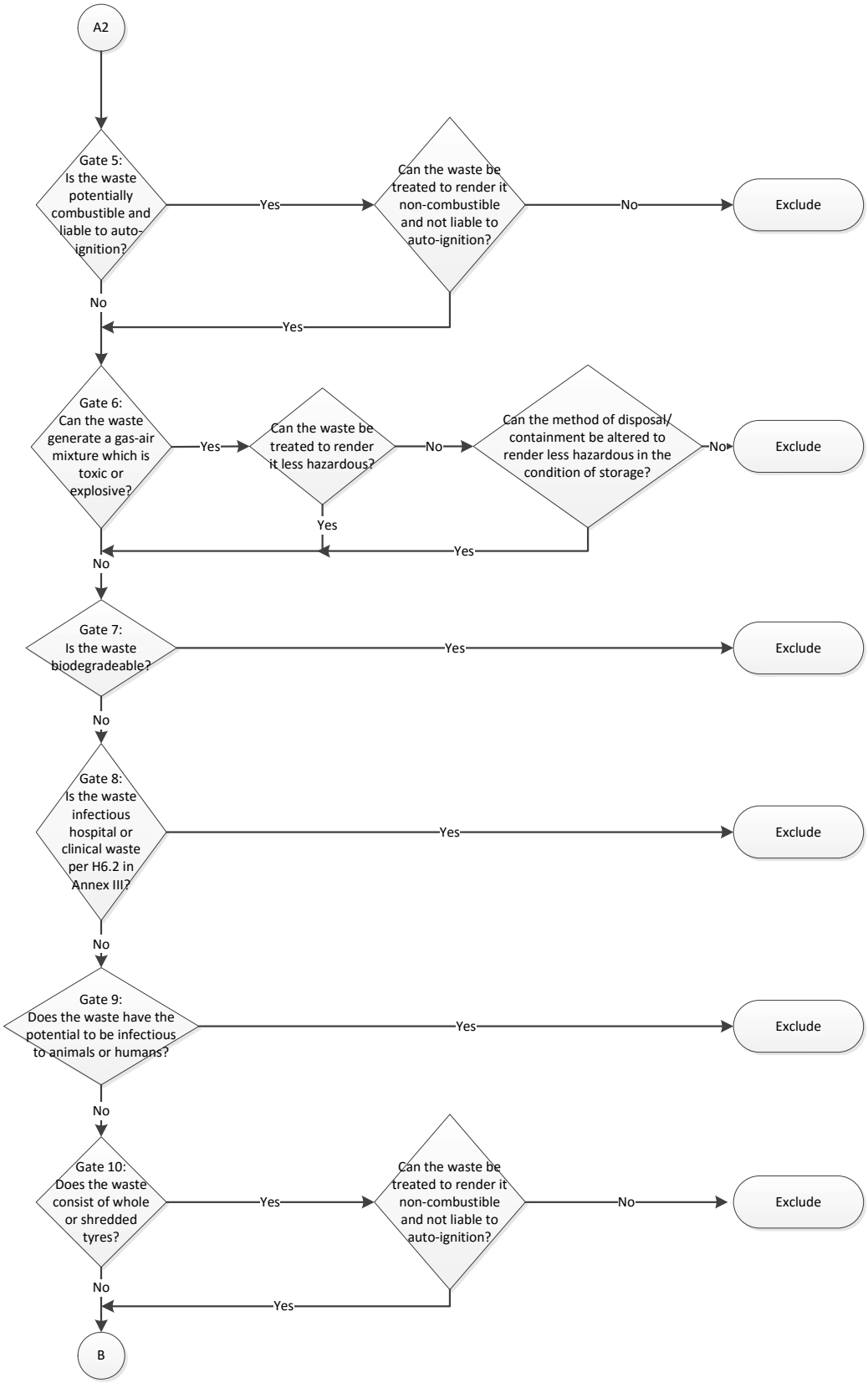
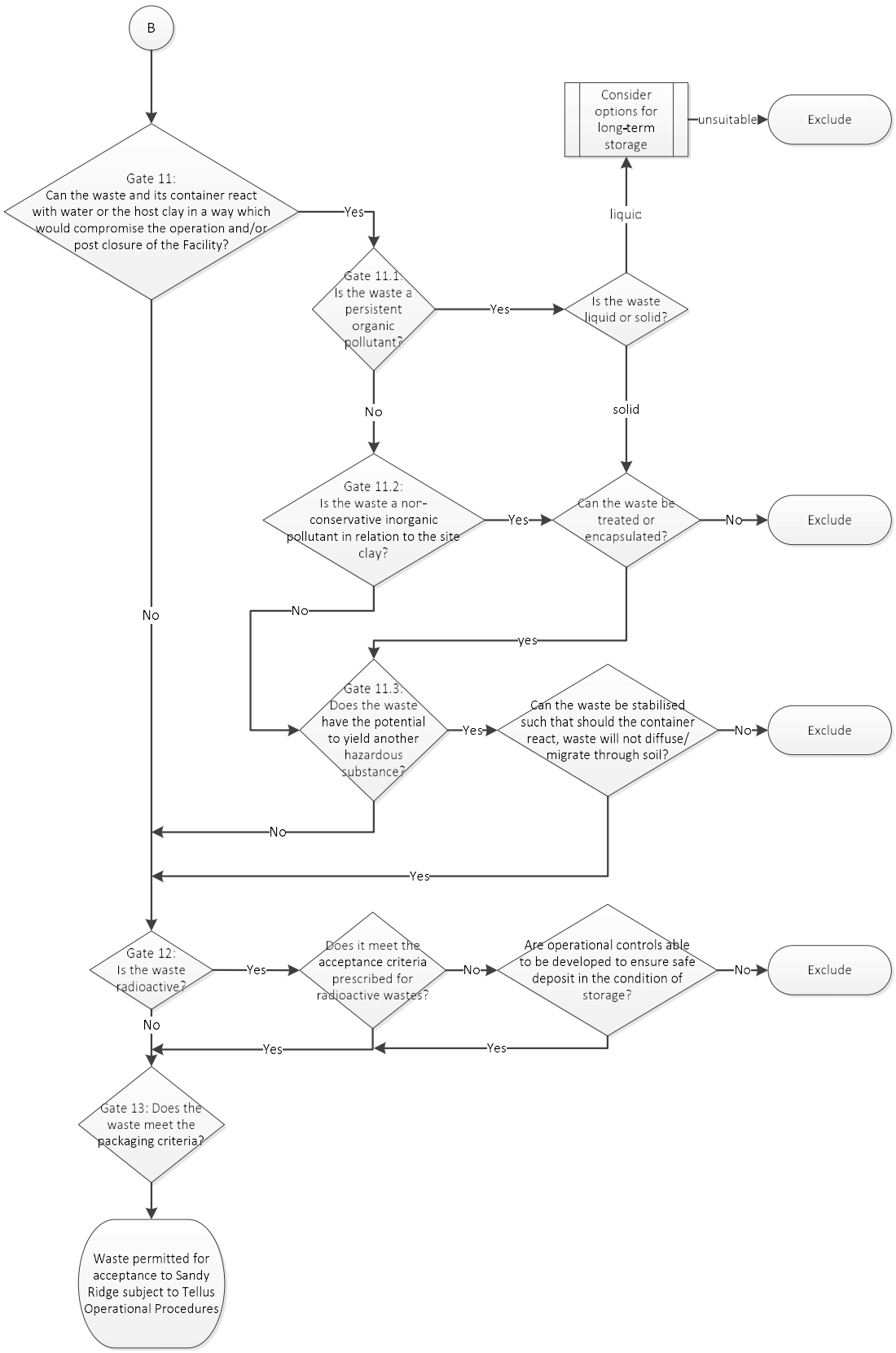
A.1 Gated waste acceptance process flow chart




A1
B
Gate 4.1: Is the waste explosive?
Yes
Can the waste be treated to render it non-explosive?
No
Exclude
Yes
No
Gate 4.2: Is the waste corrosive?
Yes
Can the waste be treated to render it non-corrosive?
No
Exclude
Yes
No
Gate 4.3: Is the waste oxidising?
Yes
Can the waste be treated to render it non-oxidising?
No
Exclude
Yes
No
Gate 4.4: Is the waste a flammable liquid?
Yes
Can the waste be treated to render it non-flammable and solid?
No
Exclude
Yes
No
Gate 4.5: Is the waste a flammable Solid?
Yes
Can the waste be treated to render it non-flammable?
No
Exclude
No
Yes
A2


A2
Gate 5: Is the waste potentially combustible and liable to auto-ignition?
Yes
Can the waste be treated to render it non-combustible and not liable to auto-ignition?
No
Exclude
Yes
No
Gate 6: Can the waste generate a gas-air mixture which is toxic or explosive?
Yes
Can the waste be treated to render it less hazardous?
No
Can the method of disposal/ containment be altered to render less hazardous in the condition of storage?
No
Exclude
Yes
Yes
No
Gate 7: Is the waste biodegradeable?
Yes
Exclude
No
Gate 8: Is the waste infectious hospital or clinical waste per H6.2 in Annex III?
Yes
Exclude
No
Gate 9: Does the waste have the potential to be infectious to animals or humans?
Yes
Exclude
No
Gate 10: Does the waste consist of whole or shredded tyres?
Yes
Can the waste be treated to render it non-combustible and not liable to auto-ignition?
No
Exclude
Yes
No
B


B
Gate 11:
Can the waste and its container react with water or the host clay in a way which would compromise the operation and/or post closure of the Facility?
Yes
No
Gate 11.1:
Is the waste a persistent organic pollutant?
Yes
No
Is the waste liquid or solid?
liquid
solid
Consider options for long-term storage
unsuitable
Exclude
Gate 11.2:
Is the waste a non-conservative inorganic pollutant in relation to the site clay?
Yes
No
Can the waste be treated or encapsulated?
No
Exclude
yes
Gate 11.3:
Does the waste have the potential to yield another hazardous substance?
Yes
No
Can the waste be stabilised such that should the container react, waste will not diffuse/ migrate through soil?
No
Exclude
Yes
Gate 12:
Is the waste radioactive?
Yes
No
Does it meet the acceptance criteria prescribed for radioactive wastes?
No
Are operational controls able to be developed to ensure safe deposit in the condition of storage?
No
Exclude
Yes
Yes
Gate 13: Does the waste meet the packaging criteria?
Waste permitted for acceptance to Sandy Ridge subject to Tellus Operational Procedures

A.2 Basel Convention Annex III: List Of Hazardous Characteristics

UN Class	Code	Characteristics
1	H1	**Explosive** An explosive substance or waste is a solid or liquid substance or waste (or mixture of substances or wastes) which is in itself capable by chemical reaction of producing gas at such a temperature and pressure and at such a speed as to cause damage to the surroundings.
3	H3	**Flammable Liquids** The word "flammable" has the same meaning as "inflammable". Flammable liquids are liquids, or mixtures of liquids, or liquids containing solids in solution or suspension (for example, paints, varnishes, lacquers, etc., but not including substances or wastes otherwise classified on account of their dangerous characteristics) which give off a flammable vapour at temperatures of not more than 60.5ºC, closed-cup test, or not more than 65.6ºC, open-cup test. (Since the results of open-cup tests and of closed-cup tests are not strictly comparable and even individual results by the same test are often variable, regulations varying from the above figures to make allowance for such differences would be within the spirit of this definition.)
4.1	H4.1	**Flammable Solids** Solids, or waste solids, other than those classed as explosives, which under conditions encountered in transport are readily combustible, or may cause or contribute to fire through friction
4.2	H4.2	Substances or wastes liable to spontaneous combustion Substances or wastes which are liable to spontaneous heating under normal conditions encountered in transport, or to heating up on contact with air, and being then liable to catch fire
4.3	H4.3	**Substances or wastes which, in contact with water, emit flammable gases** Substances or wastes which, by interaction with water, are liable to become spontaneously flammable or to give off flammable gases in dangerous quantities
5.1	H5.1	**Oxidising** Substances or wastes which, while in themselves not necessarily combustible, may, generally by yielding oxygen, cause or contribute to, the combustion of other materials.
5.2	H5.2	**Organic Peroxides** Organic substances or wastes which contain the bivalent-o-o-structure are thermally unstable substances which may undergo exothermic self-accelerating decomposition.
6.1	H6.1	**Poisonous (Acute)** Substances or wastes liable either to cause death or serious injury or to harm human health if swallowed or inhaled or by skin contact
6.2	H6.2	**Infectious Substances** Substances or wastes containing viable microorganisms or their toxins which are known or suspected to cause disease in animals or humans

8	**H8**	**Corrosives** Substances or wastes which, by chemical action, will cause severe damage when in contact with living tissue, or, in the case of leakage, will materially damage, or even destroy, other goods or the means of transport; they may also cause other hazards
9	**H10**	**Liberation of toxic gases in contact with air or water** Substances or wastes which, by interaction with air or water, are liable to give off toxic gases in dangerous quantities
9	**H11**	**Toxic (Delayed or chronic)** Substances or wastes which, if they are inhaled or ingested or if they penetrate the skin, may involve delayed or chronic effects, including carcinogenicity
9	**H12**	**Ecotoxic** Substances or wastes which, if released, present or may present immediate or delayed adverse impacts to the environment by means of bioaccumulation and/or toxic effects upon biotic systems
9	**H13**	Capable, by any means, after disposal, of yielding another material, e.g. leachate, which possess any of the characteristics listed above

A.3 Potential waste category list

Common industrial hazardous waste (NEPM basis)	
Acidic solutions or acids in solid form	B100
Animal effluent and residues (abattoir effluent, poultry and fish processing wastes)	K100
Antimony; antimony compounds	D170
Arsenic; arsenic compounds	D130
Asbestos	N220
Barium compounds (excluding barium sulphate)	D290
Basic solutions or bases in solid form	C100
Beryllium; beryllium compounds	D160
Boron compounds	D310
Cadmium; cadmium compounds	D150
Ceramic-based fibres with physio-chemical characteristics similar to those of asbestos	N230
Chlorates	D350
Chromium compounds (hexavalent and trivalent)	D140
Clinical and related wastes	R100
Cobalt compounds	D200
Containers and drums that are contaminated with residues of substances referred to in this list	N100
Copper compounds	D190
Cyanides (inorganic)	A130
Cyanides (organic)	M210
Encapsulated, chemically-fixed, solidified or polymerised wastes referred to in this list	N160
Ethers	G100
Filter cake contaminated with residues of substances referred to in this list	N190
Fire debris and fire wash waters	N140
Fly ash, excluding fly ash generated from Australian coal fired power stations	N150
Grease trap waste	K110
Halogenated organic solvents	G150
Highly odorous organic chemicals (including mercaptans and acrylates)	M260
Inorganic fluorine compounds excluding calcium fluoride	D110
Inorganic sulfides	D330
Isocyanate compounds	M220
Lead; lead compounds	D220
Mercury; mercury compounds	D120
Metal carbonyls	D100
Nickel compounds	D210
Non-toxic salts	D300
Organic phosphorous compounds	H110
Organic solvents excluding halogenated solvents	G110
Organo halogen compounds—other than substances referred to in this Table.	M160
Perchlorates	D340
Phenols, phenol compounds including chlorophenols	M150

Common industrial hazardous waste (NEPM basis)	
Phosphorus compounds excluding mineral phosphates	D360
Polychlorinated dibenzo-furan (any congener)	M170
Polychlorinated dibenzo-p-dioxin (any congener)	M180
Residues from industrial waste treatment/disposal operations	N205
Selenium; selenium compounds	D240
Soils contaminated with a controlled waste	N120
Surface active agents (surfactants), containing principally organic constituents and which may contain metals and inorganic materials	M250
Tannery wastes (including leather dust, ash, sludge's and flours)	K140
Tellurium; tellurium compounds	D250
Thallium; thallium compounds	D180
Triethylamine catalysts for setting foundry sands	M230
Tyres	T140
Vanadium compounds	D270
Waste chemical substances arising from research and development or teaching activities, including those which are not identified and/or are new and whose effects on human health and/or the environment are not known	T100
Waste containing peroxides other than hydrogen peroxide	E100
Waste from heat treatment and tempering operations containing cyanides	A110
Waste from manufacture, formulation and use of wood-preserving chemicals	H170
Waste from the production and preparation of pharmaceutical products	R140
Waste from the production, formulation and use of biocides and phytopharmaceuticals	H100
Waste from the production, formulation and use of inks, dyes, pigments, paints, lacquers and varnish	F100
Waste from the production, formulation and use of organic solvents	G160
Waste from the production, formulation and use of photographic chemicals and processing materials	T120
Waste from the production, formulation and use of resins, latex, plasticisers, glues and adhesives	F110
Waste mineral oils unfit for their original intended use	J100
Waste of an explosive nature not subject to other legislation	T200
Waste oil/water, hydrocarbons/water mixtures or emulsions	J120
Waste pharmaceuticals, drugs and medicines	R120
Waste resulting from surface treatment of metals and plastics	A100
Waste substances and articles containing or contaminated with polychlorinated biphenyls, polychlorinated napthalenes, polychlorinated terphenyls and/or polybrominated biphenyls	M100
Waste tarry residues arising from refining, distillation, and any pyrolytic treatment	J160
Wool scouring wastes	K190
Zinc compounds	D230

Waste Acceptance Criteria and Supporting Documents

TELLUS

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SANDY RIDGE FACILITY WASTE ZONING GUIDE

Final Report | August 2016

Version	Date	Description	Signatures		
			Originator	Checked	Approved
0	10/08/2016	For issue	S. Reece	J. Livesey R. Phillips	D van der Merwe

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ABBREVIATIONS

ASCC	Australian Safety and Compensation Council
The Facility	The Sandy Ridge Facility
FIBC	Flexible Intermediate Bulk Container
IWDF	Intractable Waste Disposal Facility
km	kilometres
L	Litres
m	metres
NEPM	National Environmental Protection Measure
NOHSC	National Occupational Health and Safety
NORM	Naturally Occurring Radioactive Materials
Tellus	Tellus Holdings Ltd.
WAC	Waste Acceptance Criteria
WAP	Waste Acceptance Procedures
WZG	Waste Zoning Guidelines
Zone AC	Acidic Nature
Zone AL	Alkaline Nature
Zone PT	Poisonous or Toxic
Zone R	Radioactive
Zone S	Other

DEFINITIONS

Cell - an excavated area (pit) of kaolin which is below ground level which will be used for *in cell storage* or *permanent isolation* of waste.

Conditions of storage - The term "in the conditions of storage" is used to differentiate between the generic properties of a material and how those properties may be modified when that material is placed into "in cell storage" or "permanent isolation" within a cell.

Dangerous goods – the Dangerous Goods Safety (General) Regulations 2007 defines "dangerous goods" as any substance or article that is:

a) Found to be within any of the following classes or divisions under the Australian Dangerous Goods Code: Class 1, Class 2, Class 3, Class 4, Class 5, Division 6.1, Class 8, or Class 9; unless stated otherwise within the Code.

b) named or described in Schedule 1 of the Environmental Protection (Controlled Waste) Regulations 2004

Geological repository (in the context of Sandy Ridge) - The term geological repository is used to mean a landfill facility constructed and with the equivalent properties of a Class IV or Class V Landfill as defined in Landfill Waste Classification and Waste Definitions 1996 (As amended December 2009) Western Australia Department Of Environment And Conservation. In the context of Sandy Ridge this means an arid near-surface facility used to permanently isolate waste. Geological repositories provide the highest levels of containment through the use of carefully selected natural geological barriers rather than reliance on man-made liner systems and are increasingly recognised as a cost effective and preferred method of permanently isolating difficult to manage wastes. The geological barrier provides permanent isolation of wastes from the environment over the very long term and creates additional opportunities for the future recovery and recycling of valuable materials from the waste which can re-enter the circular economy.

Hazardous waste - Component of the waste stream which by its characteristics poses a threat or risk to public health, safety or the environment (includes substances which are toxic, infectious, mutagenic, carcinogenic, teratogenic, explosive, flammable, corrosive, oxidising and radioactive). As defined in Landfill Waste Classification and Waste Definitions 1996 (As amended December 2009) Western Australia Department Of Environment And Conservation

In Cell Storage - medium to long term below ground storage of wastes inside a cell with ongoing opportunity to recover waste if required.

Intractable Waste- Waste which is a management problem by virtue of its toxicity or chemical or physical characteristics which make it difficult to dispose of or treat safely, and is not suitable for disposal in Class I, II, III and IV landfill facilities. As defined in Landfill Waste Classification and Waste

Definitions 1996 (As amended December 2009) Western Australia Department Of Environment And Conservation

Permanent Isolation - indefinite below ground storage of wastes determined suitable for acceptance.

Storage - the short term above ground storage of materials following delivery and includes the time awaiting sampling, analysis and management prior to movement for “in cell storage”.

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1 INTRODUCTION

1.1 The Sandy Ridge Facility

The proposed Sandy Ridge Facility (hereby referred to as the proposed "Facility") is a dual use kaolin mine with the voids created by mining used to store and dispose of hazardous and intractable wastes. The site is located approximately 75 km northeast of Koolyanobbing, in the Shire of Coolgardie, within the Goldfields Region of Western Australia (Figure 1-1).

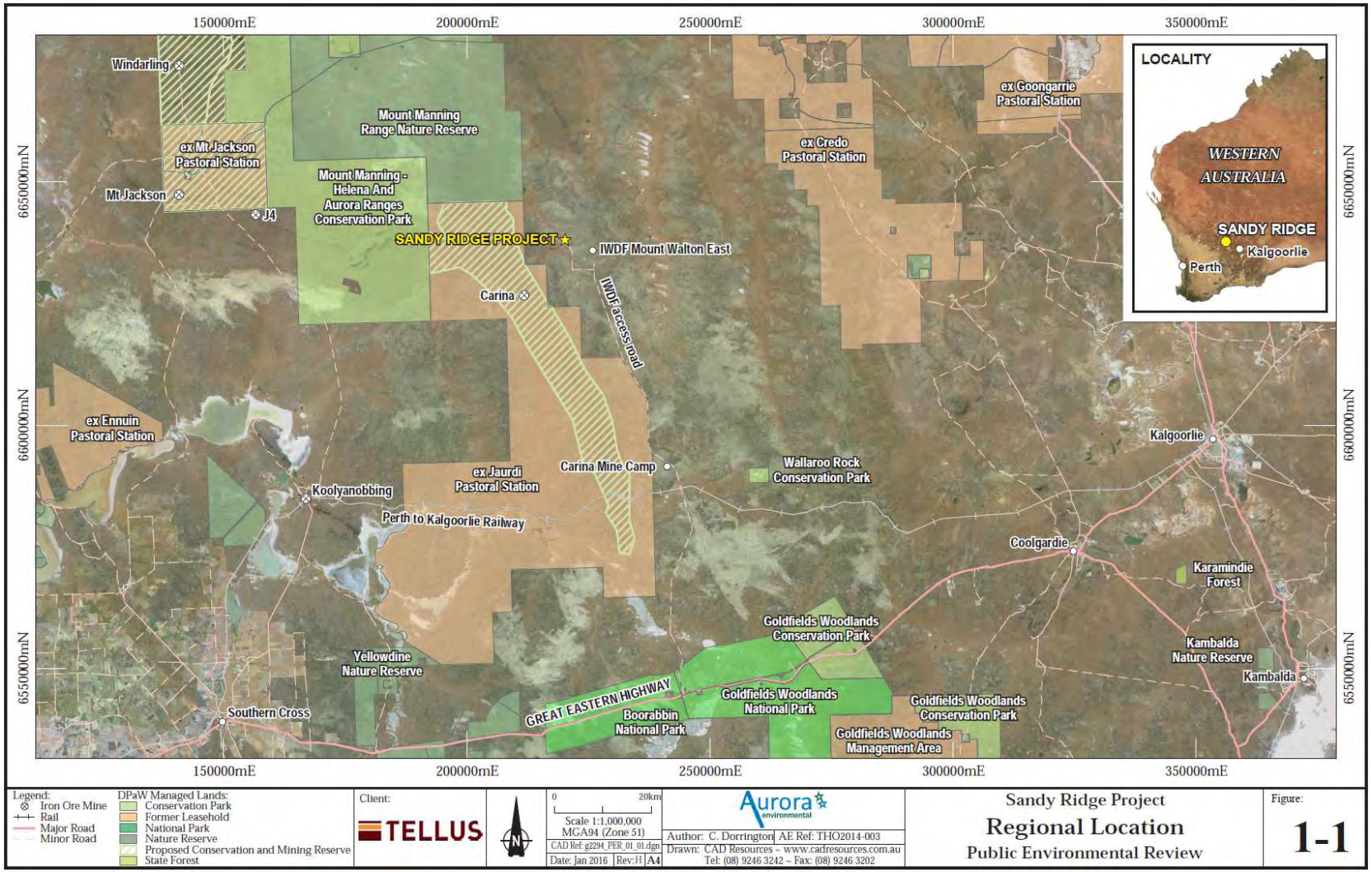
The location for the Facility was specifically chosen as its principal characteristics; semi–arid climate, high rates of evaporation, geologically stable, natural geological barriers, no regional aquifer, no surface water receptors, no flooding, low erosion rates, no heritage values, topography etc. satisfy the requirements for a near surface geological repository[1] for intractable and hazardous waste storage and isolation purposes.

There are no sensitive receptors within the immediate vicinity of the proposed Facility. The nearest operation is the Class V IWDF Mount Walton East Intractable Waste Disposal facility located approximately 6 km to the east, which operates on a campaign basis and does not have permanent residents. The nearest mining camp is the Carina Iron Ore Mine accommodation village located approximately 52 km to the south east of the proposed Facility.

The arid and remote nature of the location, absence of nearby population, coupled with the site characteristics make the site ideal for long-term storage and permanent isolation of hazardous and intractable waste.

[1] *The term geological repository is used to mean a landfill facility constructed and with the equivalent properties of a Class IV or Class V Landfill as defined in Landfill Waste Classification and Waste Definitions 1996 (As amended December 2009) Western Australia Department Of Environment And Conservation*

Figure 1-1: Sandy Ridge site location



1.2 Document aims and objectives

The aim of this document is to present guidance on the development of the Waste Zoning Guide (WZG) that will be applied at the proposed Facility. This document should be read in conjunction with the following:

- Waste Acceptance Policy.
- Waste Acceptance Criteria (WAC).
- Waste Acceptance Procedure (WAP).

This document is part of a hierarchy of documents and is a Tier 4 document, and is highlighted in Figure 1-2 below, which includes an equivalent suite of documents for Tellus' Northern Territory Chandler Project. Tier 4 documents work together with Tier 3 documents to provide an outline of operational procedures. The WZG has been developed in response to the assumed inventory for disposal which is presented as a Potential Waste Category List in Appendix A.1 of this document.

Figure 1-2: Waste Acceptance Criteria Document Hierarchy

Having established the overarching exclusion criteria to be applied at the proposed Facility in the WAC, a gated WAP using specified test methods and criteria values will be applied to determine if a waste can be accepted and to ensure that wastes which may react with each other are identified and grouped according to the principles of compatibility.

Reactive groups must be physically separated during the transport, receipt, storage and during permanent isolation, this document outlines the procedure of waste segregation and zoning.

1.3 Intended audience

This document is intended initially for use by regulators responsible for assessing the facility and issuing licences for the operation of the proposed Facility. It will be used to support the formation of

more detailed procedures to control the process by which waste producers and Tellus Staff will determine if the waste streams may be suitable for storage or permanent isolation and how they should be stored or permanently isolated in a safe manner.

The document will also be of interest to other stakeholders who wish to understand the approach being followed by Tellus for waste acceptance, including the safe storage and permanent isolation of wastes.

2 DANGEROUS GOODS SEGREGATION

2.1 Introduction

To prevent dangerous interaction, dangerous goods should be kept apart (segregated) from all other goods with which they are not compatible. Segregation can be achieved by storing and handling incompatible goods in separate areas or by the use of physical barriers or distances within the same area. Systems and procedures will be developed and enforced, and personnel involved in the storage and handling of dangerous goods will be trained and supervised to ensure segregation is maintained at all times.

2.2 Regulatory context

In Western Australia, Dangerous Goods management is enforced under the *Dangerous Goods Safety Act 2004* and is regulated under the *Dangerous Goods Safety (Storage and Handling of Non-Explosives) Regulations 2007* (the Storage and Handling Regulations). The Storage and Handling Regulations introduce modern safety standards for the manufacture, processing, storage, use and disposal of dangerous goods.

The regulations adopt, with only minor variance, the National Standard for the *Storage and Handling of Workplace Dangerous Goods* (the National Standard), as produced by the National Occupational Health and Safety Commission (NOHSC; now the Australian Safety and Compensation Council, ASCC). Western Australia has retained a licensing system for dangerous goods.

In relation to dangerous goods, 'handling' includes manufacture, process, pack, use, sell, supply, carry (including by pipeline) and disposal of dangerous goods. 'Class' means the number assigned to dangerous goods which exhibit a common single or most significant hazard determined by the criteria or listing in the *Australian Dangerous Goods Code*, an extract of the classes is included at Appendix A.2

2.3 Segregation approach

The application of waste acceptance criteria will exclude many dangerous goods from being accepted for permeant isolation at site. It is however important to recognise some wastes, which may be dangerous goods, may be delivered to site and undergo treatment on site (e.g. blending with Kaolin clay) to make a waste form which meets Tellus' WAC and is suitable for in-cell permanent isolation.

Therefore, arrangements need to be made for the safe storage of these wastes. Useful guidance for segregating incompatible dangerous goods is provided in *Australian/New Zealand Standard AS/NZS 3833 The Storage and Handling of Mixed Classes of Dangerous Goods in Packages and Intermediate Bulk Containers* which is referenced in the code of practice[2] which, in turn, supports the National

[2] *Page 29 The National Code of Practice for the Storage and Handling of Workplace Dangerous Goods NOHSC:2017(2001)*

Standard. Tellus will adopt the segregation protocols presented in AS/NZS 3833 for all waste materials that are stored on site prior to in cell permanent isolation. The Dangerous Goods segregation chart is presented in Figure 2-1

Figure 2-1: Dangerous Goods Segregation Chart (Australian Standard AS3833 figure 6.1)

CLASS		2	3	4		5		6	8
COMPRESSED GASES 2.1 Flammable	Compatible	KEEP APART	Segregate from	Segregate from	Segregate from	Segregate from		KEEP APART	KEEP APART
2.2 Non-flammable/ non-toxic	KEEP APART	Compatible	KEEP APART	Segregation may be necessary	Segregate from	Segregation may be necessary	Segregate from	Segregation may be necessary	KEEP APART
FLAMMABLE LIQUIDS (and Combustible liquids)	Segregate from	KEEP APART	Compatible	KEEP APART	Segregate from	Segregate from	Segregate from	KEEP APART	KEEP APART
FLAMMABLE SOLIDS 4.1 Flammable solids	Segregate from	Segregation may be necessary	KEEP APART	Compatible	KEEP APART	Segregate from	Segregate from	KEEP APART	Segregation may be necessary
4.2 Spontaneously combustable	Segregate from	Segregate from	Segregate from	KEEP APART	Compatible	KEEP APART	Segregate from	KEEP APART	KEEP APART
4.3 Dangerous when wet	Segregate from	Segregation may be necessary	Segregate from	Segregate from	KEEP APART	Compatible	KEEP APART	Segregate from	Segregation may be necessary	Segregation may be necessary
OXIDIZING SUBSTANCES 5.1 Oxidizing agents	Segregate from	Segregation may be necessary	Segregate from	Segregate from	Segregate from	KEEP APART	*	Segregate from	KEEP APART	KEEP APART
5.2 Organic peroxides		Segregate from		Segregate from		Segregate from	Segregate from	Compatible	KEEP APART	KEEP APART
TOXIC SUBSTANCES	KEEP APART	Segregation may be necessary	KEEP APART	KEEP APART	KEEP APART	Segregation may be necessary	KEEP APART	KEEP APART	Compatible	Segregation may be necessary
CORROSIVE SUBSTANCES	KEEP APART	KEEP APART	KEEP APART	Segregation may be necessary	KEEP APART	Segregation may be necessary	KEEP APART	KEEP APART	Segregation may be necessary	*

LEGEND:

- Compatible — Dangerous goods of the same Class should be compatible: consult MSDS or suppliers about requirements for individual substances.
- * — Dangerous goods of the same Class could be incompatible or react dangerously. Consult the MSDS or suppliers about requirements for individual substances.
- Segregation may be necessary — Segregation of these Classes may be necessary. Consult the MSDS or supplier.
- KEEP APART — Dangerous goods of these Classes should be kept apart by at least 3 m. Consult the MSDS or supplier.
- Segregate from — These combinations of dangerous goods should segregated by at least 5 m and kept in separate compounds or building compartments.
- This requirement applies to organic peroxides, for which dedicated stores or storage cabinets are recommended. Adequate separation from other buildings and boundaries is required.

NOTES:

1 In all cases, the MSDS or supplier of the goods should be consulted.

2 The segregation of dangerous goods of Division 1.4S may be necessary. Consult the MSDS or the supplier of the goods.

3 Combustible liquids shall be segregated in the same manner as flammable liquids of Class 3.

4 Dangerous goods of Class 9 should be segregated in accordance with MSDS.

6 If the dangerous goods have a Subrisk of another class, then the segregation requirements for the Subrisk need to be determined and the more stringent segregation requirements applied.

7 Where smoke detectors are to be stored, their supplier should be consulted and any specific storage and handling recommendations followed.

3 CHEMICAL WASTE ZONING

3.1 Overview

Applying the WAC (refer to WAC document) will result in a set of wastes that can be placed in a cell for permanent isolation. The application of the criteria in effect limits the hazardous properties and physical form of the wastes.

When analysing waste for acceptance, it is essential to ensure that wastes which may react with each other are identified and classified into compatible groups

Following acceptance wastes will be segregated into zones to ensure wastes that have the potential to react together are kept apart.

As well as segregating wastes during initial receipt and storage (refer to Section 2), accepted wastes must be physically separated during permanent isolation., the most appropriate zone in the facility in which to dispose of the waste will be selected by the competent person based on zone selection principles and methodology.

Waste placement at Sandy Ridge will normally occur as individual packages which are transported into the cell, and placed package by package in the assigned zones within the cells. In certain situations, bulk placement of wastes may be utilised when it has been determined as appropriate to do so by a suitably qualified person(s).

Isolation as a control measure is usually used to control physicochemical risks for hazardous chemicals because of the consequences when incompatible materials interact. Hazardous chemicals should be physically separated from any chemicals or other things that may be incompatible[3]. This is achieved by a physical separation distance, barriers, or a combination of both. At the proposed Facility these barriers may include the waste packaging, clay barriers, solidified and stabilised wastes, passive chemical barriers such as lime, calcium apatite or zeolite and prior to backfilling the use of separation distance.

3.2 Principles

There are three key principles behind zone selection:

[3] *section 4.1 Managing the Risks of Hazardous Chemicals in the Workplace – Code of Practice 2012*

Principle 1 - Keep materials with different hazardous characteristics apart.

This is a general principle resulting in the zones presented in Table 3-1. Hazardous characteristics for wastes in the poisonous, toxic and special waste zones are defined by the Basel convention presented in Appendix A.3.

Table 3-1: Zones and generic hazards

Zone #	Zone	Generic Reason
PT	Poisonous (H6.1)	Acute health effects
	Toxic (delayed or chronic) (H11)	
S	Ecotoxic (H12) and other special waste	Long term health effects and/or environmental risk (hazards often shared by substances)
R	Radioactive waste	Long term health effects and/or environmental risk

Principle 2 - Prevent the mixing of acidic and alkaline wastes.

The mixing of acid and alkaline wastes could result in a chemical reaction, although the permitted physical forms and containment of the wastes would make this highly unlikely. To ensure that wastes which are acid or alkaline in nature are stored separately two zones are to be used for irritant wastes:

Zone #	Zone	Generic Reason
AC	Irritant (acidic nature)	Chemical properties
AL	Irritant (alkaline nature)	Chemical properties

These zones take into account the potential for wastes that may be classed as **PT** [poisonous (H6.1), toxic (delayed or chronic) (H11)] or **S** [Ecotoxic (H12) and other special waste] to also display acidic or alkaline properties. Therefore, wastes which if mixed with water would generate an acidic pH leachate may need to be placed in the Irritant (acidic) Zone. Wastes which when mixed with water would generate an alkaline pH leachate may need to be placed in the Irritant (alkaline) Zone. It is not physically possible for a waste to be both acidic and alkaline in nature.

Principle 3 - Prevent the mixing of multi-hazard incompatible materials.

The first stage in minimising the risk of incompatible materials mixing is to ensure that distinctly acidic and alkaline materials are stored separately from other wastes as described in Principle 2 - Prevent the mixing of acidic and alkaline wastes.

The next stage is to minimise the risk from incompatible multi-hazard wastes. In general the combinations of hazards within the cell will result in negligible risk of reaction, as the majority of the residual hazards after the application of WAC relate to potential health and environmental effects and not reactivity.

Therefore waste possessing combinations of the following hazardous characteristics could be stored together: Poisonous (H6.1), Toxic (delayed or chronic) (H11), and Ecotoxic (H12). The Zone for multi-hazard wastes with these properties will be selected in accordance with the predominant hazard property. This will be based on hazardous property threshold concentrations for the substances in the waste.

Wastes that are an irritant and possess other hazardous properties will be considered for storage in the appropriate Irritant Zone (acidic or alkaline). This is because the substances in the waste that give rise to other hazardous properties should be stable in either the acidic or alkaline environment. Therefore if such substances escaped from containment and mixed with other acid or alkaline wastes in the same zone, it is unlikely to give rise to an incompatible reaction.

The Dangerous Goods Segregation protocols (AS/NZ 3833 Figure 6.1) will be utilised as a secondary check to ensure the substances to be located within a zone are compatible, and to determine if further risk mitigation is required within the cell such as suitable barriers between zones, or to determine any subzones that may be required within a zone, particularly with respect to the “Other Special Waste’ zone.

Finally the safety data sheets for substances within the wastes will be assessed in terms of reactivity data, to determine if any of the substances possess any unusual reactive properties. Any waste with unusual reactive properties would be subjected to further tests to determine stability, and rejected if the suitability of the waste cannot be guaranteed.

3.3 Methodology

Based on the above principles the zone for a particular waste will be selected using the following steps.

Step 1 – Single hazard waste

Wastes that have been identified as possessing one hazardous property will be placed in the appropriate zone as shown in Table 3-2 below. Safety data sheets for substances within the waste will be consulted for reactivity data, to ensure that the substances within the waste do not possess any unusual reactive properties.

Zoning in accordance with Step 1 supports compliance with principles 1 and 2 outlined above.

Table 3-2: Zones for single hazard wastes

Single Hazardous Characteristic	Zone	Zone #
Poisonous (H6.1)	Poisonous & Toxic (delayed or chronic) Zone	**PT**
Toxic (delayed or chronic) (H11)		
Irritant – acidic in nature	Irritant (acidic) Zone	**AC**
Irritant – alkaline in nature	Irritant (alkaline) Zone	**AL**
Ecotoxic (H12)	Ecotoxic and other Special Waste Zone	**S**
Radioactive waste	Long term health effects and/or environmental risk	**R**

Step 2 - Multi-hazard Hazard Wastes

The zone selected for waste possessing more than one hazardous characteristic will be determined using Table 3-3. A suitably qualified person shall make any final determination on zone selection.

Waste subjected to further tests will be re-assessed using the full acceptance decision tree.

Table 3-3: Zones for multi-hazard wastes

Hazardous Characteristics	*Poisonous (H6.1)*	Toxic (delayed or chronic)(H11)	Irritant – acidic in nature[1]	Irritant – alkaline in nature[2]	Ecotoxic (H14)	Radioactive Waste
Poisonous (H6.1)	*PT*					
Toxic (delayed or chronic)(H11)	*PT*	*PT*				
Irritant – acidic in nature[1]	*AC*	*AC*	*AC*			
Irritant – alkaline in nature[2]	*AL*	*AL*	*Not Permitted*	*AL*		
Ecotoxic (H14)	*PT*	*PT*	*AC*	*AL*	*S*	
Rad Waste	*Not Possible*	*Not Possible*	*Not Possible*	*Not Possible*	*Not Possible*	*R*

[1] Including wastes whose leachates during tests would be acidic pH [2] Including wastes whose leachates during tests would be alkaline pH

Zoning in accordance with Step 2 supports compliance with principle 3 outlined above.

The use of this zoning methodology provides guidance for a suitably qualified and experienced person to categorise and instruct the safe segregation of wastes expected at the proposed Facility for storage and permanent isolation. The suitably qualified person shall make final judgements and zoning based on their knowledge and experience.

4 RADIOACTIVE WASTE ZONING

Radioactive waste accepted for permanent isolation at Sandy Ridge falls into two broad categories of NORM and sealed sources. The zoning approach differs for each category and is summarised below.

4.1 NORM Waste

NORM waste is (unless otherwise proven) assumed to contain relatively long-lived radioisotopes such as Ra, U, and Th. NORM waste is expected to be delivered to site and placed in the following forms and placed in the appropriate R zone in accordance with the following procedure;

4.1.1 Dry solids packaged in FIBCs or drums.

These would be placed the cell (not shaft) unless of particularly high activity concentration. Higher activity NORM wastes will always be placed as deep as possible in the cell, with lower activity wastes being located closer to the surface. The minimum depth of cover required will be assessed during each waste campaign.

4.1.2 Bulk solids (e.g. contaminated soils or mineral concentrates such as monazite sand).

These will be assessed by activity level and radionuclide/particle emitter type. Higher activity materials will generally be placed deeper in the cell, but consideration will also be given to placing alpha and beta particle emitters at shallower depths as the requirement for shielding at the surface is less.

4.1.3 Sludges and liquids requiring solidification and stabilisation prior to placement.

Higher activity materials will generally be placed deeper in the cell, but consideration will also be given to placing alpha and beta particle emitters at shallower depths as the requirement for shielding at the surface is less.

4.1.4 Contaminated equipment.

Usually the nature of these materials is such that activity levels are low, and will be made lower by adding fill (grout or compacted kaolinised granite). Higher activity materials will generally be placed deeper in the cell, but consideration will also be given to placing alpha and beta particle emitters at shallower depths as the requirement for shielding at the surface is less. The materials of construction of the waste (e.g., steel pipe) and grout fill may provide a reasonable level of shielding and allow relatively shallow placement.

4.1.5 Use of NORM as backfill

Bulk solids, and solidified sludges and solidified liquid NORM wastes may be used as interstitial fill around 215 litre (L) drums inside the radioactive waste disposal shafts.

4.2 Sealed sources

Sealed sources will, whenever possible, be placed in their original shielding package or 60 L drum and cemented inside a 215 L steel drum. Depending upon the source activity and isotope, more than one source may be placed inside a 215 L cemented drum.

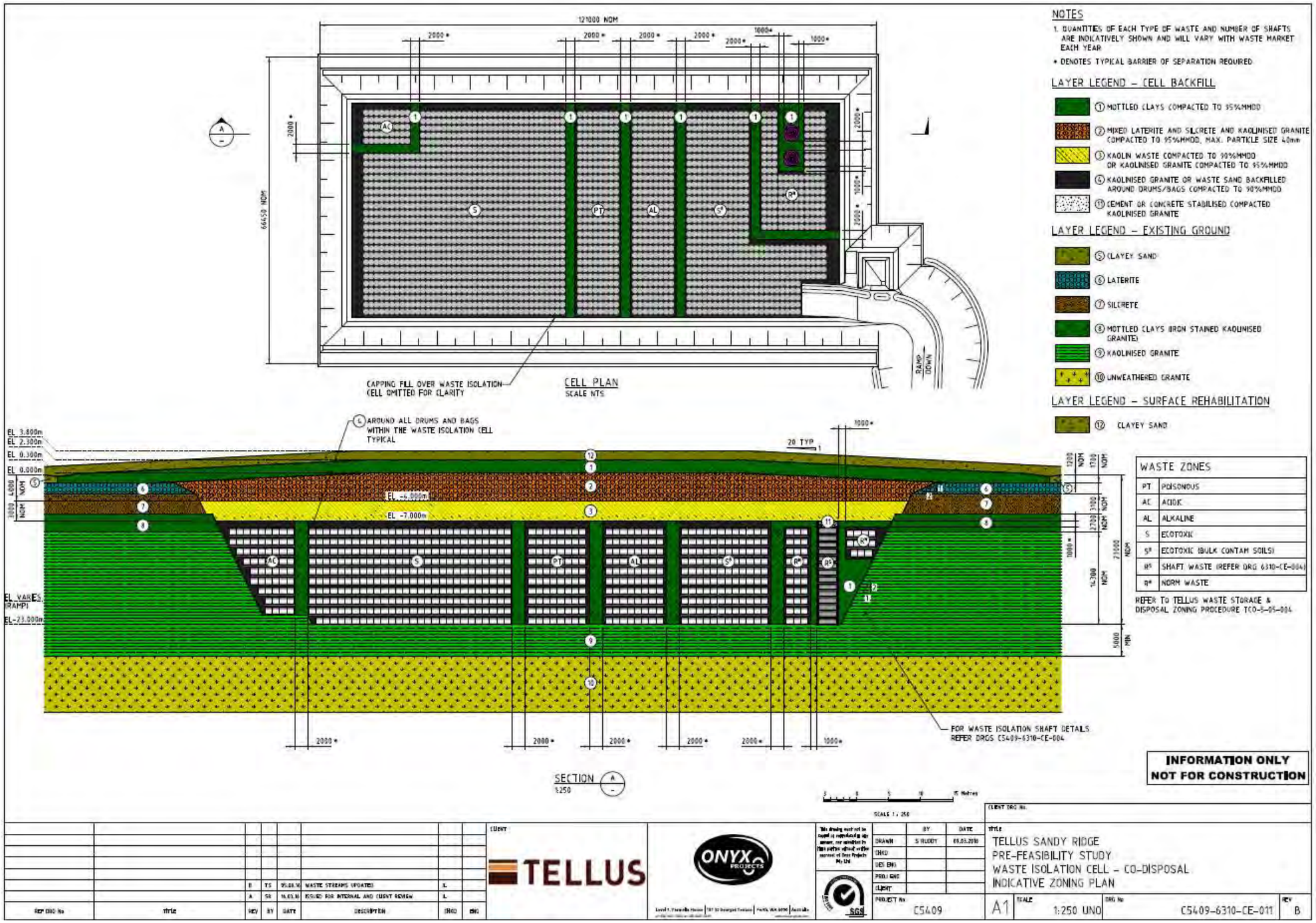
The primary requirements of the 215 L drum cementing process will be to provide short term source security and operational shielding for the staff handling and placing the waste. A secondary requirement of the 215 L drum cementing process is to provide long-term shielding and security against human intrusion.

Sealed sources will be placed in the cell according to the following hierarchy.

Table 4-1: Sealed source emplacement hierarchy

Sealed Source Characteristic	In-shaft Placement Criteria
Half-life > 3 years	Greater than 10m below natural ground level
Half-life > 20 years	Greater than 15m below natural ground level
Half-life > 30 years	Greater than 20m below natural ground level. Packages will be placed in order of half-life, with the longest lived radionuclides at the bottom.

5 INDICATIVE WASTE ZONING PLAN



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A.1 Potential Waste Category List

Common industrial hazardous waste (NEPM basis)	
Acidic solutions or acids in solid form	B100
Animal effluent and residues (abattoir effluent, poultry and fish processing wastes)	K100
Antimony; antimony compounds	D170
Arsenic; arsenic compounds	D130
Asbestos	N220
Barium compounds (excluding barium sulphate)	D290
Basic solutions or bases in solid form	C100
Beryllium; beryllium compounds	D160
Boron compounds	D310
Cadmium; cadmium compounds	D150
Ceramic-based fibres with physio-chemical characteristics similar to those of asbestos	N230
Chlorates	D350
Chromium compounds (hexavalent and trivalent)	D140
Clinical and related wastes	R100
Cobalt compounds	D200
Containers and drums that are contaminated with residues of substances referred to in this list	N100
Copper compounds	D190
Cyanides (inorganic)	A130
Cyanides (organic)	M210
Encapsulated, chemically-fixed, solidified or polymerised wastes referred to in this list	N160
Ethers	G100
Filter cake contaminated with residues of substances referred to in this list	N190
Fire debris and fire wash waters	N140
Fly ash, excluding fly ash generated from Australian coal fired power stations	N150
Grease trap waste	K110
Halogenated organic solvents	G150
Highly odorous organic chemicals (including mercaptans and acrylates)	M260
Inorganic fluorine compounds excluding calcium fluoride	D110
Inorganic sulfides	D330
Isocyanate compounds	M220
Lead; lead compounds	D220
Mercury; mercury compounds	D120
Metal carbonyls	D100
Nickel compounds	D210
Non-toxic salts	D300
Organic phosphorous compounds	H110
Organic solvents excluding halogenated solvents	G110
Organo halogen compounds—other than substances referred to in this Table.	M160
Perchlorates	D340
Phenols, phenol compounds including chlorophenols	M150

Common industrial hazardous waste (NEPM basis)	
Phosphorus compounds excluding mineral phosphates	D360
Polychlorinated dibenzo-furan (any congener)	M170
Polychlorinated dibenzo-p-dioxin (any congener)	M180
Residues from industrial waste treatment/disposal operations	N205
Selenium; selenium compounds	D240
Soils contaminated with a controlled waste	N120
Surface active agents (surfactants), containing principally organic constituents and which may contain metals and inorganic materials	M250
Tannery wastes (including leather dust, ash, sludge's and flours)	K140
Tellurium; tellurium compounds	D250
Thallium; thallium compounds	D180
Triethylamine catalysts for setting foundry sands	M230
Tyres	T140
Vanadium compounds	D270
Waste chemical substances arising from research and development or teaching activities, including those which are not identified and/or are new and whose effects on human health and/or the environment are not known	T100
Waste containing peroxides other than hydrogen peroxide	E100
Waste from heat treatment and tempering operations containing cyanides	A110
Waste from manufacture, formulation and use of wood-preserving chemicals	H170
Waste from the production and preparation of pharmaceutical products	R140
Waste from the production, formulation and use of biocides and phytopharmaceuticals	H100
Waste from the production, formulation and use of inks, dyes, pigments, paints, lacquers and varnish	F100
Waste from the production, formulation and use of organic solvents	G160
Waste from the production, formulation and use of photographic chemicals and processing materials	T120
Waste from the production, formulation and use of resins, latex, plasticisers, glues and adhesives	F110
Waste mineral oils unfit for their original intended use	J100
Waste of an explosive nature not subject to other legislation	T200
Waste oil/water, hydrocarbons/water mixtures or emulsions	J120
Waste pharmaceuticals, drugs and medicines	R120
Waste resulting from surface treatment of metals and plastics	A100
Waste substances and articles containing or contaminated with polychlorinated biphenyls, polychlorinated napthalenes, polychlorinated terphenyls and/or polybrominated biphenyls	M100
Waste tarry residues arising from refining, distillation, and any pyrolytic treatment	J160
Wool scouring wastes	K190
Zinc compounds	D230

A.2 Dangerous Goods Codes

Extract from pages 44-46 of Australian Code for the Transport of Dangerous Goods by Road & Rail Edition 7.4 Update, June 2016

Substances (including mixtures and solutions) and articles subject to this Code are assigned to one of nine classes according to the hazard or the most predominant of the hazards they present. Some of these classes are subdivided into divisions. These classes and divisions are:

Class 1: Explosives

Division 1.1: Substances and articles which have a mass explosion hazard

Division 1.2: Substances and articles which have a projection hazard but not a mass explosion hazard

Division 1.3: Substances and articles which have a fire hazard and either a minor blast hazard or a minor projection hazard or both, but not a mass explosion hazard

Division 1.4: Substances and articles which present no significant hazard

Division 1.5: Very insensitive substances which have a mass explosion hazard

Division 1.6: Extremely insensitive articles which do not have a mass explosion hazard

Class 2: Gases

Division 2.1: Flammable gases

Division 2.2: Non-flammable, non-toxic gases

Division 2.3: Toxic gases

Class 3: Flammable liquids

Class 4: Flammable solids; substances liable to spontaneous combustion; substances which, on contact with water, emit flammable gases

Division 4.1: Flammable solids, self-reactive substances and solid desensitised explosives

Division 4.2: Substances liable to spontaneous combustion

Division 4.3: Substances which in contact with water emit flammable gases

Class 5: Oxidising substances and organic peroxides

Division 5.1: Oxidising substances

Division 5.2: Organic peroxides

Class 6: Toxic and infectious substances

Division 6.1: Toxic substances

Division 6.2: Infectious substances

Class 7: Radioactive material

Class 8: Corrosive substances

Class 9: Miscellaneous dangerous substances and articles, including environmentally hazardous substances.

The numerical order of the classes and divisions is not that of the degree of danger.

Many of the substances assigned to Classes 1 to 9 are deemed, without additional labelling, as being environmentally hazardous. Wastes must be transported under the requirements of the appropriate class considering their hazards and the criteria in this Code.

Wastes not otherwise subject to this Code but covered under the Basel Convention may be transported under Class 9.

For packing purposes, substances other than those of Classes 1, 2 and 7, Divisions 5.2 and 6.2, and other than self-reactive substances of Division 4.1, are assigned to three packing groups in accordance with the degree of danger they present:

Packing group I: Substances presenting high danger;

Packing group II: Substances presenting medium danger; and

Packing group III: Substances presenting low danger.

The packing group to which a substance is assigned is indicated in the Dangerous Goods List in Chapter 3.2.

Articles are not assigned to packing groups. For packing purposes any requirement for a specific packaging performance level is set out in the applicable packing instruction.

Dangerous goods are determined to present one or more of the dangers represented by Classes 1 to 9 and divisions and, if applicable, the degree of danger on the basis of the requirements in Chapters 2.1 to 2.9.

Dangerous goods presenting a danger of a single class and division are assigned to that class and division and the degree of danger (packing group), if applicable, determined. When an article or substance is specifically listed by name in the Dangerous Goods List in Chapter 3.2, its class or division, its subsidiary risk(s) and, when applicable, its packing group are taken from this list.

Dangerous goods meeting the defining criteria of more than one hazard class or division and which are not listed by name in the Dangerous Goods List, are assigned to a class and division and subsidiary risk(s) on the basis of the precedence of hazards in 2.0.3.

A.3 ANNEX III: LIST OF HAZARDOUS CHARACTERISTICS

UN Class	Code	Characteristics
1	**H1**	**Explosive** An explosive substance or waste is a solid or liquid substance or waste (or mixture of substances or wastes) which is in itself capable by chemical reaction of producing gas at such a temperature and pressure and at such a speed as to cause damage to the surroundings.
3	**H3**	**Flammable Liquids** The word "flammable" has the same meaning as "inflammable". Flammable liquids are liquids, or mixtures of liquids, or liquids containing solids in solution or suspension (for example, paints, varnishes, lacquers, etc., but not including substances or wastes otherwise classified on account of their dangerous characteristics) which give off a flammable vapour at temperatures of not more than 60.5ºC, closed-cup test, or not more than 65.6ºC, open-cup test. (Since the results of open-cup tests and of closed-cup tests are not strictly comparable and even individual results by the same test are often variable, regulations varying from the above figures to make allowance for such differences would be within the spirit of this definition.)
4.1	**H4.1**	**Flammable Solids** Solids, or waste solids, other than those classed as explosives, which under conditions encountered in transport are readily combustible, or may cause or contribute to fire through friction
4.2	**H4.2**	Substances or wastes liable to spontaneous combustion Substances or wastes which are liable to spontaneous heating under normal conditions encountered in transport, or to heating up on contact with air, and being then liable to catch fire
4.3	**H4.3**	**Substances or wastes which, in contact with water, emit flammable gases** Substances or wastes which, by interaction with water, are liable to become spontaneously flammable or to give off flammable gases in dangerous quantities
5.1	**H5.1**	**Oxidising** Substances or wastes which, while in themselves not necessarily combustible, may, generally by yielding oxygen, cause or contribute to, the combustion of other materials.
5.2	**H5.2**	**Organic Peroxides** Organic substances or wastes which contain the bivalent-o-o-structure are thermally unstable substances which may undergo exothermic self-accelerating decomposition.
6.1	**H6.1**	**Poisonous (Acute)** Substances or wastes liable either to cause death or serious injury or to harm human health if swallowed or inhaled or by skin contact

6.2	**H6.2**	**Infectious Substances** Substances or wastes containing viable microorganisms or their toxins which are known or suspected to cause disease in animals or humans
8	**H8**	**Corrosives** Substances or wastes which, by chemical action, will cause severe damage when in contact with living tissue, or, in the case of leakage, will materially damage, or even destroy, other goods or the means of transport; they may also cause other hazards
9	**H10**	**Liberation of toxic gases in contact with air or water** Substances or wastes which, by interaction with air or water, are liable to give off toxic gases in dangerous quantities
9	**H11**	**Toxic (Delayed or chronic)** Substances or wastes which, if they are inhaled or ingested or if they penetrate the skin, may involve delayed or chronic effects, including carcinogenicity
9	**H12**	**Ecotoxic** Substances or wastes which, if released, present or may present immediate or delayed adverse impacts to the environment by means of bioaccumulation and/or toxic effects upon biotic systems
9	**H13**	Capable, by any means, after disposal, of yielding another material, e.g. leachate, which possess any of the characteristics listed above