YOONGARILLUP
Mineral Sands Project

Public Environmental Review

Response to Public Submissions
BOOK 2 – Appendices

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APPENDIX 1 ADDITIONAL TECHNICAL REPORTS – FLORA AND VEGETATION

APPENDIX 1-A GROUNDWATER DEPENDENT ECOSYSTEMS ASSESSMENT

A Review and Impact Assessment of Potential Water Drawdowns on Groundwater Dependent Ecosystems at the Proposed Yoongarillup Mineral Sands Project.

Prepared for Doral Mineral Sands Pty Ltd

January 2015

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Statement of limitations

Reliance on Data

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1 Introduction

Doral Mineral Sands Pty Ltd ('Doral') is currently planning to construct and operate a mineral sands mine, known as the 'Yoongarillup Mineral Sands Project', approximately 15 km south east of Busselton, Western Australia near the base of the Whicher Scarp. The proposed pit would be located on Mining Leases M70/459 and M70/458. The proposed Mine Pit would involve clearing up to 9 ha of native vegetation (within State Forest) and 32 ha of pasture within a 152 ha development envelope on cleared land and in Millbrook State Forest. The expected mine life is approximately three years. To enable optimum resource recovery, it is likely that mining will occur below the groundwater table and, hence, dewatering of the pits will be required (Parsons Brinckerhoff, 2015). Consequently, a drawdown of the groundwater table beneath the State Forest (and potentially further) may occur, which may impact vegetation dependent on ground water.

Ecoedge Environmental Pty Ltd ('Ecoedge') was engaged by Doral in January 2015 to conduct a review and impact assessment of modelled water drawdowns on Groundwater Dependent Ecosystems (GDEs) and other conservation values potentially adversely affected by the cone of drawdown to be used in the Public Environmental Review (PER) for the Project.

2 Limitations

Data and information used in the preparation of this report to assess and form conclusions in relation to potential impacts of water drawdowns at the Yoongarillup Mineral Sands project has been constrained by the following factors:

- There has been no field investigation of plant water-relations or ecophysiology within the Project Area
- There is very limited data available regarding water levels and stratigraphy of the Superficial Aquifer in the Project Area
- The report draws heavily on two flora and vegetation surveys (Mattiske, 2012; Ecoedge, 2014) carried out in the Project Area which did not have identification of potential groundwater dependent ecosystems, or groundwater dependent species in their scope
- Through factors outside of the Authors' control, only two weeks was available to complete the report

3 Physical Setting

3.1 Climate

The Study Area experiences a Mediterranean climate type (Köppen classification Csb) characterised by hot, dry summers and cool wet winters. The average annual rainfall at Bureau of Meteorology (BOM) gauging station 9771 (Yoongarillup) which is located approximately three km north-east of the Study Area is 845 mm/year. Most rainfall occurs from May to September. Annual potential evaporation is about 1400 mm and evapotranspiration is about 750 mm (BOM, 2013). Over the 6 years up to and including 2014 the Yoongarillup station annual rainfall as a percentage of the long-term mean (847 mm) ranged from 62% (2010) to 116% (2013). Rainfall in 2014 was 93% of the mean.

3.2 Physiography

The study area is located 15 km southeast of Busselton at the foot of the Whicher Scarp (**Figure 1**). It is located within the southern part of the Perth Basin, an elongate north–south rift trough with a series of sub-basins, shelves, troughs, and ridges. It contains up to 15 km depth of sediments that mostly accumulated from the Early Permian to late Cretaceous, with a veneer of Neogene sediments (Freeman and Donaldson, 2006). The Study Area is wholly contained within the Bunbury Trough, a sub-basin containing a Permian–Cretaceous succession up to 11 km thick wedged between the Vasse Shelf and the Yilgarn Craton.

The lower slopes of the Whicher Scarp transect the Study Area from west to east, rising from 45 mAHD[1] near the northern boundary to 90 mAHD in the south east corner (**Figure 2**). The Whicher Scarp is believed to have formed as a scarp of marine erosion during an early Pleistocene or late Tertiary period of high sea level (Playford *et al*., 1976). The Study Area contains a small area of the Swan Coastal Plain abutting the Whicher Scarp to the north, and south of the scarp (outside of the Study Area) lies the Blackwood Plateau, a gently undulating laterite and sand-covered area between the Swan Coastal Plain and Scott Coastal Plains to the south, ranging in elevation from about 50 to 180 mAHD.

[1] Metres above the Australian Height Datum (mAHD).

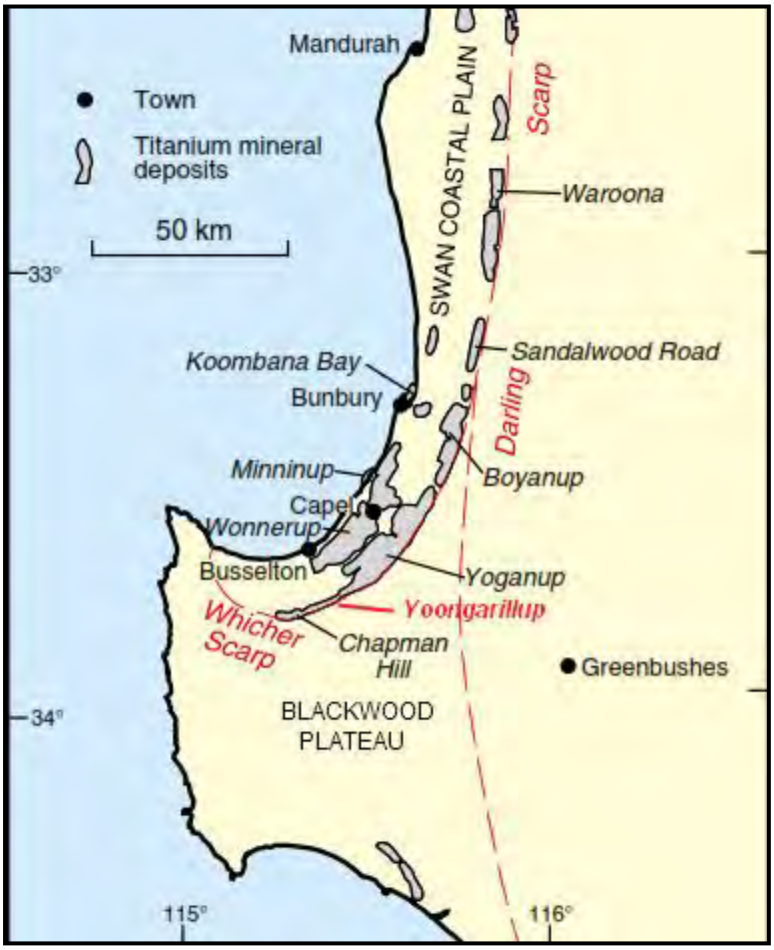
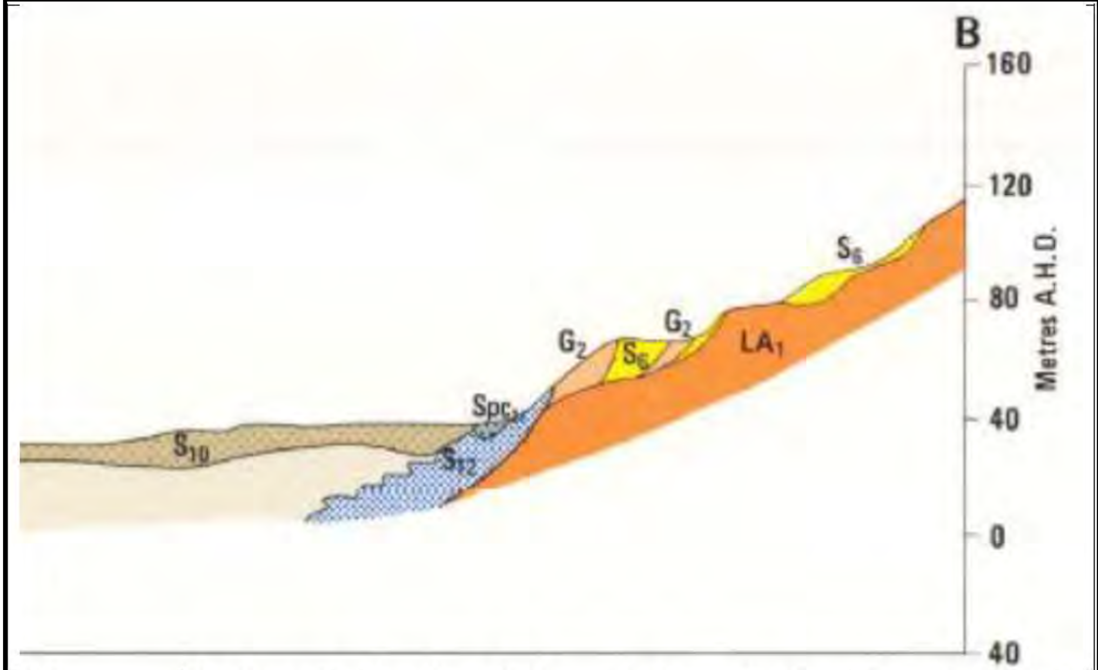


Figure 1. Location of the Study Area in a regional context (adapted from Freeman and Donaldson, 2006, p. 15).

3.3 Geology

The proposed 'Yoongarillup Mineral Sands Project' is situated on the Yoganup strandline, (stratigraphically equivalent to the Yoganup Formation), which is a wedge of sand with discontinuous concentrations of heavy minerals stretching across the coastal plain from the base of the Whicher and Darling Scarps and thinning towards the coast (Freeman and Donaldson, 2006). The Yoganup Formation (represented by 'S12' in **Figure 2**) is one of the superficial deposits in a sedimentary sequence that ranges from the Bassendean Sands (early to middle Pleistocene) at the top to Jurassic Era formations, including the units 3 and 4 of the Yarragadee Formation at depths of over -700 mAHD in the vicinity of the Study Area (Parsons and Brinckerhoff, 2013). The sequence of these formations is presented in **Table 1**, below.



S10	Sand over silt and sandy silt. Sand is very light grey at surface, yellow at depth, fine to medium grained sub-rounded quartz, local concentrations of heavy minerals, local development of coffee rock, moderately well sorted, of aolian origin
Spc	Clayey peaty sand. Grey to black with variable organic content.
S12	Sand. Yellow, fine to medium grained, sub-angular to rounded quartz with some feldspar, local local concentrations of heavy minerals, well sorted, overlying boulder and cobble conglomerates, of alluvial and marine origin.
G2	Gravel. Brown and reddish brown, ferrunginous, pisolitic, occasionally cemented in a clay silt matrix, moderately sorted, of colluvial origin.
S6	Sand. Light grey, fine to coarse, angular to sub-rounded quartz with some feldspar, moderately sorted, loose, of elluvial origin modified by colluvial processes
LA1	Laterite. Massive and cemented, occasionally vesicular, up to 4m thick. Sometimes overlain by a ferruginous gravel set in a clay-sand matrix.

Figure 2. Cross-section of the geology from the Swan Coastal Plain to the Whicher Scarp near Busselton. (From Bellford, 1987).

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Age	Stratigraphy	Maximum Thickness (m)	Lithology	Aquifer System
Quaternary-late Tertiary	Superficial Formation			
	Bassendean Sand	80	Fine to medium sub-rounded quartz sand	Superficial Aquifer
	Guildford Formation	35	Brown to dark grey clays with isolated lenses of silt and sand	Local aquitard
	Yoganup Formation	10	White to yellowish-brown unconsolidated, poorly sorted sand, gravel and pebbles with local subordinate clay, ferruginised grains and heavy mineral.	Superficial Aquifer
Cretaceous	Leederville Formation	600	Interbedded units of partly consolidated sand and shales. Generally divided into upper, predominantly shaly section (Mowen Member[2]) and lower sandy section	Leederville aquifer including the Mowen aquitard
Jurassic	Yarragadee Formation	2000	Weakly consolidated sandstone, siltstone and shales.	Yarragadee aquifer
Late Jurassic	Cockleshell Gully Formation		Angular to sub-angular, weakly cemented quartz sandstone containing accessory pyrite and garnet, and weakly consolidated	Yarragadee aquifer

Table 1. Generalised regional and local stratigraphic sequence and hydrogeology of the Study Area (from Parsons Brinckerhoff, 2013).

Drilling by Doral within the Yoongarillup Project Area to establish the size and distribution of the mineral sands resource has provided information of the depth of the various geological layers under the Project Area. Only a few holes were drilled within the State Forest south of the proposed Mine Pit so understanding of the geology within this area is limited by a lack of data. Nevertheless, sufficient data was obtained to gain some understanding of the geology above the Leederville Formation south of the Mine Pit area, the area of concern with regard to potential effects on natural values of groundwater drawdown (**Figures 3a and 3b**).

[2] A member is a named lithologically distinct part of a formation.

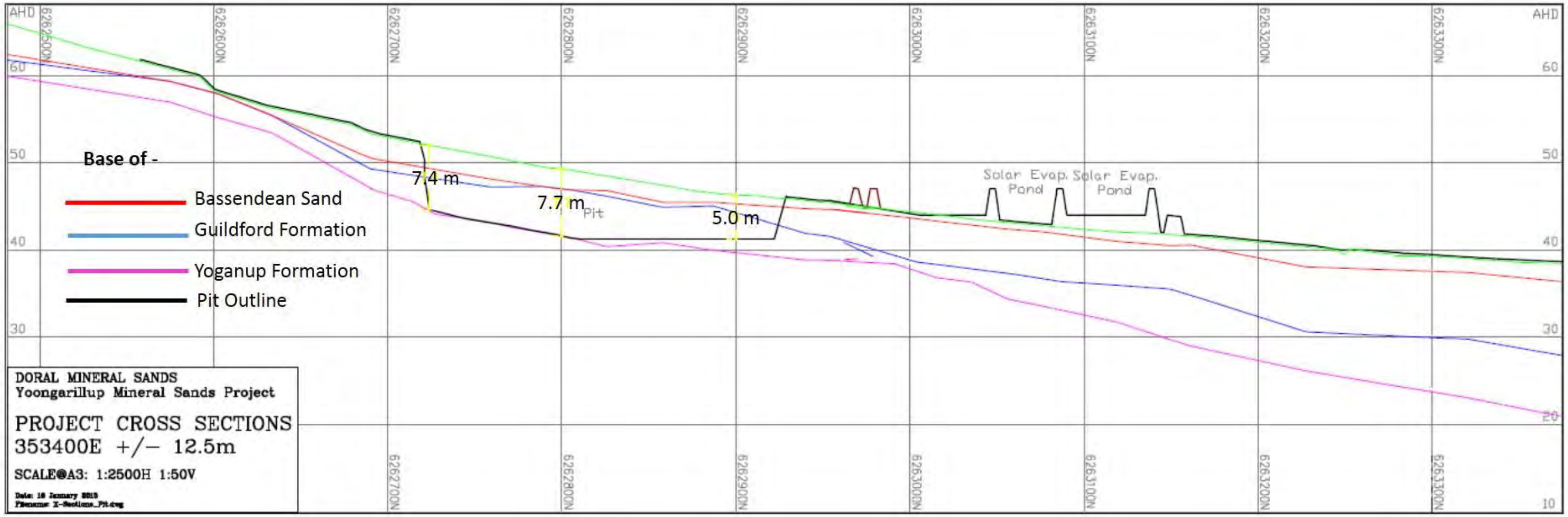

Figure 3a. Cross section (north-south) through the Project Area at Yoongarillup near the western end of the Project Area. About two thirds of the pit shown in this diagram is within the State Forest. Depths shown are to the bottom of the pit from the current ground level.

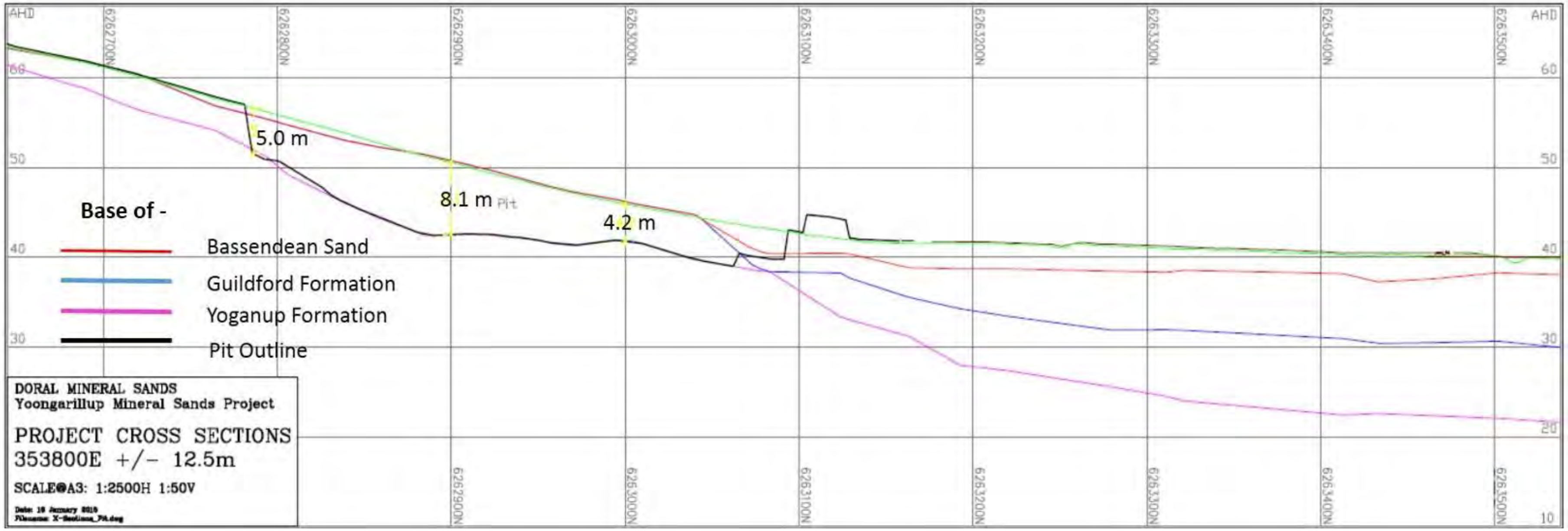

Figure 4b. Cross section (north-south) through the Project Area at Yoongarillup near the eastern end of the State Forest (just west of Sues Road). About one third of the pit shown in this diagram is within the State Forest. Depths shown are to the bottom of the pit from the current ground level.

3.4 Hydrogeology of the Project Area

Parsons Brinckerhoff (2013) carried out hydrogeological investigations and modelling for the Project Area. They recognized three aquifers occurring locally (**Table 2**).

Name	Description
Superficial Aquifer	An unconfined aquifer that comprises Bassendean Sand towards the top and Yoganup Sand towards the base. Guildford Clay is locally present between the two aquifers.
Leederville Aquifer (incorporating the Mowen Member aquitard)	A multi-layered aquifer system comprising discontinuous interbedded sequences of sandstone and clay.
Yarragadee Aquifer	Composed primarily of non-marine fluvial feldspathic, poorly sorted sandstones which are porous and poorly cemented and, hence, allow for considerable groundwater reserves.

Table 2. Aquifers local to the Yoongarillup Project Area.

The Superficial Aquifer, which is reported to underlie all of the proposed Pit Area (Parsons Brinckerhoff, 2013) is a shallow, transmissive aquifer that occurs on the surface of the Swan and Scott coastal plains. The groundwater within the Superficial Aquifer is often found close to the surface and therefore many of the wetlands and vegetation complexes found on the Superficial Aquifer on the coastal plains are groundwater dependent (Hyde, 2006). Changes in the water regime within this aquifer (such as through pumping) can affect the values of the dependent ecosystems, so it is important to map and assess the values of and risk to GDEs in the areas of future abstraction from the Superficial Aquifer on the coastal plains (Hyde, 2006; Del Borello, 2008).

In 2012, Doral installed groundwater monitoring bores for the Yoongarillup Project Area (Parsons Brinckerhoff, 2013). These bores were designed to monitor both the Superficial and the Leederville Aquifers in areas surrounding proposed mining activities. However, while those bores installed downslope of the proposed Mine Pit adequately monitor water from the Superficial Aquifer, those upslope from the pit are not screened at optimal depths to monitor the Superficial Aquifer (Doral, 2015). This includes MB03 (**Figure 4**) which is the closest bore to the State Forest that would be impacted by the proposed Mine Pit. MB03 was screened at 13.5 m in the Mowen member of the Leederville aquifer. Above this level there was at least 8 m of stiff clay and a laterite layer from 4.0 to 5.0 m overlain by yellow-brown sand (Parsons Brinckerhoff, 2013).

Monitoring data from August 2012 to November 2014 show the Static Water Level (SWL) at MB03 ranging from 10.18 to 8.26 m (depth from the surface). However, it has been noted that this bore tests the Leederville Aquifer and not the Superficial Aquifer, the base of which is considered to be at most 6 m to 9 m below the surface (Doral, 2015). It has been recommended that monthly monitoring of this site should continue as a measure of Leederville levels and quality. However, a shallow bore should also be installed up slope from MB03 to monitor the Superficial Aquifer and the potential drawdown during mining of the State Forest area (Doral, 2015).

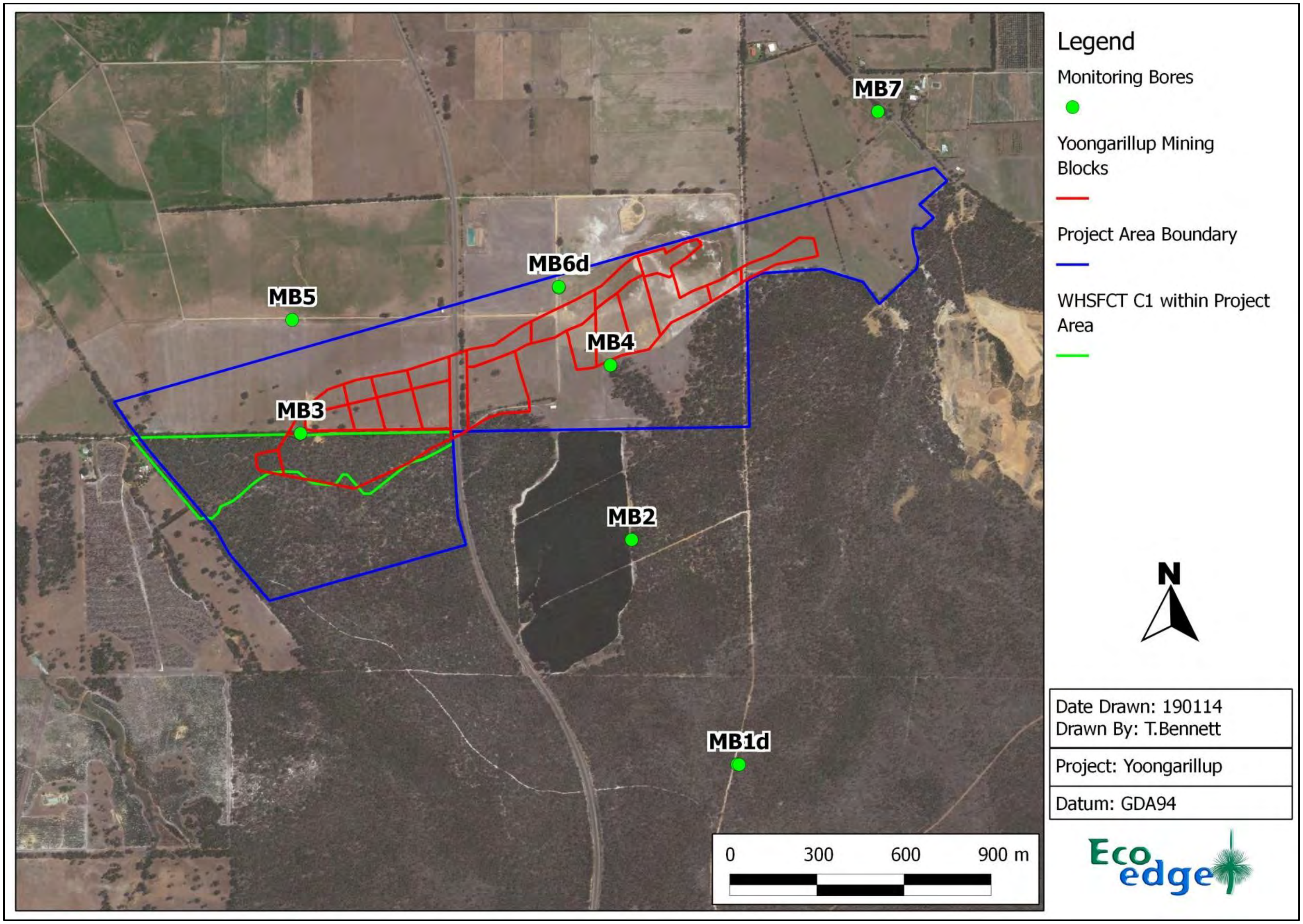

Figure 4. Monitoring bores installed within the Project Area (Doral, 2015).

The Mowen Member (into which MB03 is screened) lies below the Blackwood Plateau and beneath the western end of the Swan Coastal Plain (Water Corporation, 2005) and acts as aquitard. An aquitard is a zone within the earth that restricts the flow of groundwater from one aquifer to another. An aquitard can sometimes, if completely impermeable, be called an aquiclude. Aquitards comprise layers of either clay or non-porous rock with low hydraulic conductivity.

3.5 The Superficial Aquifer

The Superficial Aquifer (which includes the Yoganup Formation as its oldest member) is an unconfined aquifer (up to 20 m thick) that overlies the Mowen Member of the Leederville Formation within the Project Area (CSIRO, 2006). The upper surface of the Superficial Aquifer is the local watertable, which fluctuates seasonally by an amount that depends on the hydraulic conductivity of the soil and the direction of groundwater flow. The water table is generally at its highest level in spring and lowest in late autumn.

There are a number of factors that influence the rate and magnitude of recharge and discharge of the Superficial Aquifer and so control the level of the water table. The Superficial Aquifer on the Swan Coastal Plain is primarily recharged by rainfall and discharges into the ocean as well as into streams, drains, wetlands, and into the underlying Leederville or Yarragadee aquifers (CSIRO, 2006). The rate and magnitude of groundwater recharge by rainfall is dependent on rainfall patterns, land use cover (vegetation cover) and depth to the water table.

The processes of vertical rainfall infiltration and horizontal groundwater flow determine the level of the water table. The water table rises when rainfall infiltration exceeds the flow of groundwater in the winter months and declines over the summer drought period when the horizontal flow of groundwater exceeds the amount of recharge. In addition to horizontal flow, groundwater discharge also occurs through evapotranspiration of water by plants and groundwater abstraction in impacted areas. The influence of evapotranspiration on groundwater levels is greatest in habitats with a shallow depth to groundwater, and during periods when there is little recharge (Shafer *et al*., 2008; Parsons Brinckerhoff, 2013).

4 Groundwater Dependent Ecosystems

4.1 Definition

Groundwater-dependent ecosystems (GDEs) may be defined as ecosystems that require access to groundwater to meet all or some of their water requirements so as to maintain the communities of plants and animals, ecological processes they support, and ecosystem services they provide (Richardson *et al*. 2011). The same publication ('Australian Groundwater-

Dependent Ecosystems Toolbox'), defines groundwater as subsurface water located in the zone of saturation in pores, fractures in rocks and cavities.

For the purposes of defining ecosystem dependence on groundwater, groundwater is defined as "…*that water which has been below ground and would be unavailable to plants and animals were it to be extracted by pumping*" (Hatton and Evans, 1998).

Types of groundwater dependent ecosystems may include (Richardson *et al*., 2011):

1. Aquifer and cave ecosystems including stygofauna (fauna that live in groundwater) in fractured rock aquifers

2. Ecosystems dependent on surface expression of groundwater including base flow (e.g. fish in remnant aquatic pools), wetlands, mound springs and sea grass beds

3. Ecosystems dependent on subsurface presence of groundwater where roots tap into the groundwater system (via the capillary fringe). They include terrestrial vegetation that depends on groundwater fully or on a seasonal or episodic basis in order to prevent water stress and generally avoid adverse impacts to their condition. In these cases, and unlike the situation with Type 2 systems (above), groundwater is not visible from the earth surface. These types of ecosystem can exist wherever the watertable is within the root zone of the plants, either permanently or episodically.

Groundwater dependent, or phreatophytic vegetation, depends on the subsurface presence of groundwater, often accessed via the capillary fringe or vadose zone (i.e. the subsurface water just above the water table in a zone that is not completely saturated). The soil water in this zone is readily available to plant roots. As water is removed by transpiration it is continually replenished from the water table through capillary rise. Phreatophytes are therefore plants that meet their water requirements by water uptake from the groundwater or its capillary fringe (Kuginis *et al*., 2012).

4.2 Identifying Groundwater Dependent Ecosystems

Type 3 GDEs (ecosystems dependent on subsurface presence of groundwater, as defined in Section 4.1) may be difficult to identify in the field and their identification may require a detailed knowledge of local hydrogeology, ecosystems dynamics and plant physiology. Dependence on groundwater can be variable, ranging from partial and infrequent dependence, i.e. seasonal or episodic, to total (entire or obligate), continual dependence. It is often difficult, however, to determine the nature of this dependence (Serov *et al*., 2012).

5 Hydrogeological Investigations and Modelling for the Project Area

5.1 Investigations by Parsons Brinckerhoff

Parsons Brinckerhoff (2014; 2015) were engaged by Doral to conduct a groundwater investigation at the Yoongarillup Project Area to obtain a baseline hydrogeological characterisation of the site as an input to the environmental approval process. The focus of the work was to establish a hydrogeological framework to develop a conceptual model and to build a numerical groundwater flow model of the study area incorporating the proposed Yoongarillup mining area. The numerical model was then used to predict the likely drawdown, and pit inflows associated with the proposed mining activities (Parsons Brinckerhoff, 2014).

The investigation by Parsons Brinckerhoff comprised three components;

- Desktop study to establish geological and hydrogeological framework for Yoongarillup and the surrounding area and to make recommendations for new borehole locations to establish a monitoring network;
- Field Investigation comprising aquifer tests at new monitoring bores. Nine boreholes were tested and aquifer properties were determined from these tests; and
- Development of a conceptual model and numerical modelling to predict groundwater inflow to the mine pits and groundwater drawdown as a result of dewatering.

In summary, the predicted drawdowns within the Project Area from the initial investigations and modelling by Parsons Brinckerhoff were limited to 1 m in depth within the Mowen Member, up to 200 m from the Mine Pit in a northerly direction. To the south of the Mine Pit, predicted drawdown in both the Superficial Aquifer and Mowen Member was limited such that the 1 m drawdown contour is not expected to extend beyond the pit boundary within State Forest in the Project Area. In addition, no mining related drawdown was predicted in the Vasse Member of the Leederville Formation or in the Yarragadee Aquifer. There was, however, some predicted localised drawdown in both the Yarragadee Aquifer and the Vasse Member around Yarragadee water supply wells.

5.2 Perceived Limitations of the Hydrogeological Investigations and Modelling

With regard to potential GDEs within the Project Area, particularly within the State Forest adjacent to the western section of the proposed mine pit, the prediction by Parsons Brinckerhoff (2014) that no drawdown would extend beyond the pit boundary was called into question in responses to the PER by DPaW (DPaW, 2014). In particular, it was pointed out that the initial investigations and modelling focused only on the underlying (Leederville) aquifer. The response by DPaW, referred to the fact that the complex distribution of wetland dependent species in otherwise dryland environments throughout the Whicher Scarp are due to localised aquicludes (or aquitards[3]) produced by clay layers that collect rainwater and create perched aquifers. A specific criticism of the PER was that the hydrogeological investigation did not consider the potential indirect impact on surrounding vegetation supported by aquitards.

The Department of Water (DoW) also reviewed the groundwater related sections of the PER and expressed a number of comments and concerns with regard to potential impacts on the State Forest south of the proposed Mine Pit. In particular they commented with regard to a prediction of no drawdown south of the Mine Pit by Parsons Brinckerhoff (2014);

1. "Drawdown of less than 1m will extend to into State Forest 33 and have potential to impact vegetation. The vegetation will likely be accessing groundwater from the Mowen Member sediments above the Vasse Member. Whilst the modelling conducted indicates that there will not be any drawdown in the Vasse Member there will be some drawdown (downslope drainage) in the overlying Mowen Sediments and there is potential for impacts to vegetation as a result."

2. "Assessment of the… potential impacts is not possible based on the information provided in the PER and supporting hydrogeological reports. Information on the current depths to groundwater in areas adjacent to the mine pit (immediately south) is not provided. This is critical information to allow the assessment of the potential risk to groundwater dependent vegetation outside of areas to be cleared."

3. "Predicted drawdowns should be presented in addition to current seasonal fluctuations as changes in the water regime that will result during and post mining. This will allow the proponent to assess the risk to vegetation beyond the mine pit boundary."

The DoW concerns were addressed by Parsons Brinckerhoff in a review document (Parsons Brinckerhoff, 2015). As part of the review a new modelling diagram was produced, which is reproduced below (**Figure 5**).

This diagram shows predicted drawdowns for 0.1 m, 0.5 m and 1.0 m contours to illustrate the extent of the dewatered area of influence within the Superficial Aquifer and the Mowen Member, as requested by DoW. This diagram shows predicted drawdowns of up to 0.1 m up to 300 m west of the proposed Mine Pit, and from 70 m to 170 m south of the pit. Predicted drawdowns of up to 0.5 m are shown up to 70 south and 100 m west of the Mine Pit. No

[3] Aquicludes are aquitards where there is zero movement of water through the layer, this is restricted to situations with dense rock and the more general term is "aquitard".

drawdown of a metre or more is predicted outside of the proposed Mine Pit for the State Forest in the Project Area.

With regard to the DoW's concerns regarding potential drawdown impacts on the State Forest south of the Mine Pit, Parsons Brinckerhoff (2015) stated;

"It is unlikely that drawdown [will be] experienced in the Mowen Member south of the mine. Less than 1m drawdown is likely within the natural variability of the water table. …it is interpreted that groundwater in the Mowen Member is perched and therefore disconnected from the regional water table. Mining related dewatering will occur in the Superficial sediments. **It is understood that where State Forest 33 is located, no Superficial is present. The Superficial pinches out some 50-200 m south of the mining area."**

This statement by Parsons Brinckerhoff regarding no drawdown within State Forest is incorrect. Their own modelling shows that there will be a drawdown 0.1 m up to 300 m west of the proposed Mine Pit, and from 70 m to 170 m south of the pit, <u>within State Forest</u>, as stated above (refer **Figure 5**, below).

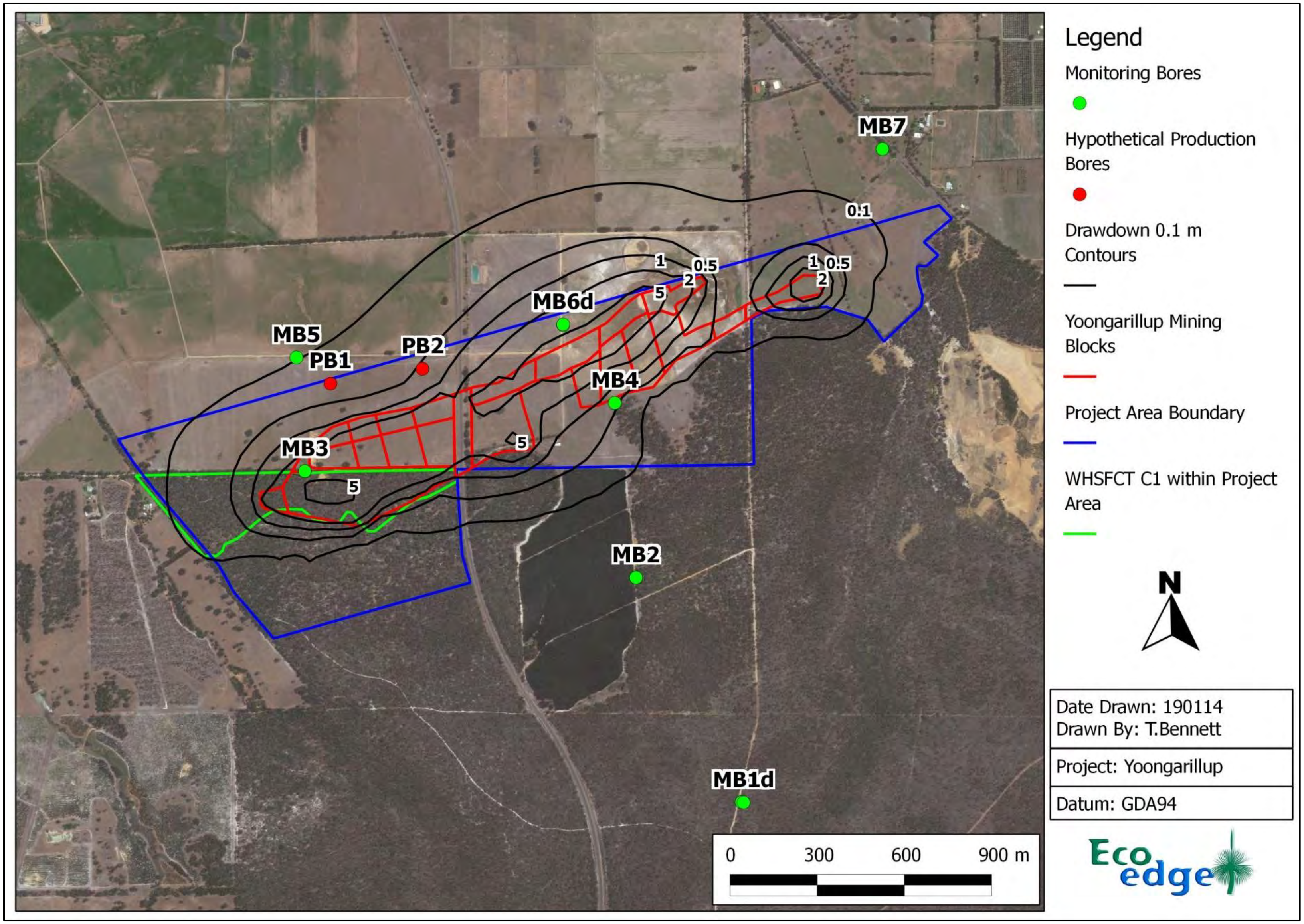

Figure 5. Potential induced drawdowns at 0.1 metre contours (Parson Brinckerhoff, 2015).

6 Potential Groundwater Dependent Ecosystems and Species and Potential Impacts of Groundwater Drawdown

6.1 Plant Communities

Vegetation and Flora surveys within the Project Area (Mattiske Consulting, 2012; Ecoedge, 2014) did not identify any areas of wetland vegetation. However, an area of sandy clay loam with dampland[4] species, such as *Banksia littoralis*, *Kunzea rostrata*, *Mirbelia dilatata* and *Taxandria linearifolia* near the southern boundary of the Project Area was identified by Ecoedge (2014). This potential GDE is shown in **Figure 6**, below, along with the locations of all 'dampland' taxa recorded by Mattiske (2012) and Ecoedge (2014). The potential GDE is mapped with reference to locations of 'dampland' taxa and surface soils. It extends through parts of three vegetation units (B, C and D) as mapped by Ecoedge (2014).

As can be seen from **Figure 6**, dampland species are scattered over much of the Project Area, however there are few situated within vegetation unit A (which is considered to be equivalent to be the priority plant community WHSFCT C1) as mapped by Ecoedge (2014). This absence of dampland species within vegetation unit A is probably because the surface soils in this community are mainly sands or loamy sands several metres deep.

Several taxa located within the potential GDE near the southern boundary of the Project Area (but generally not located outside of it) are particular evidence of a perched aquifer – these being *Banksia littoralis*, *Schoenus discifer* and *Taxandria linearifolia*.

The potential GDE within the Project Area is more than 200 m from the proposed Mine Pit and over 70 m from the predicted 0.1 m drawdown zone. Therefore there is not likely to be any indirect effect on this community caused by dewatering activity.

[4] Dampland species are defined here as being generally associated with areas of seasonally, intermittently or permanently waterlogged soils. These are usually found in shallow basins, drainage lines or over aquitards at a shallow depth.

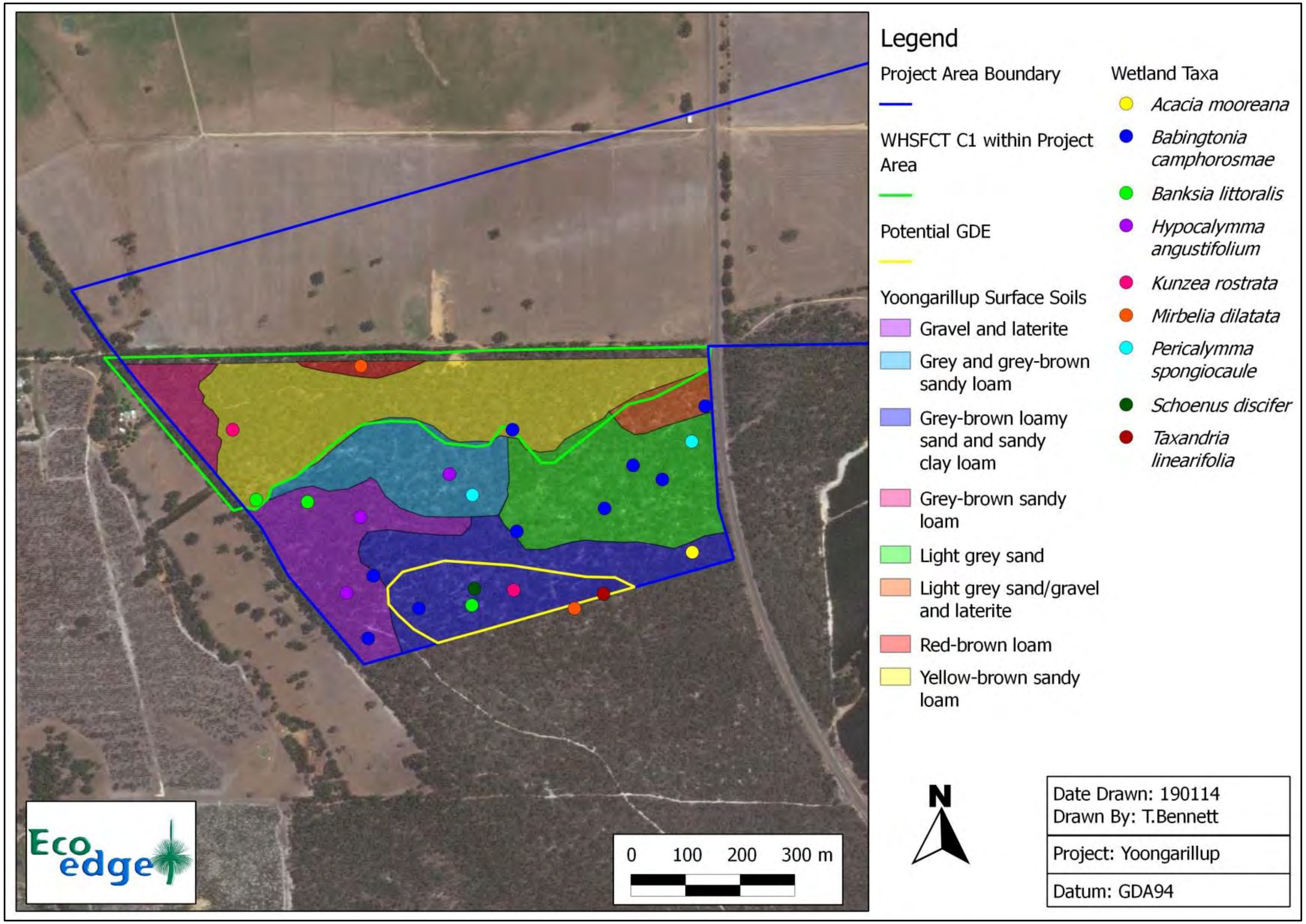

Figure 6. Location of a potential GDE and dampland species within the Yoongarillup Project Area in relation to surface soils. The boundary of vegetation unit A (WHSFCT C1) (Ecoedge, 2014) is shown.

6.2 Declared Rare Flora and Priority Flora

The distribution of DRF, Priority and Conservation Significant flora within the Project Area in relation to the proposed Pit and predicted drawdown is shown in **Figure 7**. This shows that approximately a third of the rare and conservation significant individuals are within the predicted 0.1 m drawdown zone. One of the remaining *Daviesia elongata* subsp. *elongata* (DRF) plants, not directly affected by mine pit construction, will be within a few metres of the edge of the pit and is very likely to be adversely affected by physical disturbance, drawdown or both. The other remaining plant will be within the zone of predicted 0.1 m drawdown and 40 m from the Mine Pit.

Two of the four *Conospermum paniculatum* plants (P3) not directly affected by the construction of the proposed Mine Pit will be close to the pit edge and may be adversely affected by physical disturbance, drawdown or both.

Individual plant species may be dependent, or partially dependent, on groundwater even though they do not form part of a GDE. Plants occurring above a shallow aquifer may be dependent on groundwater as a regular source of moisture, with the degree of dependency depending on the seasonal availability of groundwater and depth, and the species' rooting pattern. Some species only occur where groundwater is at a particular depth. Their loss or a decline in health or numbers may indicate an altered hydrological regime caused by a natural decline in water table levels or groundwater extraction (Groom, 2003).

Long-term studies on the Gnangara Mound near Perth have shown that groundwater-dependent *Banksia* woodlands have a strong resilience to water-drawdown coupled with a drying climate (Sommer and Froend, 2010; Canham, 2011). However, continued decline caused the vegetation to respond in abundance and composition. The change in composition was primarily manifested as a shift towards non-woody, shallow-rooted species (Sommer and Froend, 2010).

However, to the Author's knowledge there is no specific information about any of the rare or conservation significant species within the Project Area with regard to their tolerance to groundwater drawdown. None of them are known to be dependent on partial, episodic or continual access to groundwater aquifers. No information is available regarding the rooting patterns or maximum depths of the rare or conservation dependent plants in the Project Area, although their maximum rooting depths are likely to be in the range of 0.5 m to 2.0 m. It is likely that the deeper rooted species occasionally access the Superficial Aquifer, but they are unlikely to be dependent on it for their continued survival.

Except for plants within close proximity to the Mine Pit it is unlikely that there will be any long-term effect of groundwater drawdown in the range of 0.1 m to 0.5 m. Plants in close proximity (< 5 – 10 m) to the Mine Pit are at risk of direct and indirect impacts, including possible effects of opening up of the canopy by direct disturbance and increased exposure to wind and sunlight.

For plants not within close proximity to the Mine Pit, there is unlikely to be any long-term effects of a drawdown in the Superficial Aquifer of up to 0.5 m, particularly if the drawdown is temporary (as is likely) and occurs over winter.

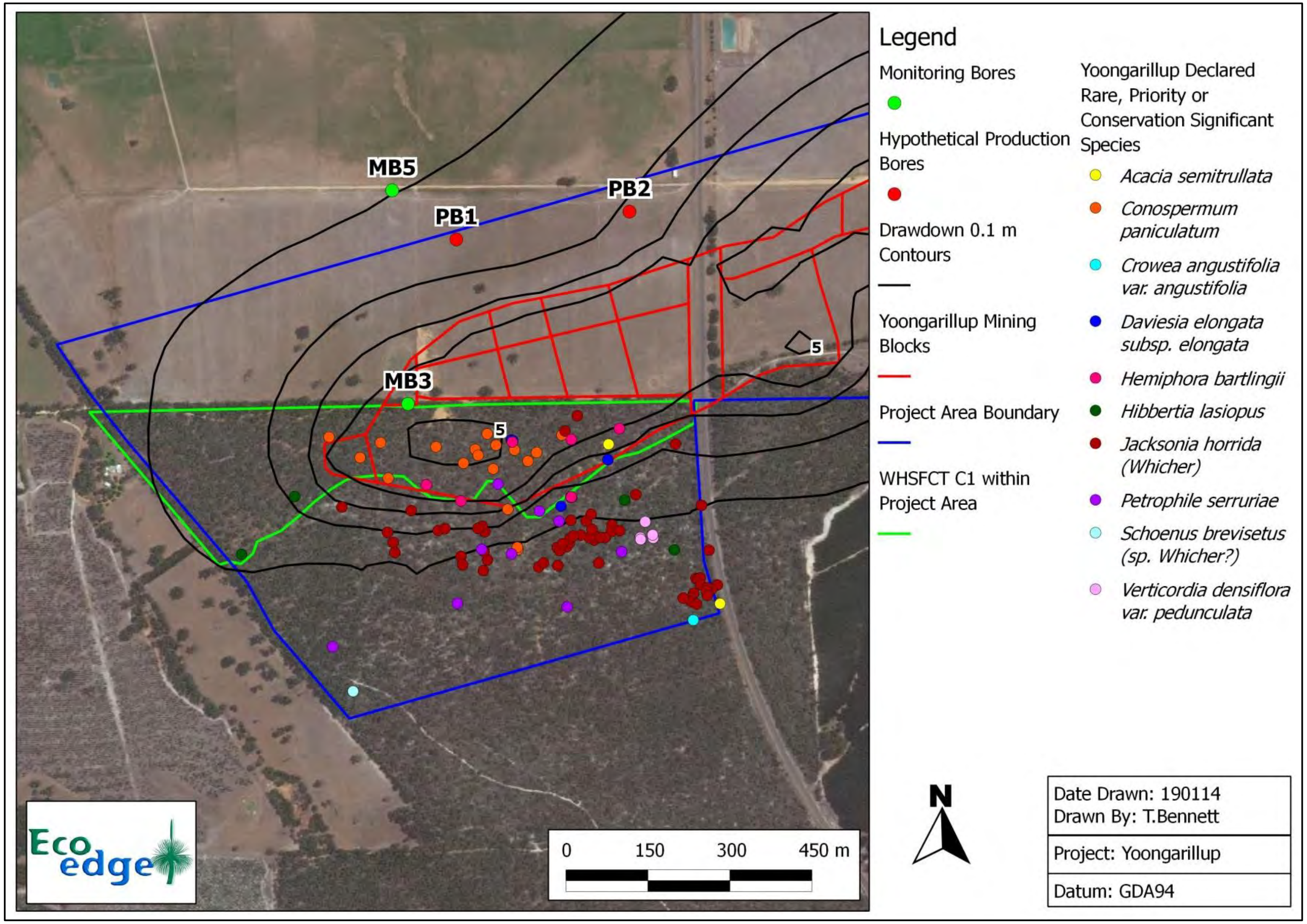

Figure 7. Location of Declared rare, Priority or conservation significant species in relation to drawdown modelling and the proposed pit location.

6.3 The Pine Plantation

Doral have requested an appraisal of potential effects of predicted groundwater drawdown on the pine plantation east of Sues Road, following concerns raised during the PER process. At the outset it should be noted that no information is available with regard to whether the pine plantation, or part of it, is accessing groundwater.

As can be seen in **Figure 8**, a small portion of the pine plantation lies within the zone of 0.1 m predicted drawdown. A monitoring bore (MB2) has been sited on the eastern side of the plantation, drilled to 18.05m depth. This bore was constructed to test portions of the Superficial Aquifer, but the slotted casing is located in a low porosity unit (Mowen Member). Nearby historic drilling by Iluka Resources suggests the base of the superficial aquifer is at most 5-10m below surface. This bore typically runs dry over the dry season and it has been recommended that the bore be replaced by a shallower bore closer to the proposed mining area (Doral, 2015).

Pinus pinaster plantations on the Gnangara Mound north of Perth apparently do not utilise groundwater when it appears they have access to it and growth of the species is mostly associated with rainfall trends (Bourke, 2004). *P. radiata* in eastern Australia has been shown to use some groundwater at locations where the watertable was within 6 m of the ground surface and where there were no distinct root-impeding layers (Benyon, *et al*. 2006).

In summary, sited as it is on moderately deep sand, it is unlikely that the pine plantation at Yoongarillup sources much of its water from groundwater. It is unlikely that a fall in the groundwater table in the region of 0.1 m will have any effect on growth in the plantation.

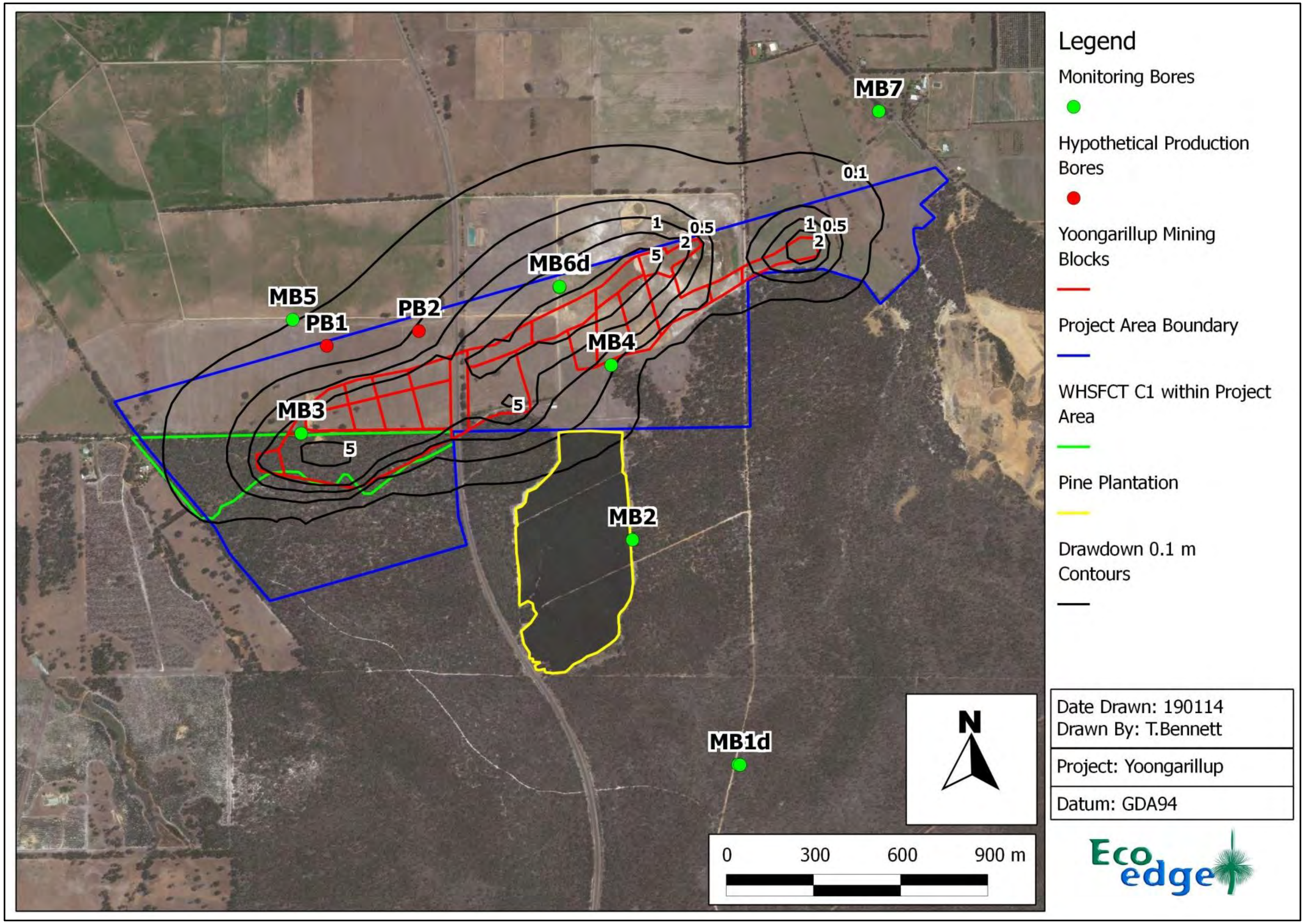

Figure 8. Location of the pine plantation in relation to monitoring bores and predicted drawdown contours.

7 Limitations of the Hydrogeological Modelling

The relatively shallow depth of the Superficial Aquifer within the Project Area south of the proposed Mine Pit (with a probable base of 6 m to 9 m depth[5]) means that some deeper rooted species are likely to be dependent on groundwater for part of the year. The dampland species shown in **Figure 5** are likely to be accessing groundwater for at least some of their requirements. However there has been no monitoring of the Superficial Aquifer within the State Forest south of the proposed Mine Pit so there is no data with regard to variations in its distribution or its depth.

Because no data from monitoring of the Superficial Aquifer within the State Forest was used in the modelling by Parsons Brinckerhoff, there is some doubt that they have adequately modelled the potential impact of Mine Pit construction. In particular, if there are localised perched aquifers above aquitards within the State Forest, then it is possible that there will be deeper drawdowns than have been modelled.

Drilling within the State Forest at Yoongarillup by Doral showed that the Yoganup Formation, overlain in places by Bassendean Sands and in others by both Bassendean Sands and the Guildford Formation extends some 50 m to 100 m upslope from the proposed Mine Pit. The Yoganup Formation may be up to 9 m deep close to the proposed Mine Pit but is generally shallower than this and "pinches out" upslope. Where it is present within the State Forest, in the western half of the Project Area, the Guildford Formation, with its relatively high clay content, may be only 2 m to 5 m from the surface within 100 m of the proposed Mine Pit.

Investigations by Soil Water Consultants (2007) at the Burekup minesite found that the Yoganup Formation overlying the Leederville Aquifer is variably saturated and represents the capillary fringe overlying the saturated (Leederville) aquifer. The degree of saturation depends on the texture of the sediments (i.e. in sand the capillary fringe may be significantly narrower than in a clayey soil). Massive laterite formation occurs at the interface between the saturated and unsaturated soil conditions in the Yoganup Formation and this is evident in places within the Yoongarillup Project Area.

With regard to the Project Area, the significance of this variation of water holding capacity within the Yoganup Formation, together with variability of water holding capacity associated with pockets of coarse sand in the Guildford Formation (Soil Water Consultants, 2007), is that the pattern of drainage into the proposed Mine Pit (and subsequent drawdown of the Superficial Aquifer) may be quite complex.

The groundwater flow modelling by Parsons Brinckerhoff did not differentiate between individual members of the Superficial Formation, and these were represented by a single

[5] Mr D. Walton, senior geologist, Doral Mineral Sands, *pers. comm*.

model layer. Because these members are laterally and vertically discontinuous, as well as heterogeneous, the associated local perched systems could not be appropriately modelled in a model of regional scale (Parsons Brinckerhoff, 2015). In consequence the predicted drawdowns shown in **Figure 7**, above, may be exceeded (or not reached) in places.

However, Doral believe that the Superficial Aquifer is insufficiently defined by exploration and tested by hydrological drilling in areas beyond 50 m - 200 m south of the proposed Mine Pit within the State Forest and the adjacent National Park. It is assumed that in some areas discontinuous portions of the Superficial Aquifer occur upslope of the proposed Mine Pit but these are unlikely to be high porosity and permeability due to the high level of clay and lateritic ironstone seen in southern drill holes. In some areas, the Mowen Member will be present below the topsoil and sub-soil, and this would indicate that perched water tables and GDEs are not largely interconnected with superficial sediments within the proposed Mine Pit area (D. Walton, *pers. comm.*).

8 Management Strategies to Limit Potential Groundwater Drawdown Impacts

Groundwater levels at Yoongarillup are closest to the surface in spring and deepest in late autumn and early winter. Consequently any plants that are utilising groundwater over the summer-autumn period will be most sensitive to a drawdown of the watertable during this period.

Doral has undertaken to carry out the following measures to mitigate any potential adverse effects flowing from mining within the State Forest (A. Walton, *pers. comm*.):

- Monitor groundwater levels on a monthly basis (incorporating the proposed additional 11 monitoring bores to adequately monitor the State Forest sub-area[6])
- Progressively backfill mining voids, as far as is practicable to minimise the timeframe excavations that intersect aquifers are open

8.1 Recommendations

1. On the basis that drawdown of groundwater over the summer-autumn period will be most likely to adversely affect plants relying on it at that time of year it is recommended that mining within the State Forest be carried out over winter when species are able to access all of their water requirements from the soil profile. It should be noted that this approach may increase the risk associated with *Phytophthora* dieback disease; as such, it is critical that appropriate hygiene measures are implemented in order to reduce the spread of this pathogen.

[6] Installation of additional bores is subject to approval from DoW and DPaW

2. In addition, Doral's intention of backfilling mining voids as quickly as is practicable is also supported to limit the duration of any increased drainage of water from within the Superficial Aquifer into the Mine Pit.

3. Doral's plan to install an additional 11 monitoring bores to test the Superficial Aquifer is supported.

4. It is also recommended that Doral carry out monitoring of soil moisture levels and vegetation health within the zone of 0.1 m (and greater) predicted drawdown.

5. It is recommended that as part of the monitoring plan, "trigger points" (or thresholds) (i.e. of groundwater or soil moisture levels, or plant health indicators) are identified, and appropriate responses formulated. This will allow for pre-defined management actions to attempt to mitigate possible adverse effects on conservation values in the Project Area.

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APPENDIX 1-B GROUNDWATER AND PLANT HEALTH MONITORING REPORT

Groundwater and Plant Health Monitoring at the Proposed Yoongarillup Mineral Sands Project - Preliminary Technical Note.

Prepared for Doral Mineral Sands Pty Ltd

February 2015

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Statement of limitations

Reliance on Data

In the preparation of this report, Ecoedge has relied on data, surveys, analyses, designs, plans and other information provided by the Client and other individuals and organisations, most of which are referred to in the report. Unless stated otherwise in the report, Ecoedge has not verified the accuracy or completeness of the data. To the extent that the statements, opinions, facts, information, conclusions and/or recommendations in the report are based in whole or in part on the data, those conclusions are contingent upon the accuracy and completeness of the data. Ecoedge will not be liable in relation to incorrect conclusions should any data, information or condition be incorrect or have been concealed, withheld, unavailable, misrepresented or otherwise not fully disclosed to Ecoedge.

Report for Benefit of Client

The report has been prepared for the benefit of the Client and for no other party. Ecoedge assumes no responsibility and will not be liable to any other person or organisation for or in relation to any matter dealt with or conclusions expressed in the report, or for any loss or damage suffered by any other person or organisation arising from matters dealt with or conclusions expressed in the report (including, without limitation, matters arising from any negligent act or omission of Ecoedge or for any loss or damage suffered by any other party relying on the matters dealt with or conclusions expressed in the report). Other parties should not rely upon the report or the accuracy or completeness of any conclusions, and should make their own enquiries and obtain independent advice in relation to such matters.

1 Introduction

Doral Mineral Sands Pty Ltd ('Doral') is currently planning to construct and operate a mineral sands mine, known as the 'Yoongarillup Mineral Sands Project', near the base of the Whicher Scarp approximately 15 km south east of Busselton, Western Australia. The proposed pit would be located on Mining Leases M70/459 and M70/458, and would involve clearing up to 9ha of native vegetation (within State Forest) and 32ha of pasture within a 152ha development envelope. The mine life is approximately three years and is proposed to be developed on cleared land and in Millbrook State Forest. To enable optimum resource recovery, it is likely that mining will occur below the groundwater table and, hence, dewatering of the pits will be required (Parsons Brinckerhoff, 2015). Consequently, a drawdown of the groundwater table beneath the State Forest (and potentially further) may occur, which may impact vegetation dependent on ground water.

A review of potential impacts of the proposed mining within Millbrook State Forest was carried out by Ecoedge (2015). The Ecoedge review drew on various floristic, geological and hydrological studies carried out for the Public Environmental Review for the Project (Doral, 2014). Zones of potential water drawdown around the proposed mine pit were modelled by Parsons Brinckerhoff (2014; 2015) and are shown in **Figure 1**, below. Also shown are monitoring bores and proposed production bore sites. It has been proposed that a further 11 bores be installed to provide better monitoring of water levels in the Superficial Aquifer within the State Forest (Doral, 2015).

Potential adverse effects of water drawdown on rare flora and a priority ecological community adjacent to the pit were discussed in Ecoedge (2015). Parks and Wildlife (2014) and the Office of the Environmental Protection Authority (OEPA) (OEPA, 2014) have expressed concerns about possible edge effects close to the proposed mine pit and within the zone of potential drawdown generally.

Ecoedge was engaged in January 2015 to prepare a report that would discuss the type and extent of potential direct and direct effects of the proposed mine pit on flora and vegetation within the State Forest, and recommend monitoring methods, "trigger points" and what might be done to mitigate the impacts.

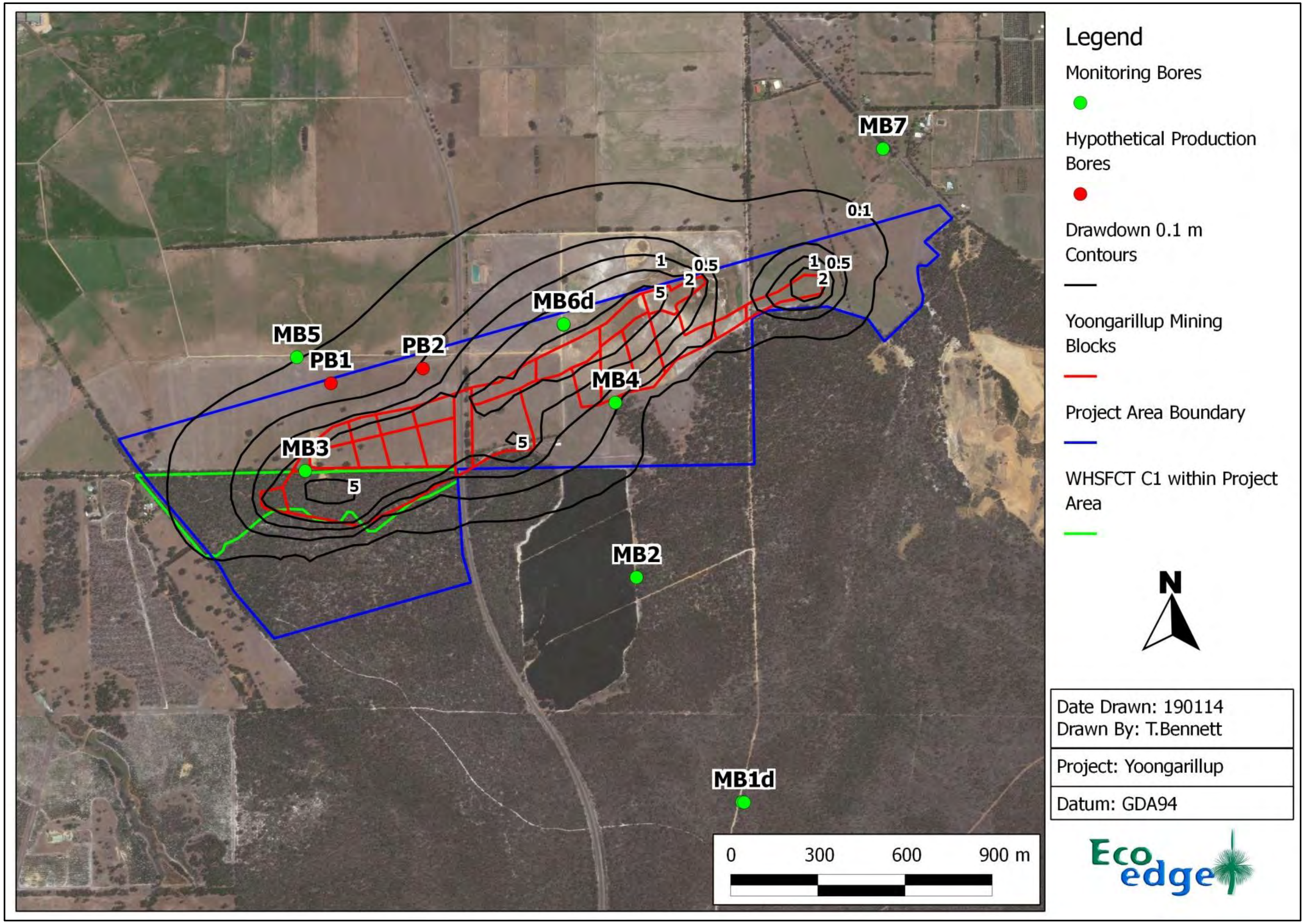

Figure 1. Potential induced drawdowns at 0.1 metre contours (Parson Brinckerhoff, 2015).

2 The Potential for Indirect Effects from the Proposed Mine Pit

2.1 Water Drawdown

The modelling by Parsons Brinckerhoff (2014; 2015) predicts drawdowns of up to 0.1 m up to 300 m west of the proposed Mine Pit, and from 70 m to 170 m south of the pit. Predicted drawdowns of up to 0.5 m are shown up to 70 south and 100 m west of the Mine Pit. A small area, especially west of the proposed mine pit is predicted to experience drawdowns of between 1m and 2 m and somewhat more than this right at the pit's edge.

As noted in Ecoedge (2015), Doral has undertaken to implement the following measures to mitigate any potential adverse effects flowing from mining within the State Forest (A. Walton, pers. comm.):

- Monitor groundwater levels on a monthly basis (incorporating the proposed additional 11 monitoring bores to adequately monitor the State Forest sub-area)
- Progressively backfill mining voids, as far as is practicable to minimise the timeframe excavations that intersect aquifers are open
- Prepare and implement a plan to manage effects on GDEs and other partially or fully groundwater dependent vegetation.

It is proposed that the current modelling by Parsons and Brinckerhoff will be supplemented by additional data from further monitoring bores in the area south of the proposed mine pit within State Forest 33. Data from these additional bores will be used to improve the knowledge of the Superficial Aquifer and allow refinement of the modelling. Consequent to this additional modelling the area potentially affected by drawdown and the predicted depths of drawdown may change.

2.2 Changed Microclimate and Subsequent Effects

The "Edge Effect" is a well-studied facet of ecology. It refers to the effect of the juxtaposition or placing side by side of contrasting environments on an ecosystem. When edges are expanded into any natural ecosystem, and the area outside the boundary is a disturbed or unnatural system, the natural ecosystem can be seriously affected for some distance in from the edge (Murcia, 1995; Kazar, 2003; Collinge, 2009). Among the changes that may take place are such microclimatic effects as increased light intensity, temperature, relative humidity and wind speed. These microclimatic variables are highly sensitive to canopy cover and vary temporally and spatially according to the density and structure of the forest. Forest edge, whether natural or as a result of anthropogenic disturbance may be thought of as a zone which has the climatic buffering effects of a canopy immediately overhead but which lacks the internal protection afforded by trees to one side, leading to highly variable conditions (Kazar, 2003).

These microclimatic effects may not only impact the edge itself, but extend in from the edge for tens of metres. The distance various edge effects extend into a forest varies markedly; a summary of data from Brazilian rainforest studies shows a one hundred-fold variation in the penetrance of various biotic and abiotic factors (Lindenmayer and Fischer, 2006). Abiotic variables, such as soil moisture, air temperature and vapour pressure deficit varied significantly up to 60 m from the edge in the Brazilian forests, and around 50 m appears to be the maximum depth for many abiotic variables to be significantly different from the forest edge (Murcia, 1995). The magnitude of edge effects, however, is likely to vary significantly according to the structure and climate in which a forest occurs.

Changed microclimate within the edge zone may subsequently lead to altered vegetation structure, tree shape, litter levels, plant health, species composition (including increased weed invasion) and faunal habitat characteristics (van Etten, 2014).

The proposed mining would increase the length of “edge” in State Forest 33 within the Yoongarillup Mineral Sands Project Area from around 570 m to 910 m (i.e. by 62%). The current forest edge has been stable for many years and while there has been some invasion by annual agricultural weeds, vegetation condition was rated as “Excellent” condition (Ecoedge, 2014). Opening up a new edge will cause the vegetation and other biotic assemblages interior to this new edge to be subject to changes in microclimatic conditions. Among the almost immediate changes that could be expected are increased average wind speed, increased insolation and decreased moisture levels in the surface soil. Other changes, including biotic changes would develop over a period of months and years.

2.3 Direct Physical Disturbance at the Forest Edge

In the process of clearing vegetation within the proposed mine pit area and digging the pit, direct damage may be done to vegetation outside of the pit area. This may come about through trees falling onto adjacent vegetation outside of the pit area, or by severing of roots during the pit excavation process.

3 Impact Zones and Monitoring

3.1 Water Drawdown

Potential impact zones within State Forest 33 at the Yoongarillup Mineral Sands Project Area are conveniently delineated by the 0.1 m, 0.5 m and 1.0 m predicted drawdown contours (Parsons Brinckerhoff, 2014; 2015). The following discussion is based on distribution of the contours as they are currently predicted, however, their placement may be changed following further modelling based on more information from the Superficial Aquifer.

The report by Ecoedge (2015) on potential groundwater dependent ecosystems (GDEs) and groundwater dependent plant species (complete or partial phreatophytes) discussed the fact that several Declared Rare Flora, Priority Flora and conservation significant flora occurred within the zone of the predicted 0.5 m and 0.1 m drawdown contours. None of these rare or conservation significant species is known to be a phreatophyte (complete or partial), and it is unlikely that a GDE occurs within the 0.5 m or 0.1 m drawdown contours. However, it is likely that several species depend on water from the Superficial Aquifer for at least part of their requirements (e.g. *Pericalymma spongiocaule* and *Babingtonia camphorosmae*).

It is unlikely that permanent damage to vegetation would be caused by a temporary drawdown in the range 0.1 m to 0.5 m. Depending on the time (i.e. season) of the drawdown, predicted falls in groundwater level of 1 m (up to 60 m from the pit) to more than 2 m (up to 30 m from the pit), particularly at the western end of the mine pit may lead to extra water stress and some mortality in partial phreatophytes (Sommer and Froend, 2011).

3.1.1 Water Monitoring Bores

As mentioned in **Section 2.1**, above, if mining within State Forest 33 is approved, Doral propose to install up to another 11 monitoring bores to adequately monitor the Superficial Aquifer within the State Forest sub-area**.**

It is recommended that fortnightly readings be taken at these bores over at least a 6 month period leading up to mining, during mining within the State Forest and for a period of at least six months following the cessation of mining.

3.1.2 Soil Moisture Measurement

It is likely that soil moisture levels will be one of the first abiotic variables to change following clearing of the mine pit area. Increased light levels and wind speed within the area adjacent to the mine pit, as well as groundwater drawdown, are likely to lead to a fall in soil moisture levels. However, the direction and magnitude of changes in soil moisture will depend on the time of clearing of the pit area, the aspect of the vegetation along the pit edge, and the length of time before canopy is re-established within the pit area following the cessation of mining.

It is recommended that neutron probe moisture meters (Chanasyk and Naeth, 1996) be used to take fortnightly readings in summer and autumn and monthly readings in winter and spring of soil moisture levels within the top 1.5 m of the soil profile (at 0.5 m depth intervals) within the 0.5 m predicted drawdown zone. Ideally the soil moisture measurement should be commenced at least 6 months prior to mining.

To give a good coverage of the 910 m interface between the mine pit and State Forest it is recommended that soil moisture monitoring take place at 100 m intervals around the pit edge[1].

It is also recommended that soil moisture at "control sites" within State Forest 33 be monitored – these sites would be in a similar landscape position but outside the predicted drawdown zone.

3.2 Changes in the Microclimate and Edge Effects

Changes in microclimatic variables as they impact on the forest edge zone can be measured directly (e.g. wind speed or air temperature) or indirectly by means of observations of biotic factors. Soil moisture levels, because they are affected by wind speed and insolation, are an aspect of microclimate addressed in **Section 1.1**. Biological edge effects can be direct (such as changes in plant health, seedling growth rates and canopy cover) or indirect (such as the amount of herbivory). Edge effect variables may also interact with one another and species may behave differently to variations in microclimatic factors due to the edge effect (Murcia, 1995).

Onset of changes in biotic factors may be relatively sudden (e.g. changes in plant health due to changes in soil moisture availability) or relatively long-term (i.e. changes in plant structure or plant species composition). It is likely that the earliest biological signs of changed microenvironmental conditions (including changed access to soil water) within State Forest 33 will be changes in plant health (or plant stress). Depending on the season, it is probable that decreased water availability, either through groundwater drawdown, drying out of the surface soil or increased evaporative demand caused by increased wind speed and solar radiation levels, will lead to a decrease in plant health. Changes in plant health cause by water stress can be detected in a number of ways, including;

1. measuring physiological variables (such as leaf or stem water potential),
2. by making observations either by using visual scale (e.g. an adaptation of that used by Stol, J., 2006 or Souter *et al*., 2009), or;
3. use of an instrument such as a chlorophyll fluorometer which estimates the photosynthetic efficiency of a plant.

It is recommended that plant health measurements using direct and/or indirect methods be carried out on at least six species found within 50 m of the proposed mine pit.

The species chosen for monitoring should include both relatively deep-rooted and shallow-rooted taxa.

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[1] When more information is obtained on the characteristics of the Superficial Aquifer within the State Forest these intervals may be able to be modified

The plant health monitoring would commence at least 6 months before mining and be carried out during and for a period after the cessation of mining.

That plant health assessments would be carried out fortnightly during mining and at least monthly before mining commences, and include "control sites" in a similar landscape position outside the zone of predicted groundwater drawdown.

The choice of monitoring methods be made following consultation with the Department of Parks and Wildlife.

4 Trigger Points and Management Actions

Trigger points (or thresholds), in the context used here, are levels of an environmental variable the exceedance of which will produce a management response. Trigger points are common in water management plans, e.g. Department of Water (2008). Trigger points and the associated management responses, which usually set out appropriate mitigation or remediation actions, are increasingly being applied in approvals for mining, such as that used for Dongara Mineral Sands Project (EPA, 2013).

An example of some of the trigger and corresponding actions for the Dongara Mineral Sands Project is given below (**Figure 2**).

With regard to the Yoongarillup Mineral Sands Project trigger points and appropriate management responses aimed at minimising edge effects to protect ecological values would need to be developed in consultation with the Department of Parks and Wildlife and tertiary institutions with expertise in this area.

Doral has already undertaken to install more groundwater monitoring bores within the State Forest, and to carry out mining as a staged process in an attempt to minimise harm to the environmental values of the adjacent State Forest. As stated above, apart from physical damage to adjacent vegetation during the clearing and pit excavation process the most likely early onset adverse impact on the vegetation adjacent to the mine pit will be plant stress as a result of declining groundwater levels or increased wind speed and insolation.

Among the management responses that could be used to mitigate groundwater drawdown are altering mining schedules or perhaps re-introducing water back into the zone where the groundwater trigger point has been exceeded. Edge effects caused by the opening up of the canopy could perhaps be mitigated by putting up a barrier to reduce wind and light penetration into the forest adjacent to the pit.

We add value Dongara Project

Trigger	Action
Groundwater levels are not lower that predicted but vegetation condition has declined more than predicted	1. Investigate cause, which could include analysis of GDE impact model 2. Review Operational Management measures and escalate where possible. 3. Increase frequency of monitoring of vegetation (impact and control transects) and groundwater monitoring to Quarterly 4. If area subject to Moderate Change has crossed predicted Low Change extent, or area subject to Large Change has crossed predicted extent of Moderate change implement remedial action on a trial basis 5. Monitor success of remedy.
Groundwater levels are lower and vegetation condition has declined more than predicted	1. Investigate cause, which could include analysis of groundwater model 2. Review Operational Management measures and escalate where possible. 3. Increase frequency of monitoring of vegetation (impact and control transects) and groundwater monitoring to Quarterly 4. If area subject to Moderate Change has crossed predicted Low Change extent, or, are subject to Large Change has crossed predicted extent of Moderate change implement remedial action on a trial basis 5. Monitor success of remedy.
Results from remote imagery analysis indicate vegetation has declined more than predicted.	1. Ground truth remote data (visit area to verify change) 2. If degree of change is clearly beyond that predicted investigate cause and implement remedial measures. 3. Monitor location and success of remedy quarterly. 4. If no change monitor annually.

Figure 2. Example of triggers and management actions for the Dongara Mineral Sands Project (Strategen, 2012).

It is recommended that trigger points for groundwater drawdown, soil moisture levels and plant health be developed in consultation in Parks and Wildlife and tertiary institutions.

It is recommended that appropriate management actions following exceedances of trigger points be developed, particularly in relation to groundwater levels.

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APPENDIX 2 VEGETATION HEALTH MONITORING ZONES

Doral

PROPOSED
YOONGARILLUP MINERAL SANDS PROJECT

Vegetation Health Monitoring Zones

DWG No: YG150306

Scale: 1:5,000 @ A3

Date: 06 / 03 / 2015

Legend

- Monitoring Zone 1
- Monitoring Zone 2
- Monitoring Zone 3
- Monitoring Zone 4

Monitoring Zones 1 includes areas up to 50m from clearing line and incorporates areas within the 1.0m drawdown contour. Monitoring Zones 2 & 4 are based on the location of the 0.1, 0.5m drawdown contours respectively and may be subject to change should validation of the groundwater model (after 6 months of operations) result in altered groundwater drawdown contours. Monitoring Zone 3 is based on mapped Potential GDE.

Meters
0 25 50 100 150 200 250

N

APPENDIX 3 ACID SULPHATE SOIL REPORT – VERSION C

SOILWATER CONSULTANTS

YOONGARILLUP DEPOSIT ASS SURVEY

Prepared for:	**DORAL MINERAL SANDS LIMITED**
Date of Issue:	31 August 2012
Project No.:	PN0208-1-5-DM-001

DOCUMENT STATUS RECORD

Project Title:	**YOONGARILLUP DEPOSIT ASS SURVEY**
Project No.:	PN0208-1-5-DM-001
Client:	DORAL MINERAL SANDS LIMITED

Revision History					
Revision Code*	Date Revised	Revision Comments	Signatures		
			Originator	Reviewer	Approved
A	13/08/2012	Internal review of draft report	SC	ASP	SC
B	14/08/2012	Draft report issued for client review	SC		
C	31/08/2012	Final report issued to client	SC		

LIMITATIONS

The sole purpose of this report and the associated services performed by Soil Water Consultants (SWC) was to conduct an acid sulfate soils (ASS) survey for the Yoongarillup Deposit. This work was conducted in accordance with the Scope of Work presented to Doral Mineral Sands Limited ('the Client').

SWC performed the services in a manner consistent with the normal level of care and expertise exercised by members of the earth sciences profession. Subject to the Scope of Work, the ASS Survey was confined solely to the Yoongarillup Deposit. No extrapolation of the results and recommendations reported in this study should be made to areas external to this project area.

In preparing this study, SWC has relied on published soil reports from various soil researchers and information provided by the Client. All information is presumed accurate and SWC has not attempted to verify the accuracy or completeness of such information. While normal assessments of data reliability have been made, SWC assumes no responsibility or liability for errors in this information. All conclusions and recommendations are the professional opinions of SWC personnel.

SWC is not engaged in reporting for the purpose of advertising, sales, promoting or endorsement of any client interests. No warranties, expressed or implied, are made with respect to the data reported or to the findings, observations and conclusions expressed in this report. All data, findings, observations and conclusions are based solely upon site conditions at the time of the investigation and information provided by the Client.

This report has been prepared on behalf of and for the exclusive use of the Client, its representatives and advisors. SWC accepts no liability or responsibility for the use of this report by any third party

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1. INTRODUCTION

Soil Water Consultants (SWC) were commissioned by Doral Mineral Sands Limited (Doral) to undertake an Acid Sulfate Soil (ASS) Survey for the proposed Yoongarillup Deposit, which is located approximately 15 km south-east of Busselton, W.A. (Figure 1.1). Mining of the heavy mineral deposits at this site will involve the excavation, stockpiling and processing of a large volume of soil; creating several separate mine pit voids (Figure 1.2). With the increasing awareness of Acid Sulfate Soils (ASS) on the Swan Coastal Plain (SCP) (DEC, 2009; 2011), an ASS Survey for the proposed Yoongarillup Deposit was required to confirm the presence or absence of Actual Acid Sulfate Soils and Potential Acid Sulfate Soils (PASS) in this region.

The approach taken in this ASS Survey followed the assessment framework outlined in the revised guidelines for the Identification and Management of Acid Sulfate Soil Hazards for Mineral Sands Operations (DEC, *in prep.*). This assessment framework is shown in Figure 1.1. Whereas the existing ASS Identification and Investigation Guidelines for small urban development projects utilise a prescriptive, laboratory-based approach, the revised guidelines adopt a more iterative risk-based approach for assessing and managing ASS, with the onus on the mining companies to prove to the stakeholders that sufficient investigation has occurred to appropriately manage the risks associated with the disturbance of sulfidic sediments.

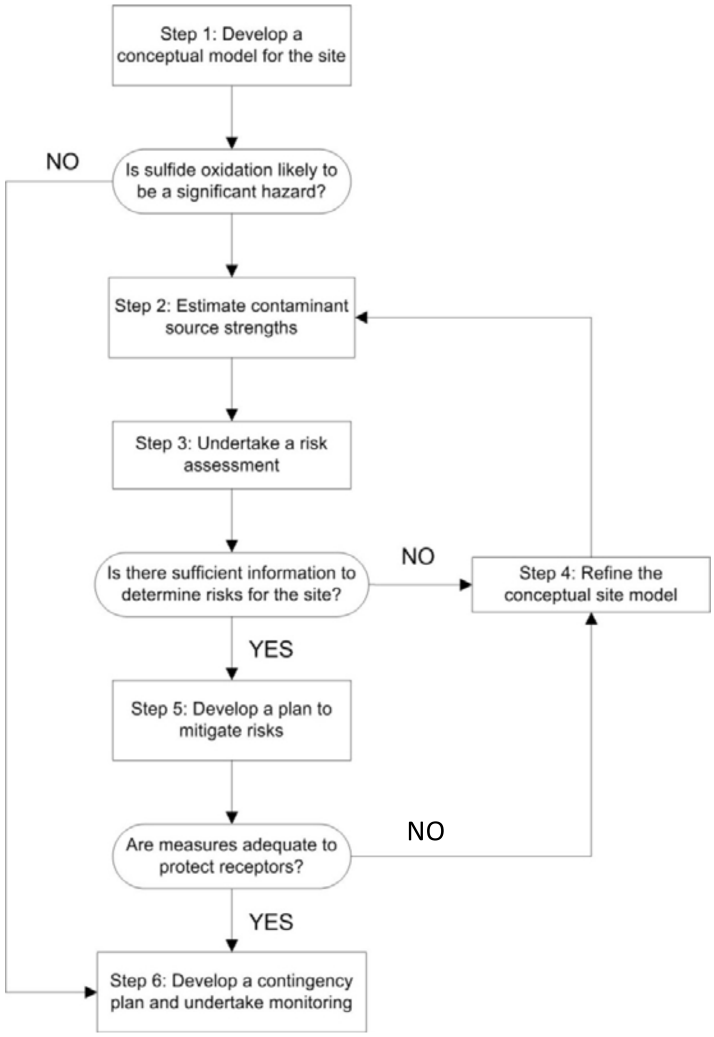


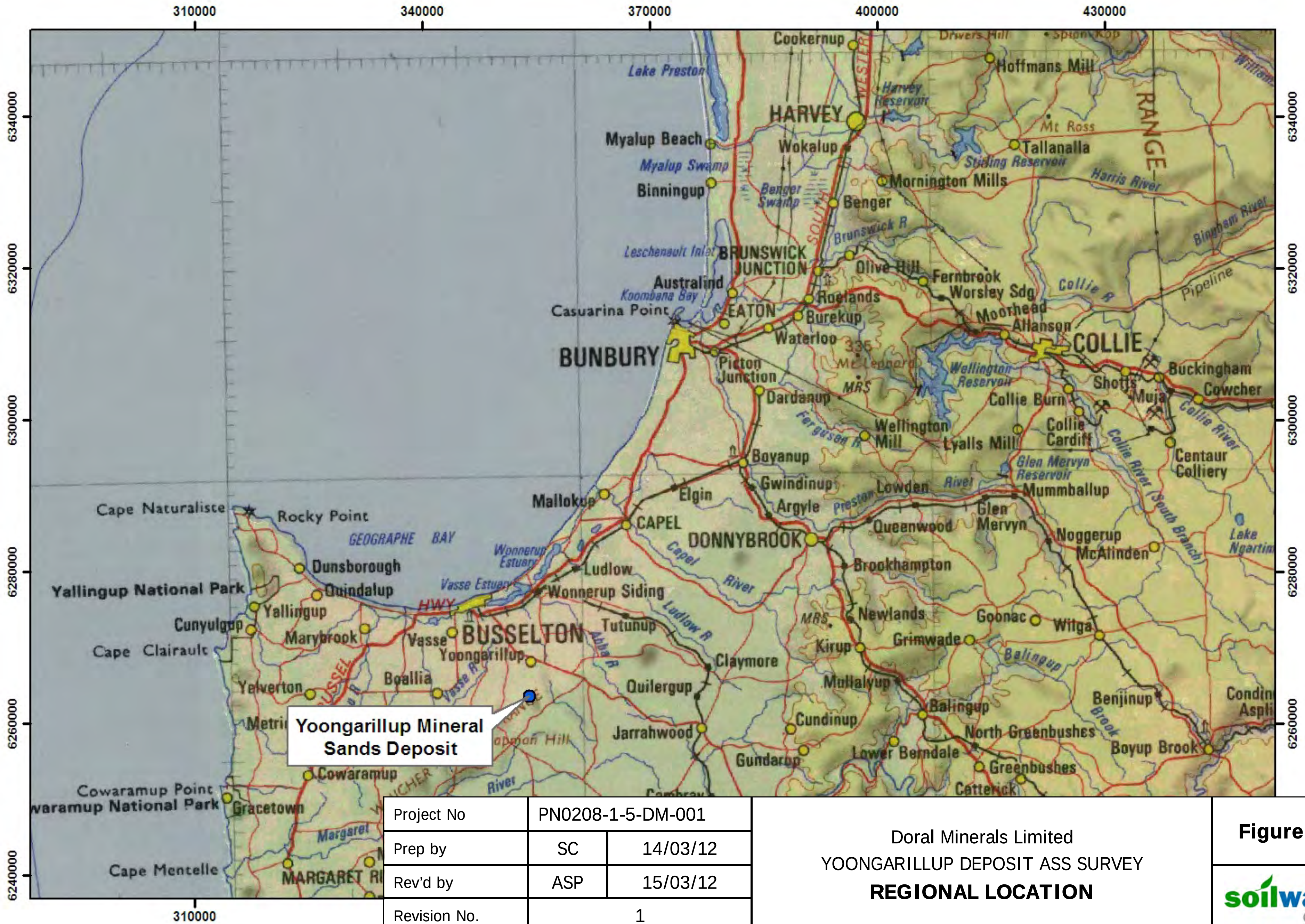
Figure 1.1: Assessment framework utilised in the revised ASS guidelines for mineral sands operations.

Other sources referred to in the preparation of this ASS Survey were:

- Treatment and Management of Disturbed Acid Sulfate Soils (DoE, 2004).
- Acid Sulfate Soils Manual (Stone *et al*., 1998).
- Analysis of Acid Sulfate Soils – Part 1: Dried sample – pre-treatment of samples (Standards Australia, 2006).
- Preparation of Acid Sulfate Soil Management Plan (ASSMP) (DoE, 2003).

The general objectives of this ASS Survey were to:

- Establish whether ASS are present or absent within the sediments to be disturbed by mining operations at the Yoongarillup Deposit.
- Quantify the pyritic content and spatial distribution of ASS at the site (i.e. determine the source strength).
- Assess the potential for both direct and indirect disturbance of ASS at this site.
- Assess the potential risk of metals release to the environment following sulfide disturbance.
- Propose strategies for the management of PASS at the proposed Yoongarillup Mine Site.



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Rev'd by	ASP	15/03/12
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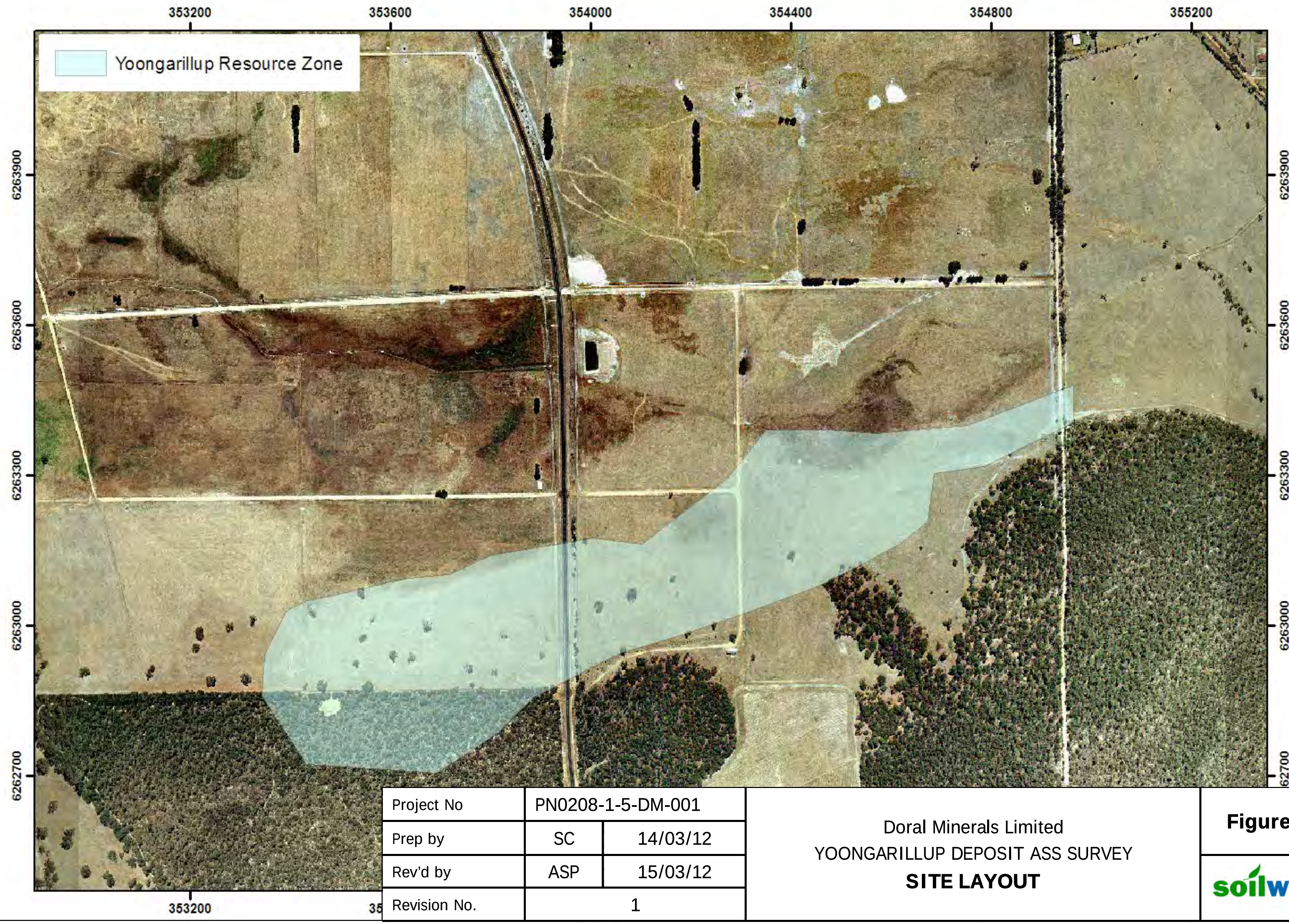
Doral Minerals Limited
YOONGARILLUP DEPOSIT ASS SURVEY
REGIONAL LOCATION

Figure 1.1

soilwater GROUP



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Doral Minerals Limited
YOONGARILLUP DEPOSIT ASS SURVEY
SITE LAYOUT

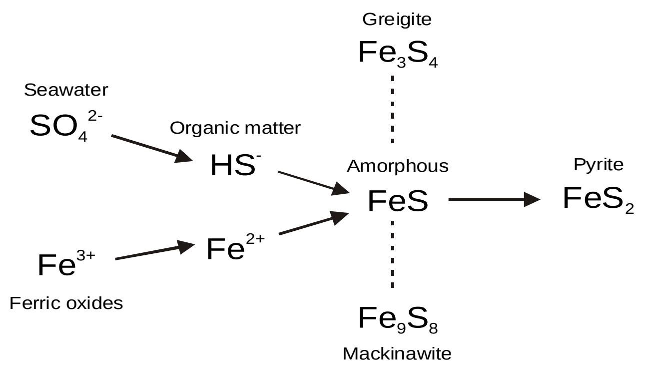
Figure 1.2

soilwater GROUP

2. ASS SOILS

2.1 FORMATION OF ASS SOILS

ASS are naturally occurring soils and sediments that contain iron sulfide minerals (predominately pyrite) (Stone *et al.*, 1998; DEC, 2009). Iron sulfide minerals form under reducing conditions (i.e. under a watertable), in the presence Fe^{3+}, SO_4^{2-} (commonly from seawater), organic matter and sulfur-reducing microorganisms (*Desulforibrio* spp.) (Shamshuddin *et al.*, 2004). Amorphous iron 'monosulfides' (FeS), which include greigite (Fe_3S_4) and mackinawite (Fe_9S_8), are typically the first iron sulfide precipitates to form and are characterised by a 'black ooze' (Bush and Sullivan, 1999). FeS is thermodynamically unstable and consequently it rapidly alters to the more stable pyrite (FeS_2) according to Equation 3.1.



Eqn. 2.1

Under reducing conditions pyrite is the most thermodynamically stable iron sulfide mineral, hence it is the most abundant iron sulfide mineral present in low-lying, estuarine environments (Berner, 1967; Bush and Sullivan, 1999). However, pyrite is metastable under oxidising conditions, and subsequently it partially alters to jarosite ($KFe_3(SO_4)_2(OH)_6$) or completely alters to iron hydroxide ($Fe(OH)_3$) and sulfuric acid (H_2SO_4), according to Equations 3.2 and 3.3. Using these equations, it can be determined that for every tonne of pyrite that oxidises, 1.6 tonnes of H_2SO_4 is produced and released into surrounding environment.

$$FeS_2 + 15/4O_2 + 5/2H_2O + 1/3K^+ \rightleftharpoons 1/3KFe_3(SO_4)_2(OH)_6 + 1/3SO_4^{2-} + 3H^+ \quad \text{Eqn. 2.2}$$

$$1/3KFe_3(SO_4)_2(OH)_6 + H_2O \rightleftharpoons Fe(OH)_3 + H^+ \ 1/3K^+ + 2/3SO_4^{2-}$$

Eqn. 2.3

Once the acid (H^+) is released into the environment (decreasing the soil and water pH) it has the potential to breakdown the structure of the soil matrix causing the release of aluminium, nutrients and heavy metals (particularly chromium and arsenic) into the soil solution, and ultimately into the groundwater.

2.2 REQUIREMENTS FOR AN ASS SURVEY

An ASS investigation is required if any of the following works are proposed (DEC, 2009):

- Soil or sediment disturbance > 100 m^3 in areas that have a high risk of ASS occurrence.
- Lowering of the watertable (either temporary or permanent) in areas shown in the ASS Risk Maps as 'high risk of actual acid sulfate soils (AASS) or potential acid sulfate soils (PASS) occurrence', or dewatering operations

in areas shown in the ASS Risk Maps as 'moderate to low risk of AASS or PASS occurrence' within 500 m from a high risk area.

- Where there is evidence of a significant risk of disturbing acid sulfate soils in areas shown in the ASS Risk Maps as 'moderate to low risk of AASS or PASS occurrence at > 3 m below natural surface'.
- Any dredging operations.
- Extractive industry works (i.e. mineral sands mining).
- Flood mitigation works including construction of levees and flood gates.
- Any works proposed in any of the areas listed in Section 3.3.

If the proposed disturbance satisfies any of the criteria listed above, then a detailed ASS Investigation, involving soil sampling and laboratory analysis of samples, will be required.

3. SCREENING LEVEL ASSESSMENT

3.1 METHODOLOGY

An ASS drilling and soil sampling program was developed to confirm the presence or absence of ASS in the proposed Disturbance Area. The DEC has established guidelines for determining the minimum number of boreholes to be drilled and the vertical sampling interval (Table 3.1). These guidelines were addressed when designing the drilling and soil sampling program.

Table 3.1: DEC sampling and analysis requirements for ASS investigations (DEC, 2009)

Extent of site project	Number of boreholes	Sampling intensity
1. Project Area		
< 1 ha	4	Every 0.25 m vertical interval
1 – 2 ha	6	Every 0.25 m vertical interval
2 – 3 ha	8	Every 0.25 m vertical interval
3 – 4 ha	10	Every 0.25 m vertical interval
> 4 ha	2 for every hectare	Every 0.25 m vertical interval
2. Volume of disturbance		
< 250 m^3	2	Every 0.25 m vertical interval
250 – 1000 m^3	3	Every 0.25 m vertical interval
> 1000 m^3	1 for every 500 m^3	Every 0.25 m vertical interval
3. Linear project		
Minor width and volume and low S (%)	@ 100 m intervals	Every 0.25 m vertical interval
Major width and volume	@ 50 m intervals	Every 0.25 m vertical interval

Drilling and soil sampling for ASS identification at the Yoongarillup Deposit occurred July of 2011. A total of 72 holes were sampled across the proposed Yoongarillup Deposit Disturbance Area during a resource infill drilling program conducted by Doral. The locations of the ASS drillholes sampled at the Yoongarillup site are shown in Figure 3.1. The spacing of the drillholes samples was such that both direct disturbance (i.e. within the proposed pit shell) and indirect disturbance (i.e. within the possible area of effect of groundwater drawdown) areas were samples sufficiently to allow an ASS risk analysis to be undertaken. To the south of the drilling area is a section of State Forest which was not drilled as the relevant environmental approvals were not in place at the time of drilling.

The depth of drilling varied from 9– 30 m (average hole depth 21 m), and all drillholes extended at least 2 m below the base of the proposed minepit. Given these depths and the nature of the sediments (i.e. heavy clay), drilling was conducted using a Reverse-circulation (RC) drill rig (Plate 3.1), which is the same as is used during mineral exploration drilling. This type of drill rig uses air to push the sample up the drill rod and out of the cyclone, with water commonly used to aid recovery of sample particularly in heavy, stiff clays. No oxidation of samples, in response to the use of air or water, has been observed to date during sample collection, even in highly reactive ASS samples (SWC, 2006). This drilling technique has been used for other ASS drilling programs on the swan coastal plain (i.e. SWC, 2007; 2008; 2009), and represents a compromise between the need to collect samples for ASS analysis and appropriateness and cost of other drilling techniques. Previous ASS sampling undertaken in the same fashion at Iluka mine sites has been accepted by the DEC, with no expressed concerns regarding the suitability of this sampling method. It is therefore considered that this drilling technique was suitable for ASS identification at the Yoongarillup site.

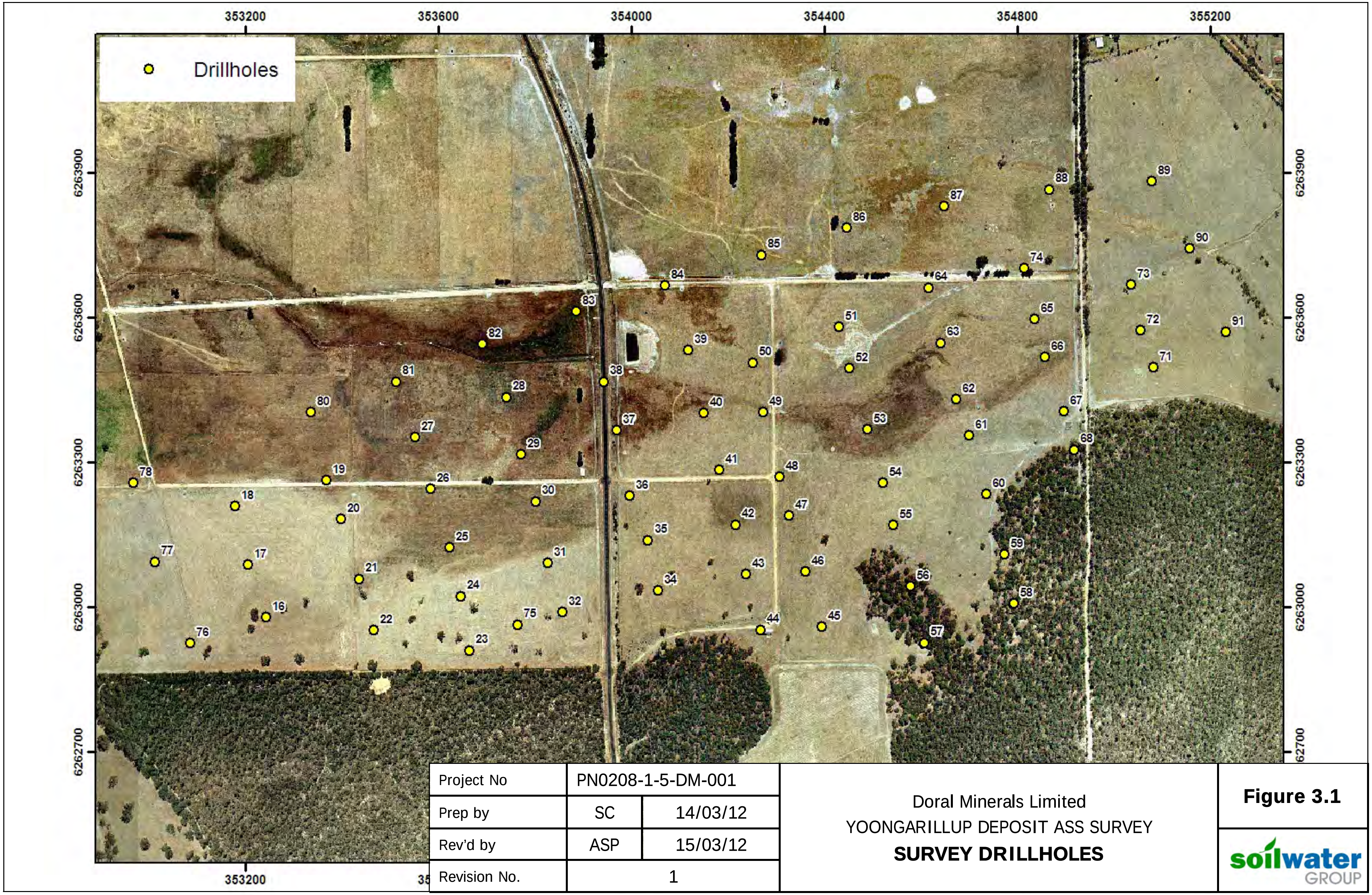
Soil samples were collected at 1 m vertical intervals over the entire drillhole length. In areas where black soils were encountered the sampling frequency was doubled (i.e. 2 per metre). This procedure was put in place as it was expected from previous studies conducted in soils of the Swan Coastal Plain (SWC, 2007; SWC, 2008) that the majority of PASS would be present in specific morphological soil types (i.e. black soils). Although this differs from the 0.25 m vertical intervals specified by the DEC (Table 3.1), it was identified as an appropriate sampling interval to accurately identify and delineate any ASS present in this area given the depths to which sampling occurred (i.e. 30 m) and the geological and soil distribution in the Disturbance Area. Based on this sampling interval and the depths drilled, a total of 1,445 samples were collected across the Disturbance Area. Samples were collected at the cyclone outlet in sealable plastic containers. To minimise potential oxidation of samples during storage air was excluded from the plastic containers where possible before sealing.

If water was used during sample recovery, then this was retained with the sample. Collection of this water was required to ensure that there is no loss of soluble acidity if AASS were present. In AASS there is a risk that any water used in the drilling process may remove the soluble acidity that is present in such soils, and if this water is lost during sample collection then an underestimation of the actual acidity may result. Research has been conducted to examine if there is significant removal of soluble acidity into the water fraction during sample collection and storage (SWC, 2005). To date, negligible transfer of soluble acidity into the water fraction has been observed, however it is still recommended that all water used during sample collection is retained with the sample and routine checks made to examine the pH and electrical conductivity (EC) of the water fraction in addition to the soil. At each sampling interval, the drill rod and cyclone was flushed clean with water to ensure no contamination of the soils between consecutive samples. This is required as trace amounts of sulfidic material remaining in the drilling equipment from previous sampling may contaminate a sample that has no sulfides present, resulting in a false positive test.

The amount of sample collected at each sampling interval varied from 0.5 to 1 kg. Collection of this amount ensured that sufficient sample was obtained for detailed chemical and physical analysis in the laboratory. Collected soil samples for each drillhole were placed into well-labelled nylon bags and placed immediately into a generator-powered field freezer located on the back of the sample vehicle (Plate 3.2). At the end of each day of drilling, the samples were transferred from the field freezer to a mobile cool room, set at –1°C for short-term storage. Stored samples were transported back to the laboratory within 24 – 48 hours of collection for field pH testing (Section 3.2).

Plate: 3.1: Collection of ASS samples using a Reverse Circulation (RC) drill rig.

Plate: 3.2: Storage of samples in field freezer.



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Doral Minerals Limited
YOONGARILLUP DEPOSIT ASS SURVEY
SURVEY DRILLHOLES

Figure 3.1

soilwater GROUP

3.2 Screen Results

pH_F & pH_{FOX} Results

A total of 1,445 samples from 72 drillholes were analysed for pH_F and pH_{FOX}. The down drillhole profiles are shown in Appendix A whilst the distribution of pH_F and pH_{FOX} for all samples is shown in Figure 3.2.

The pH_F results for all samples tested varied from 8.20 (slightly alkaline) to 4.29 (moderately acidic) with an average of 5.62. The large majority of samples tested (85%) had pH values between 5 and 7 which is typical of surficial soils on the Swan Coastal Plain (McArthur, 1991), and reflects their poor buffering capacity and the natural equilibrium which exists between the soil particle surface and the surrounding soil solution (i.e. adsorption/desorption ratios and surface hydrolysis reactions; Hsu, 1989). Approximately 5% of samples had a pH value between 4 and 5 which indicates that previous oxidation has possibly occurred within these soils (DEC, 2009). No samples tested had a $pH_F < 4$, indicating that AASS (i.e. previously oxidised soils with high actual acidity *in situ*) are unlikely to occur within the Yoongarillup deposit.

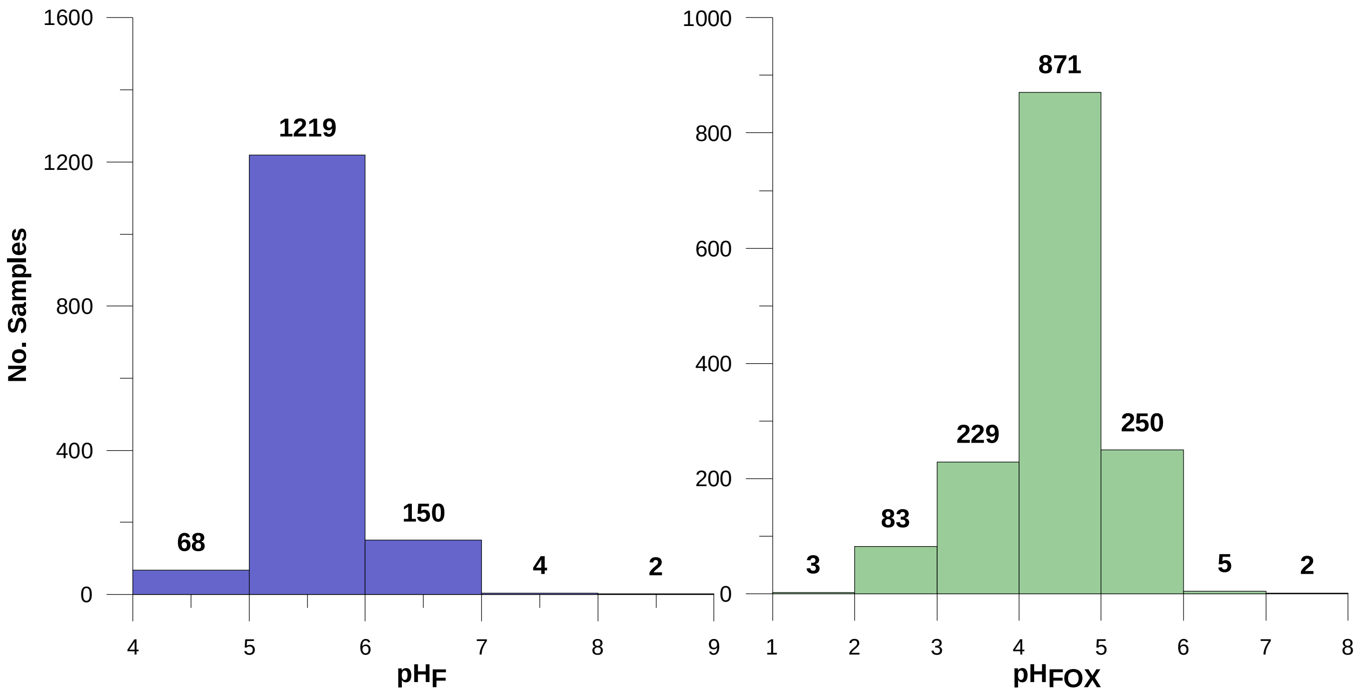
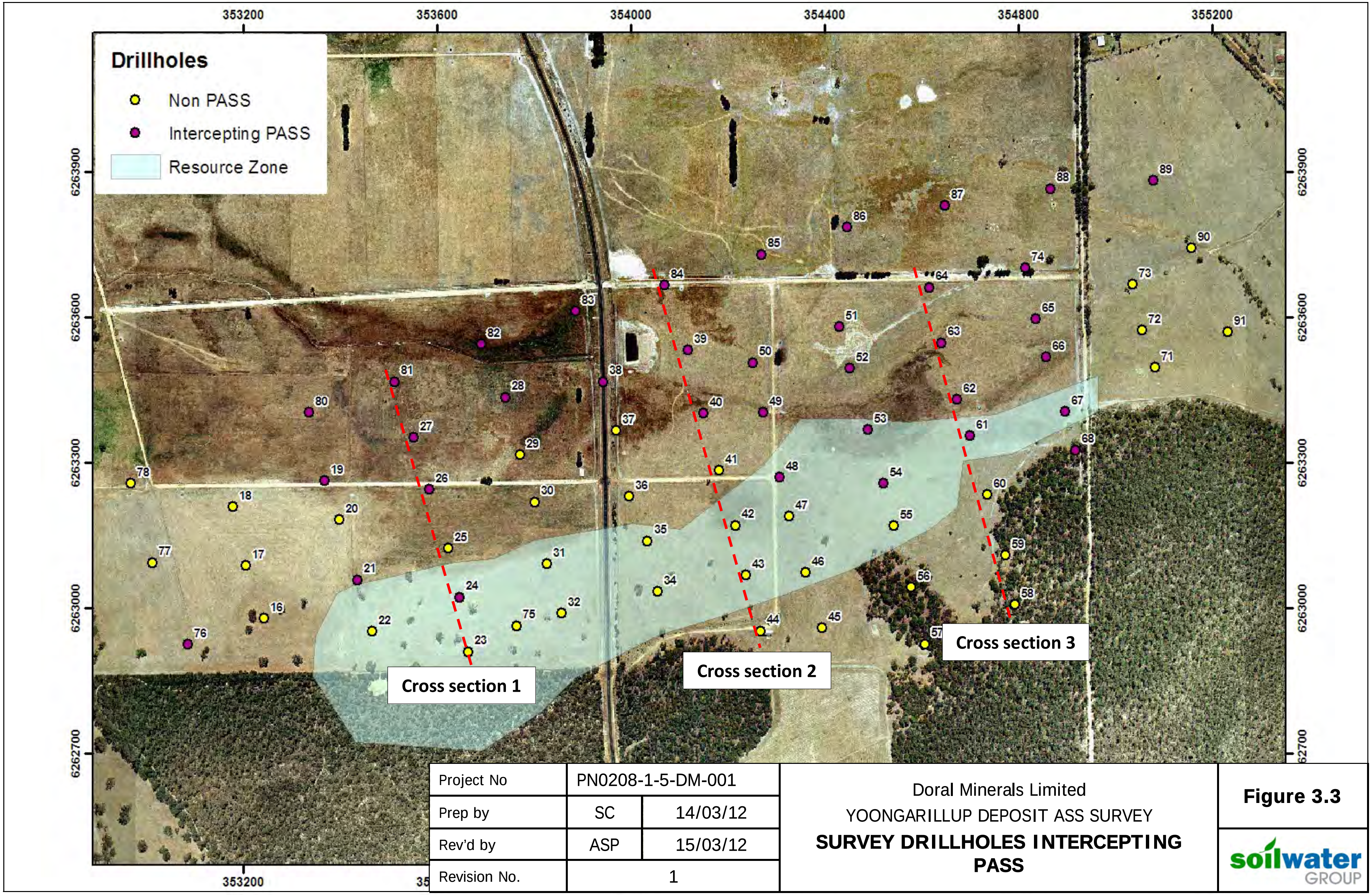


Figure 3.2: Distribution of pH_F and pH_{FOX} results.

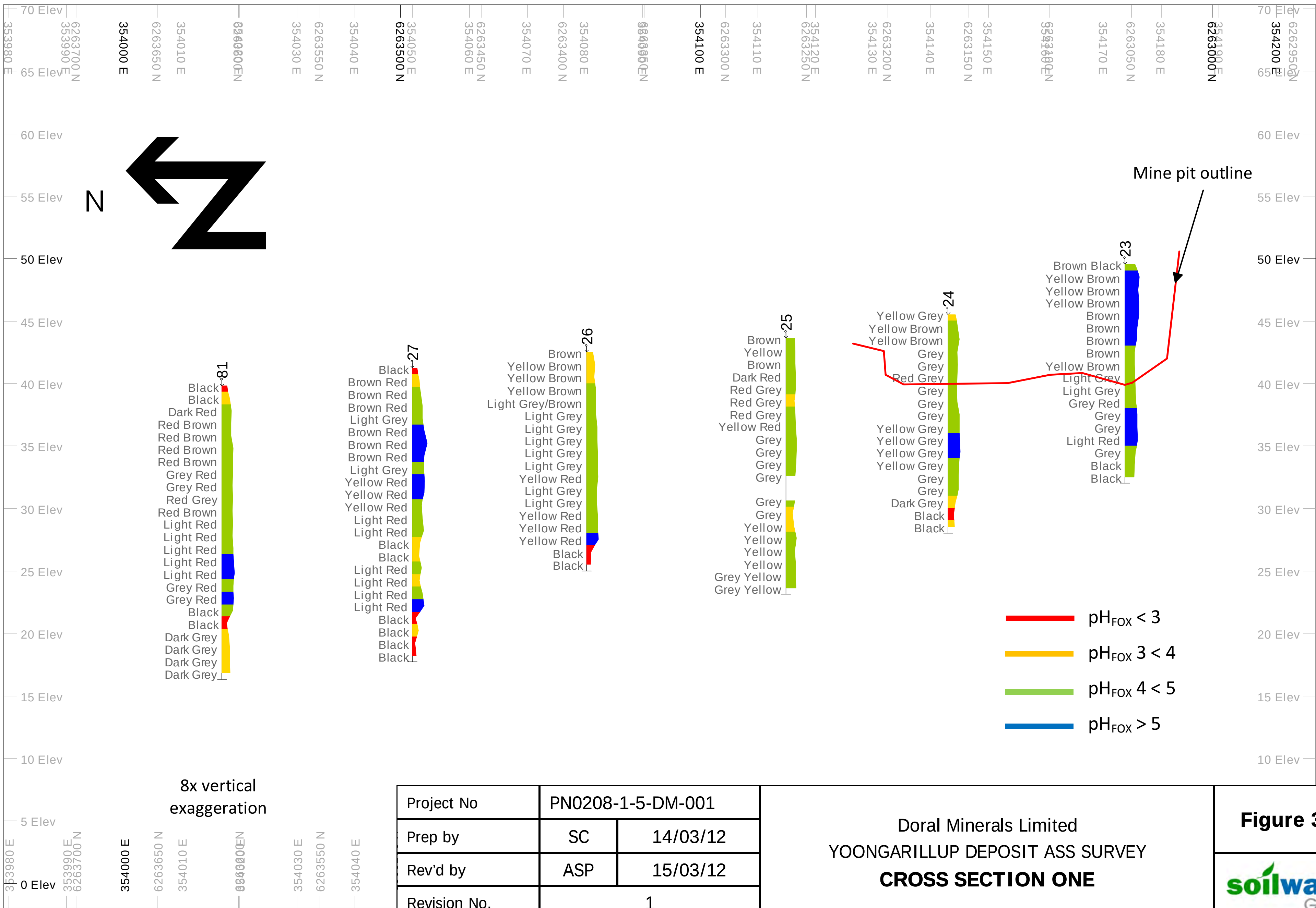
The pH_{FOX} values for all soils analysed varied from 7.79 to 1.99. Approximately 20% of the soils tested had pH_{FOX} values less than 4, indicating that potentially acid sulfate soils (PASS) are likely to be present. Of these low pH_{FOX} samples, 27% (or 6% of total samples tested) had pH_{FOX} values < 3, indicating that a portion of the soils are likely to contain significant PASS.

A review of the drillhole profiles (Appendix A) shows that the majority of these low pH_{FOX} values occur within a defined zone within the soil profile rather than being spread evenly throughout the deposit. Figure 3.3 shows an overview of the drilling program conducted, with drillholes intercepting PASS materials ($pH_{FOX} < 4$) highlighted purple. It can be seen that the PASS material encountered is concentrated in the northern drillholes surveyed. Cross sections of the drilling data were created using Downhole Explorer and these are presented in Figure 3.4. To illustrate the relationship between the sampled materials and the observed low pH_{FOX} values, the drillhole trace shows the logged colour of the material whilst the line graph shows the pH_{FOX} values recorded for each sample taken. The cross sections show that those areas which experience significant drops in pH upon oxidation (i.e. where the pH_{FOX} drops below 4, orange and 3 red) is uniformly concentrated within the dark coloured (grey to black) sandy clay materials encountered below the well sorted sand layer containing the majority of the heavy mineral concentrations (i.e. the ore). The outline of the proposed pit shell, shown in red, can be seen to be well above those areas where dark grey to black clay are deposited and which experienced the significant pH drops upon oxidation. Some areas at the top of the drillhole traces also experience pH drops, however these can be attributed to organic material present in the top portion of the soil profile and not inorganic sulfide.

The cross sections also show that these black clays are encountered predominately on the northern side of the surveyed area at the termination of the drillholes whilst matching up with the low pH_{FOX} values obtained from the laboratory screen testing. It is therefore considered that the potential for acid generation within the proposed Yoongarillup deposit will likely be confined to these soil materials (i.e. dark grey to black clays) which are encountered below the defined ore zone. As part of the ongoing ASS investigation the distribution of these greyish - black clay materials should be carefully defined and their spatial variability delineated as a precursor to establishing a management plan.



Project No	PN0208-1-5-DM-001		Doral Minerals Limited YOONGARILLUP DEPOSIT ASS SURVEY **SURVEY DRILLHOLES INTERCEPTING PASS**	**Figure 3.3**
Prep by	SC	14/03/12		soilwater GROUP
Rev'd by	ASP	15/03/12		
Revision No.	1			

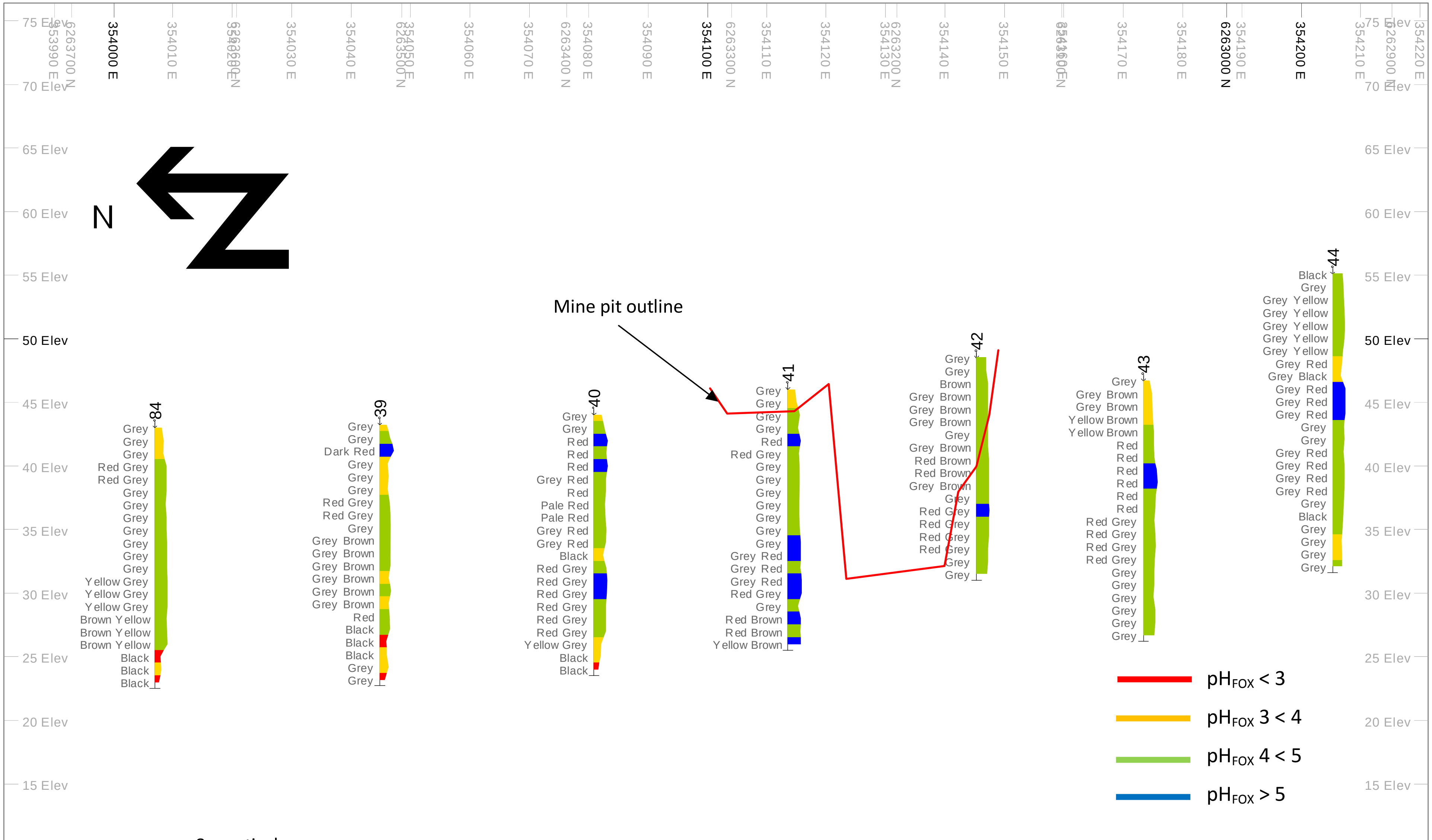


Project No	PN0208-1-5-DM-001	
Prep by	SC	14/03/12
Rev'd by	ASP	15/03/12
Revision No.	1	

Doral Minerals Limited
YOONGARILLUP DEPOSIT ASS SURVEY
CROSS SECTION ONE

Figure 3.4

soilwater GROUP



8x vertical exaggeration

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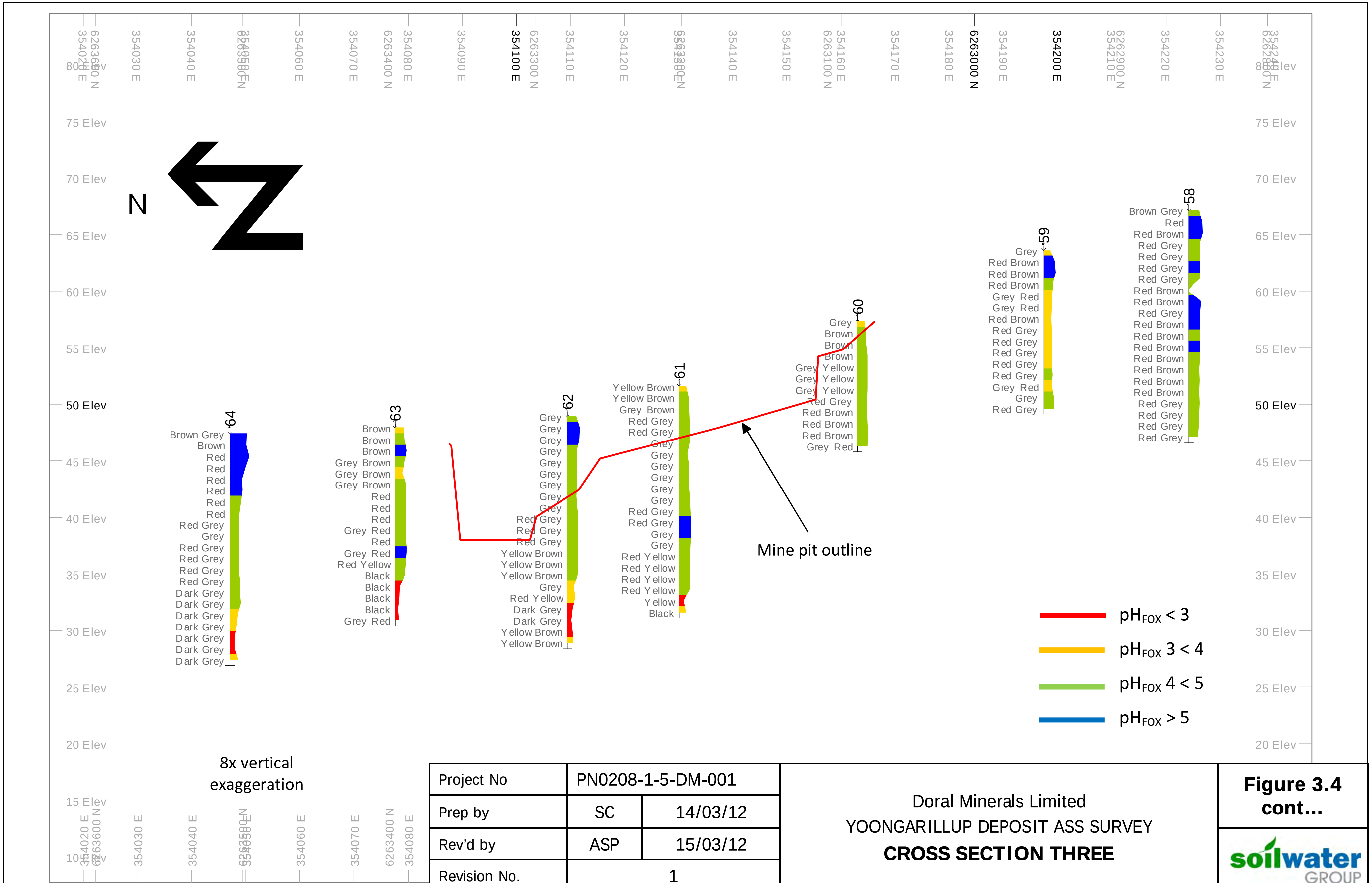
Doral Minerals Limited
YOONGARILLUP DEPOSIT ASS SURVEY
CROSS SECTION TWO

Figure 3.4 cont...

soilwater GROUP



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Doral Minerals Limited

YOONGARILLUP DEPOSIT ASS SURVEY

CROSS SECTION THREE

Figure 3.4 cont...

soilwater GROUP

4. DETAILED TESTWORK ASSESSMENT

The next step in the ASS investigation involves estimating source strengths of potential contaminants. In order to do this a range of samples from different material types were selected for detailed laboratory testing, to both confirm the results from the screen level assessment, and provide accurate estimates of source strength for potential contamination should oxidation and subsequent acid generation occur.

This further investigation included determining the acidity already present with the sediments, determining the pyritic sulfur content within the sediments through chromium reducible sulfur (S_{CR}) testing, and testing sediments to determine the potential for hydrolysis and metals release if acid generation occurs.

Laboratory analysis of selected soil samples included:

- Total Actual Acidity (TAA) on selected samples including any samples with a $pH_F < 4.0$
- Chromium Reducible Sulfur (S_{CR}) analysis on selected samples
- Leaching of non-pyritic soils (S_{CR} < 0.03 %) and pyritic (S_{CR} > 0.03 %) to determine potential hydrolysis and metals release characteristics of selected samples

In this investigation S_{CR} analysis was conducted on selected samples to quantify the amount of potential acidity present (i.e. PASS). The decision to use S_{CR} analysis is based upon the recommendation from the DEC (DEC, 2009). At the time of the field studies and laboratory analysis the DEC considered that S_{CR} analysis provided a better measure of potential acidity (i.e. from iron sulphide sources), than the Suspension Peroxide Oxidation Combined Acidity and Sulfate (SPOCAS) technique, which relies on hydrogen peroxide (H_2O_2) to oxidise all acidity sources. This technique is strongly influenced by non-pyritic sources of acidity (i.e. due to the hydrolysis of Fe and Al oxides and hydroxides) and organic matter; hence it overestimates the amount and distribution of pyrite (Sullivan *et al.*, 1999).

Samples were selected by soil colour, texture and depth within the soil profile which, along with an analysis of the screen pH and pH_{FOX} test results, enable representative sampling of the major soil types, stratigraphic layers and screen level acid – base characteristics within the project area (Table 4.1).

4.1 TAA Analysis Results

In order to quantify the amount of actual acidity present, a selection of samples (12) were tested for total actual acidity (TAA). All samples tested had a pH_F value < 6 in order to gain an understanding of the existing acidity within samples that may have had sulfide material previously oxidise. The TAA (and corresponding pH_{KCL}[1]) data for these samples is provided in Table 4.1. Existing acidity in acid sulfate soils includes 'actual' acidity (TAA) and 'retained' acidity (i.e. acidity stored in largely insoluble iron and aluminium sulfate minerals). However, as none of the samples tested returned pH_{KCL} values < 4.5, the 'retained' acidity determination was not needed. The DEC have established that the critical acidity content of a soil (either existing and/or potential), for defining an ASS, is 18 mol H^+/tonne (Table 4.2) with those samples exceeding this criteria highlighted in bold (Table 4.1). Using the derived

[1] Note pH_{KCL} is determined during TAA analysis. If the pH_{KCL} of a sample is > 6.5 then it is considered that the soil has no actual or existing acidity and no TAA analysis is required, conversely if the sample has pH_{KCL} < 6.5 it is considered to have no acid neutralising capacity (ANC; Ahern *et al.*, 2004).

equation for pH_{KCL} (Figure 4.1) and the DEC critical acidity value (18 mol H^+/tonne), the corresponding pH_{KCL} value can be determined that defines an AASS, which is given in this case as a pH_{KCL} value of 4.7.

Table 4.1: TAA and associated pH_{KCL} results.

Drillhole ID	Depth (m)	Soil colour	Soil texture	pH_{KCL}	TAA mole H^+/tonne
18	3.5	Yellow Grey	Sandy loam	5.8	4
72	5.5	Grey	Sandy clay	4.9	11
26	8.5	Light Grey	Sandy clay	4.9	10
91	9.5	Grey	Clay	4.8	14
82	10.5	Red Brown	Sandy clay	5.1	6
65	15.5	Black	Clay	5.4	8
39	16.5	Black	Sandy clay	5	12
24	17.5	Black	Sandy clay	4.9	16
68	17.5	Grey Brown	Sandy clay	5.1	10
86	**19.5**	**Black**	**Clay**	**4.5**	**50**
82	19.5	Dark Grey	Sandy clay	5.3	5
27	**20.5**	**Black**	**Clay**	**4.8**	**22**

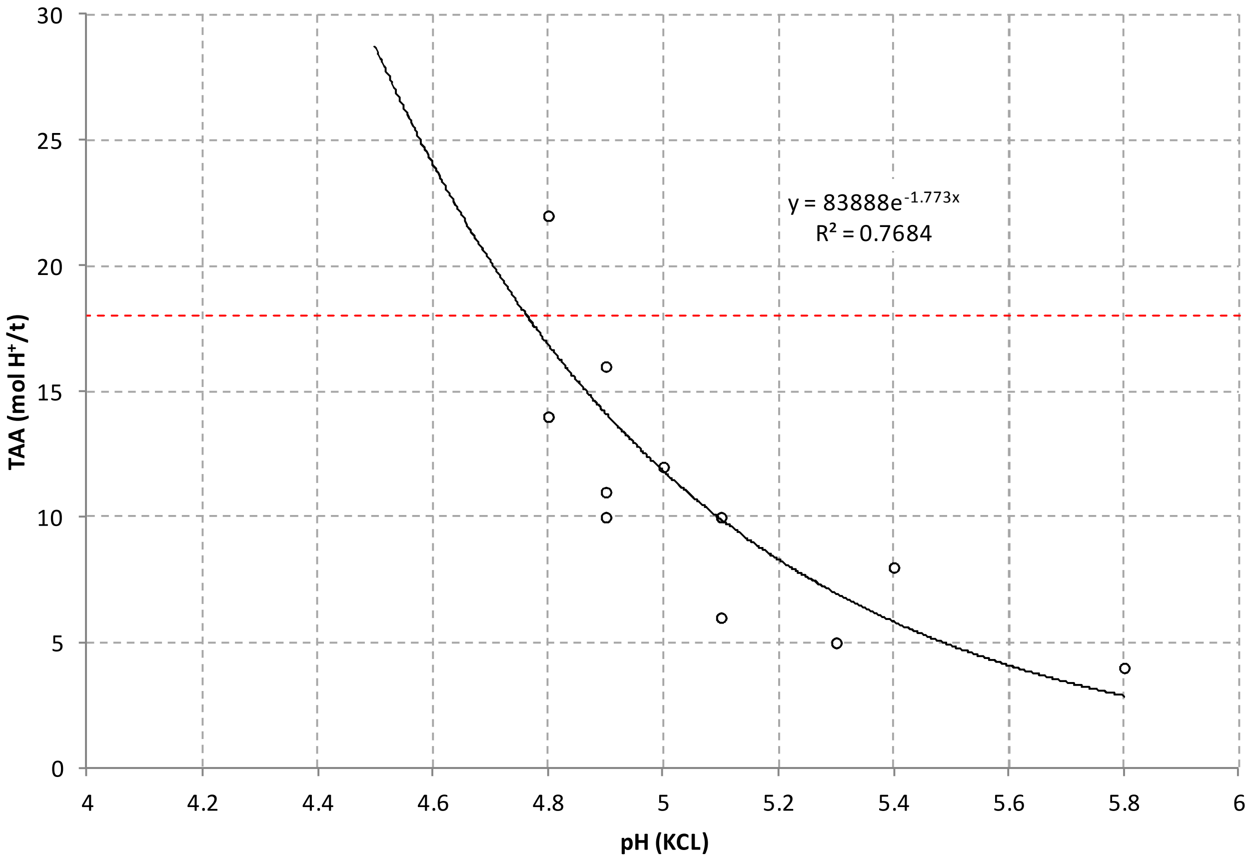

Figure 4.1: Relationship between pH_{KCL} and TAA for samples tested.

There is a pH shift of approximately +0.2 pH units with the addition of KCl solution, and thus a pH_F value of 4.9 is likely to represent 18 mol H^+/t. Although a portion of the total samples tested had TAA values exceeding the DEC action criteria of 18 mol H^+/t, it is not expected that they represent AASS, and instead reflects their inherent acidity

It is considered that this soil pH value (pH 4.9) is too high for defining AASS. The majority of soils on the SCP, with the exception of current coastal dunes, have soil pH values between 5 – 7 (McArthur, 1991). Most of the lateritic soils on the Darling and Whicher Scarp have natural soil pH values between 5 – 6, which reflects their old age, dominance of kaolinite clay fraction (i.e. low buffering capacity), and abundance of Fe and Al oxyhydroxides (McArthur and Bettenay, 1974). In addition, most topsoils and subsoils have pH values between 4.5 and 5 due to fertiliser usage, and not previous oxidation of PASS.

A more realistic soil pH for identification of AASS would be 4 for a more definitive assessment of the presence and distribution of AASS (a pH_F value of < 4 is used as part of the field assessment for AASS, Section 2).

Table 4.2: Action criteria for the identification of ASS (DEC, 2009)

Soil Material		Action criteria < 1000 tonnes ASS disturbed		Action criteria > 1000 tonnes ASS disturbed	
Soil Texture	Approx. clay content (%)	S_{CR} (%S)	TAA (mol H+/tonne)	S_{CR} (%S)	TAA (mol H+/tonne)
Coarse texture (Sands to loamy sands)	< 5	0.03	18	0.03	18
Medium texture (Sandy loams to light clays)	5 – 40	0.06	36	0.03	18
Fine texture (Medium to heavy clays and silty clays)	> 40	0.1	62	0.03	18

4.2 CHROMIUM REDUCIBLE SULFUR (S_{CR} %) CONTENT

The S_{CR} content was determined for 12 samples collected in the field. This analysis was undertaken to quantify the actual amount of pyrite (or PASS) present in the soils and to develop a relationship if possible between inorganic sulfides (S_{CR}) and lithology type (i.e. colour and texture). The total S_{CR} results from this investigation are provided in Table 4.3.

Table 4.3: Chromium reducible sulfur results for samples tested.

Drillhole ID	Depth (m)	Soil colour	Soil texture	S_{CR} (%)	Potential sulfidic acidity (mole H^+/tonne)
18	3.5	Yellow Grey	Sandy loam	<0.01	<6
72	5.5	Grey	Sandy clay	<0.01	<6
26	8.5	Light Grey	Sandy clay	<0.01	<6
91	9.5	Grey	Clay	<0.01	<6
82	10.5	Red Brown	Sandy clay	<0.01	<6
65	15.5	Black	Clay	0.01	6
39	16.5	Black	Sandy clay	<0.01	<6
24	**17.5**	**Black**	**Sandy clay**	**0.04**	**25**
68	17.5	Grey Brown	Sandy clay	<0.01	<6

Drillhole ID	Depth (m)	Soil colour	Soil texture	S_{CR} (%)	Potential sulfidic acidity (mole H^+/tonne)
86	**19.5**	**Black**	**Clay**	**0.04**	**25**
82	19.5	Dark Grey	Sandy clay	0.02	12
27	20.5	Black	Clay	<0.01	<6

The S_{CR} results varied from below detection limit (BDL, < 0.01 %) to 0.04 %, with two samples tested being above the 0.03 % cut-off specified by the DEC as an action criteria (DEC, 2009; Table 4.2). Both of the samples which exceeded the 0.03 % cut-off where characterised as black coloured clay and sandy clay materials which were obtained from below the ore layer within the deposit (i.e. below pit boundaries). These results further confirm the initial screen assessment, indicating that the presence of appreciable levels of sulfides (i.e. S_{CR} > 0.03 %) is likely to be confined to the black clay – sandy clay materials which underlie the well sorted sand zone which contains the concentrated mineral sands ore.

The net acidity of a sample is calculated through the application of Equation 4.1.

$$Net\ Acidity = Potential\ Sulfidic\ Acidity + Existing\ Acidity - Acid\ Neutralising\ Capacity \quad \text{Eqn. 4.1}$$

As the pH_{KCL} of each sample tested was < 6.5, the samples tested must be assumed to have an effective acid neutralising capacity (ANC) of zero. Although measurement of the ANC on materials with a pH_{KCL} < 6.5 can sometimes give a substantial result, these acid neutralising components are not reactive/available enough to keep pace with acid generation from sulfide oxidation. The results from this calculation are shown in Table 4.4.

Table 4.4: Net acidity of the samples tested.

Drillhole ID	Depth (m)	Soil colour	Soil texture	Net Acidity mole H^+/tonne*
18	3.5	Yellow Grey	Sandy loam	<10
72	5.5	Grey	Sandy clay	<21
26	8.5	Light Grey	Sandy clay	<16
91	9.5	Grey	Clay	<20
82	10.5	Red Brown	Sandy clay	<12
65	15.5	Black	Clay	14
39	16.5	Black	Sandy clay	<18
24	17.5	Black	Sandy clay	31
68	17.5	Grey Brown	Sandy clay	<16
86	19.5	Black	Clay	75
82	19.5	Dark Grey	Sandy clay	17
27	20.5	Black	Clay	<28

*Note this is a worst case scenario, assuming 2 moles of H^+ for each mole sulfide mineral (i.e. H_2SO_4) whereas several minerals only involve the evolution of 1.5 moles per mole such as jarosite.

4.3 MULTI-ELEMENT COMPOSITION

Element enrichment was determined using the Geochemical Abundance Index (GAI), through Equation 4.2:

$$GAI = \log_2\left(\frac{C}{1.5 * ACA}\right), \qquad \text{Eqn. 4.2}$$

with *C*= element content in sample (mg/kg) and *ACA*= average crustal abundance (Bowen, 1979). A GAI of 0 indicates that the content of the element is less than, or similar to, the average crustal abundance, a GAI of 3 corresponds to a 12-fold enrichment above the average crustal abundance, and a GAI of 6 indicates a 96-fold or greater enrichment above average crustal abundances. In general, a GAI >3 indicates significant enrichment. Elemental compositions were compared against the Department of Environment and Conservation (DEC) Ecological Investigation Levels (EIL; DEC, 2010) to identify metals and metalloids that may, if present, pose a risk to the surrounding environment or to environmental values as a result of non-acid metaliferous drainage. The EIL used by the DEC are based primarily on the Environmental Investigation Levels listed in the Australian and New Zealand Guidelines for the Assessment and Management of Contaminated Sites (ANZECC/NHMRC, 1992). They represent only screening levels, in which to provide a first-pass or a Tier 1 level of assessment for a site. It is important to note that these levels do not specifically apply to mineralised zones whereby elevated metal and metalloid contents often exceed the EIL criteria in a natural functioning ecosystem. Site specific information should therefore be used in conjunction with the EIL to assess the appropriateness of these criteria values. Therefore the values of the EIL are compared to the ACA values to provide a context within which to interpret them.

The multi-element composition of the selected materials tested in this investigation is provided in Table 4.5, whilst their corresponding enrichment, compared to average global crustal abundances, is provided in Table 4.6. Values which exceed the corresponding EIL (Table 4.5) or are above a GAI of 3 (Table 4.6) are shown in bold. The results show that only one sample (from drillhole 86 at a depth of 19.5 m) returned a level of vanadium which exceeds the Department of Environment and Conservation (DEC) Ecological Investigation Level (DEC, 2010). When this elevated level of vanadium is compared against the average crustal abundance (160 mg/kg), this sample is not considered geochemically enriched with respect to background levels, returning a GAI of 0 (i.e. less than, or similar to, average crustal abundance; Table 4.5).

The results of the GAI calculation show that elevated element contents occur in only one sample. The elevated content is of mercury which occurs in the sample taken from drillhole 82 (at a depth of 10.5 m), with significant enrichment (i.e. GAI 4) recorded. However, when compared to the associated EIL, which for mercury is 1 mg/kg it can be seen that the level does not exceed this, and indeed is significantly lower than this (< one third) for all other samples tested.

Table 4.5: Multi-element composition for samples tested.

Element	LOR (mg/kg)	EIL (mg/kg)	86	82	24	39	68	26	82	72	27	65	91	18
Ag	*0.05*	-	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	0.05
Al	*10*	-	24500	4830	10000	5390	6300	7130	4820	12900	4230	6590	15600	27300
As	*0.2*	20	1.6	1.7	1	8.5	1.4	2.8	12	<0.2	1.3	0.8	0.3	1.1
B	*5*	-	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5
Ba	*0.1*	300	110	34	89	12	21	43	16	3.4	190	11	15	7.9
Cd	*0.05*	3	0.08	0.23	0.08	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Co	*0.1*	50	20	13	10	2.9	5	5.2	7.1	7	43	4.5	1.9	9.4
Cr	*0.05*	400	88	14	23	26	16	7.4	36	21	23	19	23	48
Cu	*0.1*	100	38	8.6	12	5	7.8	5.6	1.2	1.1	28	9.5	0.8	<0.1
Fe	*5*	-	40000	13000	35000	15000	21000	6600	19000	2400	21000	72000	2200	32000
Hg	*0.02*	1	0.04	0.27	0.06	0.05	0.05	0.22	1	0.15	0.03	0.06	<0.02	0.12
Mn	*0.2*	500	120	14	28	12	11	2.6	1.9	2.4	27	18	6	6
Mo	*0.5*	40	0.5	0.7	0.6	3.1	0.6	<0.5	3.9	<0.5	0.9	0.7	<0.5	1

Ni	*1*	60	30	14	10	1	1	<1	<1	3	53	1	3	7
Pb	*0.5*	600	19	10	8.2	12	15	7.6	5.8	5.9	12	16	16	14
Sb	*0.05*	-	<0.05	<0.05	<0.05	0.32	<0.05	<0.05	0.08	<0.05	<0.05	<0.05	<0.05	<0.05
Se	*0.05*	-	0.29	0.28	0.14	0.25	0.16	0.06	0.32	<0.05	0.17	0.13	<0.05	0.15
Sn	*0.5*	50	1.1	<0.5	1.1	<0.5	0.8	<0.5	<0.5	<0.5	0.7	<0.5	<0.5	<0.5
Sr	*0.2*	-	20	4.9	8.7	3.2	4.8	9.4	5.2	1.7	6.2	2.2	8	3.8
Th	*0.05*	-	23	8.7	19	11	16	7.1	5.4	11	17	15	16	17
U	*0.01*	-	1.1	1.3	1.2	2.3	1.2	1.9	2.3	0.33	1.6	1.3	0.43	1.8
V	*0.2*	50	**170**	26	40	36	30	15	36	6.2	37	34	44	50
Zn	*5*	200	76	6.9	51	4.3	8.1	1.4	2.5	1.2	5.8	22	1.9	1.1

Table 4.6: Global abundance index for multi-element content.

Element	ACA (mg/kg)	86	82	24	39	68	26	82	72	27	65	91	18
Ag	*0.07*	0	0	0	0	0	0	0	0	0	0	0	0
Al	*8.2 %*	0	0	0	0	0	0	0	0	0	0	0	0

As	*1.5*	0	0	0	2	0	0	2	0	0	0	0	0
B	*10*	0	0	0	0	0	0	0	0	0	0	0	0
Ba	*500*	0	0	0	0	0	0	0	0	0	0	0	0
Cd	*0.11*	0	0	0	0	0	0	0	0	0	0	0	0
Co	*20*	0	0	0	0	0	0	0	0	1	0	0	0
Cr	*100*	0	0	0	0	0	0	0	0	0	0	0	0
Cu	*50*	0	0	0	0	0	0	0	0	0	0	0	0
Fe	*4.1 %*	0	0	0	0	0	0	0	0	0	0	0	0
Hg	*0.05*	0	2	0	0	0	2	**4**	1	0	0	0	1
Mn	*950*	0	0	0	0	0	0	0	0	0	0	0	0
Mo	*1.5*	0	0	0	0	0	0	1	0	0	0	0	0
Ni	*80*	0	0	0	0	0	0	0	0	0	0	0	0
Pb	*14*	0	0	0	0	0	0	0	0	0	0	0	0
Sb	*0.2*	0	0	0	0	0	0	0	0	0	0	0	0
Se	*0.05*	2	2	1	2	1	0	2	0	1	1	0	1
Sn	*2.2*	0	0	0	0	0	0	0	0	0	0	0	0

Sr	*370*	0	0	0	0	0	0	0	0	0	0	0	0
Th	*12*	0	0	0	0	0	0	0	0	0	0	0	0
U	*2.4*	0	0	0	0	0	0	0	0	0	0	0	0
V	*160*	0	0	0	0	0	0	0	0	0	0	0	0
Zn	*75*	0	0	0	0	0	0	0	0	0	0	0	0

4.4 METAL BIOAVAILABILITY

Metal bioavailability was carried out on four of the samples which underwent multi-element composition testing to investigate to what extent metals were available to leaching in solution. The Australian Standard Leaching Procedure (ASLP) was used, with the results of the ASLP presented in Table 4.7.

Table 4.7: Bioavailability of metals under neutral leachate conditions.

Drillhole ID	27		65		91		18	
Element	Solid phase (mg/kg)	% leached	Solid phase (mg/kg)	% leached	Solid phase (mg/kg)	% leached	Solid phase (mg/kg)	% leached
Ag	<0.05	-	<0.05	-	<0.05	-	0.05	-
Al	4230	0.3	6590	0.2	15600	0.1	27300	0.1
As	1.3	6.2	0.8	10.0	0.3	6.7	1.1	-
B	<5	-	<5	-	<5	-	<5	-
Ba	190	8.3	11	34.5	15	16.0	7.9	27.8
Cd	<0.05	-	<0.05	-	<0.05	-	<0.05	-
Co	43	60.5	4.5	27.1	1.9	44.2	9.4	40.4
Cr	23	0.3	19	0.1	23	0.1	48	0.1
Cu	28	5.1	9.5	-	0.8	5.0	<0.1	-
Fe	21000	0.0	72000	0.0	2200	0.1	32000	0.0
Hg	0.03	46.7	0.06	23.3	<0.02	-	0.12	10.0
Mn	27	48.9	18	3.1	6	6.3	6	5.3
Mo	0.9	-	0.7	-	<0.5	-	1	-
Ni	53	60.4	1	-	3	-	7	-
Pb	12	0.3	16	0.6	16	1.6	14	1.6
Sb	<0.05	-	<0.05	-	<0.05	-	<0.05	-
Se	0.17	82.4	0.13	-	<0.05	-	0.15	-

Sn	0.7	-	<0.5	-	<0.5	-	<0.5	-
Sr	6.2	26.8	2.2	35.5	8	15.5	3.8	51.1
Th	17	-	15	-	16	-	17	-
U	1.6	3.5	1.3	1.8	0.43	14.4	1.8	6.1
V	37	-	34	-	44	0.1	**50**	-
Zn	5.8	14.8	22	-	1.9	-	1.1	-

For the majority of elements tested the percentage of the solid phase leached under neutral conditions is typically low with values of < 5 % leached (many elements had no detectable leached percentage, i.e. below detection limit). Leach percentages > 5 % were obtained in one or more samples for the elements of As, Ba, Co, Hg, Mn, Ni, Se, Sr, U and Zn. Although these elevated leaching percentages were reported, the initial very low solid phase element content of these samples across all elements tested (Section 4.3) suggests that no leachate of environmentally significant levels of metals or metalloids is likely to occur, notwithstanding the laboratory derived moderate to low leachate percentages.

It is important to note that the standard bottle leach extraction (i.e. AS4439.3 – 1997) used in this study to quantify the mobility of the various metals and metalloids uses a generous soil/extractant ratio of 1:20. This wide ratio ensures that no common ion effects occur which may act to limit the dissolution, desorption or release of elements into the solution in contact with the solid phase, and minimises the risk of precipitation of released elements in the liquid phase. In both saturated (i.e. aquifer) or unsaturated (vadose zone) soil conditions a significantly lower soil/solution ratio occurs (<< 1:1), which minimises the contact between soil and liquid phases and consequently prevents the dissolution of most soluble salts and restricts the desorption of elements from the mineral surfaces. As a consequence of this, the moderate to low metal and metalloid mobility observed in this investigation, using the standard bottle leach extraction, is likely to represent the worst case scenario, with the predominately clay rich materials likely to have significantly lower metal mobility rates than those reported in the above results (Table 4.7).

Based on the above results and observations the potential for environmentally significant levels of metal or metalloid leachate to develop at this deposit is considered low.

5. CONCLUSIONS & RECOMMENDATIONS

An ASS survey was conducted for the Yoongarillup deposit to determine whether AAAS or PASS are likely to be present within the proposed project area and surrounds. This assessment reviewed the results from previous geological drilling within the Project Area, with the key results from this survey and associated laboratory testing program being:

- The majority of soils sampled (85 %) had *in situ* pH values (pH_F) between the ranges of 5 – 7 (slightly acidic to neutral) which is typical of soils on the Swan Coastal Plain. None of the samples tested had an *in situ* pH < 4 indicating that the presence of AASS within the Yoongarillup project area is unlikely.

- Approximately 20 % of soils tested had pH_{FOX} values < 4, with 27 % of these low pH_{FOX} soils (or 6 % of total samples tested) having pH_{FOX} values < 3. This indicates that PASS are likely to be present within the Yoongarillup Deposit project area.

- An analysis of screen testing results (pH_F and pH_{FOX}) versus soil colour via the use of 3D geological mapping software (Downhole Explorer) shows that the overwhelming majority of soils which experienced large pH drops following oxidation (i.e. pH_{FOX} < 3) were black or dark grey in colour, and occurred at the base of the drilling conducted (i.e. at or below the base of the proposed mine pit). A conservative value of pH_{FOX} 3.5 has been adopted as the upper limit for an indicator for PASS (on advice from Professor Leigh Sullivan). Being a half pH unit above the pH_{FOX} value of 3 considered by the DEC as a clear indicator that sufficient pyrite is present in the sediment sample to produce a level of acidity of environmental concern if oxidised. This value should be incorporated into geological block models to produce a spatial distribution map for PASS.

- The majority of soils sampled (10 of 12) had an S_{CR} value below that determined by the DEC as an indicator for PASS (0.03 % S_{CR}). The two samples which returned S_{CR} values > 0.03 % were both black clay to sandy clay samples from the base of the drilling conducted, further confirming that this soil material represents the majority of PASS which can potentially occur within the Yoongarillup Deposit.

- The results of multi-element analysis conducted on 12 representative samples showed no elevated levels of metals or metalloids, with only one sample returning a value above the Ecological Investigation Level for Vanadium. When compared to the average crustal abundance (ACA) for vanadium, this sample was equivalent to back ground levels for this element. No other element levels in any of the 12 samples tested exceeded the corresponding EIL.

- As the majority of identified PASS are not within the resource reserve the potential for direct disturbance is considered to be low. However there is a potential for indirect disturbance with dewatering of the mine pit possibly impacting on PASS in the later stages of mining. In order to understand the potential impacts of dewatering on PASS, a site hydrological model should be developed, along with modelled groundwater draw down curves, to enable a detailed risk assessment to be completed.

Direct Disturbance

- A review of the drilling data shows that the low pH_{FOX} values (PASS) reported in Section 3.2 are found within materials outside of the resource reserve, with the majority occurring to the north of the resource or in a sedimentary layer beneath the resource, and therefore are unlikely to be directly disturbed (i.e. excavated) during mining. The cross sections clearly show the extent of the proposed current pit boundary with the PASS areas well outside the area of direct disturbance.

- The S_{CR} results shown in 4.2 highlight that the use of soil colour as a management technique for the field identification of PASS is likely to be effective, and it is recommended that the black clay materials below the ore zone within the Yoongarillup deposit be classified as PASS. This information can then be fed into the block model along with the pH_{FOX} data and can then be used to inform both material handling and dewatering management plans.

- Although the risk of direct disturbance of PASS is considered to be low given the position of the identified PASS, management plans for the possibility of disturbance of small, localised areas should be put in place to mitigate any potential risk. Any PASS material identified during excavation (i.e. dark coloured clay soils, $pH_{FOX} < 3.5$) should be deposited within a purpose built above ground storage cell and covered with > 5 metres of clay (reddish yellow clay overburden) to ensure oxidation does not occur. At the cessation of mining and de-watering these cells can be placed back within the mine pit below the water table level to ensure reducing conditions are maintained and that no acid generation can occur.

Indirect Disturbance

A detailed hydrological study is needed to predict the effects of mine pit de-watering and the associated drawdown effects this will entail. Detailed management strategies will only be possible once these studies have been completed however a brief overview of potential management with regards to groundwater abstraction and drawdown is given below.

- Any de-watering plan should seek to minimise the impact on areas that have been identified as containing PASS from the block model. With de-watering curves minimised and the use of re-injection bores down gradient of the mine-pit examined.

- Detailed background groundwater monitoring data should be collected for use as references to enable measurement of potential changes in water quality which may occur in response to either direct or indirect PASS disturbance. This background data can also be used in the creation of 'trigger' values to identify any impacts on water quality at the earliest possible stage.

- Monitoring bores should be sited to target both areas of known PASS (i.e. targeted screening at the identified depth) and in a wider monitoring role down gradient from the project site. These bores can then be used to monitor both potential changes in groundwater quality and drawdown. Potential mitigation of drawdown within PASS zones can be managed through use of re-injection bores.

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APPENDIX A: DRILL LOG AND SCREEN LEVEL ASSESSMENT RESULTS

Peg ID	Depth	SWC ID	Soil colour	Soil texture	Comments	pHF	pHFOX
16	0.5	18297	Brown	Clay sand		6.30	3.91
16	1.5	18298	Brown Yellow	Clay sand		6.24	4.82
16	2.5	18299	Yellow	Clay sand	Minor Gravel	6.40	6.24
16	3.5	18300	Yellow	Clay sand	Minor Gravel	6.07	5.40
16	4.5	18301	Yellow Brown	Clay sand	Minor Gravel	5.97	5.34
16	5.5	18302	Light Grey	Sandy clay	Wet	5.82	5.37
16	6.5	18303	Light Grey	Sandy clay	Wet	5.76	5.32
16	7.5	18304	Light Grey	Sandy clay	Wet Pisolith	5.74	4.85
16	8.5	18305	Light Grey	Sandy clay	EOH	5.71	4.99
17	0.5	18288	Dark Grey	Clay sand		6.24	2.90
17	1.5	18289	Dark Grey	Clay sand	Ironstone Gravels	5.90	3.97
17	2.5	18290	Yellow Grey	Clay sand	Ironstone Gravels	5.99	4.87
17	3.5	18291	Yellow	Sandy loam	Ironstone Gravels	5.87	4.77
17	4.5	18292	Yellow	Sandy loam	Ironstone Gravels	5.39	4.73
17	5.5	18293	Red Brown	Clay sand	Possible Laterite	5.53	4.92
17	6.5	18294	Red Brown	Clay sand	Possible Laterite	5.61	5.09
17	7.5	18295	Red Brown	Sandy loam	Possible Laterite	5.58	4.99
17	8.5	18296	Light Red	Clay sand	EOH	5.49	5.00
18	0.5	18279	Light Grey	Clay sand	Dry Gravel	5.92	2.92
18	1.5	18280	Grey	Clay sand	Dry Gravel	5.71	4.21
18	2.5	18281	Yellow Grey	Sandy loam	Dry Gravel	5.78	4.96
18	3.5	18282	Yellow Grey	Sandy loam	Dry Gravel	5.58	5.09
18	4.5	18283	Yellow Grey	Sandy clay	Dry Gravel	5.19	4.50
18	5.5	18284	Light Grey	Sandy clay	Dry Gravel	5.13	4.28
18	6.5	18285	Brown Grey	Sandy clay	Dry Gravel	5.44	4.18
18	7.5	18286	Light Grey	Sandy clay	Dry	5.48	4.54
18	8.5	18287	Light Grey/Red	Sandy clay	EOH	5.40	4.73
19	0.5	18306	Grey	Sand		5.25	3.49
19	1.5	18307	Grey	Clay sand		5.90	4.13
19	2.5	18308	Red Brown	Clay sand	Gravels	5.87	5.50
19	3.5	18309	Red Brown	Clay sand	Lateritic Gravels	5.66	5.44
19	4.5	18310	Red	Clay sand	Lateritic Gravels	5.53	5.13
19	5.5	18311	Light Red	Sandy clay	Lateritic Gravels	5.47	4.88
19	6.5	18312	Red	Sandy clay	Grey Pisoliths	5.42	5.46
19	7.5	18313	Brown	Sandy loam	Grey Pisoliths	5.41	5.33
19	8.5	18314	Brown	Sandy loam	Grey Pisoliths	5.51	5.14
19	9.5	18315	Yellow Brown	Sandy loam	Grey Pisoliths	7.69	5.23
19	10.5	18316	Yellow Brown	Sandy loam	Grey Pisoliths	5.80	4.82
19	11.5	18317	Yellow Brown	Sandy clay	Damp	5.69	5.35
19	12.5	18318	Yellow	Sandy clay	Wet	5.60	5.17
19	13.5	18319	Yellow	Sandy clay	Wet	5.86	5.24

19	14.5	18320	Yellow	Sandy clay	Wet	5.71	5.38
19	15.5	18321	Yellow	Sandy clay	Wet	6.03	5.36
19	16.5	18322	Red Yellow	Sandy clay	Wet	6.04	4.50
19	17.5	18323	Pale Yellow Red	Clay	Wet	6.01	4.09
19	18.5	18324	Yellow	Clay	Wet	5.95	4.78
19	19.5	18325	Yellow	Clay	Wet	5.91	3.39
19	20.5	18326	Black	Clay	Wet	6.06	2.90
19	21.5	18327	Black	Clay	Wet	6.07	2.44
19	22.5	18328	Black	Clay	Wet	6.04	2.44
19	23.5	18329	Brown Black	Clay	EOH	6.03	3.06
20	0.5	18330	Grey	Sand	Dry	6.56	3.59
20	1.5	18331	Grey	Sand	Dry	5.63	3.85
20	2.5	18332	Yellow	Sandy clay	Wet	5.84	4.30
20	3.5	18333	Red	Sandy clay	Gravels	5.67	5.23
20	4.5	18334	Red	Sandy loam	Gravels	5.65	4.99
20	5.5	18335	Red Yellow	Sandy clay	Gravels	5.74	4.63
20	6.5	18336	Grey Red	Sandy clay	Mottled Pisoliths	5.62	4.78
20	7.5	18337	Grey Red	Clay sand	Mottled Pisoliths	5.61	4.88
20	8.5	18338	Grey Red	Sandy loam	Mottled Pisoliths	5.61	4.89
20	9.5	18339	Grey Red	Sandy loam	Pisoliths	5.66	4.74
20	10.5	18340	Grey Red	Sandy loam	Pisoliths	5.76	4.86
20	11.5	18341	Grey Red	Sandy loam	Pisoliths	5.96	5.35
20	12.5	18342	Red Grey	Sandy loam	Pisoliths	5.90	5.28
20	13.5	18343	Light Grey	Sandy clay	Pisoliths/Damp	5.89	5.32
20	14.5	18344	Black	Sandy clay	Pisoliths/Damp	5.90	4.39
20	15.5	18345	Light Grey	Sandy clay	Pisoliths/Damp	5.90	4.27
20	16.5	18346	Light Grey	Clay	Damp	5.96	4.70
20	17.5	18347	Light Grey	Clay	Damp	5.98	4.61
20	18.5	18348	Red Grey	Clay	Wet	5.61	5.06
20	19.5	18349	Red Grey	Clay	Wet	5.71	4.96
20	20.5	18350	Red Grey	Clay	EOH	5.76	5.02
21	0.5	18771	Grey	Sand		5.84	3.08
21	1.5	18772	Grey	Clay sand	Moist	5.78	3.75
21	2.5	18773	Grey	Clay sand	Moist	5.77	4.35
21	3.5	18774	Grey	Clay sand	Moist	5.58	4.71
21	4.5	18775	Red Grey	Sandy loam		5.51	4.61
21	5.5	18776	Red Grey	Sandy loam		5.38	4.36
21	6.5	18777	Light Grey	Sandy clay	Wet	5.47	4.42
21	7.5	18778	Light Grey	Sandy clay	Wet	5.50	4.72
21	8.5	18779	Light Grey	Sandy clay	Wet	5.71	4.73
21	9.5	18780	Light Grey	Sandy clay	Wet Piso's	6.07	4.43
21	10.5	18781	Light Grey	Sandy clay	Wet Piso's	6.09	4.56
21	11.5	18782	Light Grey/Brown	Sandy clay	Wet Piso's	6.03	4.72
21	12.5	18783	Red	Sandy clay	Wet Piso's	6.09	4.70

21	13.5	18784	Red Grey	Sandy clay	Wet Piso's	6.13	4.64
21	14.5	18785	Red Grey	Sandy clay	Wet Piso's	6.05	4.65
21	15.5	18786	Yellow Brown	Sandy clay	Wet Piso's	5.73	5.04
21	16.5	18787	Black	Clay	Wet Piso's	5.80	2.50
21	17.5	18788	Black	Clay	EOH	6.02	2.51
22	0.5	18789	Dark Grey	Sand		6.40	3.26
22	1.5	18790	Yellow Brown	Clay sand		7.28	4.52
22	2.5	18791	Yellow Brown	Clay sand		7.27	5.47
22	3.5	18792	Brown	Clay sand		6.64	5.86
22	4.5	18793	Pale Grey	Clay sand		6.43	5.83
22	5.5	18794	Grey	Clay sand		5.83	5.59
22	6.5	18795	Red Brown	Sandy loam		6.26	5.25
22	7.5	18796	Dark Red	Sandy loam	Gravels	5.91	5.82
22	8.5	18797	Pale Grey	Sandy clay	Gravels	6.05	5.50
22	9.5	18798	Pale Grey/Red	Sandy clay	Piso's/ Gravels	6.10	5.35
22	10.5	18799	Pale Grey	Sandy clay	Piso's/ Gravels	6.04	5.21
22	11.5	18800	Red	Sandy clay	Wet	5.86	5.69
22	12.5	18801	Red	Sandy clay	Wet	6.01	5.17
22	13.5	18802	Yellow Red	Sandy clay	Wet	5.85	5.21
22	14.5	18803	Yellow Red	Sandy clay	Wet	5.76	5.26
22	15.5	18804	Yellow Red	Sandy clay	Wet	5.70	5.46
22	16.5	18805	Yellow Red	Sandy clay	Wet	5.68	5.64
22	17.5	18806	Dark Red	Sandy clay	Wet	5.73	5.32
22	18.5	18807	Dark Grey	Clay	Wet	5.97	4.10
22	19.5	18808	Yellow Grey	Sandy clay	Wet	5.90	4.78
22	20.5	18809	Yellow Grey	Sandy clay	EOH	5.95	4.93
23	0.5	18846	Brown Black	Sand		6.62	4.54
23	1.5	18847	Yellow Brown	Sand		6.28	5.96
23	2.5	18848	Yellow Brown	Sand		6.35	5.61
23	3.5	18849	Yellow Brown	Clay sand		6.12	5.83
23	4.5	18850	Brown	Clay sand		5.99	5.87
23	5.5	18851	Brown	Clay sand	Gravels	5.97	5.19
23	6.5	18852	Brown	Clay sand	Gravels	5.87	5.09
23	7.5	18853	Brown	Clay sand	Gravels	5.26	4.49
23	8.5	18854	Yellow Brown	Sandy loam	Gravels	5.26	4.47
23	9.5	18855	Light Grey	Sandy clay	Gravels	5.76	4.61
23	10.5	18856	Light Grey	Sandy clay	Wet	5.42	4.70
23	11.5	18857	Grey Red	Sandy clay	Wet	5.67	4.92
23	12.5	18858	Grey	Sandy clay	Wet	6.03	5.23
23	13.5	18859	Grey	Sandy clay	Wet	6.10	5.20
23	14.5	18860	Light Red	Sandy clay	Wet	5.88	5.41
23	15.5	18861	Grey	Sandy clay	Wet	5.59	4.72
23	16.5	18862	Black	Sandy clay	Wet	5.44	4.48
23	17.5	18863	Black	Sandy clay	EOH	5.54	4.25

24	0.5	18828	Yellow Grey	Sand		6.32	3.57
24	1.5	18829	Yellow Brown	Sand		5.99	4.23
24	2.5	18830	Yellow Brown	Sand		6.16	4.87
24	3.5	18831	Grey	Sand		6.00	4.08
24	4.5	18832	Grey	Clay sand		5.88	4.23
24	5.5	18833	Red Grey	Clay sand		5.42	4.13
24	6.5	18834	Grey	Sandy clay		5.88	4.03
24	7.5	18835	Grey	Sandy clay	Piso's	5.70	4.12
24	8.5	18836	Grey	Sandy clay	Wet	6.07	4.85
24	9.5	18837	Yellow Grey	Sandy clay	Wet	5.79	4.96
24	10.5	18838	Yellow Grey	Sandy clay	Wet	5.76	5.00
24	11.5	18839	Yellow Grey	Sandy clay	Wet	5.69	5.16
24	12.5	18840	Yellow Grey	Sandy clay	Wet	5.56	4.73
24	13.5	18841	Grey	Sandy clay	Wet	5.58	4.55
24	14.5	18842	Grey	Sandy clay	Wet	5.66	4.57
24	15.5	18843	Dark Grey	Sandy clay	Wet	5.78	3.70
24	16.5	18844	Black	Sandy clay	Wet	5.68	2.93
24	17.5	18845	Black	Sandy clay	EOH	5.52	3.30
25	0.5	18864	Brown	Clay sand		5.93	4.09
25	1.5	18865	Yellow	Clay sand		5.76	4.33
25	2.5	18866	Brown	Clay sand	Gravels	5.47	4.22
25	3.5	18867	Dark Red	Sandy loam	Gravels	5.13	4.36
25	4.5	18868	Red Grey	Sandy loam		4.95	4.37
25	5.5	18869	Red Grey	Sandy loam		4.81	3.98
25	6.5	18870	Red Grey	Sandy loam		5.20	4.31
25	7.5	18871	Yellow Red	Sandy clay		5.31	4.50
25	8.5	18872	Grey	Sandy clay	Piso's	5.46	4.68
25	9.5	18873	Grey	Sandy clay	Piso's	5.62	4.68
25	10.5	18874	Grey	Sandy clay	Piso's	5.68	4.60
25	11.5	18875	Grey	Sandy clay	Piso's	5.66	4.34
25	13.5	18876	Grey	Sandy clay	Wet	5.30	4.15
25	14.5	18877	Grey	Sand	Wet	5.54	3.38
25	15.5	18878	Yellow	Sandy clay	Wet	5.60	3.86
25	16.5	18879	Yellow	Sandy clay	Wet	5.69	4.82
25	17.5	18880	Yellow	Sandy clay	Wet	5.73	4.15
25	18.5	18881	Yellow	Sandy clay	Wet	5.70	4.41
25	19.5	18882	Grey Yellow	Sandy clay	Wet	5.79	4.39
25	20.5	18883	Grey Yellow	Sandy clay	EOH	5.80	4.64
26	0.5	18810	Brown	Sand		5.47	3.15
26	1.5	18811	Yellow Brown	Sand		5.52	3.94
26	2.5	18812	Yellow Brown	Sandy clay	Gravels	5.37	3.64
26	3.5	18813	Yellow Brown	Sandy clay	Gravels	5.66	4.29
26	4.5	18814	Light Grey/Brown	Sandy clay	Gravels	5.54	4.23
26	5.5	18815	Light Grey	Sandy clay	Gravels	5.42	4.24

26	6.5	18816	Light Grey	Sandy clay	Piso's	5.55	4.58
26	7.5	18817	Light Grey	Sandy clay	Piso's	5.48	4.57
26	9.5	18819	Light Grey	Sandy clay	Wet	6.12	4.76
26	10.5	18820	Yellow Red	Sandy clay	Wet	5.50	4.97
26	11.5	18821	Light Grey	Sandy clay	Wet	5.63	4.47
26	12.5	18822	Light Grey	Sandy clay	Wet	5.54	4.46
26	13.5	18823	Yellow Red	Sandy clay	Wet	5.60	4.68
26	14.5	18824	Yellow Red	Sandy clay	Wet	5.76	4.72
26	15.5	18825	Yellow Red	Sandy clay	Wet	5.79	5.03
26	16.5	18826	Black	Sandy clay	Wet	5.68	2.50
26	17.5	18827	Black	Sandy clay	EOH	5.80	2.31
27	0.5	18449	Black	Sand		4.73	2.65
27	1.5	18450	Brown Red	Clay sand	Moist Gravels	5.50	3.48
27	2.5	18451	Brown Red	Clay sand	Moist Gravels	5.44	4.03
27	3.5	18452	Brown Red	Clay sand		5.74	4.64
27	4.5	18453	Light Grey	Sandy loam		5.68	4.65
27	5.5	18454	Brown Red	Clay sand	Dry	5.68	5.05
27	6.5	18455	Brown Red	Sandy loam	Dry	6.29	6.14
27	7.5	18456	Brown Red	Sandy loam	Dry	5.40	5.11
27	8.5	18457	Light Grey	Sandy clay	Dry	5.52	4.95
27	9.5	18458	Yellow Red	Sandy clay	Wet	5.93	5.29
27	10.5	18459	Yellow Red	Sandy clay	Wet	5.77	5.13
27	11.5	18460	Yellow Red	Sandy clay	Wet	5.73	4.34
27	12.5	18461	Light Red	Sandy clay	Wet	5.61	4.55
27	13.5	18462	Light Red	Sandy clay	Wet	5.68	4.96
27	14.5	18463	Black	Clay	Wet	5.62	3.57
27	15.5	18464	Black	Clay	Wet	5.78	3.34
27	16.5	18465	Light Red	Sandy clay		6.00	4.25
27	17.5	18466	Light Red	Sandy clay		5.98	3.54
27	18.5	18467	Light Red	Sandy clay		6.04	4.55
27	19.5	18468	Light Red	Sandy clay		6.12	5.03
27	20.5	18469	Black	Clay		5.40	2.27
27	21.5	18470	Black	Clay		5.51	3.10
27	22.5	18471	Black	Clay		5.49	1.98
27	23.5	18472	Black	Clay	EOH	5.23	2.41
28	0.5	18401	Grey	Clay sand		6.38	3.20
28	1.5	18402	Grey	Clay sand	Gravels	6.00	3.88
28	2.5	18403	Red	Clay sand	Gravels	5.98	4.40
28	3.5	18404	Red	Sandy loam	Pedsols	5.64	4.37
28	4.5	18405	Light Grey	Sandy clay		5.75	4.40
28	5.5	18406	Light Grey	Sandy clay		5.66	4.80
28	6.5	18407	Light Grey	Sandy clay	Pedo	5.72	4.90
28	7.5	18408	Light Grey	Sandy clay		5.89	4.90
28	8.5	18409	Light Grey/Red	Sandy clay	Possible sharp contact	6.02	5.11

28	9.5	18410	Yellow	Sandy clay	Moist	5.86	5.12
28	10.5	18411	Yellow Red	Clay	Moist	5.74	5.62
28	11.5	18412	Red	Sandy clay	Moist	5.86	5.68
28	12.5	18413	Red	Sandy clay	Wet	6.03	4.64
28	13.5	18414	Light Grey/Red	Sandy clay	Wet	6.10	4.60
28	14.5	18415	Light Grey/Red	Sandy clay	Wet	6.16	4.73
28	15.5	18416	Light Grey/Red	Sandy clay	Wet	5.86	5.32
28	16.5	18417	Light Grey	Sandy clay	Wet	5.86	5.41
28	17.5	18418	Light Grey	Sandy clay	Wet	5.61	2.06
28	18.5	18419	Black	Sandy clay	Wet	5.54	3.02
28	19.5	18420	Black	Clay	Wet	5.62	3.37
28	20.5	18421	Black	Clay	Wet	5.86	2.92
28	21.5	18422	Black	Clay	Wet	5.88	3.42
28	22.5	18423	Black	Clay	Wet	5.86	3.69
28	23.5	18424	Black	Clay	EOH	5.90	3.34
29	0.5	18375	Grey	Sandy loam		6.67	4.67
29	1.5	18376	Grey	Sandy clay		4.78	3.87
29	2.5	18377	Light Grey	Sandy clay	Pisolith	4.65	3.95
29	3.5	18378	Light Grey	Sandy clay	Pisolith	4.92	4.21
29	4.5	18379	Light Grey	Sandy clay	Pisolith	5.40	4.58
29	5.5	18380	Light Grey	Sandy clay	Pisolith	5.47	4.63
29	6.5	18381	Light Grey	Sandy clay	Pisolith	5.58	4.74
29	7.5	18382	Light Grey	Sandy clay	Pisolith	5.83	4.80
29	8.5	18383	Light Grey	Sandy clay	Pisolith	6.05	5.10
29	9.5	18384	Light Grey	Clay sand	Moist	5.62	5.61
29	10.5	18385	Light Grey/Red	Sandy loam	Mottled	5.50	5.54
29	11.5	18386	Red	Sandy loam	Wet	5.48	5.68
29	12.5	18387	Light Grey/Red	Sandy clay	Wet	5.80	5.05
29	13.5	18388	Yellow Red	Clay	Wet	5.85	4.77
29	14.5	18389	Light Grey/Red	Clay	Wet	5.90	4.71
29	15.5	18390	Light Grey	Sandy clay	Wet	5.92	5.18
29	16.5	18391	Light Red	Sandy clay	Wet	5.99	5.23
29	17.5	18392	Light Grey	Sandy clay	Wet	6.30	5.83
29	18.5	18393	Yellow/Grey	Sandy clay	Wet	6.00	4.99
29	19.5	18394	Yellow	Sandy clay	Wet	6.00	5.11
29	20.5	18395	Yellow	Sandy clay	Wet	6.00	5.19
29	21.5	18396	Yellow/Grey	Sandy clay	Wet	5.95	5.75
29	22.5	18397	Yellow	Sandy clay	Wet	5.95	4.86
29	23.5	18398	Light Grey	Sandy clay	Wet	6.00	4.62
30	0.5	18884	Yellow	Sand		5.35	3.72
30	1.5	18885	Yellow	Sand		5.50	3.68
30	2.5	18886	Red Yellow	Clay sand	Gravels	5.50	3.39
30	3.5	18887	Red Grey	Sandy loam	Piso's	5.38	3.80
30	4.5	18888	Red Grey	Sandy loam	Piso's	5.39	3.99

30	5.5	18889	Red Grey	Sandy clay	Piso's	5.51	4.29
30	6.5	18890	Grey	Sandy loam		5.34	4.48
30	7.5	18891	Grey	Sandy loam		5.33	4.55
30	8.5	18892	Grey	Sandy clay		5.60	4.63
30	9.5	18893	Grey	Sandy loam		5.65	4.64
30	10.5	18894	Yellow Grey	Sandy loam	Wet	5.71	4.12
30	11.5	18895	Yellow Grey	Sandy clay	Wet	5.75	4.70
30	12.5	18896	Grey	Sandy clay	Wet	5.83	4.67
30	13.5	18897	Grey	Sandy clay	Wet	5.89	4.75
30	14.5	18898	Grey	Sandy clay	Wet	6.05	5.23
30	15.5	18899	Grey	Sandy clay	Wet/Piso's	5.98	5.07
30	16.5	18900	Grey	Sandy clay	Wet/Piso's	5.97	5.39
30	17.5	18901	Grey	Sandy clay	Wet/Piso's	6.02	5.37
30	18.5	18902	Grey	Sandy clay	Wet/Piso's	6.14	5.53
30	19.5	18903	Yellow	Sandy clay	Wet/Piso's	6.06	5.48
30	20.5	18904	Yellow	Sandy clay	EOH	6.08	5.72
31	0.5	18905	Brown	Sand		6.26	3.32
31	1.5	18906	Brown	Sand		6.21	3.74
31	2.5	18907	Brown	Sand		5.80	4.07
31	3.5	18908	Brown	Sand		5.80	4.30
31	4.5	18909	Brown	Sandy loam		5.78	3.88
31	5.5	18910	Brown	Sandy loam		5.67	4.00
31	6.5	18911	Red Brown	Sandy clay		5.57	4.70
31	7.5	18912	Grey	Sandy clay	Piso's	5.67	4.87
31	8.5	18913	Grey	Sandy clay	Piso's	5.74	5.06
31	9.5	18914	Grey Yellow	Sandy clay	Piso's	5.62	5.34
31	10.5	18915	Grey Yellow	Sandy clay	Piso's	5.71	5.24
31	11.5	18916	Yellow Grey	Sandy clay	Wet	5.69	5.44
31	12.5	18917	Grey	Sandy clay	Wet	5.83	4.78
31	13.5	18918	Black	Sandy clay	Wet	5.79	3.63
31	14.5	18919	Black	Sandy clay	Wet	5.88	4.37
31	15.5	18920	Black	Clay	Wet	5.81	4.73
31	16.5	18921	Grey	Clay	Wet	5.88	4.99
31	17.5	18922	Grey	Clay	Wet	5.87	4.71
32	0.5	18923	Brown	Sand		6.21	3.14
32	1.5	18924	Brown	Sand		6.17	4.70
32	2.5	18925	Brown	Sand		6.07	4.91
32	3.5	18926	Brown	Sand		6.36	4.26
32	4.5	18927	Brown	Sand	Gravels	6.15	4.72
32	5.5	18928	Brown	Sand	Gravels	6.00	4.96
32	6.5	18929	Brown	Clay sand	Gravels	5.86	5.25
32	7.5	18930	Brown	Clay sand	Gravels	5.67	5.17
32	8.5	18931	Red	Sandy clay		5.27	4.67
32	9.5	18932	Red Grey	Sandy clay		5.69	4.85

32	10.5	18933	Red Brown	Sandy clay		5.91	5.23
32	11.5	18934	Red Brown	Sandy clay		5.99	5.36
32	12.5	18935	Grey	Sandy clay	Mottled	5.90	5.26
32	13.5	18936	Grey	Sandy clay	Mottled	5.89	5.27
32	14.5	18937	Red	Sandy clay	Wet	5.85	5.39
32	15.5	18938	Grey Red	Sandy clay	Wet	6.35	5.05
32	16.5	18939	Red Grey	Sandy clay	Wet	6.32	4.94
32	17.5	18940	Red Yellow	Sandy clay	Wet	6.35	5.22
32	18.5	18941	Pale Grey	Sandy clay	Wet	6.04	5.05
32	19.5	18942	Grey	Sandy clay	Wet	6.11	4.63
32	20.5	18943	Grey	Sandy clay	EOH	6.00	5.04
34	0.5	19306	Brown	Sand		5.63	3.44
34	1.5	19307	Yellow Brown	Sand		5.78	3.82
34	2.5	19308	Yellow Brown	Sand		5.90	4.29
34	3.5	19309	Yellow Brown	Sand		6.04	4.95
34	4.5	19310	Yellow Brown	Sand		5.85	4.82
34	5.5	19311	Brown Grey	Sand		5.60	4.71
34	6.5	19312	Red Grey	Clay sand		5.58	4.81
34	7.5	19313	Grey	Clay sand		5.47	4.91
34	8.5	19314	Red Grey	Clay sand		5.40	4.89
34	9.5	19315	Red Yellow	Sandy loam	Gravels	5.62	4.89
34	10.5	19316	Grey	Sandy clay	Wet	5.74	4.96
34	11.5	19317	Grey	Sandy clay	Wet	5.74	5.16
34	12.5	19318	Grey	Sandy clay	Wet	5.90	5.13
34	13.5	19319	Red Grey	Sandy clay	Wet	5.95	5.34
34	14.5	19320	Grey	Sandy clay	Wet piso's	5.92	4.92
34	15.5	19321	Grey	Sandy clay	Wet piso's	6.19	4.59
34	16.5	19322	Grey	Clay	Wet piso's	6.21	4.39
34	17.5	19323	Grey	Clay	Wet	6.33	4.53
34	18.5	19324	Grey Black	Clay	Wet	5.96	4.92
34	19.5	19325	Grey Black	Clay	Wet	5.85	5.29
34	20.5	19326	Grey	Clay	EOH	5.90	5.28
35	0.5	19282	Yellow Grey	Sand		6.29	3.46
35	1.5	19283	Pale Yellow	Sand		5.72	4.51
35	2.5	19284	Pale Grey	Clay sand		5.86	4.97
35	3.5	19285	Red Grey	Sand		5.86	4.69
35	4.5	19286	Grey	Sand		5.69	4.54
35	5.5	19287	Grey	Clay sand	Gravels	5.65	4.39
35	6.5	19288	Grey Red	Clay sand	Possible contact	5.56	4.32
35	7.5	19289	Red	Sandy loam		5.48	4.83
35	8.5	19290	Red Grey	Sandy clay	Piso's	5.46	4.85
35	9.5	19291	Dark Red	Sandy clay	Piso's	5.54	4.97
35	10.5	19292	Dark Red	Sandy clay	Moist	5.45	4.94
35	11.5	19293	Dark Red	Sandy clay	Moist	5.26	5.02

35	12.5	19294	Red	Sandy clay	Gravels	5.66	5.45
35	13.5	19295	Red	Sandy clay	Gravels	5.62	3.65
35	14.5	19296	Red	Sandy clay	Wet Gravels	5.66	4.96
35	15.5	19297	Yellow Red	Sandy clay	Wet Gravels	5.89	5.32
35	16.5	19298	Grey Yellow	Sandy clay	Wet Gravels	5.82	5.28
35	17.5	19299	Grey Brown	Sandy clay	Wet Gravels	5.88	5.17
35	18.5	19300	Yellow Brown	Sandy clay	Wet Gravels	5.92	5.36
35	19.5	19301	Yellow Brown	Sandy clay	Wet Gravels	5.96	5.31
35	20.5	19302	Yellow Brown	Sandy clay	Wet Gravels	5.91	5.37
35	21.5	19303	Yellow Brown	Sandy clay	Gravels	5.74	5.08
35	22.5	19304	Yellow Brown	Sandy clay	Gravels	5.74	5.07
35	23.5	19305	Yellow Brown	Sandy clay	Gravels	5.70	4.93
36	0.5	19258	Brown	Clay sand	Moist	6.08	3.21
36	1.5	19259	Yellow	Clay sand		5.78	4.06
36	2.5	19260	Grey	Sandy loam		5.76	3.82
36	3.5	19261	Red Grey	Sandy loam		5.80	4.36
36	4.5	19262	Red	Sandy clay	Gravels	5.44	4.74
36	5.5	19263	Red	Sandy clay		5.35	4.46
36	6.5	19264	Red Grey	Sandy clay		5.66	4.61
36	7.5	19265	Red Grey	Sandy clay	Piso's	5.70	4.62
36	8.5	19266	Yellow Grey	Sandy clay	Wet	5.70	4.64
36	9.5	19267	Grey	Sandy clay	Wet	5.67	4.71
36	10.5	19268	Grey	Sandy clay	Wet	5.60	4.64
36	11.5	19269	Red Grey	Sandy clay	Wet	5.71	4.89
36	12.5	19270	Red Grey	Sandy clay	Wet	5.72	4.00
36	13.5	19271	Red Brown	Sandy clay	Wet	5.56	4.89
36	14.5	19272	Red Brown	Sandy clay	Wet	5.55	5.32
36	15.5	19273	Red Brown	Sandy clay	Wet	5.80	4.90
36	16.5	19274	Yellow Brown	Sandy clay	Wet	5.80	4.95
36	17.5	19275	Pale Red	Sandy clay	Wet	5.82	4.68
36	18.5	19276	Yellow	Sandy clay	Wet	5.77	5.04
36	19.5	19277	Yellow Grey	Sandy clay	Wet	5.84	5.11
36	20.5	19278	Yellow Grey	Sandy clay	Wet	5.91	5.26
36	21.5	19279	Yellow Grey	Sandy clay	Wet	5.86	5.31
36	22.5	19280	Yellow Grey	Sandy clay	Wet	5.85	5.31
36	23.5	19281	Yellow Grey	Sandy clay	Wet	5.80	5.39
37	0.5	18984	Dark Grey	Sand		5.67	2.86
37	1.5	18985	Dark Grey	Sandy loam		5.78	4.22
37	2.5	18986	Dark Grey	Sandy clay		5.72	4.39
37	3.5	18987	Dark Grey	Sandy clay	Piso's	5.64	3.93
37	4.5	18988	Red Brown	Sandy clay	Piso's	5.65	4.11
37	5.5	18989	Grey	Sandy clay	Wet	5.85	4.34
37	6.5	18990	Grey	Sandy clay	Wet	5.58	4.59
37	7.5	18991	Grey	Sandy clay	Wet	5.56	4.69

37	8.5	18992	Grey	Sandy clay	Wet	5.69	4.72
37	9.5	18993	Grey	Sandy clay	Wet	6.36	5.12
37	10.5	18994	Grey	Sandy clay	Wet	5.87	4.97
37	11.5	18995	Grey Red	Sandy clay	Wet	5.99	5.12
37	12.5	18996	Red	Sandy clay	Wet	5.70	5.33
37	13.5	18997	Red	Sandy clay	Wet	5.74	4.98
37	14.5	18998	Red	Sandy clay	Wet	5.73	4.87
37	15.5	18999	Yellow Red	Sandy clay	Wet	5.83	5.07
37	16.5	19000	Yellow Red	Sandy clay	Wet	5.92	5.00
37	17.5	19251	Yellow Red	Sandy clay	Wet	5.82	5.27
37	18.5	19252	Yellow	Sandy clay	Wet	5.94	4.19
37	19.5	19253	Black	Sandy clay	Wet	5.78	4.53
37	20.5	19254	Black	Sandy clay	Wet	5.69	4.02
37	21.5	19255	Grey	Sandy clay	Wet	5.54	4.64
37	22.5	19256	Red Grey	Sandy loam	Wet	5.62	4.79
37	23.5	19257	Red Grey	Sandy loam	Wet	5.64	4.72
38	0.5	18962	Grey	Sand		5.64	4.00
38	1.5	18963	Red Grey	Sand	Gravels	5.20	3.41
38	2.5	18964	Red Grey	Sand	Gravels	5.41	3.77
38	3.5	18965	Red Brown	Sandy clay		5.42	3.87
38	4.5	18966	Red Brown	Sandy clay		5.54	4.33
38	5.5	18967	Red Brown	Sandy clay	Gravels	5.57	4.21
38	6.5	18968	Red Brown	Sandy clay	Gravels	5.59	4.58
38	7.5	18969	Red Brown	Sandy clay	Gravels	5.64	5.07
38	8.5	18970	Grey Brown	Sandy clay		5.60	5.06
38	9.5	18971	Grey	Sandy clay	Piso's	5.58	4.73
38	10.5	18972	Grey	Sandy clay	Moist	5.61	4.70
38	11.5	18973	Red Brown	Sandy clay	Wet	5.57	4.58
38	12.5	18974	Grey Red	Sandy clay	Wet	5.68	4.63
38	13.5	18975	Grey Red	Sandy clay	Wet	6.12	4.85
38	14.5	18976	Red Brown	Sandy clay	Wet	5.98	5.13
38	15.5	18977	Red Brown	Sandy clay	Wet	6.01	5.06
38	16.5	18978	Grey	Sandy clay	Wet	5.60	5.06
38	17.5	18979	Red Brown	Sandy clay	Wet	5.69	5.01
38	18.5	18980	Black	Clay	Wet	5.48	3.94
38	19.5	18981	Black	Clay	Wet	5.41	2.95
38	20.5	18982	Black	Clay	EOH	5.33	3.44
39	0.5	19348	Grey	Sand		5.37	3.09
39	1.5	19349	Grey	Sand		5.50	4.25
39	2.5	19350	Dark Red	Sand		5.52	5.44
39	3.5	19351	Grey	Sand	Moist	5.59	3.49
39	4.5	19352	Grey	Clay sand	Moist	5.46	3.78
39	5.5	19353	Grey	Clay sand	Moist	5.43	3.54
39	6.5	19354	Red Grey	Sandy loam	Wet	5.08	4.14

39	7.5	19355	Red Grey	Sandy clay	Wet	5.07	4.42
39	8.5	19356	Grey	Sandy clay	Wet	5.09	4.48
39	9.5	19357	Grey Brown	Sandy clay	Wet	5.40	4.36
39	10.5	19358	Grey Brown	Sandy clay	Wet	5.34	4.42
39	11.5	19359	Grey Brown	Sandy clay	Wet	5.31	4.41
39	12.5	19360	Grey Brown	Sandy clay	Wet	5.17	3.86
39	13.5	19361	Grey Brown	Sandy clay	Wet	5.12	4.64
39	14.5	19362	Grey Brown	Sandy clay	Wet	5.19	3.85
39	15.5	19363	Red	Sandy clay	Wet	5.02	4.06
39	16.5	19364	Black	Sandy clay	Wet	5.18	4.24
39	17.5	19365	Black	Sandy clay	Wet	5.07	2.98
39	18.5	19366	Black	Sandy clay	Wet	4.89	3.20
39	19.5	19367	Grey	Sandy clay	Wet	5.80	3.83
39	20.5	19368	Grey	Sandy clay	Wet	5.37	2.53
40	0.5	19369	Grey	Sand		5.78	3.51
40	1.5	19370	Grey	Sand		5.70	4.24
40	2.5	19371	Red	Sand		5.62	5.37
40	3.5	19372	Red	Clay sand		5.64	4.86
40	4.5	19373	Red	Clay sand		5.63	5.40
40	5.5	19374	Grey Red	Clay sand	Wet	5.53	4.74
40	6.5	19375	Red	Sandy loam	Wet	5.39	4.68
40	7.5	19376	Pale Red	Sandy clay	Wet	5.42	4.48
40	8.5	19377	Pale Red	Sandy clay	Wet	5.45	4.58
40	9.5	19378	Grey Red	Sandy clay	Wet	5.75	4.97
40	10.5	19379	Grey Red	Sandy clay	Wet	5.70	4.75
40	11.5	19380	Black	Sandy clay	Wet	5.78	3.79
40	12.5	19381	Red Grey	Sandy clay	Wet	5.72	4.99
40	13.5	19382	Red Grey	Sandy clay	Wet	5.55	5.29
40	14.5	19383	Red Grey	Sandy clay	Wet	5.61	5.06
40	15.5	19384	Red Grey	Sandy clay	Wet	5.73	4.79
40	16.5	19385	Red Grey	Sandy clay	Wet	5.69	4.74
40	17.5	19386	Red Grey	Sandy clay	Wet	5.60	4.82
40	18.5	19387	Yellow Grey	Sandy clay	Wet	5.70	3.24
40	19.5	19388	Black	Sandy clay	Wet	5.53	3.12
40	20.5	19389	Black	Sandy clay	Wet	5.70	2.33
41	0.5	19390	Grey	Sand		6.15	3.35
41	1.5	19391	Grey	Sand	Gravels	5.60	3.87
41	2.5	19392	Grey	Sand	Gravels	5.83	4.73
41	3.5	19393	Grey	Sandy loam	Gravels	5.85	4.10
41	4.5	19394	Red	Sandy loam	Gravels	5.65	5.08
41	5.5	19395	Red Grey	Sandy clay	Gravels	5.67	4.47
41	6.5	19396	Grey	Sandy clay	Wet	5.52	4.53
41	7.5	19397	Grey	Sandy clay	Wet	5.65	4.78
41	8.5	19398	Grey	Sandy clay	Wet	5.58	4.62

41	9.5	19399	Grey	Sandy clay	Wet	5.68	4.67
41	10.5	19400	Grey	Sandy clay	Wet	5.66	4.65
41	11.5	19401	Grey	Sandy clay	Wet	5.65	4.72
41	12.5	19402	Grey	Sandy clay	Wet	5.77	5.13
41	13.5	19403	Grey Red	Sandy clay	Wet	5.77	5.03
41	14.5	19404	Grey Red	Sandy clay	Wet	5.80	4.94
41	15.5	19405	Grey Red	Sandy clay	Wet	5.72	5.45
41	16.5	19406	Red Grey	Sandy clay	Wet	5.69	5.39
41	17.5	19407	Grey	Sandy clay	Wet	5.93	4.04
41	18.5	19408	Red Brown	Sandy clay	Wet	5.74	5.02
41	19.5	19409	Red Brown	Sandy clay	Wet	5.73	4.95
41	20.5	19410	Yellow Brown	Sandy clay	Wet	5.69	5.03
42	0.5	19411	Grey	Sand		5.87	4.02
42	1.5	19412	Grey	Clay sand		5.70	4.01
42	2.5	19413	Brown	Clay sand	Gravels	5.78	4.60
42	3.5	19414	Grey Brown	Sandy loam	Piso's	5.50	4.61
42	4.5	19415	Grey Brown	Sandy clay	Piso's	5.42	4.64
42	5.5	19416	Grey Brown	Sandy clay	Piso's	5.38	4.57
42	6.5	19417	Grey	Sandy clay	Wet	5.43	4.67
42	7.5	19418	Grey Brown	Sandy clay	Wet Gravels	5.35	4.66
42	8.5	19419	Red Brown	Sandy clay	Wet Gravels	5.44	4.94
42	9.5	19420	Red Brown	Sandy clay	Wet Gravels	5.49	4.86
42	10.5	19421	Grey Brown	Sandy clay	Wet Gravels	5.57	4.87
42	11.5	19422	Grey	Sandy clay	Wet Gravels	5.70	4.91
42	12.5	19423	Red Grey	Sandy clay	Wet	5.64	5.13
42	13.5	19424	Red Grey	Sandy clay	Wet	5.58	4.93
42	14.5	19425	Red Grey	Sandy clay	Wet	5.62	4.93
42	15.5	19426	Red Grey	Sandy clay	Wet	5.84	4.58
42	16.5	19427	Grey	Sandy clay	Wet	5.95	4.57
42	17.5	19428	Grey	Sandy clay	Wet	5.96	4.31
43	0.5	19429	Grey	Sand		5.85	3.06
43	1.5	19430	Grey Brown	Sand		5.54	3.59
43	2.5	19431	Grey Brown	Clay sand		5.69	3.87
43	3.5	19432	Yellow Brown	Clay sand	Gravels	5.71	3.95
43	4.5	19433	Yellow Brown	Sandy loam	Gravels	5.62	4.33
43	5.5	19434	Red	Sandy loam	Gravels	5.62	4.24
43	6.5	19435	Red	Sandy clay	Gravels	5.63	4.43
43	7.5	19436	Red	Sandy clay	Laterite	5.52	5.22
43	8.5	19437	Red	Sandy clay	Wet Laterite	5.48	5.53
43	9.5	19438	Red	Sandy clay	Wet Laterite	5.58	4.99
43	10.5	19439	Red	Sandy clay	Wet Laterite	5.56	4.76
43	11.5	19440	Red Grey	Sandy clay	Wet Laterite	5.63	4.48
43	12.5	19441	Red Grey	Sandy clay	Wet Piso's	5.71	4.81
43	13.5	19442	Red Grey	Sandy clay	Wet Piso's	5.61	4.94

43	14.5	19443	Red Grey	Sandy clay	Wet Piso's	5.41	4.55
43	15.5	19444	Grey	Sandy clay	Wet Piso's	5.30	4.48
43	16.5	19445	Grey	Sandy clay	Wet Piso's	5.33	4.46
43	17.5	19446	Grey	Sandy clay	Wet Piso's	5.46	4.11
43	18.5	19447	Grey	Sandy clay	Wet Piso's	5.61	4.71
43	19.5	19448	Grey	Sandy clay	Wet Piso's	5.67	4.70
43	20.5	19449	Grey	Sandy clay	Wet Piso's	5.78	4.45
44	0.5	19450	Black	Sand		6.90	4.04
44	1.5	19451	Grey	Sandy clay		6.51	4.49
44	2.5	19452	Grey Yellow	Sandy clay	Wet	6.09	4.54
44	3.5	19453	Grey Yellow	Sandy clay	Wet Gravels	5.78	4.69
44	4.5	19454	Grey Yellow	Sandy clay	Wet Gravels	5.62	4.91
44	5.5	19455	Grey Yellow	Sandy clay	Wet Gravels	5.48	4.76
44	6.5	19456	Grey Yellow	Sandy clay	Wet Gravels	4.84	4.23
44	7.5	19457	Grey Red	Sandy clay	Wet	4.81	3.97
44	8.5	19458	Grey Black	Sandy clay	Wet	4.72	3.52
44	9.5	19459	Grey Red	Sandy clay	Wet	5.24	5.15
44	10.5	19460	Grey Red	Sandy clay	Wet	5.18	5.03
44	11.5	19461	Grey Red	Sandy clay	Wet	5.22	5.15
44	12.5	19462	Grey	Sandy clay	Wet	5.05	4.64
44	13.5	19463	Grey	Sandy clay	Wet	5.09	4.70
44	14.5	19464	Grey Red	Sandy clay	Wet	5.09	4.50
44	15.5	19465	Grey Red	Sandy clay	Wet	5.35	4.76
44	16.5	19466	Grey Red	Sandy clay	Wet	5.30	4.79
44	17.5	19467	Grey Red	Sandy clay	Wet	5.34	4.75
44	18.5	19468	Grey	Sandy clay	Wet	5.30	4.56
44	19.5	19469	Black	Sandy clay	Wet	4.92	4.22
44	20.5	19470	Grey	Sandy clay	Wet	4.88	4.16
44	21.5	19471	Grey	Sandy clay	Wet	4.98	3.78
44	22.5	19472	Grey	Sandy clay	Wet	5.02	3.97
44	23.5	19473	Grey	Sandy clay	EOH	4.92	4.00
45	0.5	19474	Brown	Sand		5.95	3.78
45	1.5	19475	Grey	Clay sand	Gravels	5.92	4.60
45	2.5	19476	Grey Yellow	Clay sand	Gravels	5.42	4.67
45	3.5	19477	Grey Yellow	Clay sand	Piso's	5.29	4.40
45	4.5	19478	Grey Red	Sandy clay	Wet Gravels	5.28	4.58
45	5.5	19479	Grey Red	Sandy clay	Wet Gravels	5.26	4.33
45	6.5	19480	Grey	Sandy clay	Wet Gravels	5.32	4.60
45	7.5	19481	Grey Red	Sandy clay	Wet Gravels	5.37	4.65
45	8.5	19482	Grey Red	Sandy clay	Wet Gravels	5.35	4.77
45	9.5	19483	Grey	Sandy clay	Wet Gravels	5.47	4.71
45	10.5	19484	Grey	Sandy clay	Wet Gravels	5.26	4.82
45	11.5	19485	Grey	Sandy clay	Wet Gravels	5.39	4.85
45	12.5	19486	Grey Red	Sandy clay	Wet Gravels	5.54	4.58

45	13.5	19487	Grey Red	Sandy clay	Wet Gravels	5.64	4.80
45	14.5	19488	Grey Red	Sandy clay	Wet Gravels	5.60	4.74
45	15.5	19489	Grey Red	Sandy clay	Wet Gravels	5.70	4.66
45	16.5	19490	Grey	Sandy clay	Wet Gravels	5.73	4.66
45	17.5	19491	Grey	Sandy clay	Wet Gravels	5.75	4.72
46	0.5	19492	Brown	Sand		5.16	4.05
46	1.5	19493	Brown	Sand	Gravels	6.05	3.32
46	2.5	19494	Brown	Sand	Gravels	6.20	5.16
46	3.5	19495	Brown	Sandy loam	Gravels	5.89	3.78
46	4.5	19496	Brown Grey	Sandy clay	Gravels	5.52	4.51
46	5.5	19497	Red Brown	Sandy clay	Gravels	5.41	5.04
46	6.5	19498	Red Brown	Sandy clay	Gravels	5.38	4.48
46	7.5	19499	Brown	Sandy clay	Wet Gravels	5.40	4.55
46	8.5	DM00	Grey Brown	Sandy clay	Wet	5.29	4.44
46	9.5	DM01	Grey Brown	Sandy clay	Wet	5.30	4.93
46	10.5	DM02	Grey	Sandy clay	Wet	5.22	4.88
46	11.5	DM03	Grey	Sandy clay	Wet	5.25	4.90
46	12.5	DM04	Grey	Sandy clay	Wet	5.75	4.70
46	13.5	DM05	Grey	Sandy clay	Wet	5.84	4.69
46	14.5	DM06	Grey	Sandy clay	Wet	5.83	4.92
46	15.5	DM07	Brown Grey	Sandy clay	Wet	5.82	4.84
46	16.5	DM08	Grey	Sandy clay	Wet	5.75	4.63
46	17.5	DM09	Brown Grey	Sandy clay	Wet	5.71	4.90
47	0.5	DM10	Grey Yellow	Sand		6.02	3.09
47	1.5	DM11	Yellow	Sand	Gravels	5.68	4.16
47	2.5	DM12	Yellow	Clay sand	Gravels	5.81	4.48
47	3.5	DM13	Yellow	Sandy loam	Gravels	5.85	4.77
47	4.5	DM14	Red Yellow	Sandy loam	Gravels	5.85	5.07
47	5.5	DM15	Red	Sandy loam	Gravels	5.82	5.58
47	6.5	DM16	Red Grey	Sandy clay		5.50	4.93
47	7.5	DM17	Red Grey	Sandy clay		5.43	4.83
47	8.5	DM18	Red Grey	Sandy clay	Wet	5.57	4.97
47	9.5	DM19	Red Grey	Sandy clay	Wet	5.70	5.00
47	10.5	DM20	Grey	Sandy clay	Wet	5.68	4.87
47	11.5	DM21	Grey	Sandy clay	Wet	5.56	4.95
47	12.5	DM22	Grey	Sandy clay	Wet	5.68	4.56
47	13.5	DM23	Grey	Sandy clay	Wet	5.54	4.36
47	14.5	DM24	Grey	Sandy clay	Wet	5.51	4.26
47	15.5	DM25	Red Grey	Sandy clay	Wet	5.57	4.44
47	16.5	DM26	Red Grey	Sandy clay	Wet	5.66	4.48
47	17.5	DM27	Red Grey	Sandy clay	Wet	5.53	4.61
48	0.5	DM28	Red	Sand		5.36	3.32
48	1.5	DM29	Brown	Clay sand		5.72	3.93
48	2.5	DM30	Yellow Brown	Clay sand	Gravels	6.08	4.63

48	3.5	DM31	Grey Brown	Sandy loam	Gravels	5.80	3.82
48	4.5	DM32	Red Brown	Sandy loam	Laterite	5.42	4.89
48	5.5	DM33	Grey Brown	Sandy loam	Piso's	5.35	4.24
48	6.5	DM34	Red Grey	Sandy clay	Piso's	5.14	4.78
48	7.5	DM35	Grey	Sandy clay	Wet	5.48	4.66
48	8.5	DM36	Grey	Sandy clay	Wet	5.31	4.63
48	9.5	DM37	Grey	Sandy clay	Wet	5.25	4.71
48	10.5	DM38	Grey	Sandy clay	Wet	5.46	4.87
48	11.5	DM39	Grey	Sandy clay	Wet	5.37	4.80
48	12.5	DM40	Grey	Sandy clay	Wet	5.79	4.75
48	13.5	DM41	Grey	Sandy clay	Wet	5.71	4.34
48	14.5	DM42	Grey Red	Sandy clay	Wet	5.65	4.75
48	15.5	DM43	Grey Red	Sandy clay	Wet	5.24	5.08
48	16.5	DM44	Grey Red	Sandy clay	Wet	5.17	5.05
48	17.5	DM45	Red Yellow	Sandy clay	Wet	5.09	4.56
48	18.5	DM46	Yellow	Sandy clay	Wet	5.41	4.58
48	19.5	DM47	Yellow	Sandy clay	Wet	5.42	4.64
48	20.5	DM48	Yellow	Sandy clay	Wet	5.39	3.53
48	21.5	DM49	Black	Sandy clay	Wet	5.64	2.38
48	22.5	DM50	Black	Sandy clay	Wet	5.58	3.28
48	23.5	DM51	Black	Sandy clay	EOH	5.77	3.92
49	0.5	DM52	Grey	Sand		6.05	3.53
49	1.5	DM53	Grey Red	Sand	Gravels	6.06	4.53
49	2.5	DM54	Red Brown	Sand	Gravels	5.82	4.80
49	3.5	DM55	Red Brown	Sandy loam		5.35	4.71
49	4.5	DM56	Red Brown	Sandy loam	Gravels	5.15	4.25
49	5.5	DM57	Red Grey	Sandy clay	Wet	4.85	4.23
49	6.5	DM58	Red Grey	Sandy clay	Wet	5.32	4.13
49	7.5	DM59	Red Grey	Sandy clay	Wet Piso's	5.22	4.00
49	8.5	DM60	Grey	Sandy clay	Wet	5.31	3.99
49	9.5	DM61	Grey Red	Sandy clay	Wet	5.02	4.52
49	10.5	DM62	Grey	Sandy clay	Wet Piso's	4.83	4.47
49	11.5	DM63	Grey	Sandy clay	Wet Piso's	4.82	4.39
49	12.5	DM64	Grey	Clay	Wet Piso's	5.09	4.38
49	13.5	DM65	Grey	Clay	Wet	5.05	4.40
49	14.5	DM66	Red	Clay	Wet	5.05	4.61
49	15.5	DM67	Grey	Clay	Wet	5.00	4.13
49	16.5	DM68	Grey	Clay	Wet Sediment	5.06	3.01
49	17.5	DM69	Black	Clay	Wet	5.33	2.22
49	18.5	DM70	Black	Clay	Wet	5.64	2.25
49	19.5	DM71	Black	Clay	Wet	5.35	3.62
49	20.5	DM72	Black	Clay	Wet	5.52	3.66
50	0.5	DM73	Grey	Sand		5.67	4.83
50	1.5	DM74	Grey	Sand		5.60	4.58

50	2.5	DM75	Red	Clay sand	Laterite	5.48	4.45
50	3.5	DM76	Red	Clay sand	Laterite	5.53	4.77
50	4.5	DM77	Red	Clay sand	Laterite	5.42	4.59
50	5.5	DM78	Red Grey	Sandy loam	Wet	5.28	4.28
50	6.5	DM79	Red Grey	Sandy clay	Wet Piso's	5.23	4.55
50	7.5	DM80	Red Grey	Sandy clay	Wet Piso's	5.18	4.40
50	8.5	DM81	Grey	Sandy clay	Wet Piso's	5.12	4.37
50	9.5	DM82	Grey	Sandy clay	Wet Gravels	5.33	4.25
50	10.5	DM83	Grey	Sandy clay	Wet	5.21	4.17
50	11.5	DM84	Red Grey	Sandy clay	Wet	5.21	4.27
50	12.5	DM85	Red Grey	Clay	Wet	5.15	4.20
50	13.5	DM86	Dark Red	Clay	Wet	5.19	4.42
50	14.5	DM87	Dark Red	Clay	Wet	5.26	4.41
50	15.5	DM88	Yellow Red	Sandy clay	Wet	4.52	3.03
50	16.5	DM89	Dark Grey	Clay	Wet	4.86	2.56
50	17.5	DM90	Dark Grey	Clay	Wet	5.10	2.83
51	0.5	DM206	Grey	Sand	Laterite	5.31	3.67
51	1.5	DM207	Red	Clay sand	Laterite	5.10	4.83
51	2.5	DM208	Red	Clay sand	Laterite	4.70	5.06
51	3.5	DM209	Red	Clay sand	Laterite	5.16	5.30
51	4.5	DM210	Red	Clay sand		5.07	5.01
51	5.5	DM211	Red	Sandy clay	Moist	5.10	4.82
51	6.5	DM212	Grey Red	Sandy clay	Wet	5.28	4.51
51	7.5	DM213	Grey Red	Sandy clay	Wet	5.27	4.60
51	8.5	DM214	Grey Red	Sandy clay	Wet	5.28	4.58
51	9.5	DM215	Grey Brown	Sandy clay	Wet	5.28	4.52
51	10.5	DM216	Grey Brown	Sandy clay	Wet	5.32	4.66
51	11.5	DM217	Red Brown	Sandy clay	Wet	5.33	4.59
51	12.5	DM218	Red Grey	Sandy clay	Wet	5.41	4.61
51	13.5	DM219	Red Grey	Sandy clay	Wet	5.39	4.41
51	14.5	DM220	Yellow Brown	Sandy clay	Wet	5.40	4.64
51	15.5	DM221	Yellow Brown	Sandy clay	Wet	5.33	4.44
51	16.5	DM222	Yellow Brown	Sandy clay	Wet	5.32	4.22
51	17.5	DM223	Yellow Brown	Sandy clay	Wet	5.41	4.39
51	18.5	DM224	Grey	Sandy clay	Wet	5.64	3.47
51	19.5	DM225	Grey	Clay	Wet	5.38	3.46
51	20.5	DM226	Grey	Clay	Wet	5.46	3.25
52	0.5	DM227	Light Grey	Sand		5.85	3.79
52	1.5	DM228	Light Grey	Sand		5.61	3.66
52	2.5	DM229	Red	Clay sand	Laterite	5.04	4.28
52	3.5	DM230	Grey Red	Sandy clay	Piso's	5.50	4.41
52	4.5	DM231	Red	Sandy loam	Wet Piso's	5.48	4.40
52	5.5	DM232	Red	Sandy clay	Wet Piso's	5.33	4.48
52	6.5	DM233	Grey Red	Sandy clay	Wet	5.15	4.35

52	7.5	DM234	Grey Red	Sandy clay	Wet	5.09	4.23
52	8.5	DM235	Grey	Sandy clay	Wet	5.05	4.25
52	9.5	DM236	Grey	Sandy clay	Wet	5.11	4.27
52	10.5	DM237	Grey	Sandy clay	Wet	5.17	4.42
52	11.5	DM238	Grey	Sandy loam	Wet	5.19	4.37
52	12.5	DM239	Grey	Clay	Wet	5.48	3.73
52	13.5	DM240	Grey Red	Sandy clay	Wet	5.41	4.69
52	14.5	DM241	Red	Sandy clay	Wet	5.34	5.13
52	15.5	DM242	Black	Clay	Wet	5.00	2.12
52	16.5	DM243	Black	Clay	Wet	5.22	2.82
52	17.5	DM244	Black	Clay	Wet	5.40	2.97
53	0.5	DM245	Grey	Sand		5.85	3.95
53	1.5	DM246	Grey	Clay sand		5.27	3.47
53	2.5	DM247	Grey	Clay sand	Piso's	5.85	4.04
53	3.5	DM248	Grey Red	Sandy loam	Wet	5.26	4.04
53	4.5	DM249	Grey Red	Sandy clay	Wet	5.31	4.46
53	5.5	DM250	Grey Red	Sandy clay	Wet	5.37	4.54
53	6.5	DM251	Red Brown	Sandy clay	Wet	5.42	4.03
53	7.5	DM252	Red	Sandy clay	Wet	5.36	4.30
53	8.5	DM253	Red Brown	Sandy clay	Wet	5.34	4.23
53	9.5	DM254	Red Brown	Sandy clay	Wet	5.34	4.54
53	10.5	DM255	Red Brown	Sandy clay	Wet	5.34	4.68
53	11.5	DM256	Red Brown	Sandy clay	Wet	5.33	4.70
53	12.5	DM257	Brown Red	Sandy clay	Wet	5.27	4.36
53	13.5	DM258	Yellow Red	Sandy clay	Wet	5.36	4.23
53	14.5	DM259	Yellow	Clay	Wet	5.32	4.47
53	15.5	DM260	Black	Clay	Wet	5.69	2.19
53	16.5	DM261	Black	Clay	Wet	5.94	3.06
53	17.5	DM262	Black	Clay	Wet	5.98	3.85
54	0.5	DM263	Grey Black	Sand		5.92	3.29
54	1.5	DM264	Grey Brown	Sand		5.65	4.20
54	2.5	DM265	Pale Grey	Sand		5.82	4.61
54	3.5	DM266	Grey	Sand		6.02	4.33
54	4.5	DM267	Grey Red	Clay sand	Laterite	5.73	4.83
54	5.5	DM268	Red Grey	Sandy loam	Laterite	5.50	4.59
54	6.5	DM269	Grey Red	Sandy clay		5.48	4.65
54	7.5	DM270	Grey	Sandy clay	Piso's	5.48	4.74
54	8.5	DM271	Grey	Sandy clay	Piso's	5.72	4.81
54	9.5	DM272	Grey	Sandy clay		5.85	4.64
54	10.5	DM273	Red	Sandy clay	Wet	5.74	4.81
54	11.5	DM274	Grey Red	Sandy clay	Wet	5.43	4.46
54	12.5	DM275	Grey Red	Sandy clay	Wet	5.34	4.25
54	13.5	DM276	Grey Red	Sandy clay	Wet	5.23	4.18
54	14.5	DM277	Red Grey	Sandy clay	Wet	5.24	4.20

54	15.5	DM278	Red Grey	Sandy clay	Wet	4.89	4.56
54	16.5	DM279	Red Grey	Sandy clay	Wet	4.88	4.54
54	17.5	DM280	Red Grey	Sandy clay	Wet	4.86	4.45
54	18.5	DM281	Yellow Grey	Sandy clay	Wet	5.07	3.93
54	19.5	DM282	Grey Yellow	Sandy clay	Wet	5.12	4.04
54	20.5	DM283	Dark Grey	Clay	Wet	4.83	3.06
55	0.5	DM286	Brown Yellow	Sand		5.51	3.89
55	1.5	DM287	Brown Yellow	Sand		5.48	4.91
55	2.5	DM288	Brown Yellow	Sand		5.59	5.07
55	3.5	DM289	Brown Yellow	Clay sand		6.01	4.99
55	4.5	DM290	Brown	Clay sand		6.00	4.83
55	5.5	DM291	Brown Grey	Clay sand		5.80	4.62
55	6.5	DM292	Grey	Sandy loam	Gravels	5.43	4.09
55	7.5	DM293	Grey	Sandy clay	Wet	5.45	4.67
55	8.5	DM294	Grey	Sandy clay	Wet	5.52	4.48
55	9.5	DM295	Grey	Sandy clay	Wet	5.89	4.77
55	10.5	DM296	Grey	Sandy clay	Wet	5.76	4.67
55	11.5	DM297	Grey	Sandy clay	Wet	5.62	4.56
55	12.5	DM298	Grey Red	Sandy clay	Wet	5.31	4.86
55	13.5	DM299	Grey Red	Sandy clay	Wet	5.28	4.85
55	14.5	DM300	Red Grey	Sandy clay	Wet	5.14	4.60
55	15.5	DM301	Dark Grey	Clay	Wet	5.32	4.03
55	16.5	DM302	Yellow Grey	Sandy clay	Wet	5.12	4.36
55	17.5	DM303	Yellow Grey	Sandy clay	Wet	5.01	4.20
55	18.5	DM304	Yellow Grey	Sandy clay	Wet /Gritty	5.14	4.21
55	19.5	DM305	Yellow Grey	Sandy clay	Wet	5.11	4.21
55	20.5	DM306	Yellow Grey	Sandy clay	Wet	5.17	4.26
56	0.5	19930	Red Brown	Clay sand	Gravels	6.01	4.79
56	1.5	19931	Red Brown	Clay sand	Gravels	6.15	5.76
56	2.5	19932	Grey Red	Clay sand	Gravels	5.86	4.83
56	3.5	19933	Red Grey	Sandy clay	Gravels	5.38	4.04
56	4.5	19934	Red Grey	Sandy clay		4.90	3.47
56	5.5	19935	Red Grey	Sandy clay		4.90	3.67
56	6.5	19936	Red Grey	Sandy clay	Wet	5.00	3.67
56	7.5	19937	Grey	Sandy clay	Wet	4.95	4.01
56	8.5	19938	Grey	Sandy clay	Wet	4.90	3.96
57	0.5	19939	Grey	Sand		4.70	3.50
57	1.5	19940	Red	Clay sand	Gravels	5.82	4.13
57	2.5	19941	Brown Red	Clay sand	Gravels	5.74	3.21
57	3.5	19942	Brown Red	Clay sand	Gravels	5.61	4.12
57	4.5	19943	Grey	Clay sand	Wet	5.27	3.52
57	5.5	19944	Grey Red	Sandy clay	Wet	4.76	3.75
57	6.5	19945	Red Grey	Sandy clay	Wet	4.74	3.12
57	7.5	19946	Yellow Grey	Sandy clay	Wet	4.64	3.79

57	8.5	19947	Grey Red	Sandy clay	Wet	4.63	3.85
57	9.5	19948	Grey Yellow	Sandy clay	Wet	4.57	3.72
57	10.5	19949	Grey Yellow	Sandy clay	Wet	4.64	3.72
57	11.5	19950	Grey Yellow	Sandy clay	Wet	4.68	3.87
57	12.5	19951	Grey	Sandy clay	Wet	5.80	4.00
57	13.5	19952	Grey	Sandy clay	Wet	4.45	3.68
57	14.5	19953	Grey	Sandy clay	Wet	4.48	3.84
57	15.5	19954	Red Grey	Sandy clay	Wet	4.70	3.67
57	16.5	19955	Red Grey	Sandy clay	Wet	4.71	3.87
57	17.5	19956	Grey	Sandy clay	Wet	4.84	3.97
58	0.5	19909	Brown Grey	Sandy loam		5.60	4.65
58	1.5	19910	Red	Clay sand	Gravels	5.85	5.81
58	2.5	19911	Red Brown	Clay sand	Gravels	5.68	6.03
58	3.5	19912	Red Grey	Sandy loam	Gravels	6.16	4.74
58	4.5	19913	Red Grey	Sandy clay	Wet	5.96	4.99
58	5.5	19914	Red Grey	Clay sand	Dry	6.06	5.05
58	6.5	19915	Red Grey	Sandy clay	Wet	5.86	4.78
58	7.5	19916	Red Brown	Sandy clay	Wet		
58	8.5	19917	Red Brown	Sandy clay	Wet	5.68	5.34
58	9.5	19918	Red Grey	Sandy clay	Wet	5.56	5.02
58	10.5	19919	Red Brown	Sandy clay	Wet	5.58	5.11
58	11.5	19920	Red Brown	Sandy clay	Wet	5.52	4.88
58	12.5	19921	Red Brown	Sandy clay	Wet	5.56	5.06
58	13.5	19922	Red Brown	Sandy clay	Wet	5.51	4.92
58	14.5	19923	Red Brown	Sandy clay	Wet	5.32	4.62
58	15.5	19924	Red Brown	Sandy clay	Wet	5.47	4.78
58	16.5	19925	Red Brown	Sandy clay	Wet	5.37	4.67
58	17.5	19926	Red Grey	Sandy clay	Wet	5.46	4.81
58	18.5	19927	Red Grey	Sandy clay	Wet	5.45	4.56
58	19.5	19928	Red Grey	Sandy clay	Wet	5.36	4.51
58	20.5	19929	Red Grey	Sandy clay	Wet	5.08	4.16
59	0.5	19894	Grey	Sand		5.47	3.14
59	1.5	19895	Red Brown	Clay sand	Laterite	5.08	5.07
59	2.5	19896	Red Brown	Clay sand	Laterite	5.45	5.38
59	3.5	19897	Red Brown	Sandy loam		5.62	4.23
59	4.5	19898	Grey Red	Sandy clay	Wet	4.85	3.97
59	5.5	19899	Grey Red	Sandy clay	Wet	4.52	3.82
59	6.5	19900	Red Brown	Sandy clay	Wet	4.58	3.67
59	7.5	19901	Red Grey	Sandy clay	Wet	4.55	3.76
59	8.5	19902	Red Grey	Sandy clay	Wet	4.51	3.79
59	9.5	19903	Red Grey	Sandy clay	Wet	4.45	3.81
59	10.5	19904	Red Grey	Sandy clay	Wet	4.36	3.90
59	11.5	19905	Red Grey	Sandy clay	Wet	4.29	4.06
59	12.5	19906	Grey Red	Sandy clay	Wet	4.68	3.81

59	13.5	19907	Grey	Sandy clay	Wet	5.26	4.69
59	14.5	19908	Red Grey	Sandy clay	Wet	5.43	4.77
60	0.5	19882	Grey	Sand		5.59	3.43
60	1.5	19883	Brown	Sand	Gravels	5.60	4.15
60	2.5	19884	Brown	Sand	Gravels	5.85	4.09
60	3.5	19885	Brown	Clay sand		5.82	4.58
60	4.5	19886	Grey Yellow	Sandy clay	Wet	5.59	4.67
60	5.5	19887	Grey Yellow	Sandy clay	Wet	5.28	4.53
60	6.5	19888	Grey Yellow	Sandy clay	Wet	5.42	4.62
60	7.5	19889	Red Grey	Sandy clay	Wet	5.34	4.44
60	8.5	19890	Red Brown	Sandy clay	Wet	5.23	4.42
60	9.5	19891	Red Brown	Sandy clay	Wet	5.10	4.61
60	10.5	19892	Red Brown	Sandy clay	Wet	5.20	4.68
60	11.5	19893	Grey Red	Sandy clay	Wet	5.22	4.60
61	0.5	19792	Yellow Brown	Sand		6.35	3.43
61	1.5	19793	Yellow Brown	Sand		6.53	4.20
61	2.5	19794	Grey Brown	Sand		6.18	4.48
61	3.5	19795	Red Grey	Sand	Gravels	6.24	4.57
61	4.5	19796	Red Grey	Clay sand	Gravels	5.82	4.73
61	5.5	19797	Grey	Clay sand	Gravels	5.38	4.52
61	6.5	19798	Grey	Sandy loam	Gravels	4.98	4.02
61	7.5	19799	Grey	Sandy clay	Piso's	5.12	4.39
61	8.5	19800	Grey	Sandy clay	Piso's	5.31	4.40
61	9.5	19801	Grey	Sandy clay	Wet	5.64	4.50
61	10.5	19802	Grey	Sandy clay	Wet	5.71	4.83
61	11.5	19803	Red Grey	Sandy clay	Wet	5.70	4.99
61	12.5	19804	Red Grey	Sandy clay	Wet	5.72	5.19
61	13.5	19805	Grey	Sandy clay	Wet	5.48	5.09
61	14.5	19806	Grey	Sandy clay	Wet	5.31	4.91
61	15.5	19807	Red Yellow	Sandy clay	Wet	5.42	4.69
61	16.5	19808	Red Yellow	Sandy clay	Wet	5.36	4.65
61	17.5	19809	Red Yellow	Sandy clay	Wet	5.40	4.63
61	18.5	19810	Red Yellow	Sandy clay	Wet	5.43	4.59
61	19.5	19811	Yellow	Sandy clay	Wet	5.34	2.50
61	20.5	19812	Black	Clay	Wet	5.57	3.48
62	0.5	19771	Grey	Sand		6.20	4.10
62	1.5	19772	Grey	Sand		6.25	5.39
62	2.5	19773	Grey	Sand		5.90	5.23
62	3.5	19774	Grey	Sandy loam	Piso's	6.27	4.27
62	4.5	19775	Grey	Sandy loam	Wet Piso's	5.96	4.46
62	5.5	19776	Grey	Sandy loam	Wet Piso's	6.20	4.47
62	6.5	19777	Grey	Sandy clay	Wet Piso's	5.68	4.42
62	7.5	19778	Grey	Sandy clay	Wet Piso's	5.80	4.15
62	8.5	19779	Grey	Sandy clay	Wet Piso's	5.67	4.42

62	9.5	19780	Red Grey	Sandy clay	Wet	5.50	4.77
62	10.5	19781	Red Grey	Sandy clay	Wet	5.38	4.77
62	11.5	19782	Red Grey	Sandy clay	Wet	5.36	4.68
62	12.5	19783	Yellow Brown	Sandy clay	Wet	5.37	4.60
62	13.5	19784	Yellow Brown	Sandy clay	Wet	5.36	4.58
62	14.5	19785	Yellow Brown	Sandy clay	Wet	5.33	4.57
62	15.5	19786	Grey	Sandy clay	Wet	5.34	3.34
62	16.5	19787	Red Yellow	Sandy clay	Wet	5.32	3.70
62	17.5	19788	Dark Grey	Clay	Wet	5.46	2.80
62	18.5	19789	Dark Grey	Clay	Wet	5.24	2.38
62	19.5	19790	Yellow Brown	Sandy clay	Wet	5.33	2.79
62	20.5	19791	Yellow Brown	Sandy clay	Wet	5.33	3.08
63	0.5	19754	Brown	Sand		6.50	3.95
63	1.5	19755	Brown	Sand		6.52	4.31
63	2.5	19756	Brown	Clay sand	Piso's	6.82	5.10
63	3.5	19757	Grey Brown	Sandy loam	Wet	5.69	4.24
63	4.5	19758	Grey Brown	Sandy loam	Wet	5.32	3.40
63	5.5	19759	Grey Brown	Sandy clay	Wet	5.43	4.99
63	6.5	19759	Red	Clay sand	Wet Laterite	5.43	4.99
63	7.5	19760	Red	Sandy loam	Wet	5.46	4.95
63	8.5	19761	Red	Sandy clay	Wet	5.50	4.82
63	9.5	19762	Grey Red	Sandy clay	Wet	5.09	4.74
63	10.5	19763	Red	Sandy clay	Wet	4.97	4.89
63	11.5	19764	Grey Red	Sandy clay	Wet	4.89	5.04
63	12.5	19765	Red Yellow	Sandy clay	Wet	5.36	4.83
63	13.5	19766	Black	Clay	Wet	5.35	4.51
63	14.5	19767	Black	Clay	Wet	5.44	2.69
63	15.5	19768	Black	Clay	Wet	5.68	2.44
63	16.5	19769	Black	Sandy clay	Wet	5.59	2.06
63	17.5	19770	Grey Red	Sandy clay	Wet	5.58	2.33
64	0.5	DM307	Brown Grey	Sand		8.20	7.01
64	1.5	DM308	Brown	Sand		8.05	6.77
64	2.5	DM309	Red	Clay sand	Laterite	7.85	7.79
64	3.5	DM310	Red	Sandy loam	Wet Laterite	6.82	6.56
64	4.5	DM311	Red	Sandy loam	Dry Laterite	5.61	5.24
64	5.5	DM312	Red	Sandy clay	Wet	5.68	5.33
64	6.5	DM313	Red	Sandy clay	Moist	5.49	4.87
64	7.5	DM314	Red	Sandy clay	Piso's	5.41	4.48
64	8.5	DM315	Red Grey	Sandy clay	Piso's	5.18	4.17
64	9.5	DM316	Grey	Sandy clay	Piso's	5.13	4.25
64	10.5	DM317	Red Grey	Sandy clay	Wet	5.08	4.33
64	11.5	DM318	Red Grey	Sandy clay	Wet	5.23	4.23
64	12.5	DM319	Red Grey	Sandy clay	Wet	5.20	4.14
64	13.5	DM320	Red Grey	Sandy clay	Wet	5.20	4.64

64	14.5	DM321	Dark Grey	Sandy clay	Wet	5.47	4.59
64	15.5	DM322	Dark Grey	Sandy clay	Wet	5.38	4.69
64	16.5	DM323	Dark Grey	Clay	Wet	5.48	3.72
64	17.5	DM324	Dark Grey	Clay	Wet	5.86	3.28
64	18.5	19751	Dark Grey	Clay	Wet	5.84	2.69
64	19.5	19752	Dark Grey	Clay	Wet	5.73	2.68
64	20.5	19753	Dark Grey	Clay	Wet	6.59	3.95
65	0.5	19813	Dark Brown	Sand		5.92	3.28
65	1.5	19814	Dark Brown	Sandy loam	Gravels	5.53	4.19
65	2.5	19815	Yellow Brown	Sandy clay	Moist	5.58	4.00
65	3.5	19816	Dark Brown	Sandy loam	Moist	5.47	3.66
65	4.5	19817	Dark Brown	Sandy loam	Moist	5.55	2.89
65	5.5	19818	Yellow Grey	Sandy clay	Wet	5.89	3.97
65	6.5	19819	Red	Sandy clay	Wet Coarse	5.43	3.56
65	7.5	19820	Red Yellow	Sandy clay	Wet	5.63	4.18
65	8.5	19821	Red Yellow	Sandy clay	Wet	5.71	4.12
65	9.5	19822	Grey	Sandy clay	Wet	5.49	4.45
65	10.5	19823	Grey	Sandy clay	Wet	5.33	4.85
65	11.5	19824	Grey Yellow	Sandy clay	Wet	5.28	5.03
65	12.5	19825	Red Grey	Sandy clay	Wet	5.39	4.55
65	13.5	19826	Black	Clay	Wet Gravels	5.18	2.56
65	14.5	19827	Black	Clay		5.41	2.08
65	16.5	19829	Black	Clay		5.58	2.97
65	17.5	19830	Black	Clay		5.73	3.25
66	0.5	19831	Grey	Clay sand	Wet	5.01	3.33
66	1.5	19832	Grey	Clay sand	Wet	5.43	3.10
66	2.5	19833	Grey	Clay sand	Wet	5.37	3.41
66	3.5	19834	Grey	Sandy clay	Wet Gravels	5.55	3.36
66	4.5	19835	Brown Grey	Sandy loam	Wet Gravels	5.77	3.98
66	5.5	19836	Brown Grey	Sandy clay	Wet	5.76	4.21
66	6.5	19837	Grey	Sandy clay	Wet	5.90	3.52
66	7.5	19838	Grey	Sandy clay	Wet	5.77	3.61
66	8.5	19839	Yellow Brown	Sandy clay	Wet	5.50	4.64
66	9.5	19840	Red	Sandy clay	Wet	5.03	4.30
66	10.5	19841	Red	Sandy clay	Wet	5.17	4.28
66	11.5	19842	Red Yellow	Sandy clay	Wet	5.24	4.14
66	12.5	19843	Grey	Sandy clay	Wet	5.28	2.00
66	13.5	19844	Dark Grey	Clay	Wet	5.23	2.26
66	14.5	19845	Dark Grey	Clay	Wet	5.54	2.99
67	0.5	19846	Grey	Sand		6.64	4.55
67	1.5	19847	Red	Clay sand	Piso's	5.04	4.05
67	2.5	19848	Red	Clay sand	Piso's	5.05	4.39
67	3.5	19849	Red Grey	Sandy loam		5.21	4.46
67	4.5	19850	Grey	Sandy clay	Moist	5.03	4.32

67	5.5	19851	Red Grey	Sandy clay	Wet	5.10	4.47
67	6.5	19852	Red Grey	Sandy clay	Wet	5.21	4.61
67	7.5	19853	Grey	Sandy clay	Wet	5.31	4.34
67	8.5	19854	Grey	Sandy clay	Wet	5.45	4.38
67	9.5	19855	Grey	Sandy clay	Wet	5.55	2.23
67	10.5	19856	Grey	Sandy clay	Wet	5.57	3.38
67	11.5	19857	Grey	Sandy clay	Wet	5.55	4.08
67	12.5	19858	Black	Clay	Wet	5.49	2.64
67	13.5	19859	Dark Grey	Clay	Wet	5.46	3.44
67	14.5	19860	Grey Brown	Sandy clay	Wet	5.65	4.02
68	0.5	19861	Red Grey	-	Laterite	5.19	3.18
68	1.5	19862	Brown	Sandy loam	Gravels	5.56	3.76
68	2.5	19863	Grey Brown	Sandy loam	Gravels	5.44	4.31
68	3.5	19864	Grey	Sandy clay	Piso's	5.43	3.80
68	4.5	19865	Grey	Sandy clay	Wet	4.82	3.55
68	5.5	19866	Grey	Sandy clay	Wet	4.73	2.96
68	6.5	19867	Grey	Sandy clay	Wet	5.05	3.60
68	7.5	19868	Grey	Sandy clay	Wet	4.87	3.71
68	8.5	19869	Grey	Sandy clay	Wet	4.86	3.86
68	9.5	19870	Grey Brown	Sandy clay	Wet	5.05	4.18
68	10.5	19871	Red	Sandy clay	Wet	5.12	4.36
68	11.5	19872	Red Brown	Sandy clay	Wet	5.13	4.37
68	12.5	19873	Red Brown	Sandy clay	Wet	5.24	4.38
68	13.5	19874	Red Brown	Sandy clay	Wet	5.25	4.33
68	14.5	19875	Red Brown	Sandy clay	Wet	5.51	4.69
68	15.5	19876	Red Brown	Sandy clay		5.57	4.77
68	16.5	19877	Grey Brown	Sandy clay		5.63	4.08
68	17.5	19878	Grey Brown	Sandy clay		5.66	4.52
68	18.5	19879	Grey Brown	Sandy clay		5.61	2.41
68	19.5	19880	Brown Grey	Sandy clay		5.77	3.59
68	20.5	19881	Brown Grey	Sandy clay		5.72	3.96
71	0.5	20306	Grey	Sand		6.12	4.11
71	1.5	20307	Brown	Sand		5.90	4.74
71	2.5	20308	Brown	Clay sand		5.84	4.52
71	3.5	20309	Grey	Sandy loam	Wet	5.84	3.69
71	4.5	20310	Grey	Sandy clay	Wet	5.42	3.69
71	5.5	20311	Grey	Sandy clay	Wet	4.90	3.65
71	6.5	20312	Grey	Sandy clay	Wet	5.00	4.13
71	7.5	20313	Red Grey	Sandy clay	Wet	4.98	4.38
71	8.5	20314	Red Grey	Sandy clay	Wet	4.99	4.41
71	9.5	20315	Red Grey	Sandy clay	Wet	5.25	4.60
71	10.5	20316	Red Grey	Sandy clay	Wet	5.25	4.67
71	11.5	20317	Red Grey	Sandy clay	Wet	5.25	4.66
71	12.5	20318	Red Yellow	Sandy clay	Wet	5.50	4.74

71	13.5	20319	Red Yellow	Sandy clay	Wet	5.53	4.95
71	14.5	20320	Yellow Grey	Sandy clay	Wet	5.45	5.05
71	15.5	20321	Red Yellow	Sandy clay	Wet	5.70	4.68
71	16.5	20322	Red Yellow	Sandy clay	Wet	5.69	4.79
71	17.5	20323	Grey	Clay	Wet	5.92	4.11
72	0.5	20285	Grey	Sand	Wet	6.13	3.71
72	1.5	20286	Brown Grey	Sand	Wet	5.94	4.59
72	2.5	20287	Grey Brown	Clay sand	Wet	5.67	4.20
72	3.5	20288	Grey Brown	Sandy clay	Wet	5.09	4.19
72	4.5	20289	Grey Brown	Sandy clay	Wet	5.13	3.98
72	5.5	20290	Grey	Sandy clay	Wet	5.38	4.36
72	6.5	20291	Grey	Sandy clay	Wet	5.38	4.48
72	7.5	20292	Grey	Sandy clay	Wet	5.44	4.54
72	8.5	20293	Grey	Sandy clay	Wet	5.56	4.52
72	9.5	20294	Grey	Sandy clay	Wet	5.45	4.64
72	10.5	20295	Grey	Sandy clay	Wet	5.55	4.83
72	11.5	20296	Grey	Sandy clay	Wet	5.61	4.81
72	12.5	20297	Red Brown	Sandy clay	Wet	5.58	4.84
72	13.5	20298	Red Brown	Sandy clay	Wet	5.50	4.71
72	14.5	20299	Red Brown	Sandy clay	Wet	5.50	4.74
72	15.5	20300	Red Grey	Sandy clay	Wet	5.65	4.94
72	16.5	20301	Red Brown	Sandy clay	Wet	5.76	4.66
72	17.5	20302	Red Brown	Sandy clay	Wet	5.70	4.83
72	18.5	20303	Red Brown	Sandy clay		5.78	4.81
72	19.5	20304	Grey	Clay		6.05	4.01
72	20.5	20305	Red Brown	Sandy clay		5.85	4.95
73	0.5	20261	Grey	Sand		6.02	3.48
73	1.5	20262	Grey Yellow	Sand	Gravels	5.91	4.24
73	2.5	20263	Red Yellow	Clay sand	Gravels	5.70	4.71
73	3.5	20264	Red	Sandy loam	Gravels	5.00	4.38
73	4.5	20265	Grey Red	Sandy loam		4.79	3.99
73	5.5	20266	Grey	Sandy clay	Wet	5.12	4.38
73	6.5	20267	Grey	Clay	Wet	5.08	4.13
73	7.5	20268	Grey	Clay	Wet	5.05	4.16
73	8.5	20269	Grey	Clay	Wet	5.07	4.17
73	9.5	20270	Grey	Clay	Wet	5.32	4.36
73	10.5	20271	Grey	Clay	Wet	5.44	4.44
73	11.5	20272	Grey	Sandy clay	Wet	5.49	4.60
73	12.5	20273	Red Brown	Sandy clay	Wet	5.49	4.85
73	13.5	20274	Red Brown	Sandy clay	Wet	5.48	4.62
73	14.5	20275	Grey	Clay	Wet	5.26	4.47
73	15.5	20276	Grey	Clay	Wet	5.19	4.32
73	16.5	20277	Grey Brown	Sandy loam	Wet	5.65	4.24
73	17.5	20278	Grey Brown	Sandy loam	Wet	5.47	4.43

73	18.5	20279	Red Grey	Sandy clay	Wet	5.73	4.89
73	19.5	20280	Red Grey	Sandy clay	Wet	5.79	4.98
73	20.5	20281	Red Grey	Sandy clay		5.76	4.97
73	21.5	20282	Yellow Grey	Sandy clay	Gravels	5.68	5.18
73	22.5	20283	Yellow Grey	Sandy clay	Gravels	5.69	5.29
73	23.5	20284	Yellow Red	Sandy clay	Wet	5.77	5.21
74	0.5	DM187	Grey	Sand		5.84	3.21
74	1.5	DM188	Grey	Sand		5.88	4.35
74	2.5	DM190	Black	Sand	Gravels	5.96	4.65
74	3.5	DM191	Grey	Sand	Gravels	5.80	4.40
74	4.5	DM192	Grey Yellow	Sand	Gravels	5.30	4.32
74	5.5	DM193	Red Grey	Sand	Piso's	5.25	4.14
74	6.5	DM194	Grey	Sandy clay	Moist	5.44	4.54
74	7.5	DM195	Grey	Sandy clay	Gravels	5.38	4.56
74	8.5	DM196	Red Brown	Sandy clay	Gravels	5.49	4.95
74	9.5	DM197	Grey	Sandy clay		5.52	4.51
74	10.5	DM198	Grey	Sandy clay	Wet	5.42	4.60
74	11.5	DM199	Grey	Sandy clay	Wet	5.58	4.78
74	12.5	DM200	Red Brown	Sandy clay	Wet	5.64	5.03
74	13.5	DM201	Red Grey	Sandy clay	Wet	5.71	4.97
74	14.5	DM202	Red Grey	Sandy clay	Wet	5.71	5.11
74	15.5	DM203	Red Brown	Sandy clay	Wet	5.62	4.56
74	16.5	DM204	Red Brown	Sandy clay	Wet	5.70	4.26
74	17.5	DM205	Grey Black	Clay	Wet	5.16	3.42
75	0.5	18944	Brown	Sand		5.93	3.79
75	1.5	18945	Brown	Sand		5.84	4.76
75	2.5	18946	Brown	Sand		5.89	4.99
75	3.5	18947	Brown	Clay sand		5.81	4.21
75	4.5	18948	Brown	Sandy loam		5.76	4.95
75	5.5	18949	Brown	Sandy loam	Gravels	5.78	4.57
75	6.5	18950	Red Brown	Sandy loam	Gravels	5.74	4.43
75	7.5	18951	Red Brown	Sandy loam	Gravels	5.75	4.00
75	8.5	18952	Red Brown	Sandy loam	Gravels	5.75	4.00
75	9.5	18953	Grey	Sandy clay	Piso's	5.93	4.53
75	10.5	18954	Grey	Sandy clay	Piso's	5.97	4.79
75	11.5	18955	Grey	Sandy clay	Piso's	5.57	4.77
75	12.5	18956	Grey	Clay sand	Coarse	5.99	5.25
75	13.5	18957	Grey	Sandy clay		6.00	5.42
75	14.5	18958	Red Grey	Sandy clay	Moist	5.97	4.81
75	15.5	18959	Grey Red	Clay	Heavy	5.90	4.74
75	16.5	18960	Grey Red	Clay	Wet	5.60	4.24
75	17.5	18961	Black	Clay	Wet	5.50	4.24
76	0.5	18255	Dark Grey	Sand	Some Gravel	5.23	2.93
76	1.5	18256	Dark Grey	Clay sand	Some Gravel	5.63	4.69

76	2.5	18257	Yellow Grey	Clay sand	Dry	5.68	5.59
76	3.5	18258	Yellow	Sandy clay	Dry		
76	4.5	18259	Yellow	Sandy loam	Dry	5.51	5.57
76	5.5	18260	Yellow Brown	Sandy loam	Dry	5.32	4.95
76	6.5	18261	Yellow Brown	Sandy loam	Dry	5.25	4.99
76	7.5	18262	Red	Sandy loam	Dry	5.18	4.61
76	8.5	18263	Red	Sandy loam	Dry	5.12	4.61
76	9.5	18264	Red	Sandy clay	Wet	5.38	4.89
76	10.5	18265	Light Grey	Sandy clay	Wet	5.37	4.75
76	11.5	18266	Light Grey	Sandy clay	Pisolith	5.38	4.69
76	12.5	18267	Light Grey	Sandy clay	Pisolith	5.35	4.73
76	13.5	18268	Light Grey	Sandy clay	Pisolith	5.40	4.60
76	14.5	18269	Light Grey	Sandy clay	Pisolith	5.39	4.51
76	15.5	18270	Light Grey	Sandy clay	Pisolith	5.56	4.97
76	16.5	18271	Light Grey	Sandy clay	Pisolith	5.74	5.16
76	17.5	18272	Light Grey	Sandy clay	Pisolith	5.61	5.22
76	18.5	18273	Red	Sandy clay	Pisolith	5.85	5.38
76	19.5	18274	Black	Clay	Pisolith	5.12	2.12
76	20.5	18275	Black	Clay	Pisolith	5.41	2.24
76	21.5	18276	Black	Clay	Pisolith	5.67	3.34
76	22.5	18277	Black	Clay	Pisolith	5.72	3.21
76	23.5	18278	Black	Clay	EOH	5.63	2.76
77	0.5	17883	Yellow Grey	Sand	Dry	6.06	3.02
77	1.5	17884	Yellow	Sandy clay	Wet	6.11	5.20
77	2.5	17885	Yellow	Sandy clay	Wet	6.19	5.55
77	3.5	17886	Yellow	Sandy clay	Dry	6.00	5.64
77	4.5	17887	Yellow	Sandy clay	Gravels	5.51	5.19
77	5.5	17888	Red Yellow	Sandy clay	Gravels	5.47	5.00
77	6.5	17889	Red	Sandy clay	Gravels	5.44	4.68
77	7.5	17890	Red	Sand	Dry	5.43	4.73
77	8.5	17891	Light Grey	Sand	Dry	5.49	4.71
77	9.5	17892	Light Grey	Sandy clay	Dry	5.51	4.82
77	10.5	17893	Light Grey	Sandy clay	Pisoliths	5.52	4.77
77	11.5	17894	Light Grey	Sand	Dry	5.56	4.97
77	12.5	17895	Light Grey	Sand	Dry	6.05	5.76
77	13.5	17896	Grey Red	Sand	Dry	5.98	5.09
77	14.5	17897	Dark Red	Clay Sand	Dry	5.72	4.95
77	15.5	17898	Dark Red	Clay Sand	Wet	5.58	4.96
77	16.5	17899	Red	Sandy clay	Wet	5.47	4.86
77	17.5	17900	Red Grey	Sandy clay	Mottled	5.51	4.78
77	18.5	18252	Red	Sandy clay	Mottled	5.71	4.79
77	19.5	18253	Brown Red	Sandy loam	Mottled	5.83	5.03
77	20.5	18254	Yellow Red	Sandy clay	EOH	5.86	4.76
78	0.5	17862	Dark Grey	Sand	Dry	5.40	2.02

78	1.5	17863	Grey	Clay sand	Dry	4.64	4.13
78	2.5	17864	Grey	Clay sand	Dry	5.65	4.64
78	3.5	17865	Yellow Grey	Clay sand	Dry	5.63	4.38
78	4.5	17866	Red Grey	Clay sand	Dry	5.54	4.69
78	5.5	17867	Red	Clay sand	Dry	5.40	5.14
78	6.5	17868	Red	Clay sand	Dry	5.41	4.83
78	7.5	17869	Red Grey	Clay sand	Dry	5.30	4.77
78	8.5	17870	Red	Sandy loam	Dry	5.27	4.73
78	9.5	17871	Red	Clay	Wet	5.38	4.52
78	10.5	17872	Red Brown	Clay	Wet	5.53	4.68
78	11.5	17873	Red Grey	Sandy clay	Wet	5.62	4.94
78	12.5	17874	Red	Sandy clay	Dry	5.76	5.33
78	13.5	17875	Red	Sand	Dry	5.58	5.39
78	14.5	17876	Yellow	Sandy clay	Groundwater	5.61	4.76
78	15.5	17877	Yellow	Sandy clay	Groundwater	5.85	5.13
78	16.5	17878	Yellow	Sandy clay	Groundwater	5.94	5.33
78	17.5	17879	Yellow	Sandy clay	Groundwater	6.02	5.19
78	18.5	17880	Yellow	Sandy clay	Groundwater	5.71	4.32
78	19.5	17881	Yellow	Sandy clay	Groundwater	5.86	5.09
78	20.5	17882	Yellow	Sandy clay	EOH	5.78	4.43
80	0.5	18351	Black	Sand		5.73	3.01
80	1.5	18352	Yellow Black	Sandy loam	Gravels	6.16	3.48
80	2.5	18353	Yellow Black	Sandy loam	Gravels	6.17	3.07
80	3.5	18354	Light Grey	Sandy clay		5.90	3.73
80	4.5	18355	Red Brown	Sandy clay	Gravels	5.56	4.23
80	5.5	18356	Red Brown	Sandy clay	Gravels	5.76	4.80
80	6.5	18357	Brown	Sandy clay	Gravels	5.51	4.75
80	7.5	18358	Brown	Sandy clay		5.70	4.89
80	8.5	18359	Light Grey	Sandy clay	Wet	5.92	4.97
80	9.5	18360	Yellow Brown	Sandy clay	Wet	5.54	4.72
80	10.5	18361	Yellow Red	Sandy clay	Wet	5.74	4.78
80	11.5	18362	Yellow Red	Sandy clay	Wet	5.73	4.35
80	12.5	18363	Light Red	Clay	Wet	5.30	4.26
80	13.5	18364	Yellow	Clay	Wet	5.34	4.46
80	14.5	18365	Light Grey	Clay	Wet	5.46	4.77
80	15.5	18366	Red Yellow	Sandy clay	Wet	5.87	4.91
80	16.5	18367	Red Yellow	Sandy clay	Wet	5.86	4.95
80	17.5	18368	Black	Sandy clay	Wet	5.84	3.19
80	18.5	18369	Black	Sandy clay	Wet	5.68	2.69
80	19.5	18370	Dark Grey	Sandy clay	Wet	5.82	2.29
80	20.5	18371	Dark Grey	Sandy clay	Wet	6.07	2.92
80	21.5	18372	Black	Clay	Wet	5.80	2.87
80	22.5	18373	Dark Grey	Clay	Wet	5.90	2.54
80	23.5	18374	Dark Grey	Clay	EOH	5.81	2.10

81	0.5	18473	Black	Sand		5.48	2.84
81	1.5	18474	Black	Clay sand		5.25	3.61
81	2.5	18475	Dark Red	Clay sand		5.61	4.29
81	3.5	18476	Red Brown	Sandy loam		5.56	4.17
81	4.5	18477	Red Brown	Sandy loam		5.64	4.10
81	5.5	18478	Red Brown	Sandy loam		5.81	4.90
81	6.5	18479	Red Brown	Clay sand	Dry	5.92	4.76
81	7.5	18480	Grey Red	Sandy loam	Piso	5.97	4.79
81	8.5	18481	Grey Red	Sandy loam	Wet	6.33	4.64
81	9.5	18482	Red Grey	Sandy clay	Wet	5.99	4.72
81	10.5	18483	Red Brown	Sandy clay	Wet	6.08	4.61
81	11.5	18484	Light Red	Sandy clay	Wet	5.99	4.75
81	12.5	18485	Light Red	Sandy clay	Wet	6.17	4.65
81	13.5	18486	Light Red	Sandy clay	Wet	6.20	4.97
81	14.5	18487	Light Red	Sandy clay	Wet	6.36	5.07
81	15.5	18488	Light Red	Sandy clay	Wet	6.27	5.35
81	16.5	18489	Grey Red	Sandy clay	Wet	6.26	4.87
81	17.5	18490	Grey Red	Sandy clay	Wet	6.33	5.03
81	18.5	18491	Black	Sandy clay	Wet	6.21	4.76
81	19.5	18492	Black	Sandy clay	Wet	5.36	2.74
81	20.5	18493	Dark Grey	Sandy clay	Wet	5.92	3.42
81	21.5	18494	Dark Grey	Sandy clay	Wet	6.04	3.67
81	22.5	18495	Dark Grey	Sandy clay	Wet	5.36	3.65
81	23.5	18496	Dark Grey	Sandy clay	Wet	5.67	3.85
82	0.5	18425	Grey	Sand		5.69	2.58
82	1.5	18426	Grey	Clay sand		5.26	2.94
82	2.5	18427	Grey Red	Clay sand	Gravels	5.54	3.82
82	3.5	18428	Grey Red	Sandy loam		5.68	5.22
82	4.5	18429	Grey Red	Sandy loam	Pedsols	5.68	4.75
82	5.5	18430	Red	Sandy loam	Pedsols	5.68	4.88
82	6.5	18431	Grey Red	Sandy loam	Pedsols	5.63	4.15
82	7.5	18432	Grey Red	Sandy clay	Pedsols	5.85	5.00
82	8.5	18433	Grey Red	Sandy clay	Pedsols	6.04	5.18
82	9.5	18434	Red Brown	Sandy clay		5.78	5.48
82	10.5	18435	Red Brown	Sandy clay		5.78	4.99
82	11.5	18436	Red Brown	Sandy clay	Moist	5.90	4.11
82	12.5	18437	Red Brown	Sandy clay	Wet	5.91	4.98
82	13.5	18438	Red Brown	Sandy clay	Wet	5.86	5.16
82	14.5	18439	Red Brown	Sandy clay	Wet	5.87	5.26
82	15.5	18440	Dark Brown	Sandy clay	Wet	5.80	4.52
82	16.5	18441	Dark Brown	Sandy clay	Wet	5.78	1.99
82	17.5	18442	Dark Brown	Sandy clay	Wet	6.01	2.51
82	18.5	18443	Grey	Sandy clay	Wet	5.82	4.29
82	19.5	18444	Dark Grey	Sandy clay	Wet	5.75	2.93

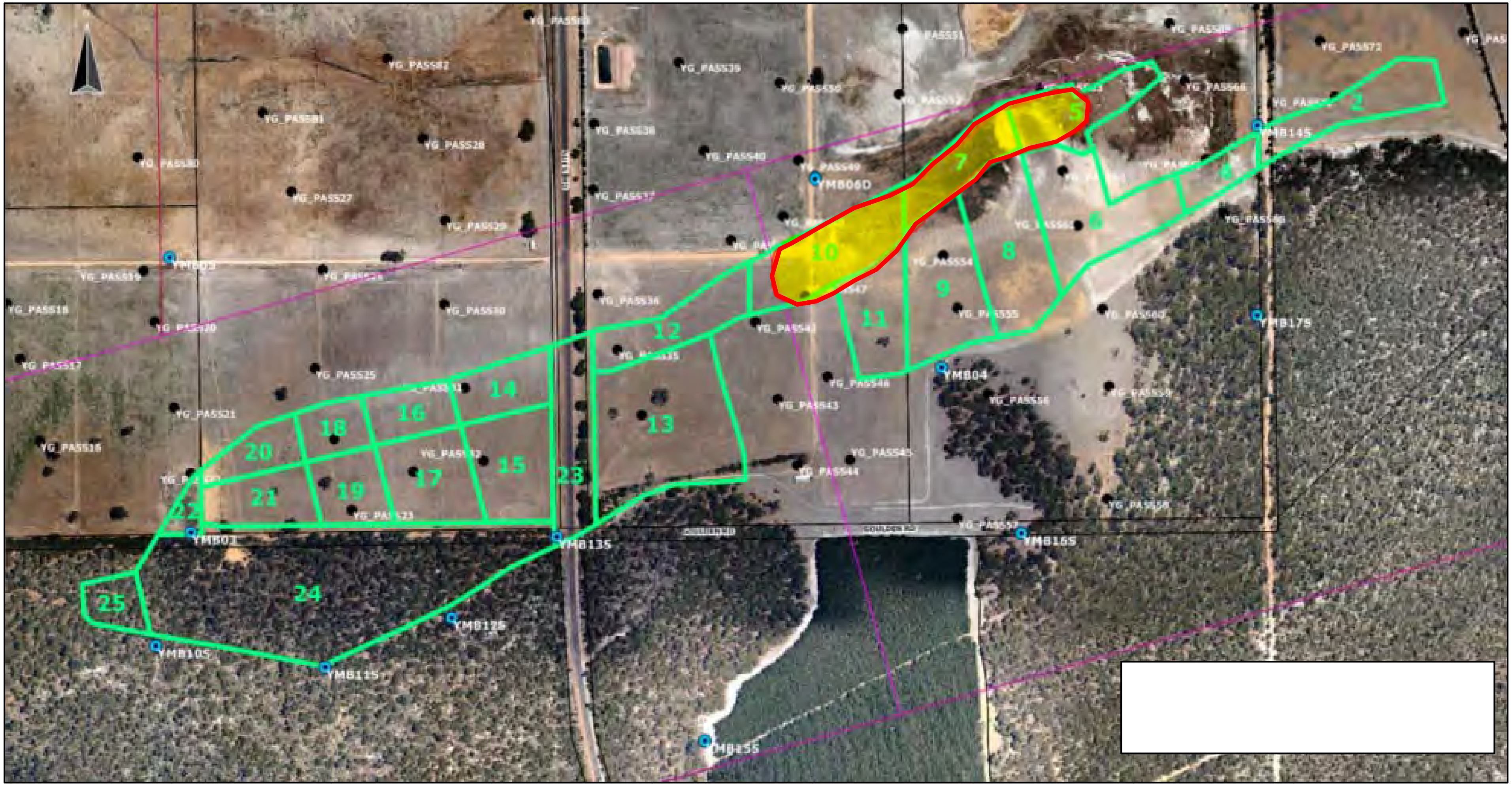
82	20.5	18445	Dark Grey	Sandy clay	Wet	5.67	3.12
82	21.5	18446	Black	Sandy clay	Wet	5.85	3.63
82	22.5	18447	Black	Sandy clay	Wet	5.94	3.79
82	23.5	18448	Yellow Grey	Sandy clay	EOH	5.75	2.34
83	0.5	18497	Black	Clay sand		6.17	2.84
83	1.5	18498	Grey	Sand		5.51	2.92
83	2.5	18499	Dark Red	Sandy clay		5.74	3.45
83	3.5	18500	Light Grey/Red	Sandy clay		5.78	4.10
83	4.5	18751	Dark Red	Sandy clay	pisos	5.63	4.32
83	5.5	18752	Dark Red	Sandy clay	Gravels	5.62	4.38
83	6.5	18753	Dark Red	Sandy clay		5.45	4.71
83	7.5	18754	Dark Red	Sandy clay		5.44	4.82
83	8.5	18755	Light Grey/Red	Sandy clay		5.36	4.75
83	9.5	18756	Grey Red	Sandy clay	Wet	5.40	4.63
83	10.5	18757	Light Grey	Sandy clay	Wet	5.31	4.64
83	11.5	18758	Red	Sandy clay	Wet	5.32	4.81
83	12.5	18759	Yellow Red	Sandy clay	Wet	5.57	5.07
83	13.5	18760	Yellow Red	Sandy clay	Wet	5.60	4.99
83	14.5	18761	Red	Sandy clay	Wet	5.57	4.80
83	15.5	18762	Light Red	Sandy clay	Wet	5.64	4.46
83	16.5	18763	Light Red	Sandy clay	Wet	5.63	4.51
83	17.5	18764	Light Red	Sandy clay	Wet	6.76	4.68
83	18.5	18765	Grey	Sandy clay	Wet	5.44	2.70
83	19.5	18766	Grey	Sandy clay	Wet	5.47	2.87
83	20.5	18767	Grey	Sandy clay	Wet	5.47	2.74
83	21.5	18768	Black	Clay	Wet	5.49	2.25
83	22.5	18769	Black	Clay	Wet	5.49	3.14
83	23.5	18770	Black	Clay	EOH	5.58	2.47
84	0.5	19327	Grey	Sand		6.13	3.23
84	1.5	19328	Grey	Sandy loam		5.33	3.85
84	2.5	19329	Grey	Sandy loam		5.65	3.69
84	3.5	19330	Red Grey	Sandy clay	Piso's	5.33	4.63
84	4.5	19331	Red Grey	Sandy clay	Wet	5.22	4.63
84	5.5	19332	Grey	Sandy clay	Wet	5.26	4.66
84	6.5	19333	Grey	Sandy clay	Wet	5.23	4.45
84	7.5	19334	Grey	Sandy clay	Wet	5.17	4.57
84	8.5	19335	Grey	Sandy clay	Wet	5.25	4.63
84	9.5	19336	Grey	Sandy clay	Wet	5.47	4.81
84	10.5	19337	Grey	Sandy clay	Wet	5.85	4.80
84	11.5	19338	Grey	Sandy clay	Wet	5.85	4.79
84	12.5	19339	Yellow Grey	Sandy clay	Wet	5.54	4.97
84	13.5	19340	Yellow Grey	Sandy clay	Wet	5.05	4.89
84	14.5	19341	Yellow Grey	Sandy clay	Wet	5.47	4.84
84	15.5	19342	Brown Yellow	Sandy clay	Wet	5.52	4.62

84	16.5	19343	Brown Yellow	Sandy clay	Wet	5.53	4.70
84	17.5	19344	Brown Yellow	Sandy clay	Wet	5.56	4.96
84	18.5	19345	Black	Sandy clay	Wet	5.19	2.68
84	19.5	19346	Black	Sandy clay	Wet	5.51	3.05
84	20.5	19347	Black	Sandy clay	Wet	5.76	2.18
85	0.5	DM91	Grey	Sand		6.34	3.26
85	1.5	DM92	Grey Brown	Sand	Gravels	6.07	4.06
85	2.5	DM93	Grey Brown	Sand	Gravels	5.97	4.06
85	3.5	DM94	Red	Sand	Laterite	5.72	4.70
85	4.5	DM95	Red	Loamy sand	Laterite	5.60	4.76
85	5.5	DM96	Red Brown	Loamy sand	Gravels	5.54	4.57
85	6.5	DM97	Red Brown	Sandy clay	Moist piso's	5.48	4.77
85	7.5	DM98	Red Brown	Sandy clay	Moist piso's	5.50	4.70
85	8.5	DM99	Red Grey	Sandy clay	Moist piso's	5.51	4.66
85	9.5	DM100	Grey	Sandy clay	Moist	5.56	4.69
85	10.5	DM101	Red Grey	Sandy clay	Wet	5.53	4.83
85	11.5	DM102	Red Grey	Sandy clay	Wet	5.57	4.92
85	12.5	DM103	Red Grey	Sandy clay	Wet	5.92	4.90
85	13.5	DM104	Red Grey	Sandy clay	Gravels	5.77	5.03
85	14.5	DM105	Red Grey	Sandy clay	Wet	5.54	5.09
85	15.5	DM106	Red Brown	Clay sand	Wet	5.15	2.94
85	16.5	DM107	Black	Clay	Wet	5.31	2.08
85	17.5	DM108	Black	Clay	Wet	5.40	2.74
86	0.5	DM109	Grey	Clay sand		5.97	3.41
86	1.5	DM110	Grey	Sandy loam		5.91	4.30
86	2.5	DM111	Grey Black	Sandy loam		6.38	3.97
86	3.5	DM112	Grey Yellow	Sandy clay		5.85	4.09
86	4.5	DM113	Grey Red	Sandy clay	Piso's	5.72	5.10
86	5.5	DM114	Grey Red	Sandy clay	Wet	5.64	5.02
86	6.5	DM115	Red Brown	Sandy clay	Wet Gravels	5.60	5.15
86	7.5	DM116	Red Brown	Sandy clay	Wet Gravels	5.58	4.96
86	8.5	DM117	Grey	Sandy clay	Wet	5.64	4.66
86	9.5	DM118	Grey	Sandy clay	Wet	5.55	4.83
86	10.5	DM119	Grey	Sandy clay	Wet	5.62	4.62
86	11.5	DM120	Grey Red	Sandy clay	Wet Gravels	5.62	4.94
86	12.5	DM121	Red Grey	Sandy clay	Wet	5.71	4.91
86	13.5	DM122	Red Grey	Sandy clay	Wet	5.86	4.95
86	14.5	DM123	Red Grey	Sandy clay	Wet	5.78	5.05
86	15.5	DM124	Grey	Sandy clay	Wet	5.79	5.30
86	16.5	DM125	Black	Clay	Wet	5.78	5.18
86	17.5	DM126	Black	Clay	Wet	5.68	3.00
86	18.5	DM127	Black	Clay	Wet	5.69	3.13
86	20.5	DM129	Black	Clay	Wet	5.88	3.17
87	0.5	DM130	Grey	Sand		6.33	3.72

87	1.5	DM131	Grey	Sand	Gravels	6.12	4.62
87	2.5	DM132	Grey	Sand	Gravels	5.87	4.64
87	3.5	DM133	Grey Red	Sand	Gravels	5.86	4.94
87	4.5	DM134	Red	Clay sand	Laterite	5.78	5.38
87	5.5	DM135	Red	Clay sand	Laterite	5.74	5.04
87	6.5	DM136	Red Grey	Sandy loam	Moist	5.48	5.07
87	7.5	DM137	Red Grey	Sandy clay	Wet Gravels	5.48	5.09
87	8.5	DM138	Red Grey	Sandy clay	Wet Gravels	5.52	4.97
87	9.5	DM139	Grey	Sandy clay	Wet Gravels	5.67	5.94
87	10.5	DM140	Grey	Sandy clay	Wet Gravels	5.60	4.81
87	11.5	DM141	Grey	Sandy clay	Wet	5.59	4.87
87	12.5	DM142	Red Grey	Sandy clay	Wet	5.55	4.63
87	13.5	DM143	Grey	Sandy clay	Wet	6.39	3.63
87	14.5	DM144	Yellow Red Grey	Sandy clay	Wet	5.32	4.05
87	15.5	DM145	Grey Red Yellow	Sandy clay	Wet	5.68	4.66
87	16.5	DM146	Red Yellow	Sandy clay	Wet	5.81	4.61
87	17.5	DM147	Yellow	Clay sand	Wet	5.74	4.86
87	18.5	DM148	Red	Clay sand	Wet	5.76	4.99
87	19.5	DM149	Red	Sandy loam	Wet	5.72	5.36
87	20.5	DM150	Red	Sandy loam	Wet	5.82	4.59
87	21.5	DM151	Red	Sandy clay	Wet	5.79	3.63
87	22.5	DM152	Red	Sandy clay	Wet	5.74	4.34
87	23.5	DM153	Red	Sandy clay	Wet	5.82	3.91
88	0.5	DM154	Grey	Sand		5.93	3.71
88	1.5	DM155	Grey	Sand	Gravels	5.65	4.65
88	2.5	DM156	Grey	Sand	Gravels	5.85	4.34
88	3.5	DM157	Red Grey	Clay sand	Gravels	5.58	4.93
88	4.5	DM158	Red Grey	Sandy loam	Piso's	5.67	5.06
88	5.5	DM159	Red Grey	Sandy loam	Piso's	5.70	4.99
88	6.5	DM160	Grey	Sandy clay	Wet	5.69	5.00
88	7.5	DM170	Red Grey	Sandy clay	Wet	5.61	5.20
88	8.5	DM171	Red Grey	Sandy clay	Wet	5.59	5.31
88	9.5	DM172	Grey	Sandy clay	Wet	5.69	5.11
88	10.5	DM173	Grey	Sandy clay	Wet	5.69	5.00
88	11.5	DM174	Grey	Sandy clay	Wet	5.68	4.90
88	12.5	DM175	Grey	Sandy clay	Wet	5.74	4.98
88	13.5	DM176	Grey	Sandy clay	Wet	5.70	4.97
88	14.5	DM177	Grey	Sandy clay	Wet	5.75	4.99
88	15.5	DM178	Grey	Sandy clay	Wet	5.75	4.94
88	16.5	DM179	Grey	Sandy clay	Wet	5.83	5.02
88	17.5	DM180	Grey	Sandy clay	Wet	5.79	4.83
88	18.5	DM181	Grey	Sandy clay	Wet	5.75	5.01
88	19.5	DM182	Grey Black	Clay	Wet	5.11	3.73
88	20.5	DM183	Grey Black	Clay	Wet	5.13	3.43

88	21.5	DM184	Dark Grey Black	Clay	Wet	5.75	2.79
88	22.5	DM185	Dark Grey	Clay	Wet	5.86	3.34
88	23.5	DM186	Dark Grey	Clay	Wet	6.17	3.06
89	0.5	19957	Grey	Sand		5.76	3.80
89	1.5	19958	Grey	Clay sand	Gravels	5.82	4.02
89	2.5	19959	Grey Brown	Clay sand	Wet	5.75	4.82
89	3.5	19960	Grey Brown	Sandy loam	Wet	5.82	4.98
89	4.5	19961	Red Brown	Sandy loam	Wet	5.69	4.36
89	5.5	19962	Red	Sandy loam	Wet	5.68	4.89
89	6.5	19963	Red Grey	Sandy clay	Wet	5.53	4.76
89	7.5	19964	Red Grey	Sandy clay	Wet	5.52	4.52
89	8.5	19965	Red Grey	Sandy clay	Wet	5.43	4.63
89	9.5	19966	Red Grey	Sandy clay	Wet	5.64	4.48
89	10.5	19967	Red Grey	Sandy clay	Wet	5.58	4.78
89	11.5	19968	Grey	Sandy clay	Wet	5.63	4.29
89	12.5	19969	Grey	Clay	Wet	5.65	4.47
89	13.5	19970	Grey	Clay	Wet	5.53	4.41
89	14.5	19971	Grey	Clay	Wet	5.54	4.43
89	15.5	19972	Grey	Clay	Wet	5.48	4.66
89	16.5	19973	Grey	Clay	Wet	5.49	4.73
89	17.5	19974	Grey Red	Sandy clay	Wet	5.47	4.70
89	18.5	19975	Red Grey	Sandy clay	Wet	5.53	4.73
89	19.5	19976	Red Grey	Sandy clay	Wet	5.68	5.48
89	20.5	19977	Red Yellow	Sandy clay	Wet	4.67	5.58
89	21.5	19978	Red Yellow	Sandy clay	Wet	6.01	4.41
89	22.5	19979	Yellow Grey	Sandy clay	Wet	6.06	5.48
89	23.5	19980	Yellow Grey	Sandy clay	Wet	6.05	5.29
89	24.5	19981	Yellow Grey	Sandy clay	Wet	6.13	5.37
89	25.5	19982	Grey	Sandy clay	Wet	6.13	5.24
89	26.5	19983	Grey	Sandy clay	Wet	6.21	5.33
89	27.5	19984	Grey	Sandy clay	Wet	6.10	5.34
89	28.5	19985	Dark Grey	Clay	Wet	5.75	2.66
89	29.5	19986	Dark Grey	Clay	EOH	5.73	3.34
90	0.5	19987	Grey	Sand	Gravels	6.40	4.53
90	1.5	19988	Yellow Brown	Clay sand	Gravels	6.27	4.82
90	2.5	19989	Grey	Clay sand	Gravels	6.47	4.11
90	3.5	19990	Grey Yellow	Sandy loam		5.76	5.35
90	4.5	19991	Red	Sandy loam	Laterite	5.62	5.54
90	5.5	19992	Red	Sandy loam	Laterite	5.57	5.14
90	6.5	19993	Red Grey	Sandy clay		5.54	4.41
90	7.5	19994	Grey	Sandy clay	Wet	5.44	4.49
90	8.5	19995	Grey	Sandy clay	Wet	5.49	4.41
90	9.5	19996	Grey	Sandy clay	Wet	5.38	4.60
90	10.5	19997	Grey	Sandy clay	Wet	5.37	4.59

90	11.5	19998	Grey	Sandy clay	Wet	5.42	4.68
90	12.5	19999	Grey	Sandy clay	Wet	5.55	4.72
90	13.5	20000	Grey	Sandy clay	Wet	5.54	4.90
90	14.5	20251	Grey	Sandy clay	Wet	5.57	4.77
90	15.5	20252	Red Grey	Sandy clay	Wet	5.52	5.01
90	16.5	20253	Grey	Clay	Wet	5.66	4.89
90	17.5	20254	Grey	Clay	Wet	5.74	4.86
90	18.5	20255	Grey Brown	Sandy clay	Wet	5.82	5.25
90	19.5	20256	Grey Brown	Sandy clay	Wet	5.82	4.89
90	20.5	20257	Red Grey	Sandy clay	Wet	5.80	4.91
90	21.5	20258	Yellow Red	Sandy clay	Wet	5.74	5.08
90	22.5	20259	Yellow Red	Sandy clay	Wet	5.81	5.17
90	23.5	20260	Yellow Red	Sandy clay	Wet	5.85	5.14
91	0.5	20324	Brown Grey	Sand	Gravels	6.16	4.42
91	1.5	20325	Grey Brown	Sand	Gravels	5.97	5.36
91	2.5	20326	Grey Brown	Clay sand	Gravels	5.62	5.23
91	3.5	20327	Red Grey	Sandy loam	Gravels	5.20	4.04
91	4.5	20328	Red Grey	Sandy clay	Gravels	5.26	4.32
91	5.5	20329	Red	Sandy clay	Wet	5.08	4.69
91	6.5	20330	Red	Sandy clay	Wet	5.33	4.48
91	7.5	20331	Red Grey	Sandy clay	Wet	5.26	4.56
91	8.5	20332	Grey	Clay	Wet	5.39	4.59
91	9.5	20333	Grey	Clay	Wet	5.52	4.70
91	10.5	20334	Grey	Clay	Wet	5.67	4.73
91	11.5	20335	Grey	Clay	Wet	5.62	4.92
91	12.5	20336	Grey Red	Sandy clay	Wet	5.63	4.98
91	13.5	20337	Grey Red	Sandy clay	Wet	5.63	4.98
91	14.5	20338	Grey Red	Sandy clay	Wet	5.61	4.96
91	15.5	20339	Red Grey	Sandy clay	Wet	5.41	4.31
91	16.5	20340	Red Grey	Sandy clay	Wet	5.45	4.31
91	17.5	20341	Red Grey	Sandy clay	Wet	5.50	4.22
91	18.5	20342	Red Brown	Sandy clay	Wet	5.67	4.71
91	19.5	20343	Red Yellow	Sandy clay	Wet	5.70	4.84
91	20.5	20344	Red Yellow	Sandy clay	Wet	5.72	4.92
91	21.5	20345	Grey	Sandy clay	Wet	5.83	4.44
91	22.5	20346	Grey	Sandy clay	Wet	5.86	4.75
91	23.5	20347	Yellow Grey	Sandy clay	EOH	5.78	4.29



Potential Acid Sulphate Soil – Location within 3 metres of Pit Floor

APPENDIX 4 RESPONSE TO DEPARTMENT OF WATER COMMENTS – PREPARED BY PARSONS BRINCKERHOFF

PARSONS BRINCKERHOFF

Memo

Date 21 January 2015

To Amy Walton

From Carsten Kraut

Ref 2200516B-RES-MEM-001 RevA

Subject Response to DoW review of Yongarillup hydrogeological investigation and modelling report 2200516A-RES-RPT-7634 presented in Public Environmental Review Assessment No. 1938

1. Introduction

Doral Mineral Sands Pty Ltd (Doral) are seeking to extract ore from the Yoongarillup Mineral Sands Deposit located within Mining Tenements M70/458 and M70/459, 17 km southeast of Busselton. In relation to the proposed operation, Doral released a Public Environmental Review (PER) document in October, 2014 (EPA Assessment No. 1938/EPBC Reference: 2012/6521).

The Department of Water (DoW) reviewed the groundwater related sections of the PER and this memorandum specifically addresses their comments and concerns.

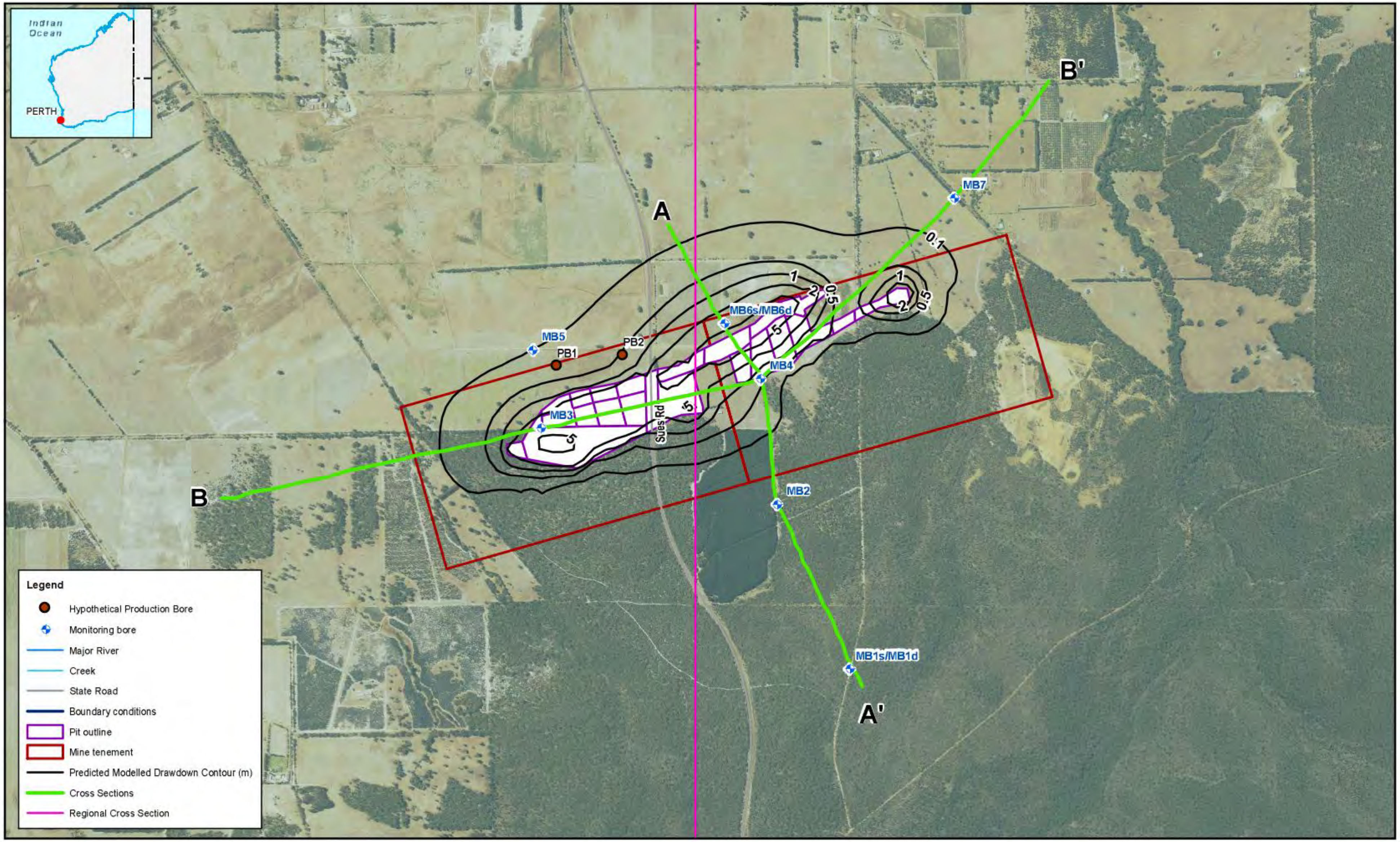
2. Responses to DoW comments

The DoW comments and Parsons Brinckerhoffs responses are tabulated in attachment A.

Regional cross section showing model grids and layers are shown in attachment B and local cross sections showing the ore body and measured water levels are shown in attachment C.

In response to the DoW review comments, the potential induced drawdowns are shown at 0.1 metre contour intervals in Figure 2.1. Figure 2.1 also shows the locations of the two local cross sections shown in attachment C.

PARSONS BRINCKERHOFF



Doral	N 0 250 500 Meters Scale: 1:23,678 at A4 Coord. System.: MGA50 GDA94	Drawing No.: 2172609A_GIS_F025_C1	**Doral Mineral Sands Pty Ltd** *Responses to DoW comments – additional information*
	NOT REQUIRED	Revision: B / Date: 16/01/2015	
PARSONS BRINCKERHOFF		Drawn By: SH / MG / Checked by: SF	Cross section lines, hypothetical production bores and modelled drawdown in Layer 1
		Data Source: Landgate; SLIP (2011)	Figure 2- 1

GIS File: \\Apperfil01\proj\D\Doral Mineral Industries\2172609a YOONGARILLUP GROUNDWATER MODEL\10 GIS\Projects\Drawings Figures Sketches\2172609A GIS F025 C1.mxd

PARSONS BRINCKERHOFF

Yours sincerely

Carsten Kraut
Principal Hydrogeologist

List of references

Barnett et al, 2012, *Australian groundwater modelling guidelines*, Waterlines report, National Water Commission, Canberra

List of attachments

A – Parsons Brinckerhoffs responses to comments by Dow
B – Regional cross section showing model grids and layers
C – Local cross sections showing the ore body and measured water levels

PARSONS BRINCKERHOFF

Attachment A - Parsons Brinckerhoff Response to Comments by Dow

<table>
<tr><th>Item</th><th>Page in letter</th><th>Comment</th><th>Response</th></tr>
<tr><td>1</td><td>2</td><td>PB to clarify value for max expected annual extraction volume from the Superficial aquifer</td><td>Based on the modelling undertaken in 2013/2014, the maximum annual inflow (and extraction rate) from the Superficial is estimated at 0.22 GL (~ 7 L/s) for 2017 (mining year 3). The annual estimated inflows are summarised on the table below.
<table>
<tr><th>Year</th><th>Gl/year</th></tr>
<tr><td>2015</td><td>0.03</td></tr>
<tr><td>2016</td><td>0.02</td></tr>
<tr><td>2017</td><td>0.22</td></tr>
<tr><td>2018</td><td>0.01</td></tr>
</table></td></tr>
<tr><td>2</td><td>2</td><td>There is a lack of clarity regarding the draw from the Superficial aquifer and the Yarragadee aquifer. Table 3-1 of PER, under Operational Elements, identifies dewatering 'extraction of no more than 1.6 GL per annum' – while Table 3-2 identifies water supply sources of '1.6 GL per annum from the Yarragadee aquifer' with 'pit dewater and rainfall catchment' supplementing 'the abstracted water where possible'</td><td>It is proposed that 1.6 GL per annum is drawn from the Yarragadee aquifer for mine water supply purposes, and a smaller volume is drawn from the Superficial aquifers in association with the limited dewatering required to allow dry mining conditions. The proposed Superfical aquifer draw is shown on the table above.</td></tr>
<tr><td>3</td><td>2</td><td>An updated plan showing both the 0.5 and 0.1 m drawdown contours to illustrate the extent of the dewatered area of influence within the Superficial aquifer and the Mowen Member (refer to Figures 3-8 and 3-9 of the modelling report)</td><td>Refer to Figure 1</td></tr>
<tr><td>4</td><td>3</td><td>Detailed hydrogeological cross-sections of the ore body showing relationships between individual units of the Superficial Formation (eg Guildford and Yoganup formations) and the Leederville Formation (Mowen and Vasse Members)</td><td>Refer to attachment B and C
Note that the groundwater flow model does not differentiate between individual members of the Superficial formations, which is represented by a single model layer. These members are laterally and vertically discontinuous and heterogeneous and the associated local perched systems cannot be appropriately simulated in a model of regional scale.</td></tr>
</table>

Item	Page in letter	Comment	Response
5	3	The PER has indicated that the combined abstraction will only impact 1m drawdown at 90 m distance from the production bores in the Yarragadee, and 1m at 80m distance within the lower Leederville (Vasse) Member. In assessing the drawdown at 50 L/sec using the Theis equation, the predicted drawdown is estimated by the Dow to be approximately 2.7m at 90m within the Yarragadee aquifer. At 25 l/sec there is 1.5m drawdown at 90m so it is suspected that there are errors in their analysis. There is also drawdown beyond 90m.	The Theis (1935)[1] unsteady-state equation is a simplified solution contingent on conditions and assumptions which are not all relevant in this instance (no recharge/leakage from layers above, horizontal flow, isotropic homogeneous aquifer and so forth). Parsons Brinckerhoff considers the numerical model better accommodates the complexities of the system and more accurately predicts the likely drawdown.
6	4	There is no long term groundwater level data available in model grid to validate calibration. Model hydraulic parameters were estimated using slug tests on drilled monitoring bores which can be misleading due to the monitoring bore construction; that is, testing the gravel packing around the screen interval rather than the aquifer material. ...... Due to the scarcity of all data and the model calibration and construction, the drawdowns could be buffered (meaning the full extent of drawdown hasn't been realised yet.	The model is not intended to be a standalone document for approval purposes. The model results and an accompanying Operating Strategy will be used to support a 5C application to abstract groundwater. The model is calibrated to steady state conditions and shows good calibration for 74 boreholes, which is considered to be an adequate number of calibration targets for the model domain. Slug test results have also been compared against literature values to increase confidence and hydraulic parameters were adjusted during calibration. The current model may be classified as a Class 2 model, which is adequate for the purpose of predicting inflow and drawdown of a proposed mine, according to the Australian Groundwater modelling guidelines (Barnet et al, 2012, Table 2-1: Model confidence level classification—characteristics and indicators).
7	4	It is recommended that Doral install a series of pit perimeter monitoring bores and perpendicular transects extending from the pit perimeter monitoring bores into the Yoganup and Leederville aquifers that will delineate the models accuracy and prediction of the simulated 350m (1m contour) drawdown cone. This will determine the actual drawdown dimensions and thus can be used to recalibrate the model for better prediction and monitoring.	11 bores are proposed to be installed in order to provide calibration data and allow measurement of water levels in the Superficial Aquifers during operation. The proposed bores are located adjacent to the pit perimeter in the direction of potentially sensitive receptors (forest activities and residents)

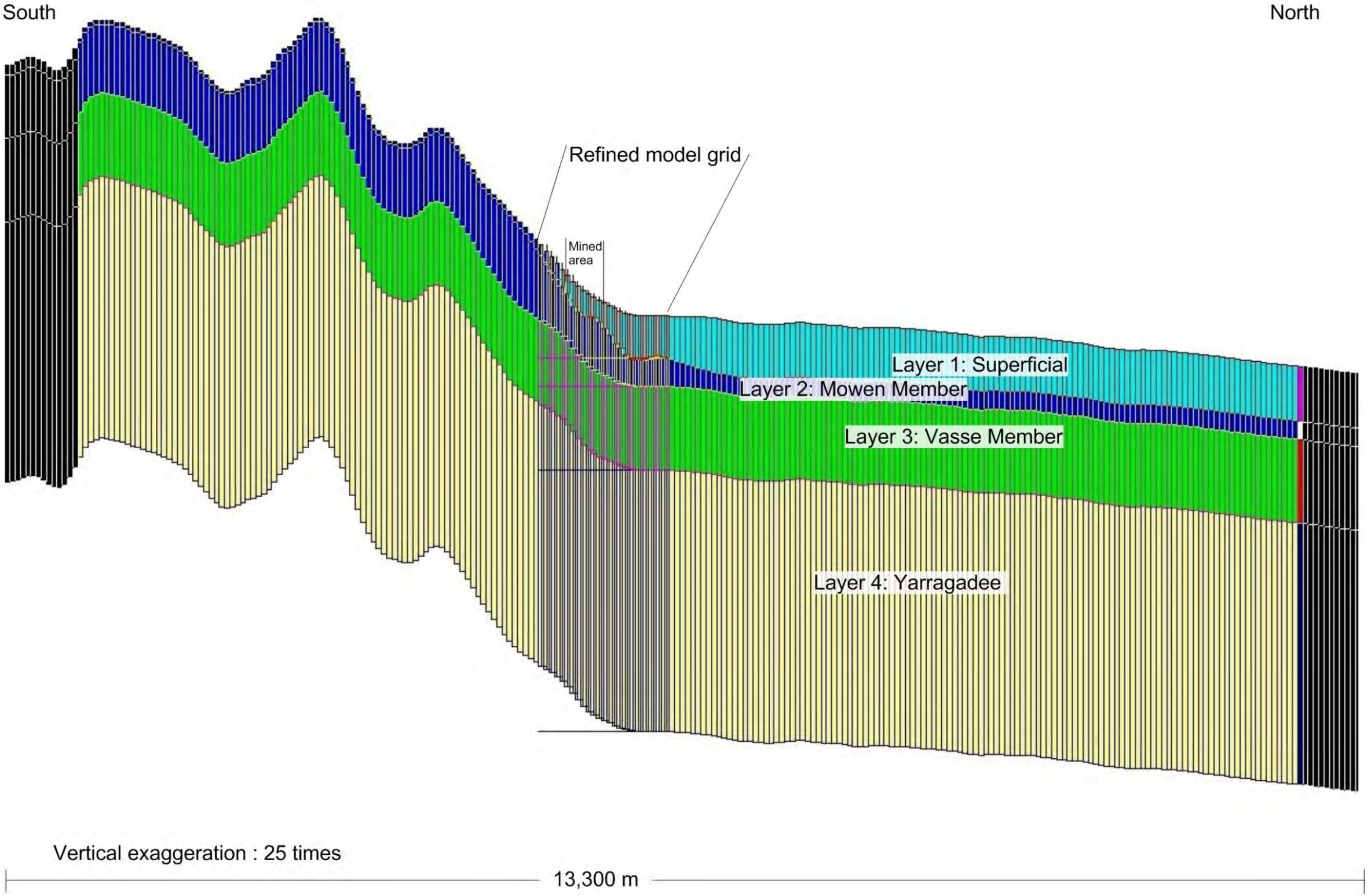
[1] Theis, C.V., 1935. The relation between the lowering of the piezometric surface and the rate and duration of discharge of a well using groundwater storage, Am. Geophys. Union Trans., vol. 16, pp. 519-524.

8	4	**General comments and recommendations about the groundwater modelling:**	
9		Recharge applied is higher around the pit area and is high for general forested recharge	Recharge was a calibration constraint and was adjusted to produce a good fit to the measured water levels. To the south of the pit, recharge may be higher into the edge of the Superficial due to increased runoff (limited rainfall infiltration in the outcropping Mowen Member). To the east, recharge may be higher due to enhanced recharge to the Superficial formations near the Sabina River.
10		Model boundaries do not to be necessarily constrained by topography	The model boundaries generally follow surface catchment boundaries, which often coincide with groundwater divides and therefore act as no flow boundaries.
11		Yarragadee Parameters are to high in Kz direction	Acknowledged, this was a reporting error, the model and the modelled kz was 10% of kx, consistent with other layers.
12		A transient model is required	The model is transient for predictive purposes; however, calibration was to available (steady state) data.
13		Linear recovery and linear drawdown lacks seasonality	The seasonality was not modelled in order to predict the mining induced impacts rather than natural variations.
14		No cumulative drawdown from other groundwater users is accommodated	As the modelled drawdown does not extend to other groundwater users, a cumulative assessment is considered not necessary
15		There are no climate scenarios	The proposed LOM is about 3 years, from 2015 to 2018, and the effect of climate change is not considered significant.
16		Requires an external model review	All models may benefit from an independent review. However, the relatively small proposed scale of abstraction and duration of operations (3 years) suggest the potential for impacts to occur is limited.
17		Reproduce contours at 0.5 and 0.1m to detail the full extent of dewatering and production drawdown impacts	See Figure 1
18	5	The comparison of groundwater drawdown to current seasonal fluctuations is misleading. Drawdown in the Mowen Member sediments will be in addition to seasonal fluctuations already experienced	see above, item 13
19	5	Details of any proposed monitoring to manage potential risks to the vegetation adjacent to the mine pits is lacking. The commitment to recalibrate the model groundwater model is supported but should be complimented by commitments to establish adequate monitoring bores to assess the progression of groundwater drawdown beyond the pit boundary.	Additional monitoring bores are proposed, see above item 7. An Operating Strategy will be prepared to support the 5C abstraction licence application which will highlight trigger levels, monitoring commitments and mitigation measures.

20	5	Drawdown of less than 1m will extent to into State Forest 33 and have potential to impact vegetation. The vegetation will likely be accessing groundwater from the Mowen Member sediments above the Vasse Member. Whilst the modelling conducted indicates that there will not be any drawdown in the Vasse Member there will be some drawdown (downslope drainage) in the overlying Mowen Sediments and there is potential for impacts to vegetation as a result.	The predicted drawdowns presented on Figure 2.1 suggest that the extent of drawdown to the South, where low permeability Mowen Member sediments outcrop, is limited. Additionally, vegetation may be accessing perched water within the Mowen Member sediments and relict discontinuous Superficial Sediments in the vicinity of State Forest 33 (cross sections (Appendix C)) which is disconnected from the regional water table and therefore unlikely to be impacted by mining activities.
21	5	Assessment of the above potential impacts is not possible based on the information provided in the PER and supporting hydrogeological reports. Information on the current depths to groundwater in areas adjacent to the mine pit (immediately south) is not provided. This is critical information to allow the assessment of the potential risk to groundwater dependent vegetation outside of areas to be cleared.	MB04 is located immediately south of the mined area. The bore was drilled to 20 metres, intersecting 2 metres of Superficial and clayey Mowen Member sediments. The depth to water at this location is > 10m. As indicated in item 7, 11 bores are proposed to be installed in order to provide calibration data and allow measurement of water levels in the Superficial Aquifers during operation. The proposed bores are located adjacent to the pit perimeter in the direction of potentially sensitive receptors (forest activities and residents)
22	7	The Model is required to be updated to a transient model, have new parameter estimation completed, recalibration including all other groundwater use within the model boundary, detailed sensitivity and predictive analysis and a new prediction of drawdown established that can then be compared to the monitoring data collected through bores established in the above recommendations	see item 6
		Recharge estimation needs to be more robust and transparent as the estimates applied around the pit are unusually high, is high for general forested recharge and requires transient estimation	see item 6 and item 9
		Yarragadee parameters are too high in kz direction and a pump test of each bore is required to determine parameters then used in the transient calibration	see item 11 and item 6
		Two climate scenarios should be developed. A 5 year wet and dry period post 1975 should be used to determine drawdown over the 3 year mine life. This will provide robust drawdown predictions.	see item 15
		The recalibrated transient model requires an external model review	see item 16

23	8	Current groundwater levels and predicted 0.5 and 0.1m drawdown contours should be provided and used to support the assessment of risk to vegetation beyond the boundary of the mine pit	see item 3
		Predicted drawdowns should be presented in addition to current seasonal fluctuations as changes in the water regime that will result during and post mining. This will allow the proponent to assess the risk to vegetation beyond the mine pit boundary.	The existing vegetation exists within natural, seasonal, fluctuations. This assessment is focussed on the additional drawdowns that may occur (in addition to the natural fluctuation) and which has potential to impact vegetation. As shown, the changes in groundwater level are likely to be limited away from the immediate mining area during mining, and return to natural levels once mining ceases.

Attachment B - Regional cross section showing model grids and layers



South
North
Refined model grid
Mined area
Layer 1: Superficial
Layer 2: Mowen Member
Layer 3: Vasse Member
Layer 4: Yarragadee
Vertical exaggeration : 25 times
13,300 m

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Attachment C - Local cross sections showing the ore body and measured water levels

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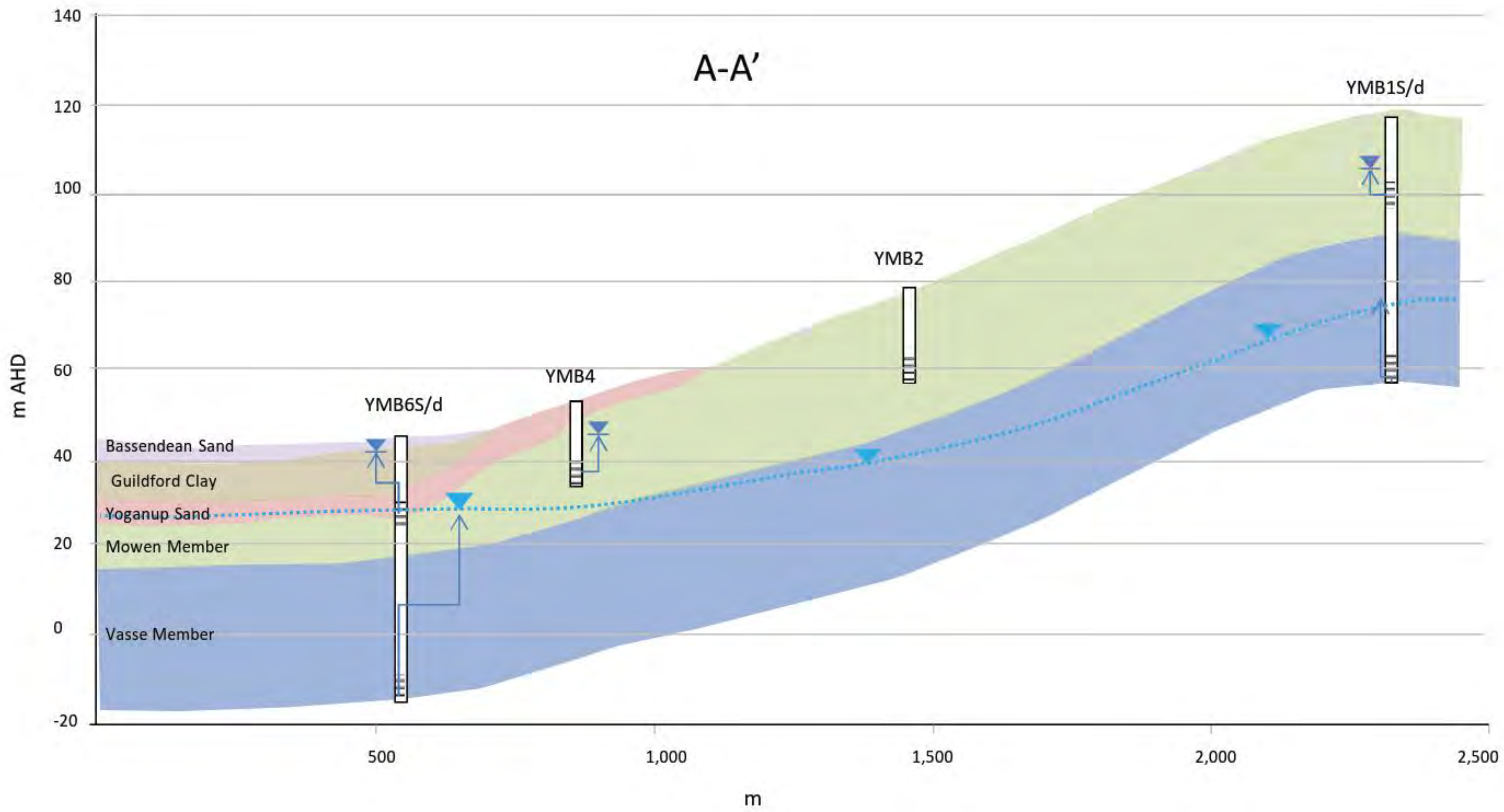
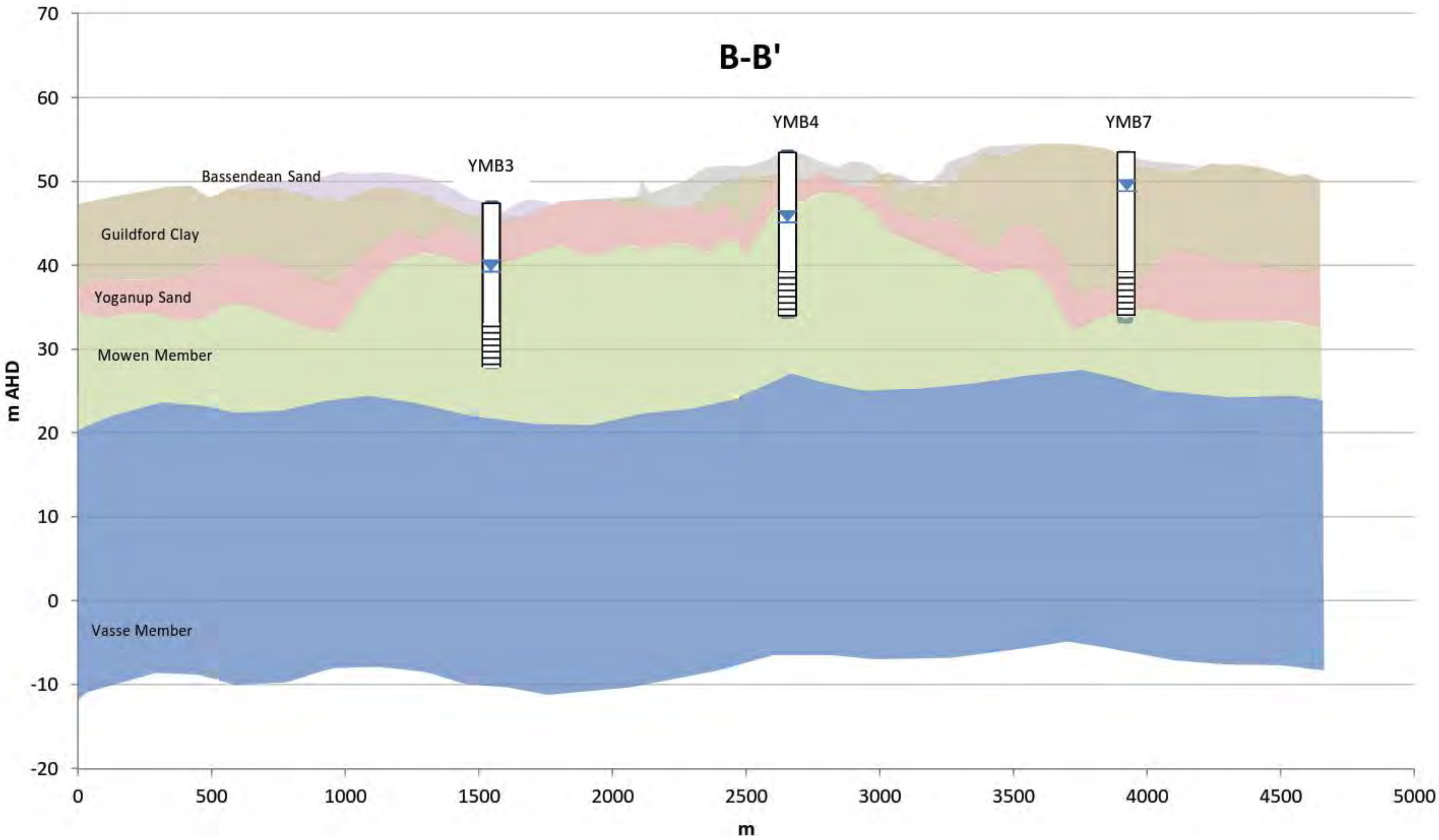
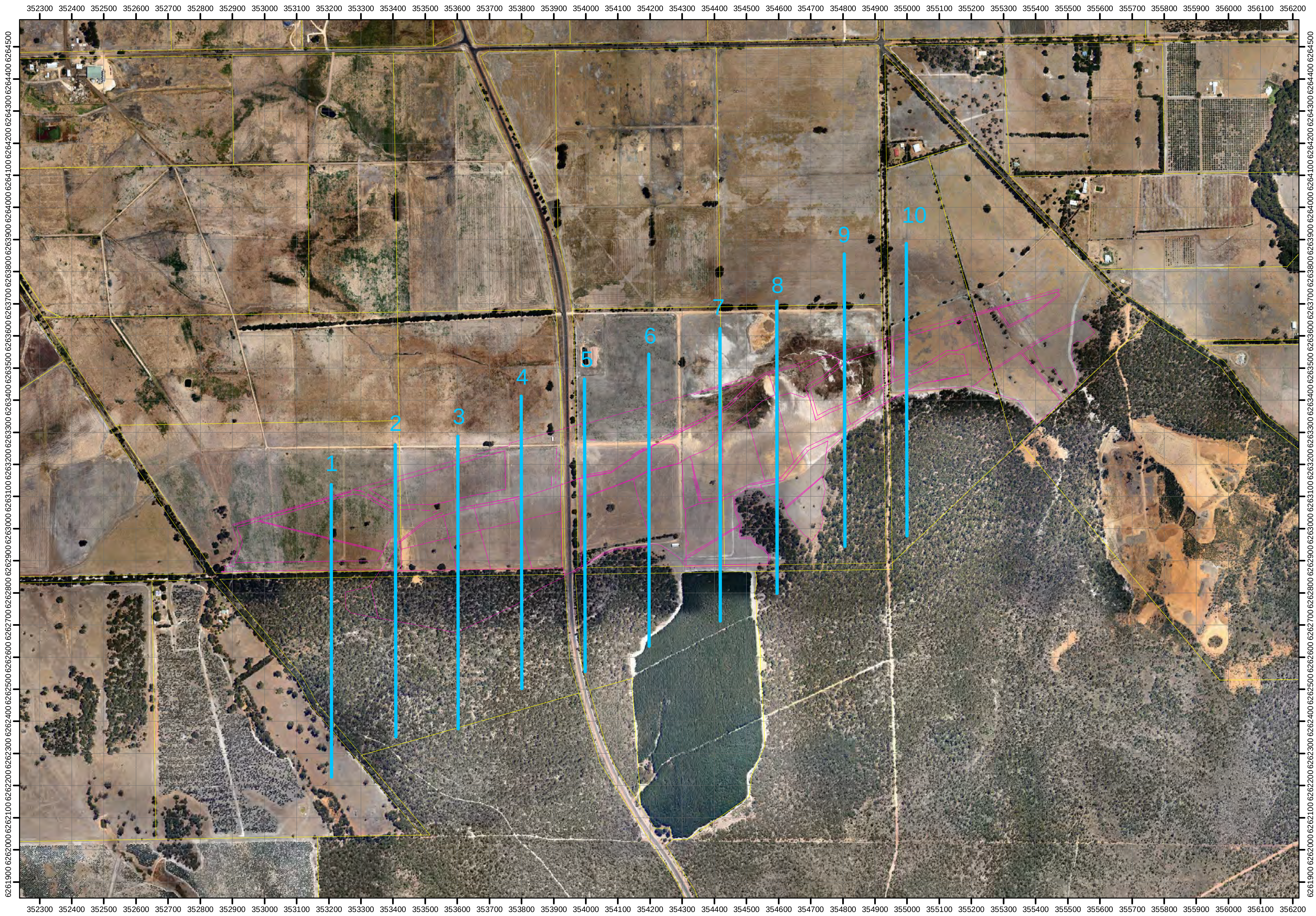


PARSONS BRINCKERHOFF



APPENDIX 5 PIT CROSS SECTIONS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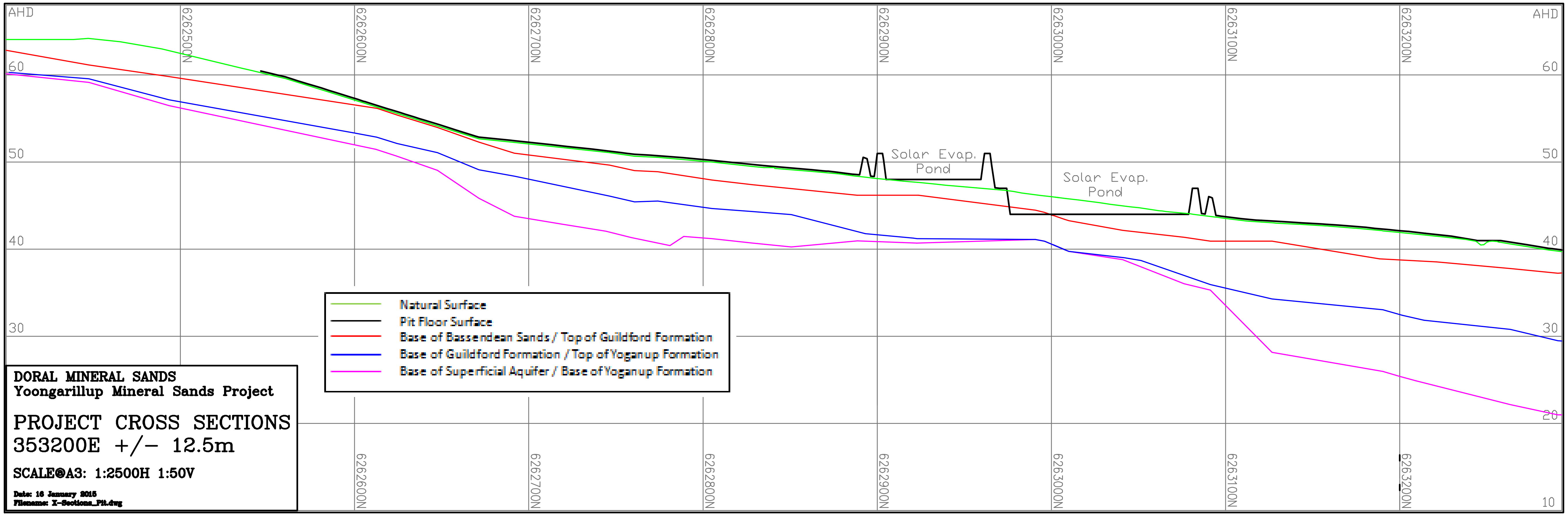
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Solar Evap. Pond
Natural Surface
Pit Floor Surface
Base of Bassendean Sands / Top of Guildford Formation
Base of Guildford Formation / Top of Yoganup Formation
Base of Superficial Aquifer / Base of Yoganup Formation
DORAL MINERAL SANDS
Yoongarillup Mineral Sands Project
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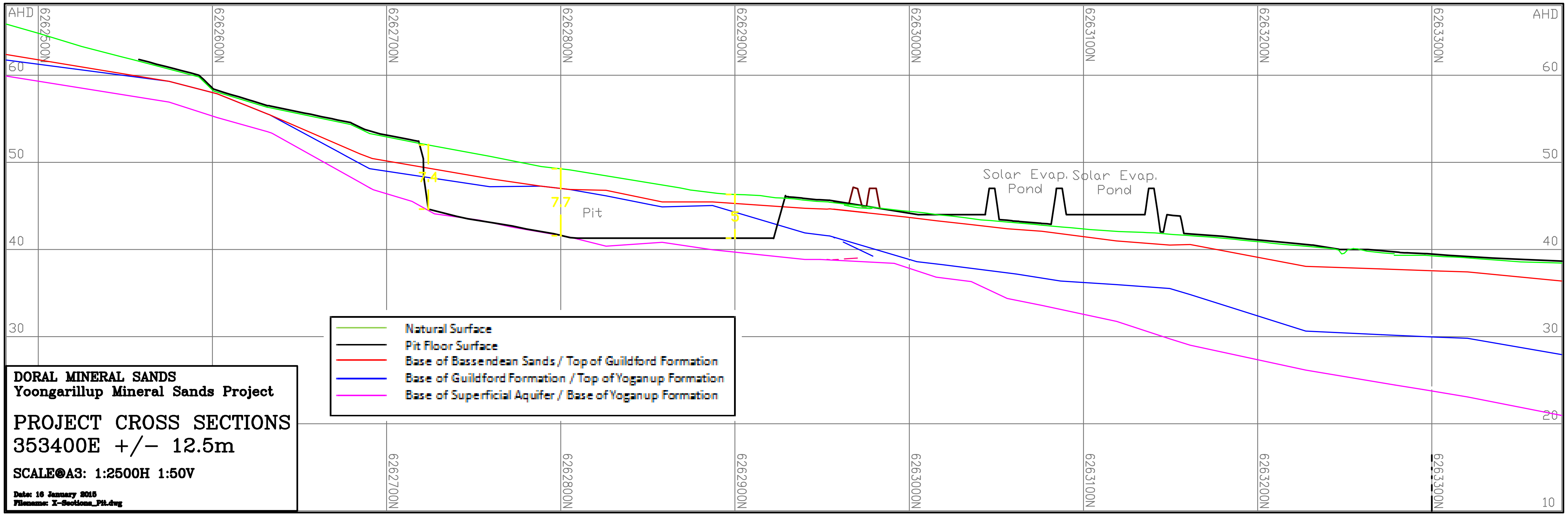
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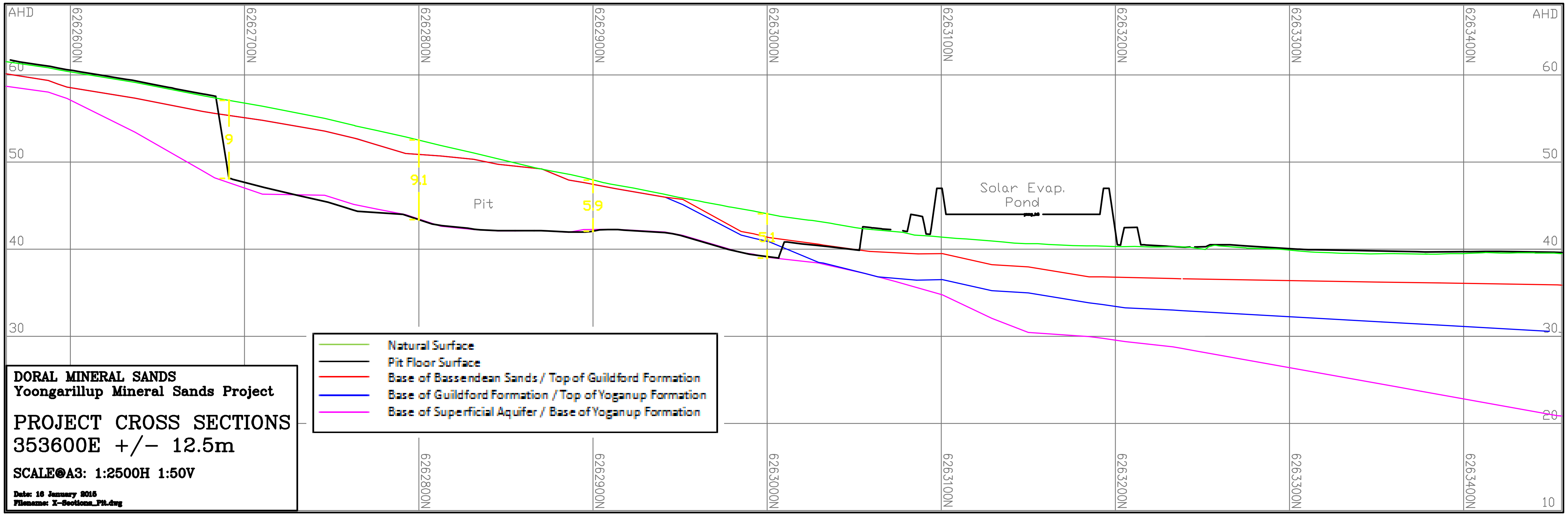
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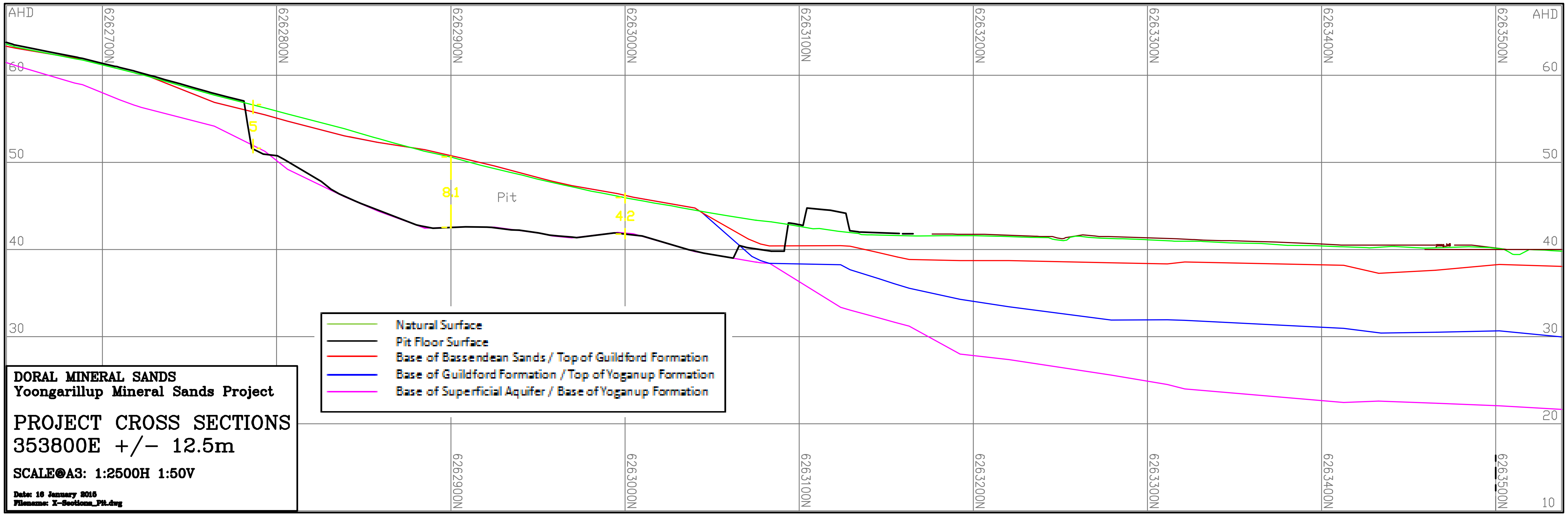
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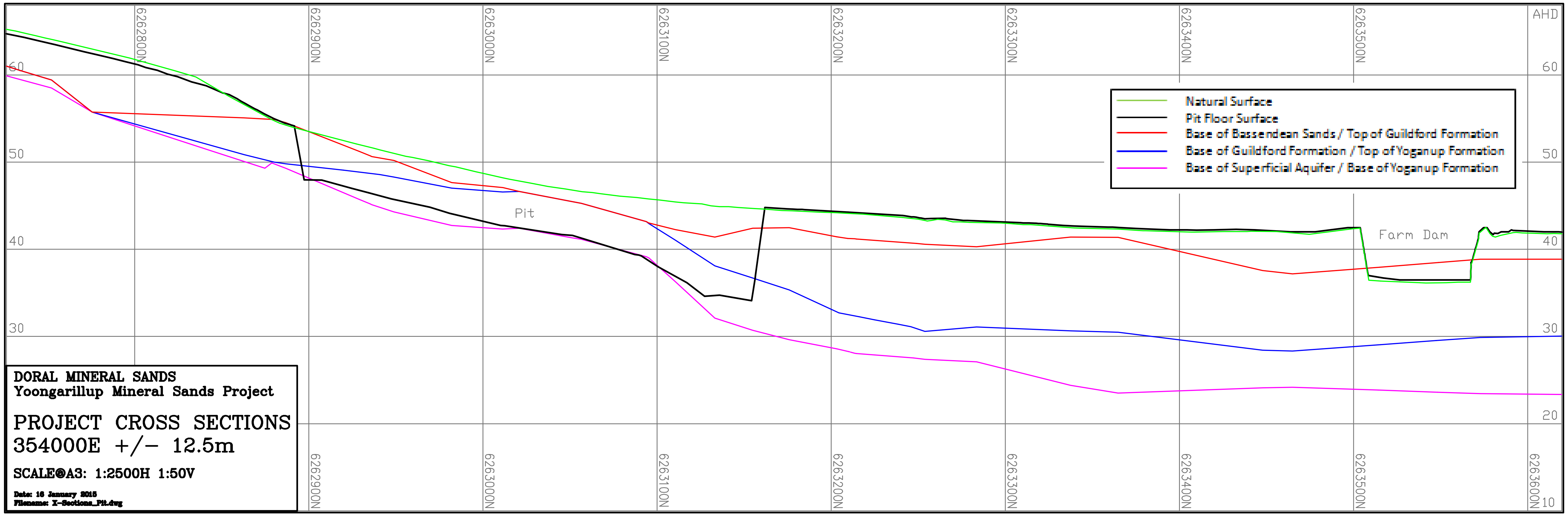

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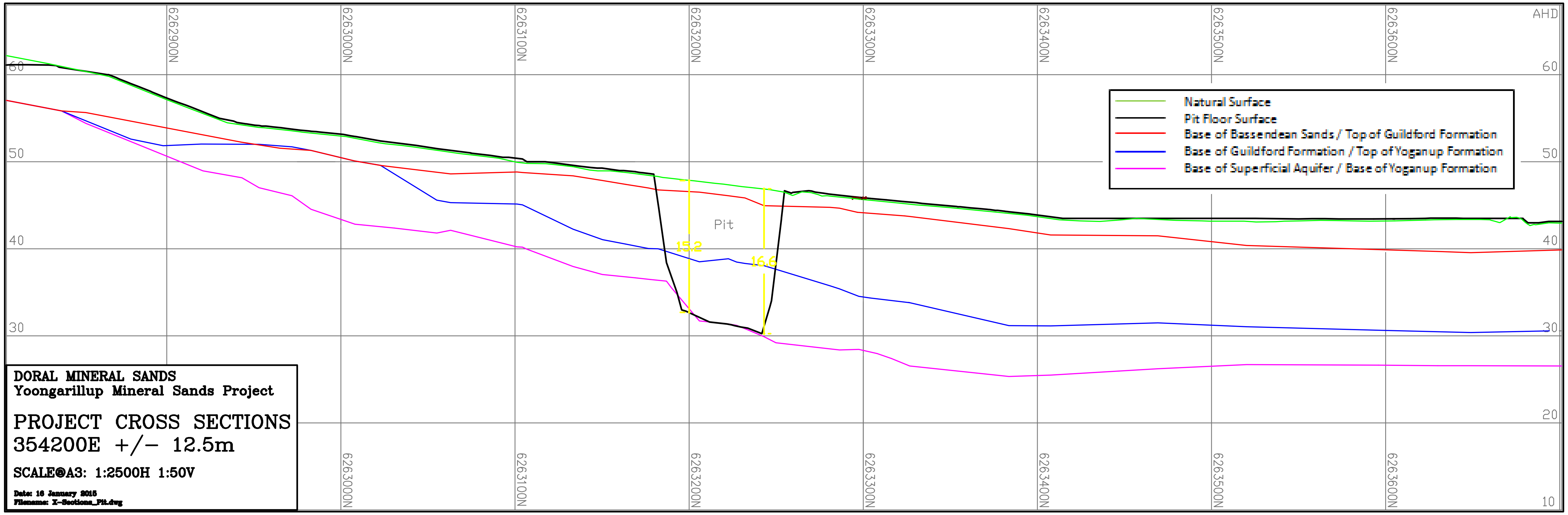

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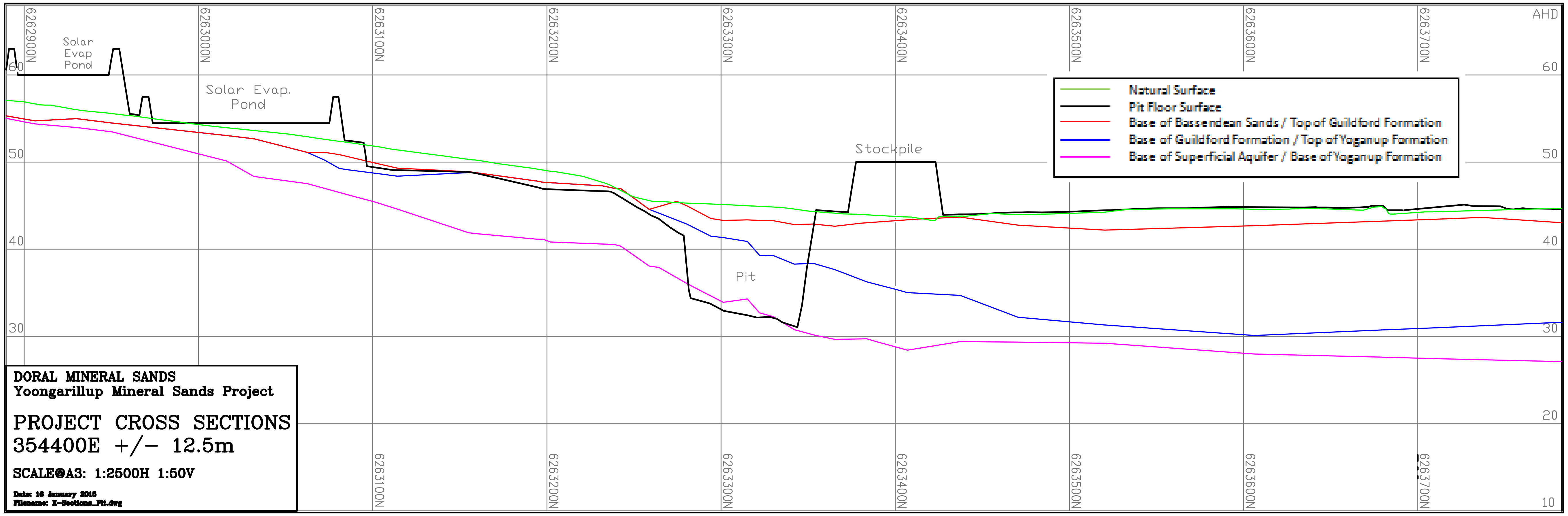
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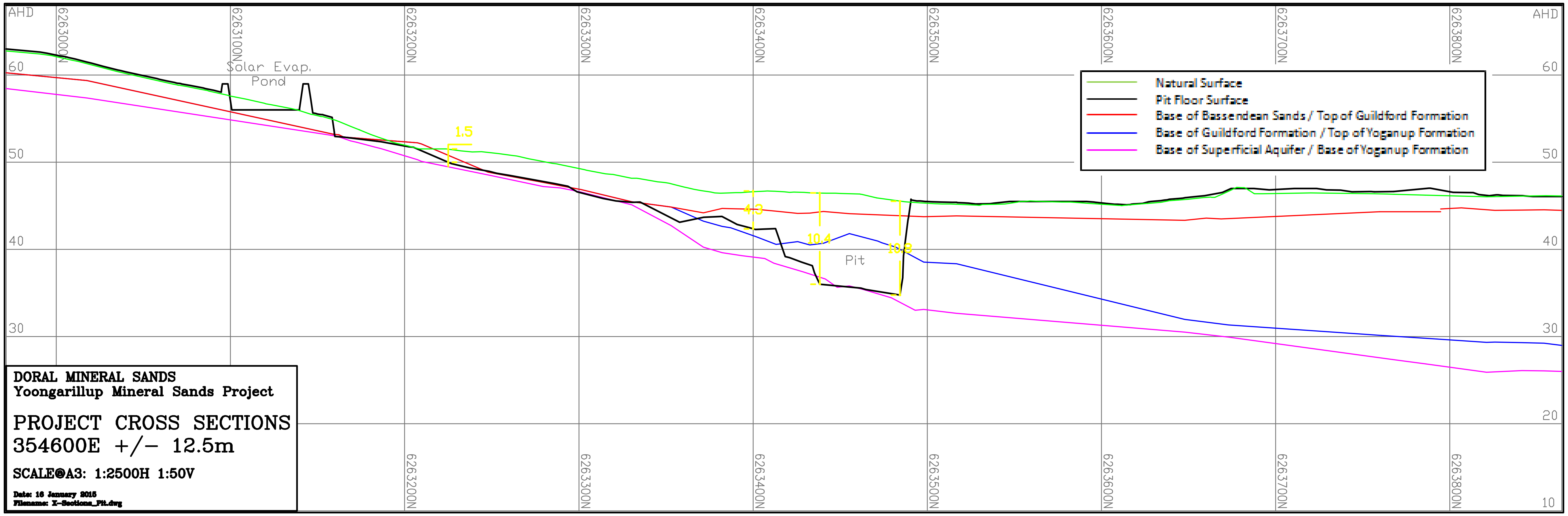
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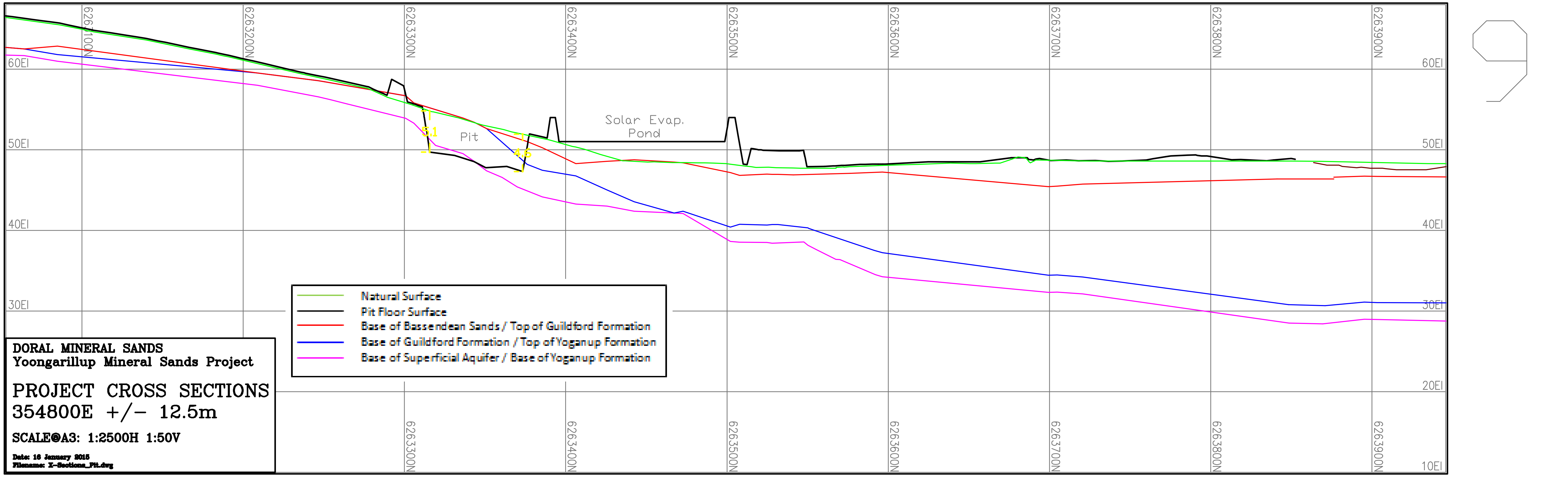
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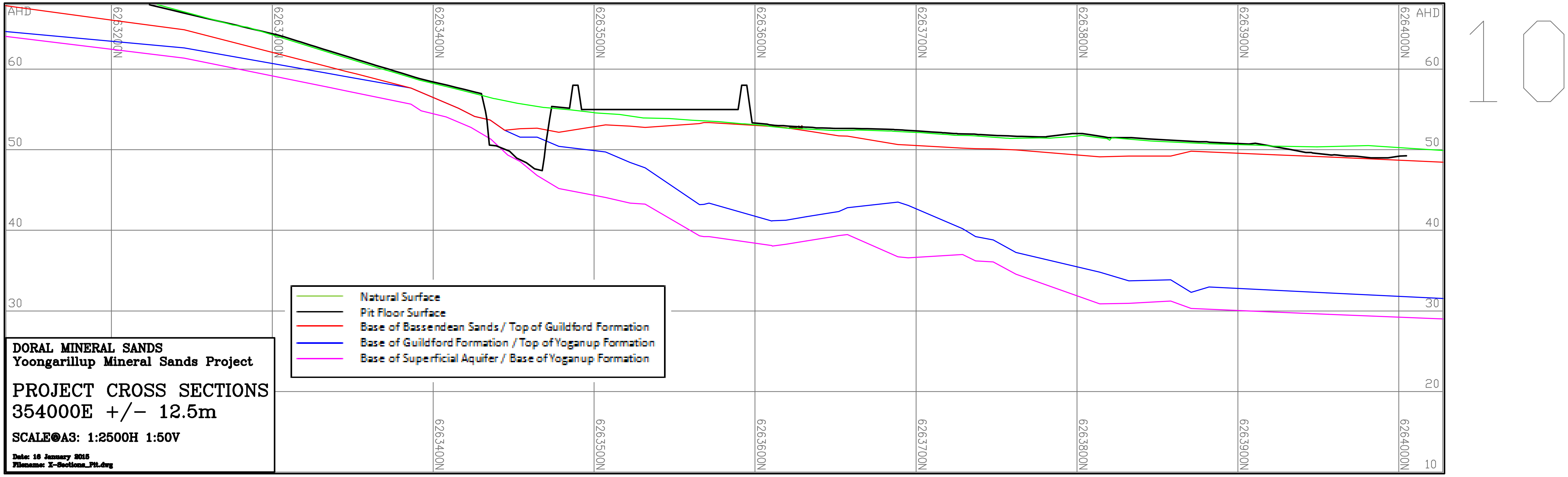
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APPENDIX 6 PROPOSED NEW MONITORING BORES

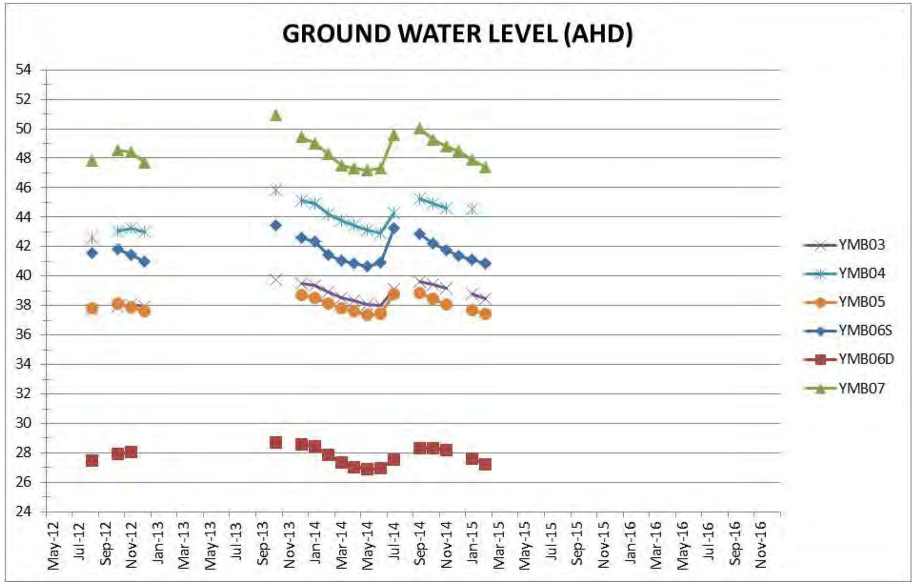
Proposed New Monitoring Bore Location

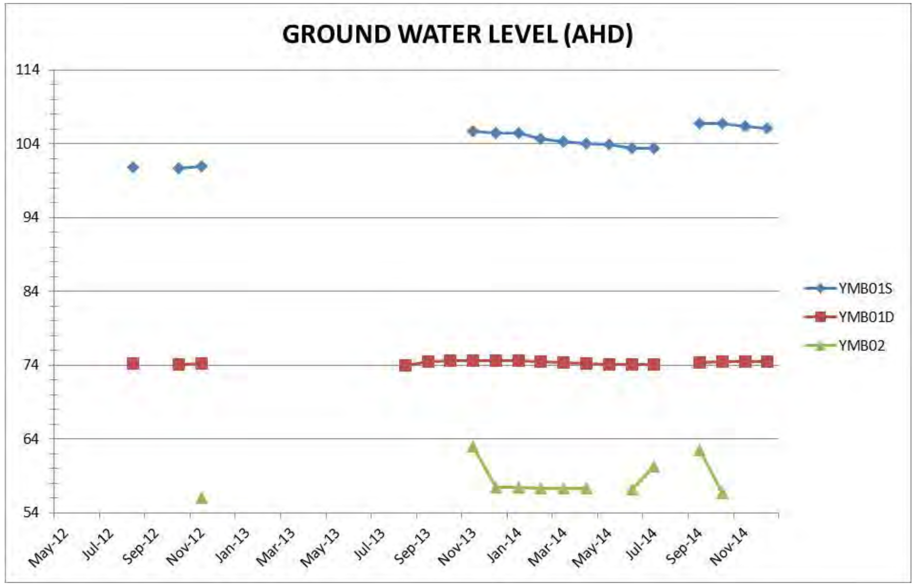
APPENDIX 7 SURFACE WATER MONITORING SITES

Surface Water Monitoring Sites

APPENDIX 8 GROUNDWATER WATER LEVELS -

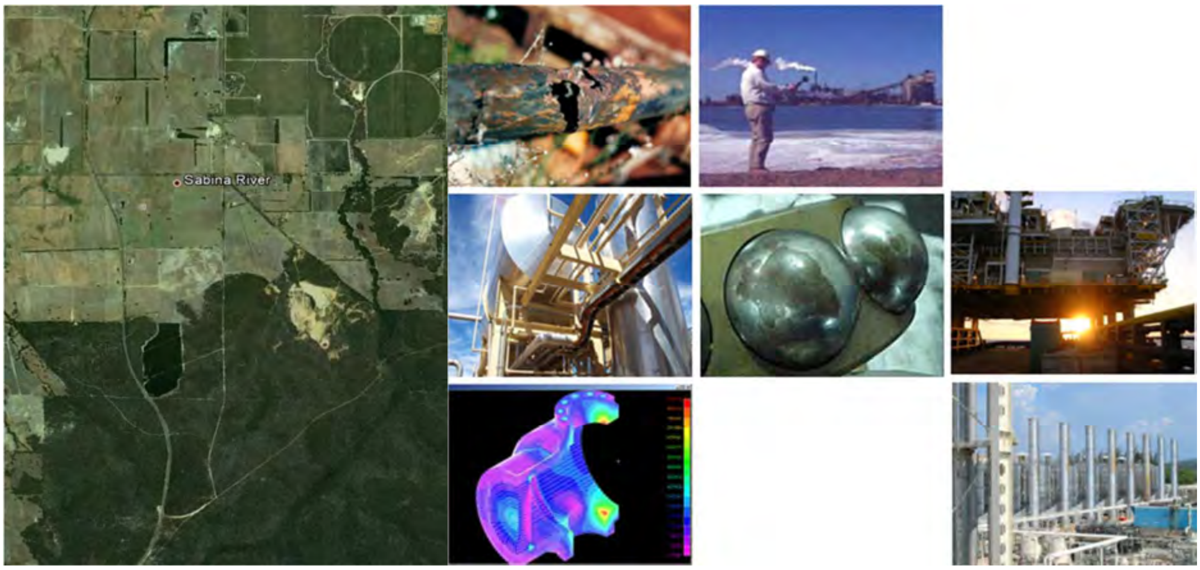
Seasonal Variation of Groundwater Levels





APPENDIX 9 NOISE MODELLING – REVISED ASSESSMENT

ENVIRONMENTAL NOISE IMPACT ASSESSMENT OF THE PROPOSED YOONGARILLUP MINING OPERATIONS



DORAL MINERAL SANDS PTY LTD

Rpt01-1370684-Rev2-2 April 2015

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Client: Doral Mineral Sands Pty Ltd

Client Contact: Craig Bovell / Amy Walton

SVT Contact: Roy Ming

SVT Office: Perth

SVT Job No: 1370684

SVT Document No: Rpt01-1370684-Rev2-2 April 2015

Rev	Description	Prepared	Reviewed	Date
2	Issued for use	Roy Ming	Jim McLoughlin	2 April 2015
1	Issued for use	Roy Ming	Jim McLoughlin	10 February 2014
0	Issued for use	Roy Ming	Jim McLoughlin	15 January 2014

SVT Engineering Consultants
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EXECUTIVE SUMMARY

SVT has been commissioned by Doral Mineral Sands Pty Ltd (Doral) to undertake an environmental noise impact assessment of their proposed Yoongarillup mining operations in the southwest of Western Australia. The proposed mine site is located approximately 17 km to the south east of Busselton and approximately 200 km south of Perth.

An acoustic model was developed in September 2012 to assess the noise impact[1] of the proposed Yoongarillup mining operations, and then was updated[2] in early 2014 to incorporate the changes of the mining schedules and mining plan. Recently Doral has refined the mining schedules and mining plan, and wants to include:

- four (4) more noise-sensitive premises in the noise impact assessment; and
- two noise control options (recommended by SVT in 2014[2]) in their mining plan.

The acoustic model has been re-updated to include the above changes, and to reflect the modification of the mining schedules and mining plan.

Six operational scenarios (one construction scenario and five mining scenarios) have been modelled. Sixteen (16) closest noise sensitive premises have been selected for detailed noise impact assessment. Point and contour calculations have been performed for worst-case meteorological conditions. Tonality assessments in received noise levels have been undertaken based on the dominating noise sources and their noise emission contributions. It is shown that tonality is likely to be evident at some receiver locations under some operating conditions.

Table A summarises the worst-case noise levels at the 16 closest noise sensitive premises. The values expressed in ***bold italic*** have included the 5dB tonality adjustment.

Table A: Adjusted noise levels in dB(A) for worst-case operating conditions.

Closest Residences	S1	S2		S3		S4		S5		S6	
	Day	Day	Night	Day	Night	Day	Night	Day	Night	Day	Night
R1	31.8	24.3	24.8	31.5	26.3	32.0	26.0	26.8	24.7	27.2	22.5
R2	***53.2***	32.9	33.1	***45.2***	31.2	***45.1***	34.0	31.1	28.9	33.4	30.0
R3	***49.3***	32.4	32.7	37.3	30.4	37.7	31.6	31.3	28.8	32.9	30.3
R4	26.9	21.4	22.0	25.1	21.3	25.6	18.5	20.7	16.9	22.9	16.9
R5	29.3	26.9	27.4	27.9	25.0	28.6	22.3	24.1	20.6	26.3	20.7

[1] "Environmental noise impact assessment of the proposed Yoongarillup mining operations" SVT report (NO: Rpt01-1253922-RevA-5 September 2012).

[2] "Environmental noise impact assessment of the proposed Yoongarillup mining operations" SVT report (NO: Rpt01-1370684-Rev1-10 February 2014).

Closest Residences	S1	S2		S3		S4		S5		S6	
	Day	Day	Night	Day	Night	Day	Night	Day	Night	Day	Night
R6	31.3	29.9	30.3	31.9	30.4	31.4	25.7	27.5	24.1	29.7	24.1
R7	26.5	27.1	27.6	27.7	26.8	29.2	25.9	30.2	22.8	31.2	23.0
R8	29.8	31.3	31.7	31.2	30.4	33.1	29.7	38.3	27.9	38.2	28.8
R9	27.7	29.0	29.4	29.0	28.2	31.0	27.4	36.6	25.4	36.7	27.9
R10	27.2	28.3	28.7	28.4	27.5	30.4	26.7	37.1	24.6	37.3	28.6
R11	26.7	30.3	30.8	30.2	29.7	31.1	28.6	36.3	27.0	36.4	30.8
R12	21.2	20.3	20.7	21.3	20.4	23.7	20.1	29.5	19.2	26.9	23.1
R13	22.9	23.3	23.9	23.7	22.9	26.4	22.1	30.1	19.2	30.7	22.9
R14	26.2	26.9	27.4	27.4	26.5	29.1	25.9	30.7	22.7	31.5	23.0
R15	26.1	26.7	27.3	27.3	26.5	28.9	25.7	30.2	22.5	31.1	22.7
R16	24.7	25.1	25.6	25.7	24.9	27.4	24.1	28.4	20.8	29.5	21.0

Noise management in Western Australia is implemented through the *Environmental Protection (Noise) Regulations 1997* (the *Regulations*) and its *Amendment 2013* which operate under the Environmental Protection Act (EPA) 1986. The *Regulations* specify the noise level adjustments incurred for noise exhibiting intrusive or dominant characteristics and the maximum allowable noise limits (assigned noise levels) at noise-sensitive premises.

According to *Regulation* 13, no assigned noise levels apply for the construction period (scenario 1) at noise-sensitive premises, as long as "*the construction work is carried out in accordance with control of environmental noise practices*" set out in AS 2436-2010 Guide to noise and vibration control on Construction, Demolition and Maintenance Sites.

Comparisons between the assigned noise levels and the (adjusted) worst-case noise levels predicted at the closest residences for the proposed mining operations indicate that all of the adjusted worst-case noise levels are below the assigned noise levels. Full compliance will be achieved for the proposed Yoongarillup mining operations.

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1. INTRODUCTION

SVT has been commissioned by Doral Mineral Sands Pty Ltd (Doral) to undertake an environmental noise impact assessment of their proposed Yoongarillup mining operations in the southwest of Western Australia. The proposed mine site is located approximately 17 km to the south east of Busselton and approximately 200 km south of Perth.

An acoustic model was developed in September 2012 to assess noise impact[3] of the proposed Yoongarillup mining operations, and then was updated[4] in early 2014 to incorporate the changes of the mining schedules and mining plan including changes to stockpiles, solar evaporation ponds and the processing plant. Twelve (12) closest noise sensitive premises have been selected for detailed assessment of noise impacts. SVT has recommended several noise control options for achieving compliance. Recently Doral has refined the mining schedules and mining plan, and would like to include the followings:

- four (4) more noise-sensitive premises in the noise impact assessment; and
- two noise control options (recommended by SVT in 2014[4]) in their mining plan.

The acoustic model has been re-updated to include the above changes, and to reflect the modification of the mining schedules and mining plan. This report presents the environmental noise impact assessment of the revised mining operations.

Figure 1 in Appendix A presents an aerial view of the proposed mine site and surrounding area including the closest residences. The proposed mining pits are green-coloured with yellow boundary and the solar evaporate ponds (SEPs) are pink-coloured with blue edges. The top/subsoil stockpiles are red-coloured. Figure 2 provides the proposed mine site layout including the number of the proposed mining pits.

[3] "Environmental noise impact assessment of the proposed Yoongarillup mining operations" SVT report (NO: Rpt01-1253922-RevA-5 September 2012).

[4] "Environmental noise impact assessment of the proposed Yoongarillup mining operations" SVT report (NO: Rpt01-1370684-Rev1-10 February 2014).

2. SUMMARY OF LEGISLATION

Noise management in Western Australia is implemented through the *Environmental Protection (Noise) Regulations 1997* (the *Regulations*) and its *Amendment 2013* which operate under the Environmental Protection Act 1986. The *Regulations* specify maximum noise levels (assigned noise levels) which are the highest noise levels that can be received at noise-sensitive (residential), commercial and industrial premises.

Assigned noise levels have been set differently for noise sensitive premises, commercial premises, and industrial premises. For noise sensitive premises, ie residences, an "influencing factor" is incorporated into the assigned noise levels. The influencing factor depends on land use zonings within circles of 100 metres and 450 metres radius from the noise receiver, including:

- the proportion of industrial land use zonings;
- the proportion of commercial zonings; and
- the presence of major roads.

For noise sensitive residences, the time of day also affects the assigned levels.

The regulations define three types of assigned noise level:

- L_{Amax} assigned noise level means a noise level which is not to be exceeded at any time;
- L_{A1} assigned noise level which is not to be exceeded for more than 1% of the time;
- L_{A10} assigned noise level which is not to be exceeded for more than 10% of the time.

The L_{A10} noise limit is the most significant for this study since this is representative of continuous noise emissions from the proposed mine site.

Table 2-1 presents the assigned noise levels for noise-sensitive (residential), commercial and industrial premises.

Table 2-1: Assigned noise levels in dB(A).

Type of premises receiving noise	Time of day	Assigned Noise Levels dB(A)		
		$L_{A\,10}$	$L_{A\,1}$	$L_{A\,max}$
Noise sensitive premises: highly sensitive area	0700 to 1900 hours Monday to Saturday	45+ influencing factor	55+ influencing factor	65+ influencing factor
	0900 to 1900 hours Sundays and public holidays	40+ influencing factor	50+ influencing factor	65+ influencing factor
	1900 to 2200 hours all days	40+ influencing factor	50+ influencing factor	55+ influencing factor
	2200 hours on any day to 0700 hours Monday to Saturday and 0900 hours Sunday and public holidays	35+ influencing factor	45+ influencing factor	55+ influencing factor

Type of premises receiving noise	Time of day	Assigned Noise Levels dB(A)		
		$L_{A\,10}$	$L_{A\,1}$	$L_{A\,max}$
Noise sensitive premises: any area other than highly sensitive area	All hours	60	75	80
Commercial premises	All hours	60	75	80
Industrial and utility premises other than those in the Kwinana Industrial Area	All hours	65	80	90
Industrial and utility premises in the Kwinana Industrial Area	All hours	75	85	90

Corrections for Characteristic of Noise

Noise levels at the receiver are required to be adjusted if the noise exhibits intrusive or dominant characteristics, i.e. if the noise is impulsive, tonal, or modulating. Table 2-2 presents the adjustments incurred for noise that exhibits intrusive or dominant characteristics. That is, if the noise is assessed as having tonal, modulating or impulsive characteristics, then the measured or predicted noise levels are adjusted, by the amounts given in Table 2-2. The adjusted noise levels must now comply with the assigned noise levels. *Regulation* 9 sets out objective tests to assess whether the noise is taken to be free of these characteristics.

Table 2-2: Adjustments for intrusive or dominant noise characteristics.

Adjustment where noise emission is not music these adjustments are cumulative to a maximum of 15 dB		
Where tonality is present	Where modulation is present	Where impulsiveness is present
+5 dB	+5 dB	+10 dB

An assessment of tonality is performed in Section 5.1 based on the worst-case noise levels predicted at the closest noise sensitive receivers for each of mining scenarios.

Influencing Factors

Influencing factors vary from residence to residence depending on the surrounding land use. Traffic flows on roads in the vicinity of the proposed mine site are insufficient for any of the roads to be classified as either major or secondary roads and therefore no transport factors apply.

Sixteen (16) of the nearest noise sensitive (residential) locations surrounding the proposed mine site (within 2km from the proposed mining pits and SEPs) have been selected (provided by Doral) for detailed assessment of noise impacts. These residential locations are shown in Figure 1 in Appendix A. Most of the closest residences are located at more than 450m away from the mining pits or SEPs except R2, R3 and R9 to R11. R2 is the closest residence to the proposed mining pits (about 391m away from pit 25 and 155m away from a topsoil stockpile and SEP). The calculated influencing factor ranges from 0.05 dB to 0.83 dB, which are rounded to 0 dB and 1 dB according to the *Regulations*. Table 2-3 presents the calculated assigned noise levels for the 16 selected residential locations close to the proposed mine site.

Table 2-3: Assigned noise levels (L_{A10}) in dB(A)

Closest Residents	Influencing Factor in dB	Assigned Noise levels (L_{A10}) in dB(A)		
		Day	Evening	Night
R2 and R3	1	46	41	36
Others	0	45	40	35

3. METHODOLOGY

3.1 Noise Modelling

An acoustic model has been developed using SoundPlan v7.1 program developed by SoundPLAN LLC. This program calculates sound pressure levels at nominated receiver locations or produces noise contours over a defined area of interest around the noise sources. SoundPlan can be used to model different types of noises, such as industrial noise, traffic noise and aircraft noise, and it has been recognised internationally including in Australia. The inputs required in SoundPlan are noise source data, ground topographical data, meteorological data and receiver locations.

SoundPlan provides a range of prediction algorithms that can be selected by the user. The CONCAWE[5,6] prediction algorithm has been selected for this study. The acoustic model has been used to generate noise contours for the area surrounding the mine site and also to predict noise levels at the nearby noise sensitive (residential) locations.

The acoustic model does not include noise emissions from any source other than the proposed mining operations. Therefore, noise emissions from other neighbouring industrial sources, road traffics, animals, domestic sources, etc. are excluded from the modelling.

3.2 Noise Modelling Scenarios

The following six (6) scenarios have been modelled to represent the worst-case operations, as shown in Table 3-1 below.

Table 3-1: Operating scenarios considered in the acoustic model.

Scenarios	Activities	Operating Time	Likely Operating Period
1	Construction Phase	Day	From June 2015 to September 2015
2	Ore mining at pits 14 & 15	Day/Night	December 2015
3	Ore mining at pit 21 Overburden removal in pit 24	Day/Night	May 2016
4	Ore mining at pit 25 Overburden removal in pit 24	Day/Night	September 2016
5	Ore mining at pit 7 Overburden removal in pits 2 & 4	Day/Night	February 2018
6	Ore mining at pit 2 Dry slimes removal in SEPs Backfilling to pits 8, 9, 11 & 13	Day/Night	April 2018

[5] CONCAWE (Conservation of Clean Air and Water in Europe) was established in 1963 by a group of oil companies to carry out research on environmental issues relevant to the oil industry.

[6] *The propagation of noise from petroleum and petrochemical complexes to neighbouring communities,* CONCAWE Report 4/81, 1981

Doral has advised the followings:

- The proposed construction activities happen during day-time of Mondays to Saturdays only while the proposed mining operations are planned to be 24 hours per day, 7 days a week.
- Overburden removal occurs only during day-time of Mondays to Saturdays excluding Sundays and public holidays.
- Overburden fleet and ore fleet will not operate simultaneously in the same pit at any time.
- Top/subsoil stockpiles outside the pits are built during the construction phase, and they are about 2.5m high.
- Noise bunds and topsoil/vegetation stockpiles on unmined pits are temporary, and they are about 2.5m to 3m high. Those temporary bunds/stockpiles are built during the construction phase and will be removed when the areas are mined.
- One silenced 8" diesel dewatering pump operates at one mining pit at any given time except for scenario 1, in which no dewatering pump is required.
- The mining unit will be located within the mining pit.
- Watercart operates during day time only as required.

Initial modelling results indicated that for scenario 3 the day-time noise level received at R2 could have tonal components and its adjusted value may exceed the assigned noise level if Dozer/ Excavator/Trucks are used for overburden removal in pit 25 or in the west part of pit 24. To achieve compliance at R2 for scenario 3, two Carry Graders are proposed to replace Dozer/ Excavator/Trucks, and a 6.5m high noise barrier will be built along the west edge of pit 25, as shown in Figure 6 in Appendix B.

Doral has confirmed that the following two noise control options, recommended by SVT in early 2014[7], will be included in their revised mining designs:

Option 1: Build a 2.5m high noise barrier along the west edge of pit 25, as shown in Figures 8 and 9 in Appendix B. This noise barrier aims to achieve compliance at R2 and R3 for the mining operation of scenario 4.

Option 2: Build 5.5m high noise bunds along the north and east edges of pit 2, as shown in Figures 10 to 13 in Appendix B. This option aims to achieve compliance for the day-time operations of scenario 5 and for the night-time operations of scenario 6.

During mining periods the fixed plant including pit-dewatering pumps operates 24 hours per day. Figures 3 to 13 in Appendix B show the assumed operating locations of fixed plant and mobile equipment for each scenario. The equipment operating locations are assumed according to the mining schedules shown in Table B1 in Appendix B provided by Doral and by consulting with Doral representatives.

[7] "Environmental noise impact assessment of the proposed Yoongarillup mining operations" SVT report (NO: Rpt01-1370684-Rev1-10 February 2014).

3.3 Input Data

3.3.1 Topography

Topographical information for the region surrounding the proposed mine site was obtained from the information provided by Doral. The ground contours include the mining pits, SEPs, top/subsoil stockpiles and temporary ore stockpiles.

No building effects are considered in the model. An absorptive ground is assumed for propagation over land while reflective ground is assumed for the SEPs.

3.3.2 Noise Emission Data

Table 3-2 presents the sound power levels of the mobile equipment and fixed plant.

Table 3-2: Measured sound power levels for proposed fixed plant and mobile equipment.

Equipment	Octave Band Sound Power Levels in dB(lin)									O/A dB(A)
	31.5	63	125	250	500	1k	2k	4k	8k	
Fixed Plant										
Feed Hoper	97.9	97.7	90.8	90.8	88.2	84.9	79.9	77.9	68.4	**90.2**
Mining Unit	116.3	108.0	105.9	103.1	103.3	102.6	98.5	96.2	89.5	**106.8**
Concentrator	111.5	113.4	108.8	105.0	101.6	101.1	99.0	96.8	89.9	**106.4**
Tails Booster Pump	81.7	85.3	86.8	83.8	84.7	84.0	94.1	87.4	82.6	**96.7**
Silenced 8" Diesel Dewatering Pump	101.8	117.9	105.6	104.0	96.0	94.6	93.5	87.3	80.4	**101.6**
Lighting Tower (Diesel Powered)	106.4	95.1	97.2	89.2	83.5	80.7	76.0	71.7	69.9	**87.5**
Mobile Equipment										
CAT D7 Dozer	107.4	105.9	113.7	111.2	109.0	106.0	102.6	97.5	90.5	**111.3**
Carry Grader	101.9	106.8	104.8	105.7	103.8	104.5	100.1	94.8	88.3	**108.0**
D400 Watercart	101.1	101.9	114.7	102.1	101.4	101.7	100.2	96.6	90.9	**107.1**
Komatsu PC 600 Excavator	94.1	105.3	115.3	106.1	99.4	95.6	87.3	80.3	72.5	**103.6**
CAT980 FEL	104.1	105.4	113.8	103.9	106.5	105.3	102.8	97.7	92.6	**109.9**
CAT740 Truck with Hot Tub Exhaust System	95.0	94.1	101.3	100.7	98.8	96.6	93.3	88.5	81.1	**101.4**

3.3.3 Receiving Premises

The location of noise sensitive premises has been provided by Doral. Figure 1 in Appendix A shows the representative residences close to the proposed mine site. R13 represents a receiver standing on the top floor of a two-storey house while the others are the receivers of single-storey houses.

3.3.4 Meteorology

SoundPlan calculates noise levels for defined meteorological conditions. In particular, temperature, relative humidity, wind speed and direction data are required as input to the model.

For the noise modelling SVT has used the worst case meteorological conditions suggested by the EPA (*Environmental Protection Act 1986*) Guidance note No 8 for assessing noise impact from new developments as the upper limit of the meteorological conditions investigated. Table 3-3 presents the worst-case meteorological conditions for noise emission from the proposed mine site.

Table 3-3: Worst-case meteorological conditions for noise emission from the mine site.

Time of day	Temperature Celsius	Relative Humidity	Wind speed	Pasquill Stability Category
Day (0700 --- 1900)	20° Celsius	50%	4 m/s	E
Evening (1900 --- 2200)	20° Celsius	50%	4 m/s	E
Night (2200 --- 0700)	15° Celsius	50%	3 m/s	F

4. MODELLING RESULTS

4.1 Point Calculations

Point calculations have been performed at each of the 16 closest noise sensitive locations for a range of day and night time meteorological conditions including calm conditions and worst-case winds in 8 cardinal directions. As stated in section 3.2, the equipment operating during Sundays and public holidays is the same as that operating during nights. Therefore, the worst-case day-time noise levels for Sundays and public holidays will be very similar to the night-time noise levels.

The full point calculation results are presented in Table 4-1 to Table 4-11. It can be seen that wind direction has a big impact on the noise levels received at the closest residential locations.

Table 4-12 summarises the predicted worst-case noise levels in dB(A) for each scenario. Table 4-13 presents the maximum values of predicted worst-case noise levels in dB(A) for each scenario, the occurring residential locations and the wind directions.

Table 4-1: Predicted day-time noise levels in dB(A) for scenario 1 – construction phase.

Closest Residences	Predicted day-time noise levels in dB(A) for scenario 1 (Calm & worst-case conditions)								
	N	NE	E	SE	S	SW	W	NW	Calm
R1	31.8	31.8	31.4	22.3	18.9	18.9	20.8	30.8	26.1
R2	47.9	48.2	48.2	45.4	37.4	36.6	36.6	41.4	43.6
R3	43.4	44.3	44.3	43.7	34.6	32.0	32.0	33.6	39.3
R4	14.7	22.9	26.9	26.9	26.9	20.4	14.4	14.2	21.0
R5	16.6	20.3	29.1	29.3	29.3	28.0	18.4	16.6	23.6
R6	18.6	20.1	28.9	31.3	31.3	31.1	23.6	18.6	25.7
R7	14.2	14.2	15.3	25.0	26.5	26.5	26.4	17.9	20.7
R8	18.0	17.5	17.7	23.4	29.8	29.8	29.8	26.1	24.2
R9	16.5	15.5	15.5	19.2	27.6	27.7	27.7	26.2	22.0
R10	16.7	15.4	15.4	17.8	27.1	27.2	27.2	26.7	21.6
R11	16.7	14.6	14.6	16.3	26.6	26.7	26.7	26.6	21.0
R12	12.6	8.9	8.9	9.8	19.5	21.2	21.2	21.2	15.4
R13	12.5	11.4	11.4	13.5	22.9	22.7	22.7	22.7	17.1
R14	14.0	14.0	14.8	23.8	26.2	26.2	26.2	18.5	20.5
R15	13.9	13.9	14.8	24.3	26.1	26.1	26.1	17.9	20.4
R16	12.5	12.5	13.4	23.1	24.7	24.7	24.7	16.3	18.8

Table 4-2: Predicted day-time noise levels in dB(A) for scenario 2 – mining operations.

Closest Residences	Predicted day-time noise levels in dB(A) for scenario 2 (Calm & worst-case conditions)								
	N	NE	E	SE	S	SW	W	NW	Calm
R1	24.3	24.3	24.3	18.3	12.7	12.7	13.1	20.5	19.4
R2	32.5	32.9	32.9	32.6	24.2	21.8	21.8	23.5	28.4
R3	31.4	32.4	32.4	32.2	24.3	21.1	21.1	22.4	27.8
R4	10.5	20.5	21.4	21.4	21.4	12.5	9.4	9.4	16.0
R5	14.6	20.6	26.8	26.9	26.9	22.8	15.0	14.5	21.5
R6	17.7	20.8	29.7	29.9	29.9	29.2	19.4	17.7	24.8
R7	15.0	15.0	16.8	26.8	27.1	27.1	26.9	17.5	21.8
R8	19.7	19.5	19.8	26.5	31.3	31.3	31.3	26.3	26.4
R9	17.9	17.0	17.0	21.6	28.9	29.0	29.0	26.5	23.9
R10	17.7	16.2	16.2	19.3	28.1	28.3	28.3	27.6	23.1
R11	20.6	18.4	18.4	20.3	30.1	30.3	30.3	30.1	25.0
R12	12.6	8.8	8.8	9.6	18.4	20.3	20.3	20.2	15.1
R13	12.9	11.6	11.6	14.3	23.3	23.3	23.3	23.0	18.0
R14	14.8	14.8	16.1	26.0	26.9	26.9	26.8	18.1	21.6
R15	14.7	14.7	16.2	26.4	26.7	26.7	26.6	17.4	21.5
R16	13.0	13.0	14.4	24.9	25.1	25.1	25.0	15.6	19.7

Table 4-3: Predicted night-time noise levels in dB(A) for scenario 2 – mining operations.

Closest Residences	Predicted night-time noise levels in dB(A) for scenario 2 (Calm & worst-case conditions)								
	N	NE	E	SE	S	SW	W	NW	Calm
R1	24.8	24.8	24.8	23.7	17.3	15.7	17.9	24.6	24.6
R2	33.1	33.1	33.1	33.1	29.1	25.3	25.0	28.2	32.7
R3	32.5	32.7	32.7	32.7	29.4	24.9	24.2	27.1	32.2
R4	15.6	22.0	22.0	22.0	22.0	18.5	13.4	12.7	22.0
R5	19.5	26.2	27.4	27.4	27.4	27.1	20.1	17.9	27.2
R6	21.8	26.2	30.3	30.3	30.3	30.2	24.5	21.3	30.0

Closest Residences	Predicted night-time noise levels in dB(A) for scenario 2 (Calm & worst-case conditions)								
	N	NE	E	SE	S	SW	W	NW	Calm
R7	18.9	18.6	21.8	27.5	27.6	27.6	27.6	23.0	27.3
R8	24.5	22.7	24.6	31.3	31.7	31.7	31.7	31.2	31.3
R9	22.8	20.3	21.4	27.1	29.4	29.4	29.4	29.2	29.1
R10	22.7	19.7	20.3	25.0	28.7	28.7	28.7	28.7	28.4
R11	25.6	22.0	21.9	25.3	30.8	30.8	30.8	30.8	30.5
R12	18.1	12.7	11.7	14.3	20.6	20.7	20.7	20.7	20.5
R13	17.8	14.9	15.5	20.1	23.9	23.9	23.9	23.9	23.9
R14	18.9	18.2	21.2	27.3	27.4	27.4	27.4	23.8	27.2
R15	18.7	18.1	21.2	27.2	27.3	27.3	27.3	23.2	27.0
R16	16.9	16.4	19.5	25.6	25.6	25.6	25.6	21.4	25.5

Table 4-4: Predicted day-time noise levels in dB(A) for scenario 3 – mining operations.

Closest Residences	Predicted day-time noise levels in dB(A) for scenario 3 (Calm & worst-case conditions)								
	N	NE	E	SE	S	SW	W	NW	Calm
R1	31.5	31.5	31.4	23.4	17.9	17.9	19.1	29.2	26.2
R2	37.0	40.2	40.2	40.0	33.2	27.0	27.0	28.0	35.2
R3	33.3	37.3	37.3	37.2	31.9	24.4	24.2	24.8	32.3
R4	12.6	21.6	25.1	25.1	25.1	18.3	12.0	11.9	19.5
R5	15.1	19.6	27.8	27.9	27.9	26.9	16.5	15.0	22.5
R6	18.9	21.1	31.0	31.9	31.9	31.5	22.5	18.9	26.6
R7	15.1	15.1	16.6	26.7	27.7	27.7	27.6	18.5	22.3
R8	19.4	19.0	19.1	25.5	31.1	31.2	31.2	26.8	26.1
R9	17.6	16.6	16.6	21.0	28.9	29.0	29.0	26.9	23.7
R10	17.5	16.0	16.0	18.9	28.2	28.4	28.4	28.0	23.0
R11	20.3	18.2	18.2	20.0	30.0	30.2	30.2	30.0	24.8

Closest Residences	Predicted day-time noise levels in dB(A) for scenario 3 (Calm & worst-case conditions)								
	N	NE	E	SE	S	SW	W	NW	Calm
R12	13.0	9.3	9.3	10.3	20.0	21.3	21.3	21.2	15.9
R13	12.8	11.5	11.5	14.1	23.7	23.6	23.6	23.6	18.2
R14	14.8	14.8	15.9	25.4	27.4	27.4	27.3	19.2	22.0
R15	14.7	14.7	16.0	25.9	27.3	27.3	27.3	18.6	21.9
R16	13.1	13.1	14.4	24.5	25.7	25.7	25.7	16.8	20.2

Table 4-5: Predicted night-time noise levels in dB(A) for scenario 3 – mining operations.

Closest Residences	Predicted night-time noise levels in dB(A) for scenario 3 (Calm & worst-case conditions)								
	N	NE	E	SE	S	SW	W	NW	Calm
R1	26.3	26.3	26.3	24.2	18.3	17.5	19.7	26.1	26.0
R2	31.1	31.2	31.2	31.2	27.1	27.7	23.7	26.6	30.5
R3	30.2	30.4	30.4	30.4	26.9	24.6	22.5	25.1	29.8
R4	14.7	21.3	21.3	21.3	21.3	16.0	13.0	12.0	21.3
R5	17.2	23.0	25.0	25.0	25.0	21.8	18.4	15.9	24.8
R6	21.4	25.3	30.3	30.4	30.4	25.6	26.0	21.6	30.0
R7	18.2	17.6	20.7	26.8	26.8	25.9	26.8	23.0	26.6
R8	23.3	21.3	23.0	29.4	30.4	29.7	30.4	30.0	30.0
R9	21.7	19.0	20.0	25.4	28.2	27.4	28.2	28.0	27.9
R10	21.6	18.5	19.0	23.4	27.5	26.7	27.5	27.5	27.3
R11	24.7	21.1	20.9	24.1	29.7	28.6	29.7	29.7	29.4
R12	17.7	12.3	11.3	13.9	20.3	20.1	20.4	20.4	20.2
R13	16.8	13.8	14.3	18.8	22.9	22.1	22.9	22.9	23.0
R14	18.2	17.2	19.9	26.5	26.5	25.9	26.5	23.8	26.4
R15	17.9	17.2	20.1	26.4	26.5	25.7	26.5	23.2	26.3
R16	16.2	15.5	18.4	24.9	24.9	24.1	24.9	21.4	24.8

Table 4-6: Predicted day-time noise levels in dB(A) for scenario 4 – mining operations.

Closest Residences	Predicted day-time noise levels in dB(A) for scenario 4 (Calm & worst-case conditions)								
	N	NE	E	SE	S	SW	W	NW	Calm
R1	32.0	32.0	31.9	26.0	20.4	20.2	20.7	27.9	26.7
R2	37.3	40.1	40.1	39.9	33.8	29.4	29.4	30.1	35.5
R3	34.1	37.7	37.7	37.6	32.0	26.5	26.4	27.0	32.8
R4	14.6	23.2	25.6	25.6	25.6	17.9	13.9	13.9	20.0
R5	16.8	21.4	28.6	28.6	28.6	25.9	17.5	16.7	23.1
R6	19.7	22.0	31.0	31.4	31.4	30.9	21.7	19.7	26.1
R7	17.3	17.3	18.8	28.7	29.2	29.2	29.1	19.9	23.7
R8	21.6	21.4	21.7	28.5	33.1	33.1	33.0	27.7	27.9
R9	19.9	19.3	19.3	24.0	31.0	31.0	31.0	27.9	25.7
R10	19.7	18.6	18.6	22.0	30.3	30.4	30.4	29.1	25.0
R11	21.1	19.3	19.3	21.4	30.9	31.1	31.1	30.9	25.7
R12	15.1	12.4	12.4	13.4	23.1	23.7	23.7	23.7	18.3
R13	15.9	15.0	15.0	17.7	26.4	26.3	26.3	25.5	20.8
R14	17.3	17.3	18.4	28.2	29.1	29.1	29.0	20.5	23.6
R15	17.1	17.1	18.4	28.3	28.9	28.9	28.9	19.9	23.5
R16	15.5	15.5	16.8	26.9	27.4	27.4	27.4	18.2	21.8

Table 4-7: Predicted night-time noise levels in dB(A) for scenario 4 – mining operations.

Closest Residences	Predicted night-time noise levels in dB(A) for scenario 4 (Calm & worst-case conditions)								
	N	NE	E	SE	S	SW	W	NW	Calm
R1	26.0	26.0	26.0	23.4	18.4	17.5	20.0	25.8	25.6
R2	33.7	34.0	34.0	34.0	31.6	27.7	27.0	29.2	33.3
R3	31.1	31.6	31.6	31.6	29.3	24.6	23.7	26.0	30.9
R4	12.3	18.5	18.5	18.5	18.5	16.0	10.5	9.6	18.5
R5	14.9	21.0	22.3	22.3	22.3	21.8	15.6	13.5	22.0
R6	17.8	22.2	25.6	25.7	25.7	25.6	21.3	17.5	25.3

Closest Residences	Predicted night-time noise levels in dB(A) for scenario 4 (Calm & worst-case conditions)								
	N	NE	E	SE	S	SW	W	NW	Calm
R7	17.4	16.8	19.8	25.9	25.9	25.9	25.9	22.4	25.8
R8	22.8	20.9	22.5	28.8	29.7	29.7	29.7	29.4	29.3
R9	21.0	18.4	19.4	24.7	27.4	27.4	27.4	27.3	27.1
R10	20.8	17.8	18.3	22.7	26.7	26.7	26.7	26.6	26.5
R11	23.6	19.9	19.8	23.0	28.5	28.6	28.6	28.6	28.3
R12	17.4	12.1	11.2	13.7	20.1	20.1	20.1	20.1	20.0
R13	16.0	13.0	13.5	18.1	22.1	22.1	22.1	22.1	22.2
R14	17.7	16.7	19.3	25.9	25.9	25.9	25.9	23.4	25.8
R15	17.3	16.5	19.3	25.7	25.7	25.7	25.7	22.7	25.6
R16	15.5	14.7	17.6	24.1	24.1	24.1	24.1	20.9	24.0

Table 4-8: Predicted day-time noise levels in dB(A) for scenario 5 – mining operations.

Closest Residences	Predicted day-time noise levels in dB(A) for scenario 5 (Calm & worst-case conditions)								
	N	NE	E	SE	S	SW	W	NW	Calm
R1	26.8	26.7	26.7	22.5	15.2	14.9	15.0	20.6	21.2
R2	30.8	31.1	31.1	30.8	21.9	19.8	19.8	21.6	26.1
R3	30.9	31.3	31.3	31.2	22.4	20.0	20.0	21.3	26.1
R4	10.8	20.6	20.4	20.4	20.7	10.8	9.4	9.4	15.0
R5	13.5	22.5	24.0	24.0	24.1	16.8	12.8	12.8	18.7
R6	16.5	23.9	27.4	27.5	27.5	23.1	16.6	16.1	22.3
R7	18.4	18.7	25.4	30.1	30.2	30.1	26.1	19.0	24.8
R8	26.9	27.1	32.4	37.8	38.3	38.2	35.9	28.5	33.2
R9	24.9	24.8	26.1	34.7	36.6	36.6	36.2	29.0	31.4
R10	25.8	25.5	25.9	32.7	37.0	37.1	36.9	32.1	31.9
R11	26.8	25.3	25.3	27.3	35.8	36.3	36.3	35.7	31.3

Closest Residences	Predicted day-time noise levels in dB(A) for scenario 5 (Calm & worst-case conditions)								
	N	NE	E	SE	S	SW	W	NW	Calm
R12	23.4	18.7	18.6	19.0	25.3	29.4	29.5	29.3	24.2
R13	19.1	18.4	18.4	22.7	29.9	30.1	30.1	27.1	24.6
R14	18.9	19.0	24.3	30.5	30.7	30.6	27.6	19.8	25.3
R15	18.4	18.6	24.4	30.1	30.2	30.1	26.7	19.2	24.8
R16	16.7	16.8	21.7	28.3	28.4	28.4	25.5	17.5	22.9

Table 4-9: Predicted night-time noise levels in dB(A) for scenario 5 – mining operations.

Closest Residences	Predicted night-time noise levels in dB(A) for scenario 5 (Calm & worst-case conditions)								
	N	NE	E	SE	S	SW	W	NW	Calm
R1	24.7	24.7	24.7	24.4	17.1	15.2	17.1	24.4	24.7
R2	28.9	28.9	28.9	28.9	24.3	21.1	21.1	24.3	28.4
R3	28.8	28.8	28.8	28.8	24.9	21.1	20.7	23.6	28.4
R4	11.2	16.9	16.9	16.9	16.9	12.6	8.5	8.1	16.9
R5	13.8	20.5	20.6	20.6	20.6	19.9	13.4	11.8	20.4
R6	16.6	21.7	24.1	24.1	24.1	23.9	18.1	15.7	23.8
R7	14.7	14.6	18.0	22.8	22.8	22.8	22.8	18.1	22.5
R8	21.2	19.8	21.6	27.5	27.9	27.9	27.9	27.0	27.4
R9	19.5	17.3	18.3	23.3	25.4	25.4	25.4	25.1	25.0
R10	19.2	16.5	17.0	20.9	24.6	24.6	24.6	24.5	24.2
R11	22.7	19.2	18.9	21.7	27.0	27.0	27.0	27.0	26.6
R12	17.3	11.7	10.5	12.8	19.0	19.2	19.2	19.2	19.0
R13	13.7	10.9	11.4	15.4	19.2	19.2	19.2	19.2	19.1
R14	14.8	14.4	17.3	22.7	22.7	22.7	22.7	19.0	22.4
R15	14.4	14.2	17.4	22.5	22.5	22.5	22.5	18.2	22.2
R16	12.6	12.3	15.5	20.7	20.8	20.8	20.8	16.4	20.5

Table 4-10: Predicted day-time noise levels in dB(A) for scenario 6 – mining operations.

Closest Residences	Predicted day-time noise levels in dB(A) for scenario 6 (Calm & worst-case conditions)								
	N	NE	E	SE	S	SW	W	NW	Calm
R1	27.2	27.2	27.2	23.6	15.7	15.2	15.3	20.5	21.6
R2	32.5	33.4	33.4	33.1	24.3	21.6	21.6	23.1	28.2
R3	31.8	32.9	32.9	32.7	24.3	21.1	21.1	22.4	27.6
R4	12.3	22.9	22.6	22.6	22.9	12.7	10.8	10.8	16.9
R5	14.9	23.4	26.3	26.3	26.3	19.0	14.3	14.3	20.7
R6	17.8	24.0	29.6	29.7	29.6	25.3	18.1	17.6	24.2
R7	18.9	18.9	23.8	31.1	31.2	31.2	28.4	19.8	25.7
R8	25.9	26.0	28.9	37.5	38.2	38.1	37.4	28.4	32.9
R9	24.6	24.5	25.5	34.1	36.7	36.7	36.4	29.5	31.3
R10	25.5	25.2	25.4	31.7	37.2	37.3	37.2	32.6	31.9
R11	25.9	24.4	24.4	27.4	36.1	36.4	36.4	35.3	31.2
R12	19.6	15.8	15.8	16.6	25.2	26.9	26.9	26.7	21.7
R13	19.4	18.7	18.7	23.3	30.6	30.7	30.7	27.7	25.1
R14	19.2	19.2	22.9	31.3	31.5	31.5	30.0	20.6	26.0
R15	18.7	18.8	23.0	30.9	31.1	31.1	29.1	19.9	25.5
R16	17.1	17.2	20.8	29.3	29.5	29.5	28.0	18.4	23.8

Table 4-11: Predicted night-time noise levels in dB(A) for scenario 6 – mining operations.

Closest Residences	Predicted night-time noise levels in dB(A) for scenario 6 (Calm & worst-case conditions)								
	N	NE	E	SE	S	SW	W	NW	Calm
R1	22.5	22.5	22.5	22.0	15.2	13.2	15.0	21.6	22.5
R2	30.0	30.0	30.0	30.0	25.4	21.9	21.8	25.1	29.7
R3	30.2	30.3	30.3	30.3	26.2	22.1	21.7	24.6	29.9
R4	11.3	16.9	16.9	16.9	16.9	12.6	8.5	8.2	17.0
R5	13.8	20.5	20.7	20.7	20.7	19.9	13.4	11.9	20.5

Closest Residences	Predicted night-time noise levels in dB(A) for scenario 6 (Calm & worst-case conditions)								
	N	NE	E	SE	S	SW	W	NW	Calm
R6	16.7	21.7	24.1	24.1	24.1	23.8	18.1	15.7	23.8
R7	14.9	15.2	19.0	23.0	23.0	23.0	22.7	18.1	22.6
R8	22.1	21.8	25.4	28.5	28.8	28.8	28.1	27.0	28.2
R9	21.6	20.6	22.6	26.9	27.9	27.9	27.9	25.9	27.3
R10	22.6	21.0	22.3	27.2	28.6	28.6	28.6	27.6	28.0
R11	26.3	23.2	23.3	26.5	30.8	30.8	30.8	30.8	30.1
R12	21.6	16.2	15.0	16.9	22.6	23.1	23.1	23.1	22.5
R13	16.9	14.6	15.5	20.6	22.9	22.9	22.9	22.7	22.6
R14	15.1	15.0	18.8	22.9	23.0	23.0	22.7	19.0	22.6
R15	14.7	14.8	18.6	22.7	22.7	22.7	22.5	18.3	22.4
R16	12.8	12.9	16.8	21.0	21.0	21.0	20.8	16.5	20.7

Table 4-12: Summary of worst-case noise levels in dB(A).

Closest Residences	S1	S2		S3		S4		S5		S6	
	Day	Day	Night	Day	Night	Day	Night	Day	Night	Day	Night
R1	31.8	24.3	24.8	31.5	26.3	32.0	26.0	26.8	24.7	27.2	22.5
R2	48.2	32.9	33.1	40.2	31.2	40.1	34.0	31.1	28.9	33.4	30.0
R3	44.3	32.4	32.7	37.3	30.4	37.7	31.6	31.3	28.8	32.9	30.3
R4	26.9	21.4	22.0	25.1	21.3	25.6	18.5	20.7	16.9	22.9	16.9
R5	29.3	26.9	27.4	27.9	25.0	28.6	22.3	24.1	20.6	26.3	20.7
R6	31.3	29.9	30.3	31.9	30.4	31.4	25.7	27.5	24.1	29.7	24.1
R7	26.5	27.1	27.6	27.7	26.8	29.2	25.9	30.2	22.8	31.2	23.0
R8	29.8	31.3	31.7	31.2	30.4	33.1	29.7	38.3	27.9	38.2	28.8
R9	27.7	29.0	29.4	29.0	28.2	31.0	27.4	36.6	25.4	36.7	27.9
R10	27.2	28.3	28.7	28.4	27.5	30.4	26.7	37.1	24.6	37.3	28.6

Closest Residences	S1	S2		S3		S4		S5		S6	
	Day	Day	Night	Day	Night	Day	Night	Day	Night	Day	Night
R11	26.7	30.3	30.8	30.2	29.7	31.1	28.6	36.3	27.0	36.4	30.8
R12	21.2	20.3	20.7	21.3	20.4	23.7	20.1	29.5	19.2	26.9	23.1
R13	22.9	23.3	23.9	23.7	22.9	26.4	22.1	30.1	19.2	30.7	22.9
R14	26.2	26.9	27.4	27.4	26.5	29.1	25.9	30.7	22.7	31.5	23.0
R15	26.1	26.7	27.3	27.3	26.5	28.9	25.7	30.2	22.5	31.1	22.7
R16	24.7	25.1	25.6	25.7	24.9	27.4	24.1	28.4	20.8	29.5	21.0

Table 4-13: Predicted maximum noise levels in dB(A) and occurring locations.

	S1	S2		S3		S4		S5		S6	
	Day	Day	Night	Day	Night	Day	Night	Day	Night	Day	Night
Maximum Noise Level in dB(A)	48.2	32.9	33.1	40.2	31.2	40.1	34.0	38.3	28.9	38.2	30.8
Residential Location	R2	R2	R2	R2	R2	R2	R2	R8	R2	R8	R11
Wind Directions	NE - E	NE - E	N - SE	NE - E	NE - SE	NE - E	NE - SE	S	N - SE	S	S - NW

4.2 Noise Contours

Noise contours have been prepared for the worst-case meteorological conditions given in Table 3-3 for day and night time sound propagation. The noise contours are presented in Figures 14 to 24 in Appendix C, starting from 25 dB(A) to 60 dB(A) with a 5 dB interval. These noise contours represent the worst-case noise propagation envelopes, i.e. worst-case propagation in all directions simultaneously.

5. COMPLIANCE ASSESSMENT

5.1 Tonality Assessment

Assessment of tonality in received noise emissions depends on the existing level of ambient noise (i.e. whether tonality is likely to protrude above background noise) as well as the severity and duration of any tonality. The *Regulations* specify two criteria for assessing tonality, (Regulation 9(1)). The first is based on instantaneous sound pressure levels and the second is based on average sound pressure levels. Very strong tonality which protrudes significantly above background noise may satisfy the first criteria. Less severe tonality may satisfy the second criteria provided that it persists for at least 10% of the representative assessment period.

Many of the items of equipment for the proposed mining activities will have some degree of tonality when measured at source. However, this tonality may not always be evident at the receivers for the following reasons:

- Tonality may not protrude above ambient noise.
- Tonality from particular items of equipment may be masked by noise received from other equipment.
- The level of noise emissions from items of mobile equipment will vary depending on their locations (which may be continuously changing).
- The severity and pitch of the tonality from mobile equipment will change depending on operating conditions.

Therefore, in order to assess the likelihood of tonality being evident in received noise it is necessary to review which equipment dominates noise levels at each receiver.

Since the assigned noise levels are no less than 45 dB(A) for days of Mondays to Saturdays and 35 dB(A) for nights at the residences of interest, the tonality assessment will be made at the receiver locations where the overall noise level is greater than 40 dB(A) for day-time operations and 30 dB(A) for night-time mining operations. Tables D1 to D7 in Appendix D present the assessment of whether or not tonality is likely to be evident at the receiving locations for the proposed construction and mining operations. The assessment has been undertaken for worst-case sound propagation conditions at each receiver location.

No tonality adjustment is required in cases where noise from a watercart dominates the predicted noise levels. The watercart does not generally operate in a confined area and is more likely to be deployed over a large area. Consequently any tonality will be transient and unlikely to persist for 10% of the representative assessment period.

Although the tonality assessment was undertaken for worst-case weather conditions, it is assumed that the findings apply for all prevailing conditions. According to the *Regulations*, predicted and measured noise levels should be adjusted by adding 5.0 dB if they contain tonal components. Therefore, some values presented in Table 4-1 to Table 4-12 for these locations for particular wind directions will also need to be adjusted before comparing predicted levels with the assigned noise limits.

Table 5-1 summarizes the adjusted worst-case day and night time noise levels. The adjusted values are expressed in ***bold italic***.

Table 5-1: Adjusted worst-case noise levels in dB(A) due to the presence of tonality characteristics.

Closest Residences	S1	S2		S3		S4		S5		S6	
	Day	Day	Night	Day	Night	Day	Night	Day	Night	Day	Night
R1	31.8	24.3	24.8	31.5	26.3	32.0	26.0	26.8	24.7	27.2	22.5
R2	***53.2***	32.9	33.1	***45.2***	31.2	***45.1***	34.0	31.1	28.9	33.4	30.0
R3	***49.3***	32.4	32.7	37.3	30.4	37.7	31.6	31.3	28.8	32.9	30.3
R4	26.9	21.4	22.0	25.1	21.3	25.6	18.5	20.7	16.9	22.9	16.9
R5	29.3	26.9	27.4	27.9	25.0	28.6	22.3	24.1	20.6	26.3	20.7
R6	31.3	29.9	30.3	31.9	30.4	31.4	25.7	27.5	24.1	29.7	24.1
R7	26.5	27.1	27.6	27.7	26.8	29.2	25.9	30.2	22.8	31.2	23.0
R8	29.8	31.3	31.7	31.2	30.4	33.1	29.7	38.3	27.9	38.2	28.8
R9	27.7	29.0	29.4	29.0	28.2	31.0	27.4	36.6	25.4	36.7	27.9
R10	27.2	28.3	28.7	28.4	27.5	30.4	26.7	37.1	24.6	37.3	28.6
R11	26.7	30.3	30.8	30.2	29.7	31.1	28.6	36.3	27.0	36.4	30.8
R12	21.2	20.3	20.7	21.3	20.4	23.7	20.1	29.5	19.2	26.9	23.1
R13	22.9	23.3	23.9	23.7	22.9	26.4	22.1	30.1	19.2	30.7	22.9
R14	26.2	26.9	27.4	27.4	26.5	29.1	25.9	30.7	22.7	31.5	23.0
R15	26.1	26.7	27.3	27.3	26.5	28.9	25.7	30.2	22.5	31.1	22.7
R16	24.7	25.1	25.6	25.7	24.9	27.4	24.1	28.4	20.8	29.5	21.0

5.2 Compliance Assessment

5.2.1 Construction Phase

Doral has advised that the construction activities will occur during day-time of Mondays to Saturdays only.

According to *Regulation* 13, no assigned noise levels apply for the construction period (scenario 1) at noise-sensitive premises, as long as "*the construction work is carried out in accordance with control of environmental noise practices"* set out in AS 2436-2010 Guide to noise and vibration control on Construction, Demolition and Maintenance Sites.

5.2.2 Mining Operations

Table 5-2 and Table 5-3 compare the adjusted worst-case noise levels and the assigned noise levels at the 16 closest residential locations. It can be seen that the adjusted worst-case noise levels are below the assigned noise levels at every residential location. No noise level exceedance is predicted.

Table 5-2 : Compliance assessment for day-time operations of Mondays to Saturdays.

Closest Residences	Assigned Noise Levels in dB(A)	Worst-case Daytime Noise Levels in dB(A)				
		Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6
R1	45	24.3	31.5	32.0	26.8	27.2
R2	46	32.9	***45.2***	***45.1***	31.1	33.4
R3	46	32.4	37.3	37.7	31.3	32.9
R4	45	21.4	25.1	25.6	20.7	22.9
R5	45	26.9	27.9	28.6	24.1	26.3
R6	45	29.9	31.9	31.4	27.5	29.7
R7	45	27.1	27.7	29.2	30.2	31.2
R8	45	31.3	31.2	33.1	38.3	38.2
R9	45	29.0	29.0	31.0	36.6	36.7
R10	45	28.3	28.4	30.4	37.1	37.3
R11	45	30.3	30.2	31.1	36.3	36.4
R12	45	20.3	21.3	23.7	29.5	26.9
R13	45	23.3	23.7	26.4	30.1	30.7
R14	45	26.9	27.4	29.1	30.7	31.5
R15	45	26.7	27.3	28.9	30.2	31.1
R16	45	25.1	25.7	27.4	28.4	29.5

Table 5-3 : Compliance assessment for night-time operations.

Closest Residences	Assigned Noise Levels in dB(A)	Worst-case Night-time Noise Levels in dB(A)				
		Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6
R1	35	24.8	26.3	26.0	24.7	22.5
R2	36	33.1	31.2	34.0	28.9	30.0
R3	36	32.7	30.4	31.6	28.8	30.3
R4	35	22.0	21.3	18.5	16.9	16.9
R5	35	27.4	25.0	22.3	20.6	20.7
R6	35	30.3	30.4	25.7	24.1	24.1
R7	35	27.6	26.8	25.9	22.8	23.0
R8	35	31.7	30.4	29.7	27.9	28.8
R9	35	29.4	28.2	27.4	25.4	27.9
R10	35	28.7	27.5	26.7	24.6	28.6
R11	35	30.8	29.7	28.6	27.0	30.8
R12	35	20.7	20.4	20.1	19.2	23.1
R13	35	23.9	22.9	22.1	19.2	22.9
R14	35	27.4	26.5	25.9	22.7	23.0
R15	35	27.3	26.5	25.7	22.5	22.7
R16	35	25.6	24.9	24.1	20.8	21.0

The noise levels for evening time are not predicted and should be very close to the night-time noise levels because the same mining equipment is used.

As stated in section 3.2, the equipment operating during the daytime of Sundays and public holidays is the same as that operating during nights. Therefore, the worst-case day-time noise levels for Sundays and public holidays will be very similar to the worst-case night-time noise levels.

Table 2-3 shows that the night-time assigned noise levels are 5 dB lower than the evening-time assigned noise levels or the day-time assigned noise levels of Sundays and public holidays. Table 5-3 shows that no exceedance is predicted for the night-time operations. Therefore, compliance will be achieved during evenings and for the day-time operations of Sundays and public holidays.

It can be concluded that full compliance will be achieved for the proposed Yoongarillup mining operations.

APPENDIX A : AERIAL VIEW OF THE MINE SITE AND SURROUNDING AREA

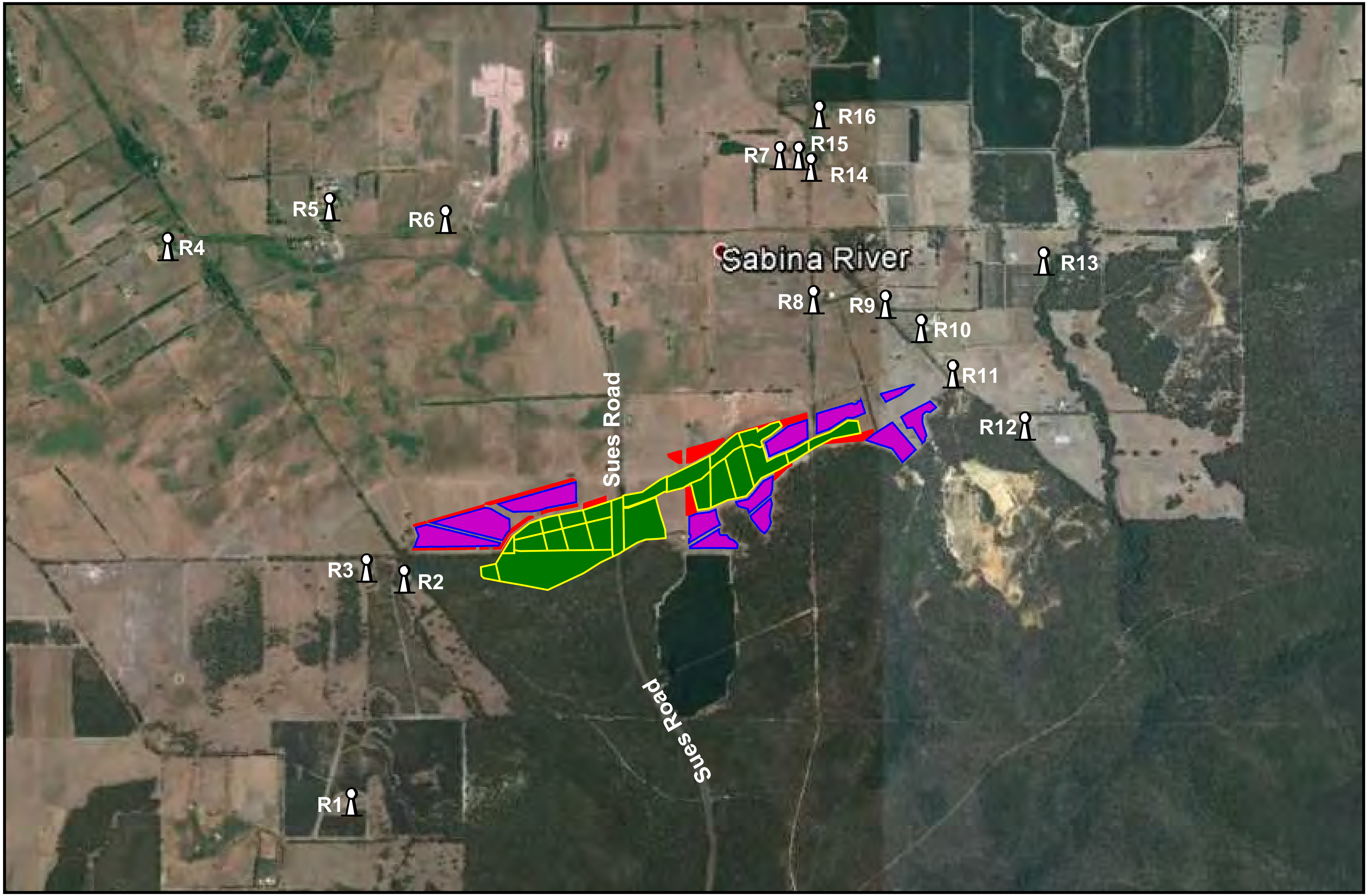


Figure 1. Aerial view of proposed mine site and surrounding area including the closest residences.

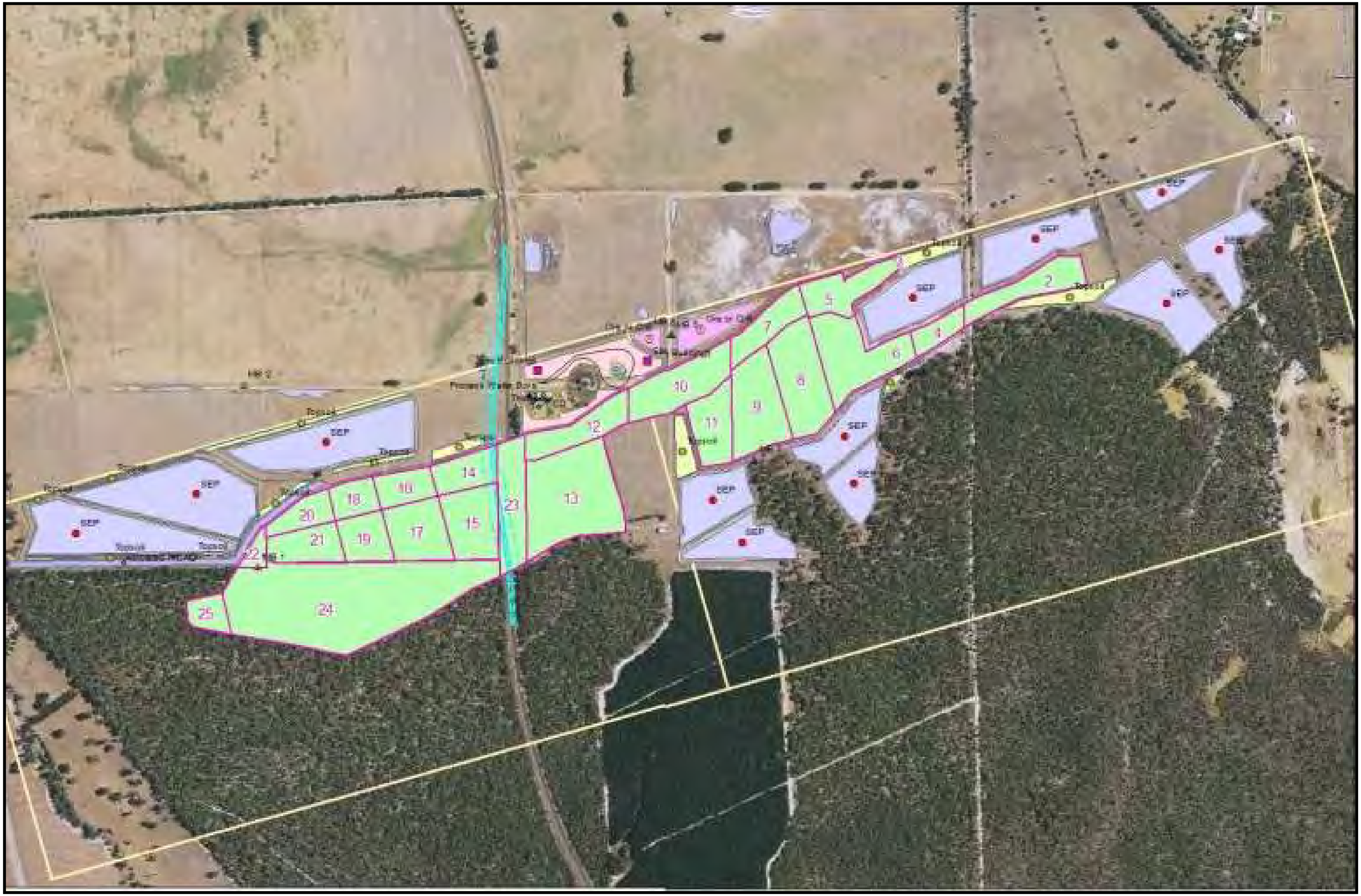


Figure 2. Proposed mine site layout including the number of mining pits.

APPENDIX B : EQUIPMENT SCHEDULES AND LOCATIONS

Figure 3: Assumed operating locations of the mobile equipment for scenario 1 - construction phase.

Figure 4: Assumed operating locations of the fixed plant and mobile equipment for day-time scenario 2.

Figure 5: Assumed operating locations of the fixed plant and mobile equipment for night-time scenario 2.

Figure 6: Assumed operating locations of the fixed plant and mobile equipment for day-time scenario 3.

Figure 7: Assumed operating locations of the fixed plant and mobile equipment for night-time scenario 3.

Figure 8: Assumed operating locations of the fixed plant and mobile equipment for day-time scenario 4.

Figure 9: Assumed operating locations of the fixed plant and mobile equipment for night-time scenario 4.

Figure 10: Assumed operating locations of the fixed plant and mobile equipment for day-time scenario 5.

Figure 11: Assumed operating locations of the fixed plant and mobile equipment for night-time scenario 5.

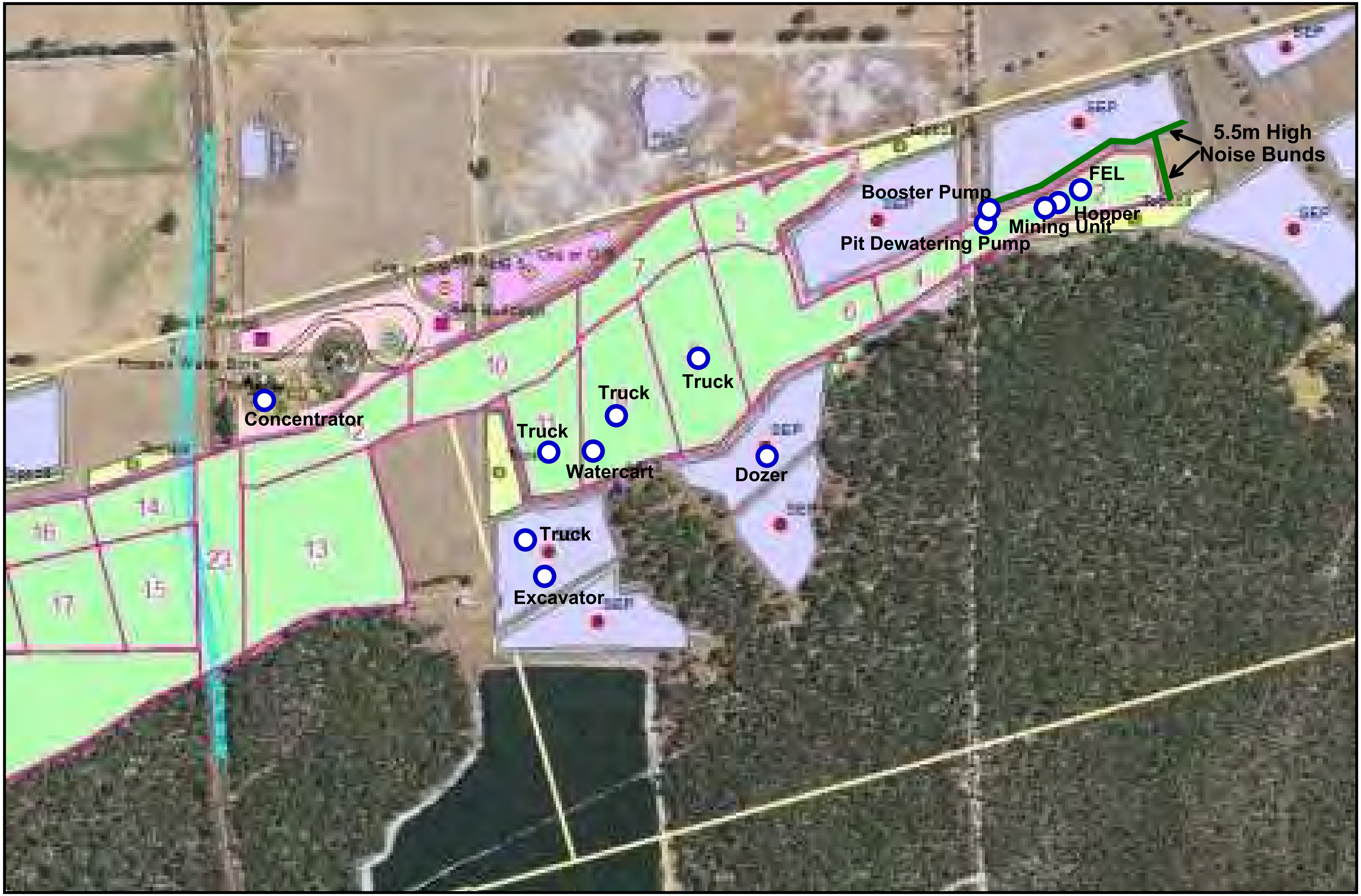


Figure 12: Assumed operating locations of the fixed plant and mobile equipment for day-time scenario 6.

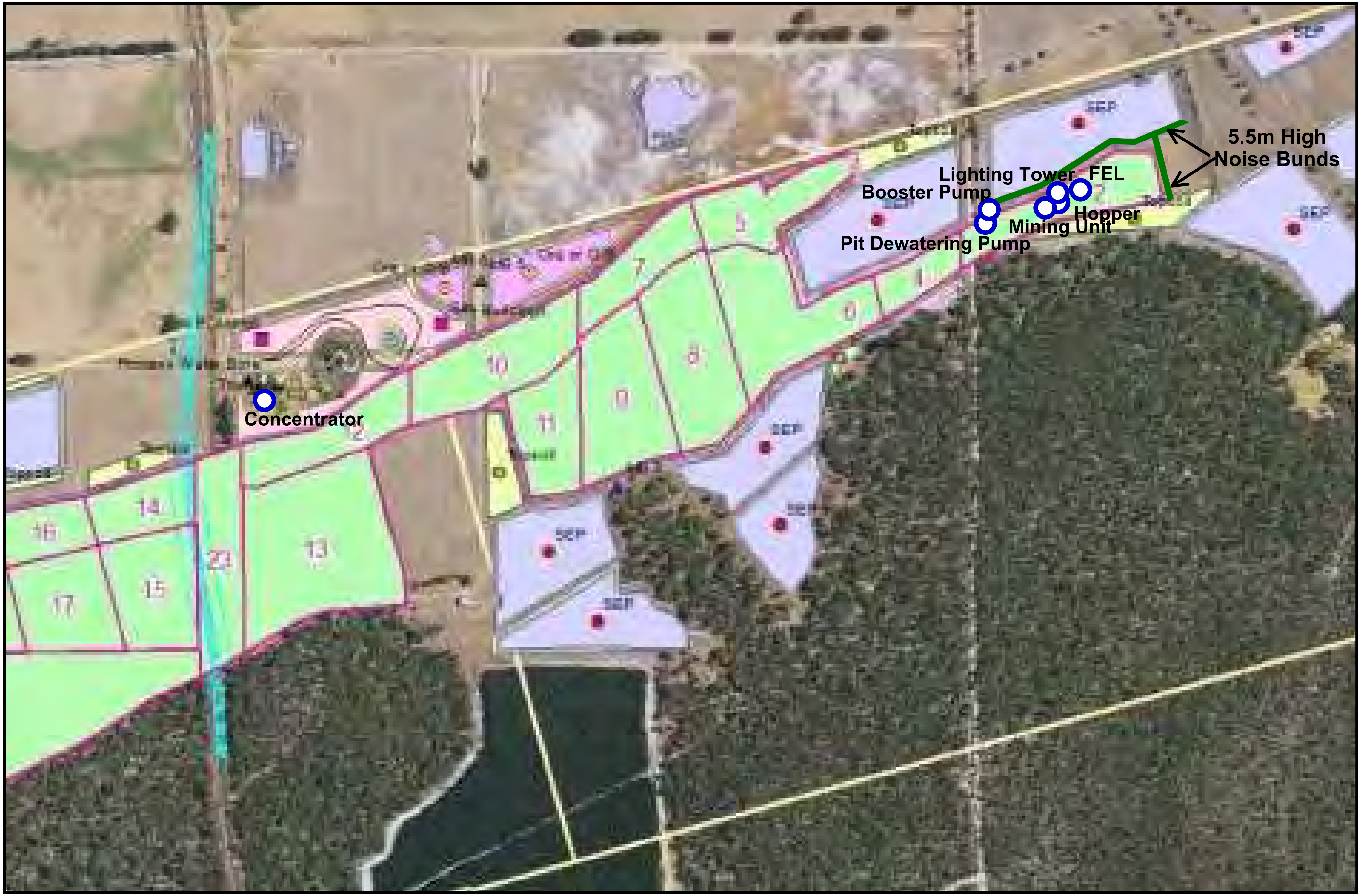
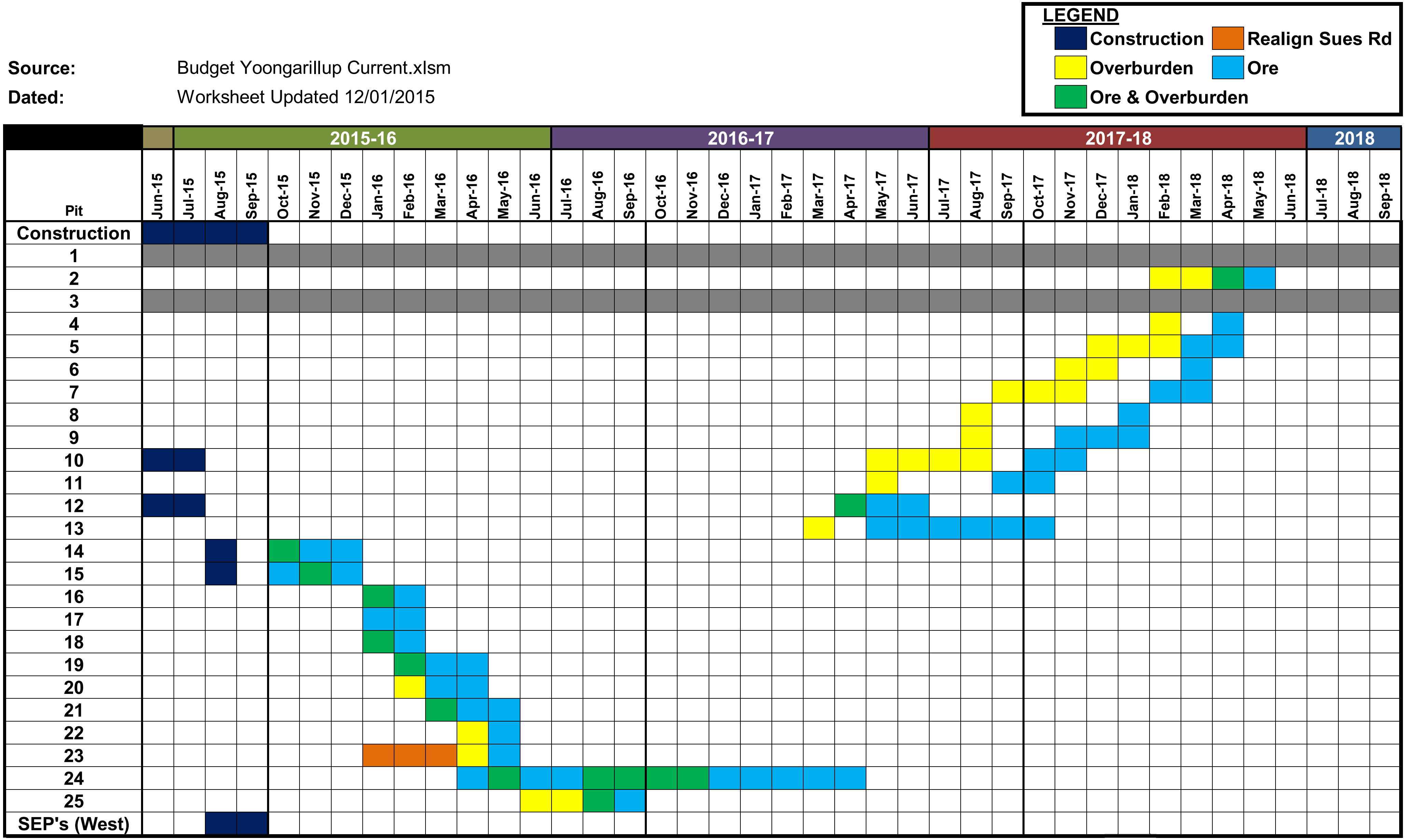


Figure 13: Assumed operating locations of the fixed plant and mobile equipment for night-time scenario 6.

Table B1: PROPOSED MINING SCHEDULE for YOONGARILLUP PROJECT

Source: Budget Yoongarillup Current.xlsm

Dated: Worksheet Updated 12/01/2015



APPENDIX C : NOISE CONTOURS

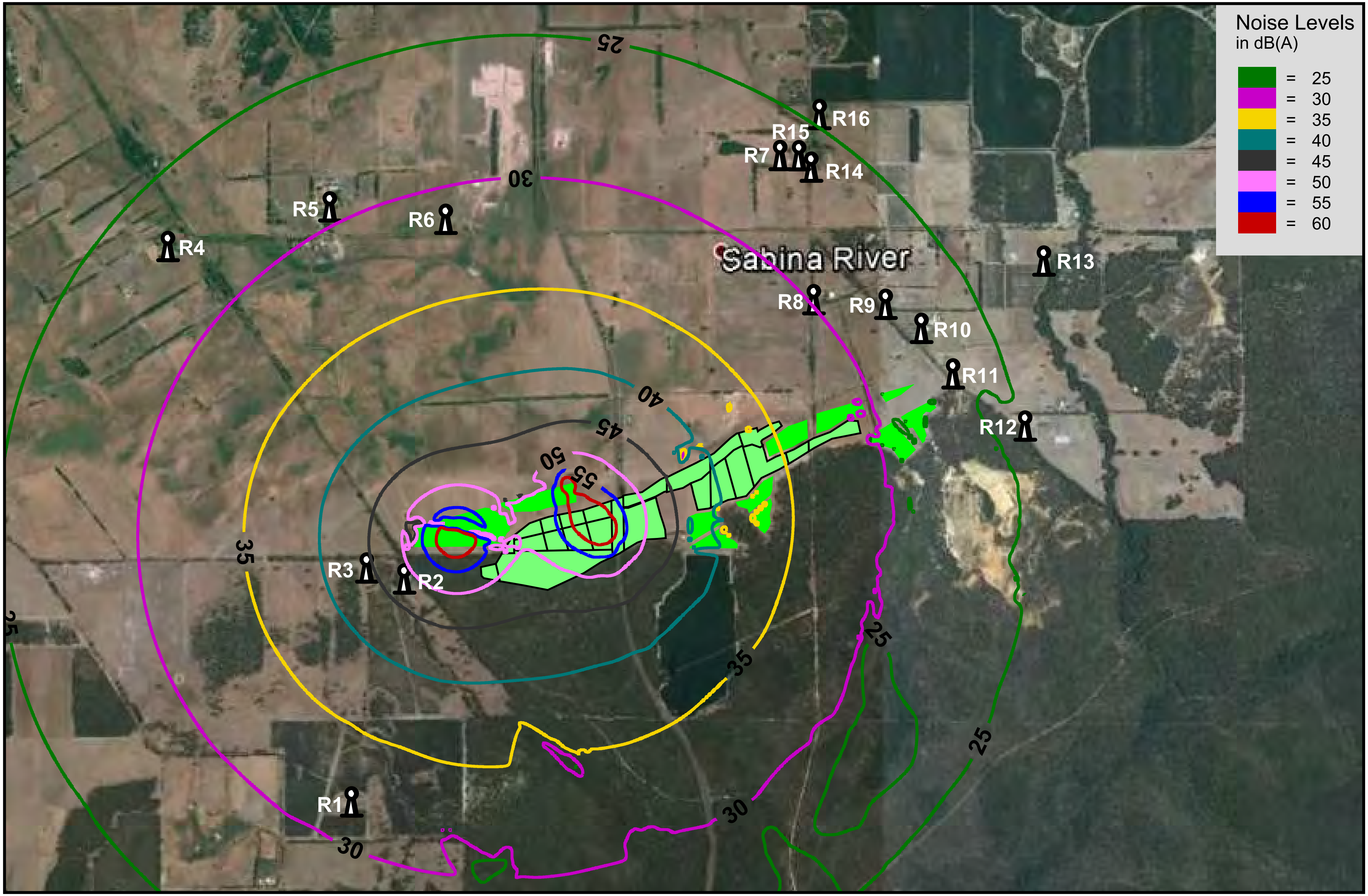


Figure 14: Worst-case daytime noise level contours for scenario 1 - construction phase.

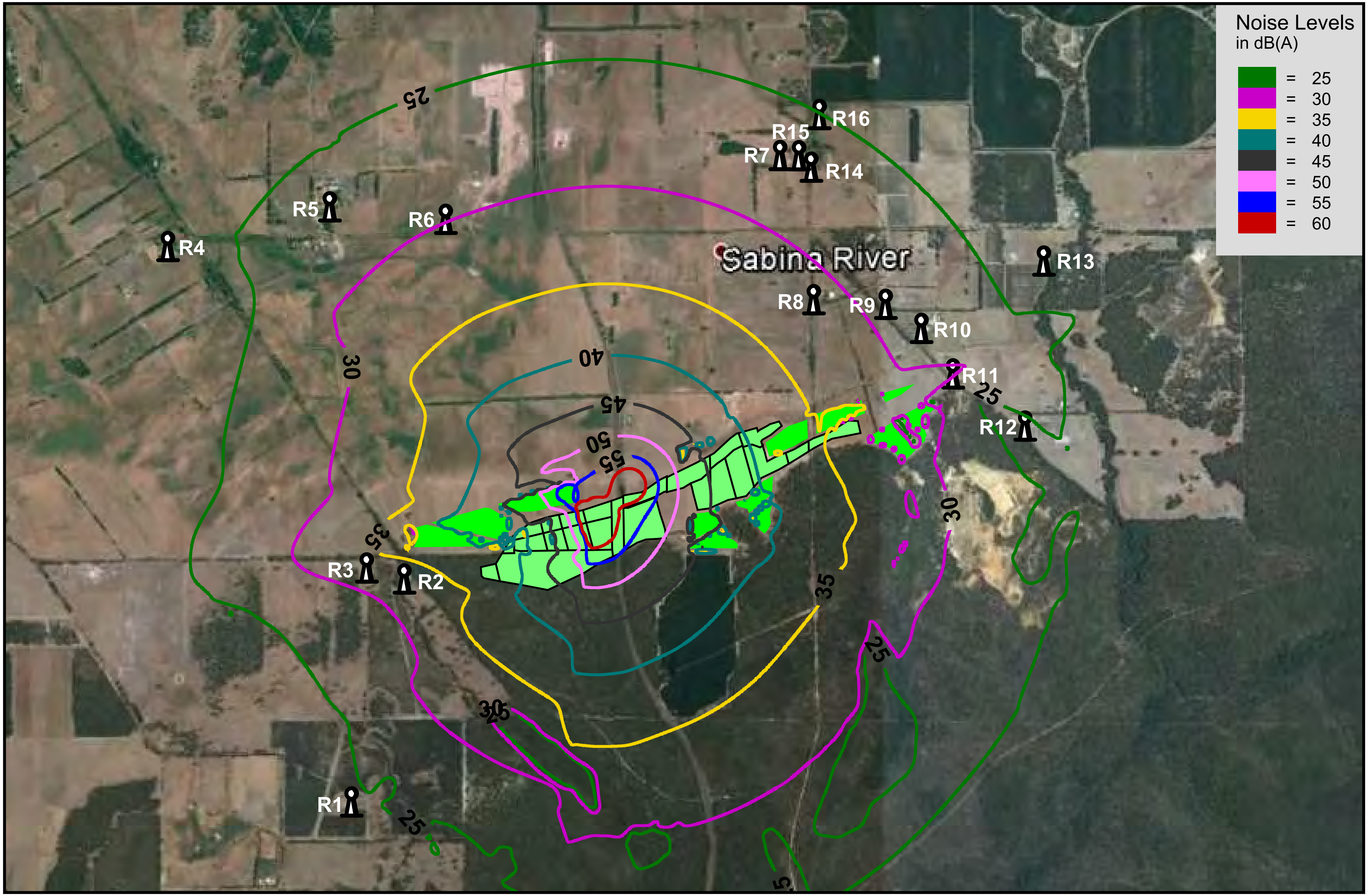


Figure 15: Worst-case daytime noise level contours for scenario 2 - Mining operations.

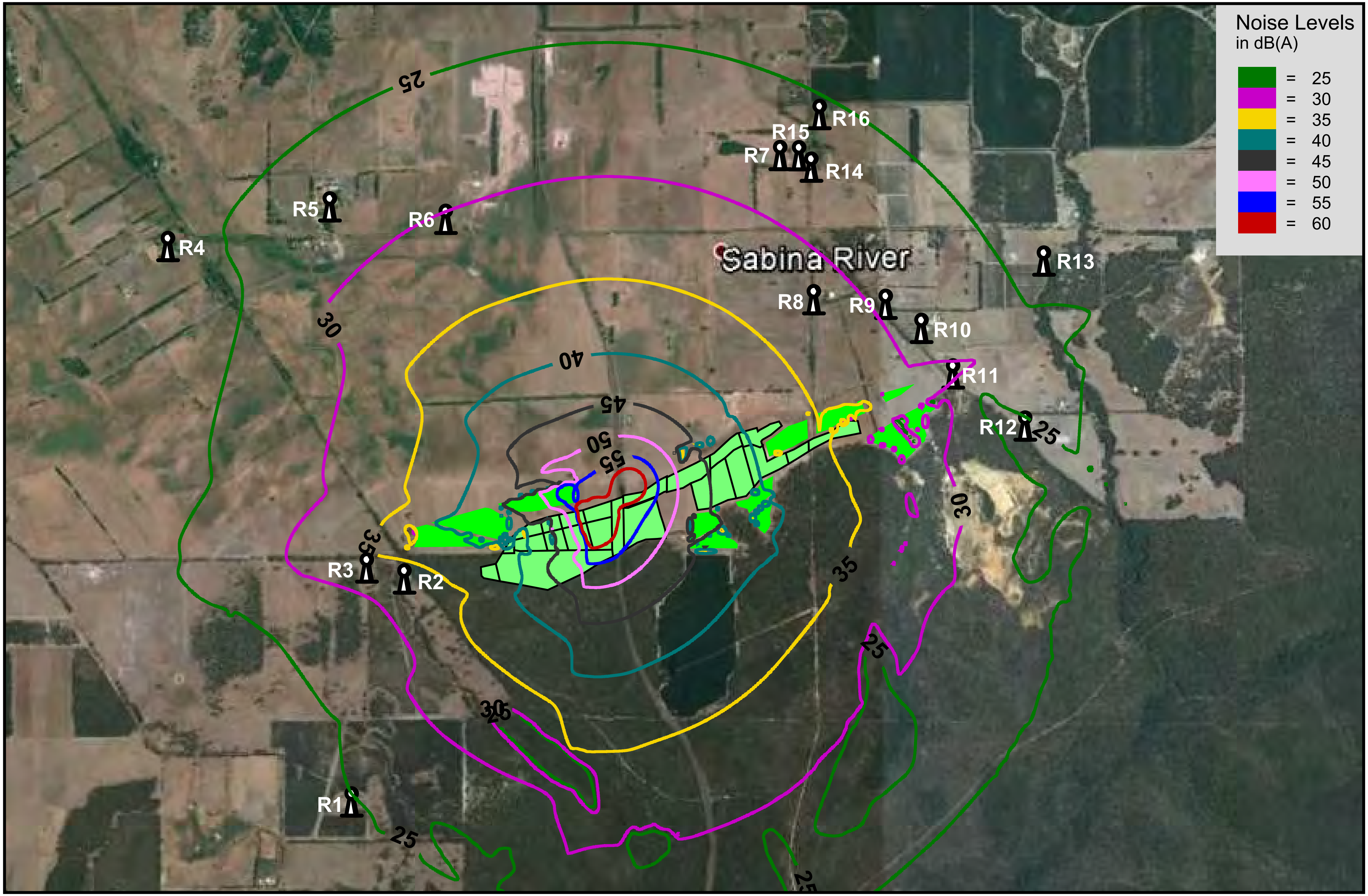


Figure 16: Worst-case night-time noise level contours for scenario 2 - Mining operations.

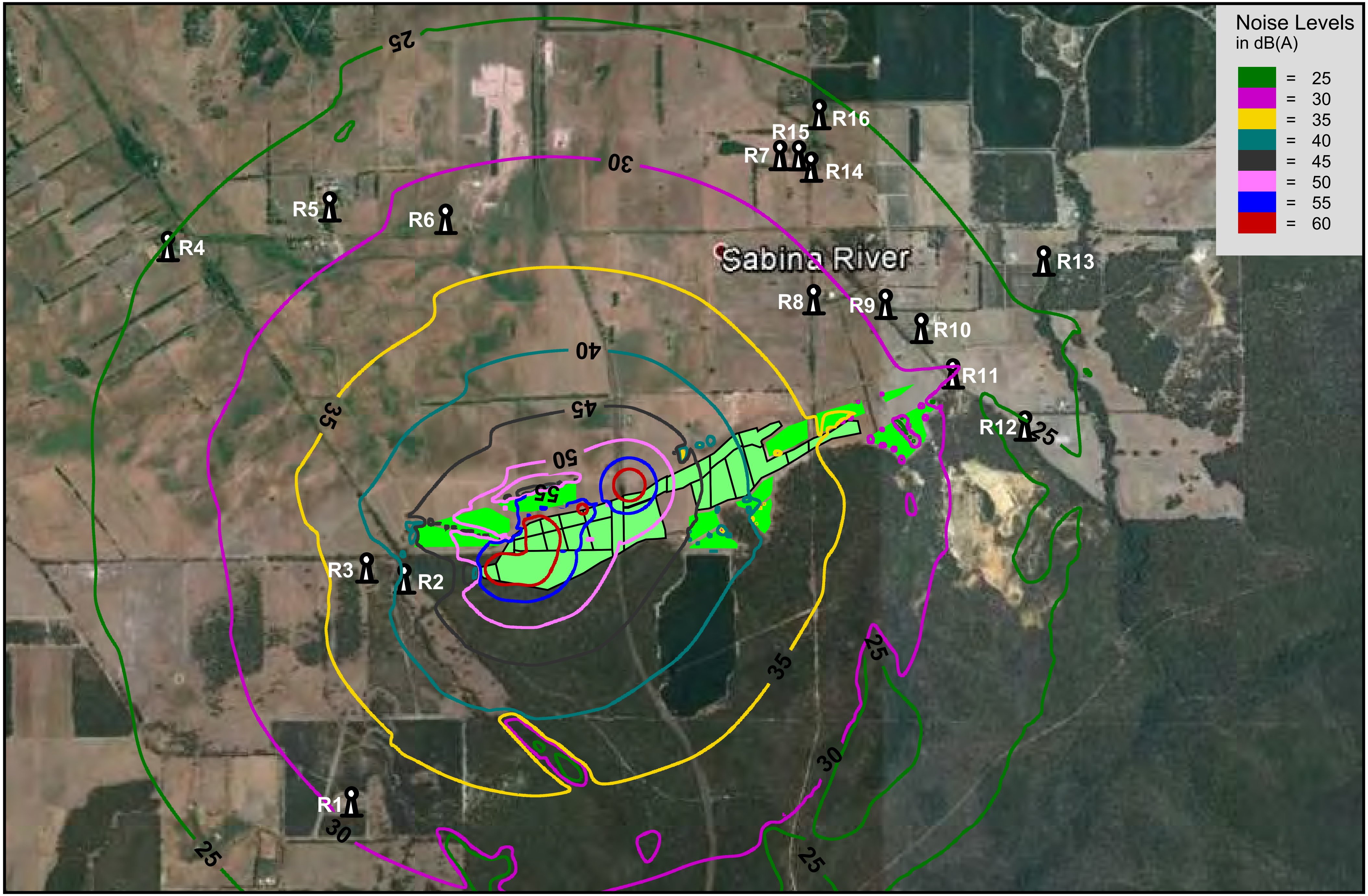


Figure 17: Worst-case daytime noise level contours for scenario 3 - Mining operations.

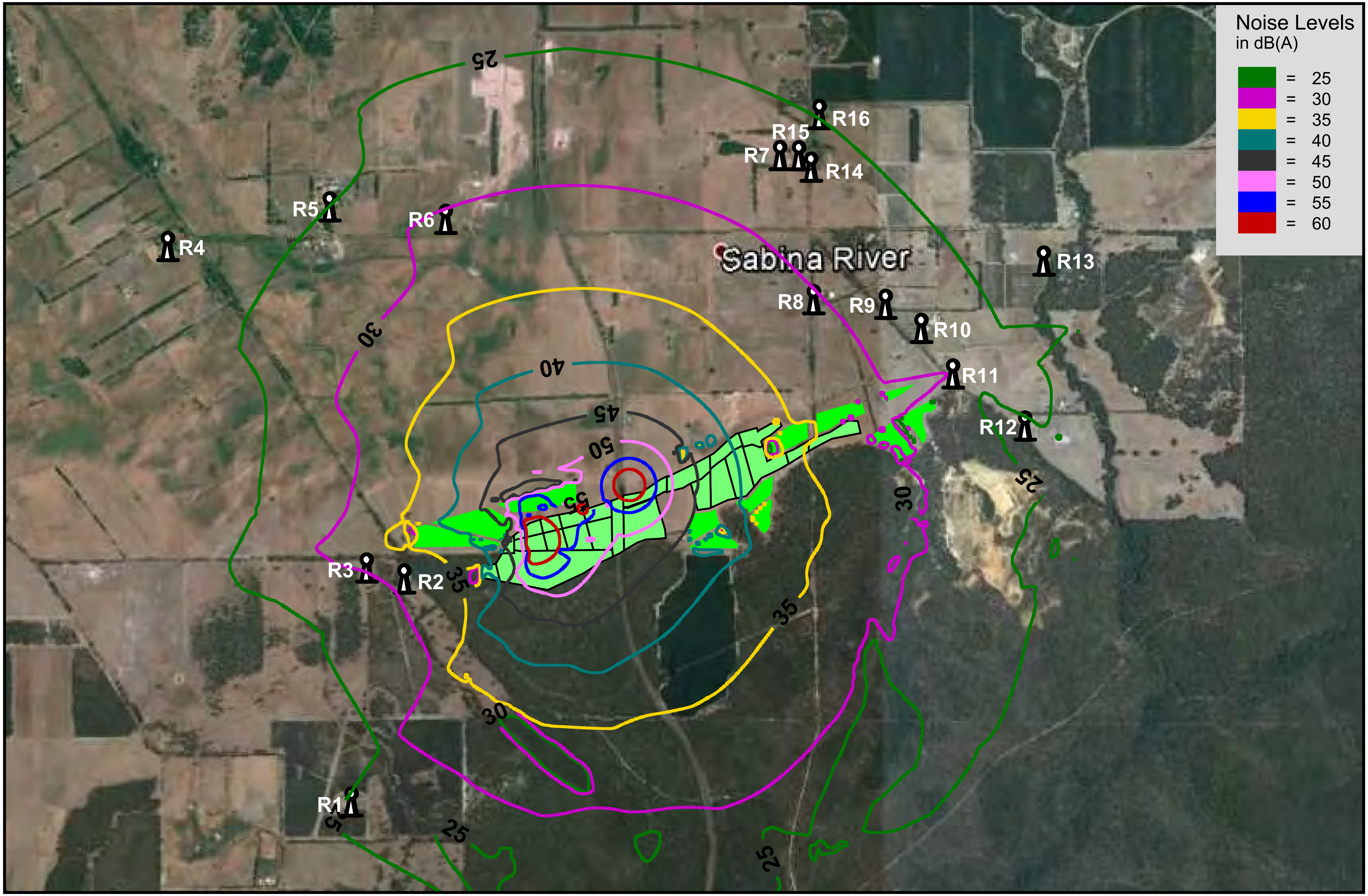


Figure 18: Worst-case night-time noise level contours for scenario 3 - Mining operations.

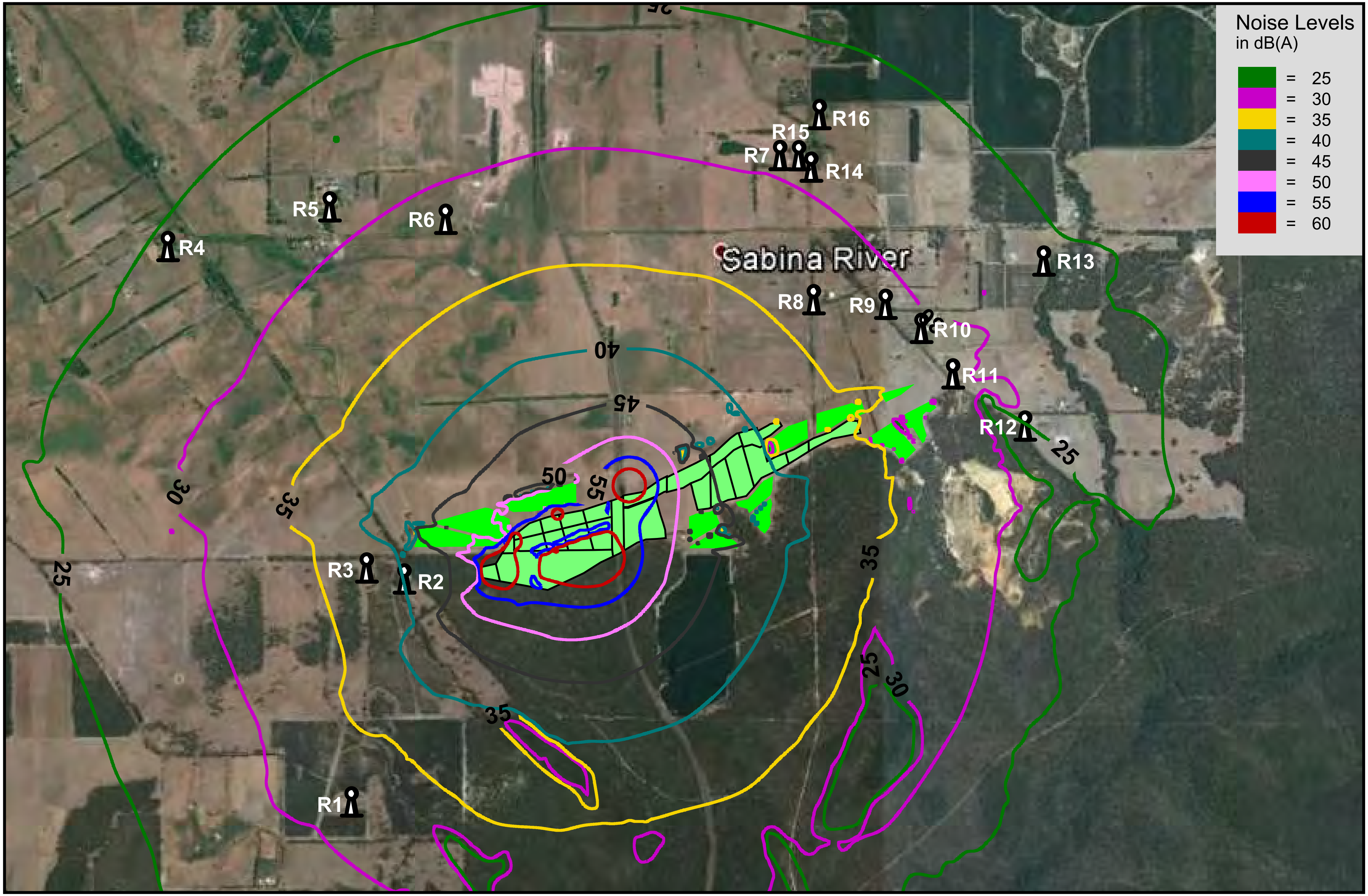


Figure 19: Worst-case daytime noise level contours for scenario 4 - Mining operations.

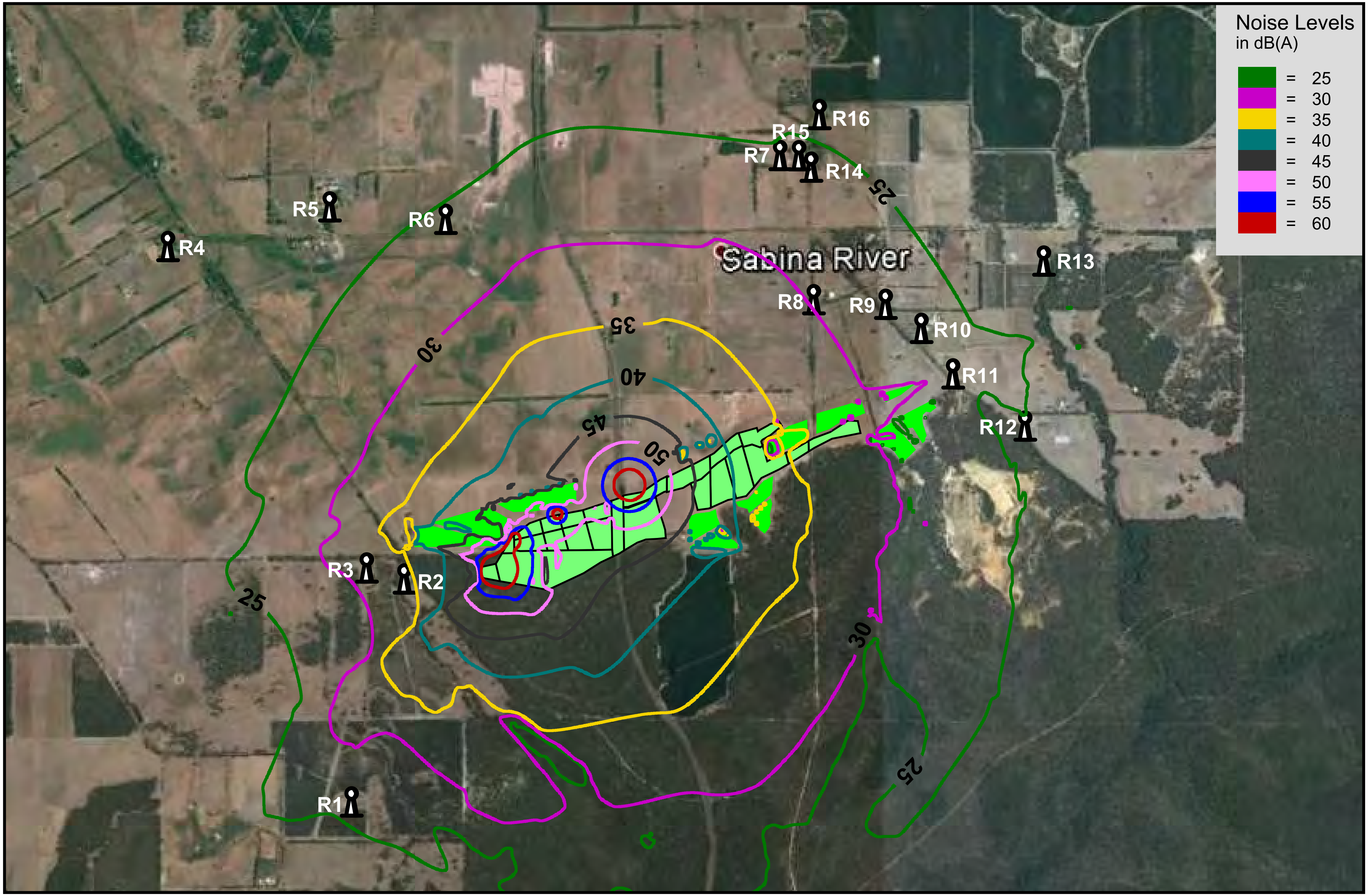


Figure 20: Worst-case night-time noise level contours for scenario 4 - Mining operations.

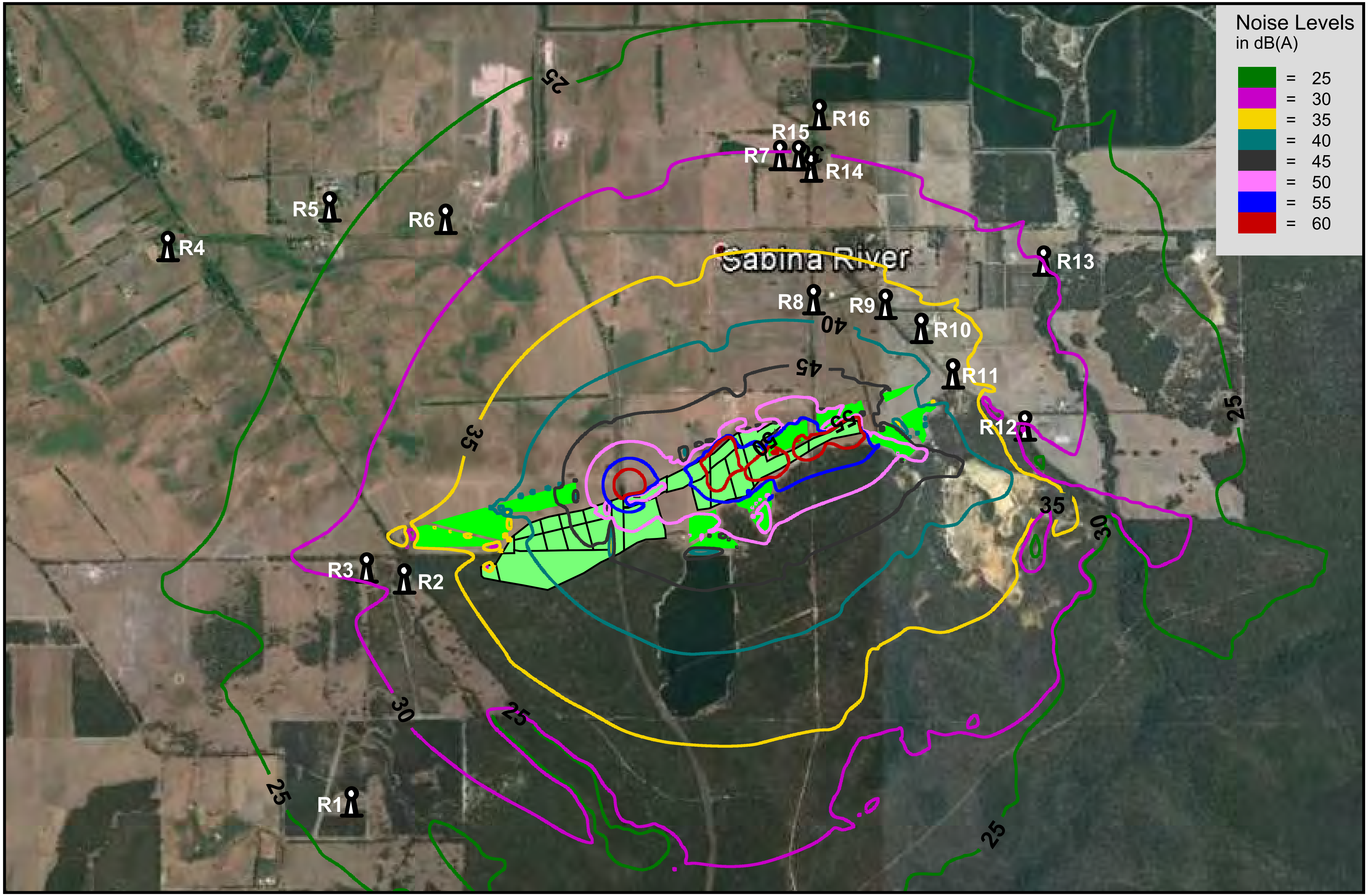


Figure 21: Worst-case daytime noise level contours for scenario 5 - Mining operations.

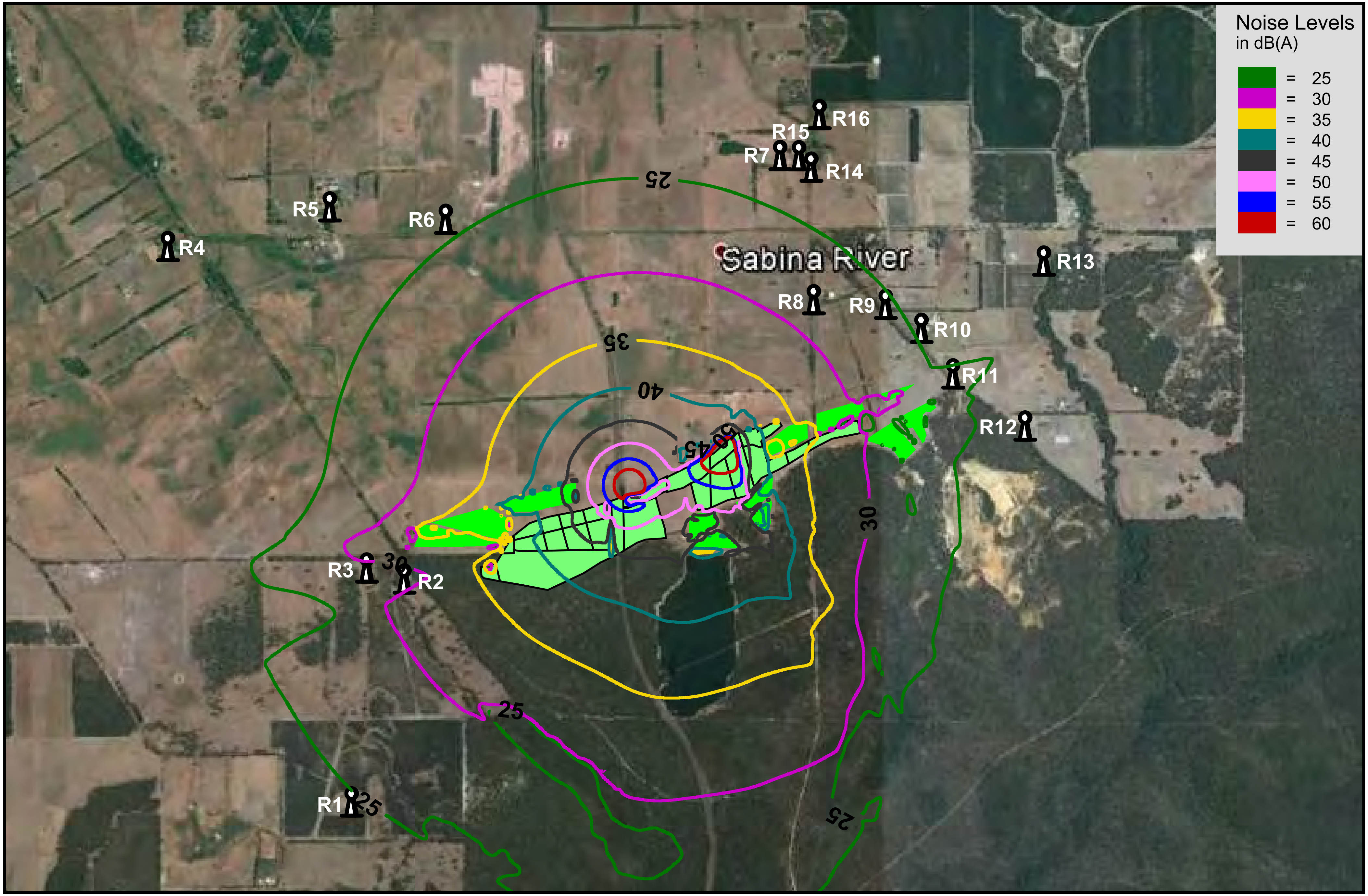


Figure 22: Worst-case night-time noise level contours for scenario 5 - Mining operations.

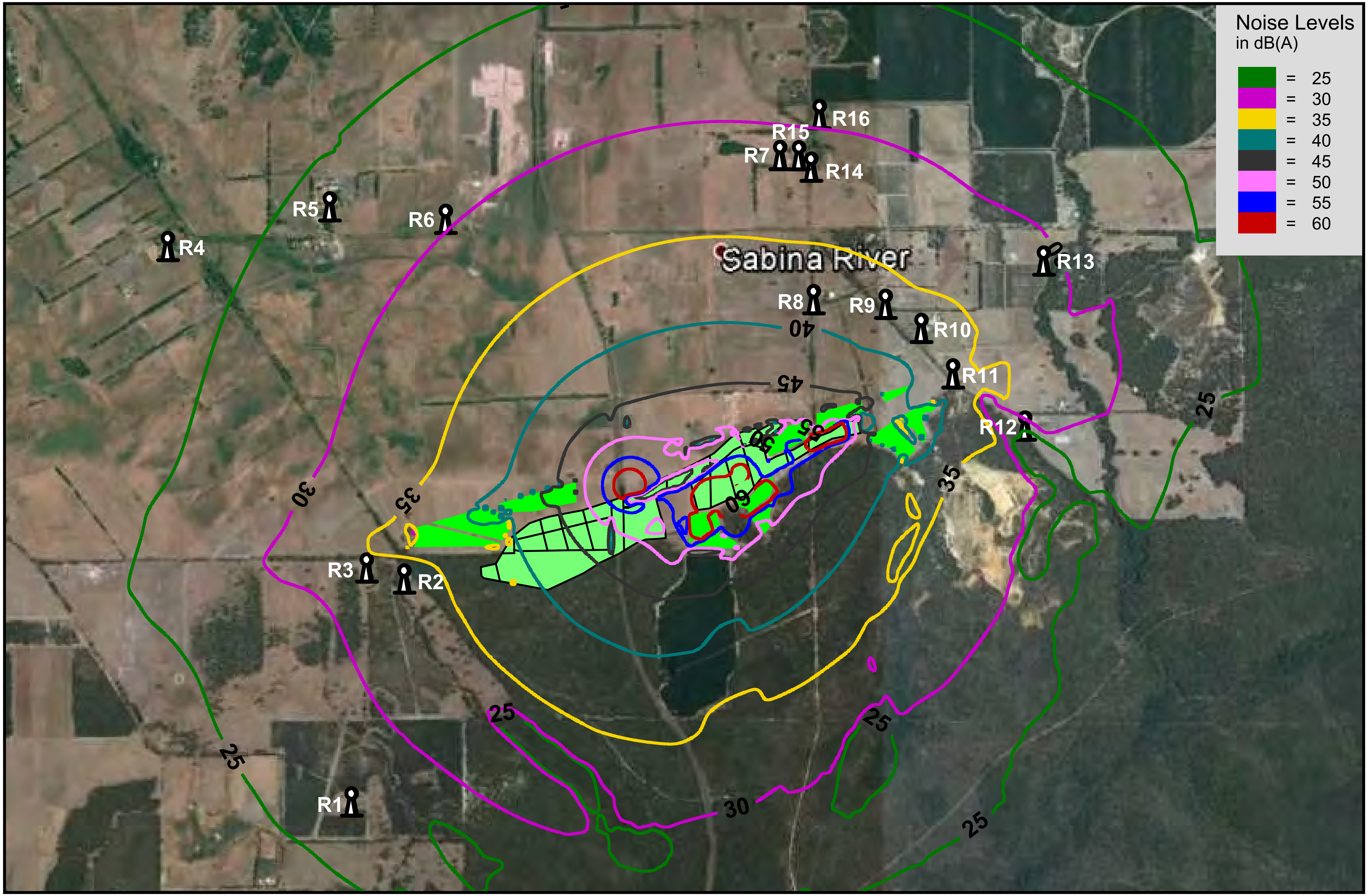


Figure 23: Worst-case daytime noise level contours for scenario 6 - Mining operations.

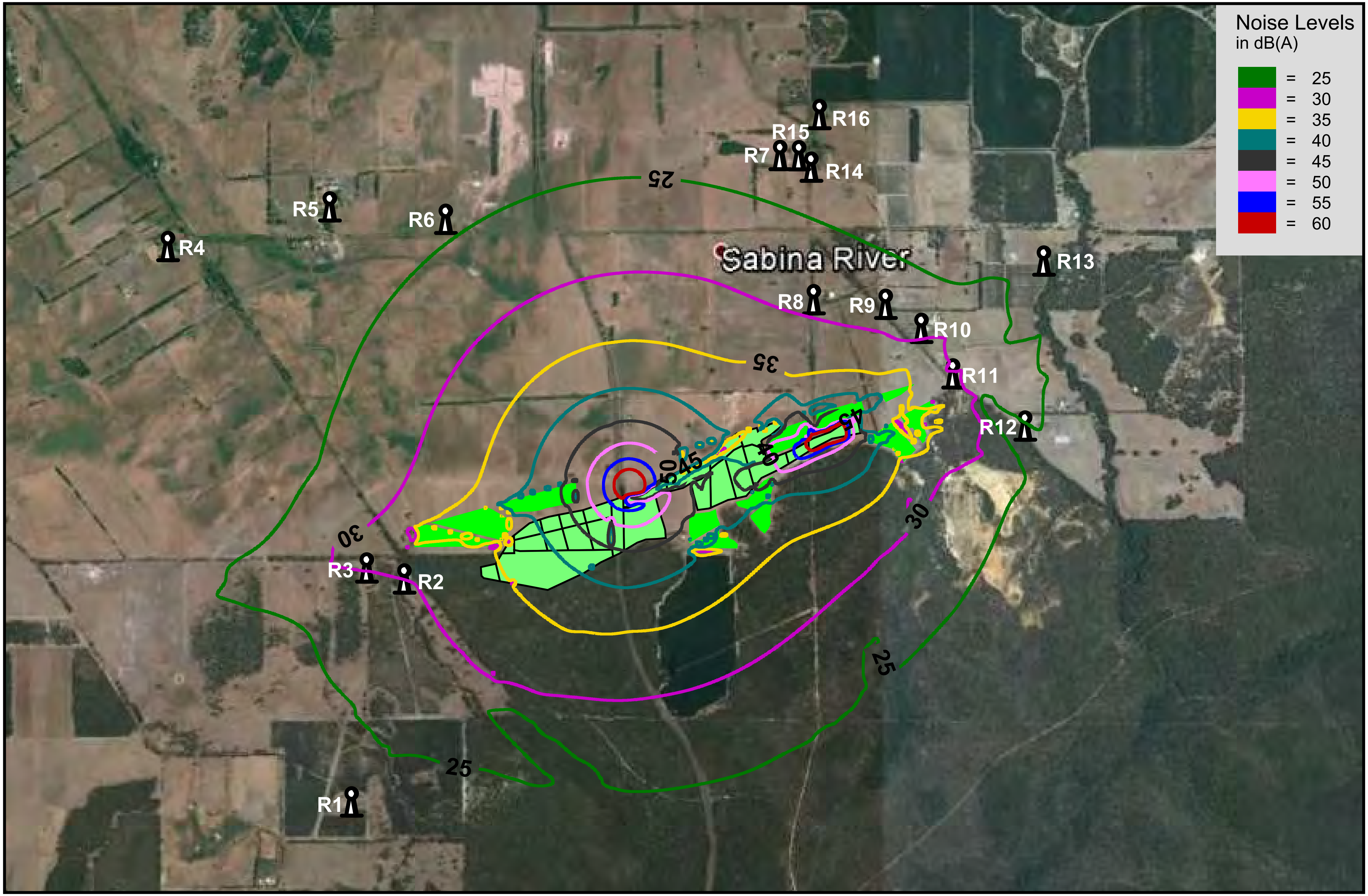


Figure 24: Worst-case night-time noise level contours for scenario 6 - Mining operations.

APPENDIX D : TONALITY ANALYSIS

Table D1: Tonality Assessment – Day-time Scenario 1 for Construction.

Scenario 1 – Day-time Constructions				
Locations	Contributors	Levels	Tonal	Comments
R2	Dozer	48.0	Yes	Noise emission from Dozer dominates.
	Watercart	31.1		
	Trucks	30.5		
R3	Dozer	44.0	Yes	
	Watercart	28.9		
	Trucks	28.5		

Table D2: Tonality Assessment – Night-time Scenario 2 for Mining Operations.

Scenario 2 - Night-time Mining Operations				
Locations	Contributor	Levels	Tonal	Comment
R2	Mining Unit	29.8	No	Mining Unit is the most dominant source, and contributes a similar level as the concentrator.
	Concentrator	28.5		
	Pit Dewatering Pump	24.1		
R3	Mining Unit	29.0	No	
	Concentrator	28.5		
	Pit Dewatering Pump	23.9		
R6	FEL 980	27.2	No	Noise contributions from dominating sources are at similar levels and may not be distinguishable. Any tonality from individual sources likely to mask each other.
	Mining Unit	24.3		
	Concentrator	24.0		
R8	FEL 980	28.0	No	
	Concentrator	26.9		
	Mining Unit	25.4		
R11	FEL 980	27.1	No	
	Concentrator	25.8		
	Mining Unit	24.6		

Table D3: Tonality Assessment – Day-time Scenario 3 for Mining Operations.

Scenario 3 – Day-time Mining Operations				
Locations	**Contributors**	**Levels**	**Tonal**	**Comments**
R2	Carry Graders	39.6	Yes	Carry Graders are the most dominant noise source.
	Concentrator	28.2		
	Mining Unit	24.9		

Table D4: Tonality Assessment – Night-time Scenario 3 for Mining Operations.

Scenario 3 - Night-time Mining Operations				
Location	**Contributor**	**Levels**	**Tonal**	**Comment**
R2	Concentrator	28.5	No	Concentrator is the most dominant noise source.
	Mining Unit	25.1		
	FEL 980	21.0		
R3	Concentrator	28.5	No	
	Mining Unit	22.4		
	Pit Dewatering Pump	19.2		
R6	FEL 980	27.2	No	Noise contributions from dominating sources are at similar levels and may not be distinguishable. Any tonality from individual sources likely to mask each other.
	Mining Unit	24.7		
	Concentrator	24.0		
R8	Concentrator	26.9	No	
	FEL 980	25.5		
	Mining Unit	23.0		

Table D5: Tonality Assessment – Day-time Scenario 4 for Mining Operations.

Scenario 4 - Day-time Mining Operations				
Locations	**Contributor**	**Levels**	**Tonal**	**Comment**
R2	Dozer	35.7	Yes	Noise emission from Dozer dominates. Noise from the Watercart is transient.
	Watercart	32.9		
	Trucks	31.8		

Table D6: Tonality Assessment – Night-time Scenario 4 for Mining Operations.

Scenario 4 - Night-time Mining Operations				
Locations	**Contributor**	**Levels**	**Tonal**	**Comment**
R2	Mining Unit	30.5	No	Noise emission from Mining Unit dominates.
	Concentrator	28.5		
	FEL 980	25.9		
R3	Concentrator	28.5	No	Concentrator noise dominates
	Mining Unit	26.0		
	FEL 980	21.5		

Table D7: Tonality Assessment – Night-time Scenario 6 for Mining Operations.

Scenario 6 – Night-time Mining Operations				
Locations	**Contributors**	**Levels**	**Tonal**	**Comments**
R2	Concentrator	28.5	No	Noise emission from Concentrator dominates. Any tonal noise components will be masked by the Concentrator noise.
	FEL 980	22.9		
	Mining Unit	20.0		
R3	Concentrator	28.5	No	
	FEL 980	23.5		
	Mining Unit	20.6		
R11	Concentrator	25.8	No	Noise contributions from dominating sources are at similar levels.
	Mining Unit	24.4		
	Pit Dewatering Pump	24.4		

APPENDIX 10 VISUAL IMPACT ASSESSMENT

Visual Impact Assessment of the Proposed Yoongarillup Mineral Sand Mine

WOODLANDS

Prepared by Myles Bovell
Registered Landscape Architect AILA
Woodlands.
January 2015.

Contents

1. OUTLINE OF THE PROPOSED MINE.

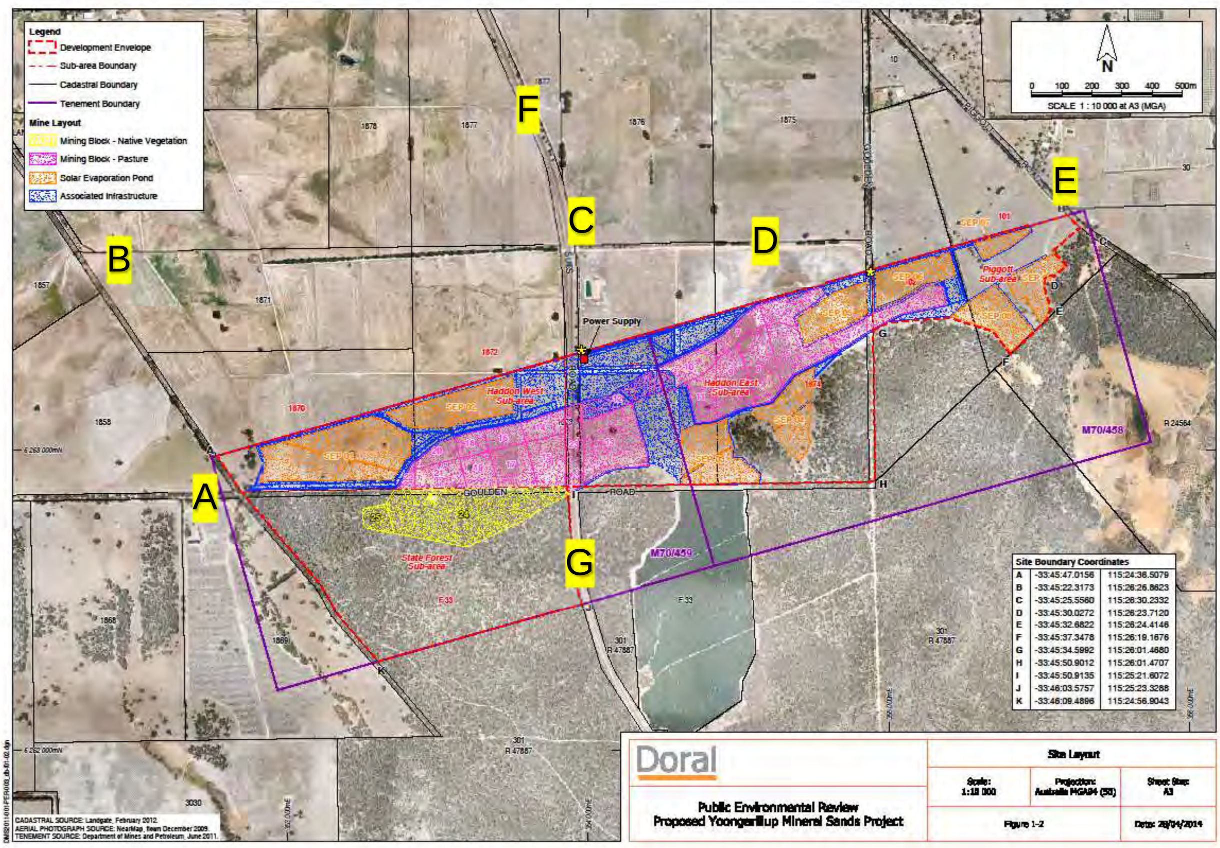
Doral Mineral Sands Pty Ltd is proposing to develop the Yoongarillup Mineral Sands Project, located 17 km southeast of Busselton and 250 km south of Perth, Western Australia. The proposed operations are located within the bounds of Mining Leases M70/0458 and M70/0459.

The proposed mine site will have a total ground disturbance of 95.7 ha. Approximately 86.8 ha of the disturbance area is located on previously cleared land (currently used for farming pasture, dairy and beef cattle). The remaining 8.9 ha is located within State Forest No. 33.

2. PURPOSE OF THIS ASSESSMENT.

With regards to public comment received as part of the Public Environmental Review (PER) process, Doral has undertaken further investigation into the visual amenity of the landscape with respect to comments made by its neighbouring landowners.

Comments and images in this document are provided by an independent Registered Landscape Architect from the seven locations shown below in order to evaluate the likely impacts of the project from an aspect of visual amenity.



3. VISUAL ELEMENTS OF THE PROPOSED SAND MINE

1. 'Wet Plant' concentrator at 18.5m high.
2. Perimeter earth bunds and stockpiles.
3. Indirect light spill from night-time floodlighting.
4. Partial visual aspects of pit and machinery from particular locations of elevation.

Figure 1. Typical view of the 'Wet Plant' concentrator at approximately 1250m without bunding in place.

(Picture reference Dardanup Mine)

Figure 2. Typical earth bund

4. OVERVIEW OF EXISTING LANDSCAPE CHARACTER

The current visual character of the land is that is it generally flat with a gentle incline towards the remnant bushland to the south. The site is set amongst rolling agricultural farmland which has a few good stands and lines of retained trees; and is set against a backdrop of pine plantation and Whicher National Park, divided by the major road artery in Sues Road.

The area has been historically cleared and grazed for many years and as a result continues to be majority farmland and pasture. Recent activities in the area involve minor sand and gravel extraction however the region continues typically as an agricultural environment.

5. INVESTIGATION OF LOCATIONS OF SIGNIFICANCE

LOCATION A
Adjacent residents 1, 2 and 3.

This location is and will remain heavily vegetated at the verge of the access road, and the creation of the earth bund which forms the banking walls of solar evaporation pond which will have a service life of 3 years at the south-west of the proposed site will visually screen the consequent mining activity to the north-east.

The visual impact at this location is considered low due to low traffic volume, the existence of considerable remnant bushland vegetation; the visual appearance of this vista will only change by way of an earth bund.

Visual impression of 3m bund at LOCATION A

LOCATION B
Adjacent residents 4 and 5.

This location has a sufficient distance of 2km from the proposed mine boundary and enough existing vegetation not to be a concern for visual impact; given that the measures undertaken by the proponents are carried out such as the implementation of flood-light locations, orientations and shutters; and earth bund for the solar evaporation ponds which surround the proposed mine site.

NO PHOTO REQUIRED

The visual impact of the mine proposal at this location is considered low.

LOCATION C

This location along Sues Road will retain the existing stand of trees which will act as a sufficient screen to soften the visual impact of the proposed sand mine from this vista, and is a considerable distance from the proposed mine boundary at 1.8kms.

The visual impact of the proposed sand mine from this location is considered low.

LOCATION D

This location may benefit from the use of privacy screening (eg. shade cloth fencing) along the road verge to reduce visibility of the mine site from a travelling vehicle however this is likely to be less favourable due to the aspect of enclosure as a result. A distant earth bund screen as proposed would give the least visually impacting result when travelling by vehicle along Yoongarillup Road.

Artist impression of earth bund

Artist impression of shade cloth privacy screen along the road verge

LOCATION E.

This location facing west-southwest will be partially screened by an earth mound used to create a solar evaporation pond. As suggested previously, the presence of a privacy screen such as shade cloth, may assist to remove the visual presence of the mine site however is likely to be less favourable due the reduced visibility of the natural landscape which surrounds.

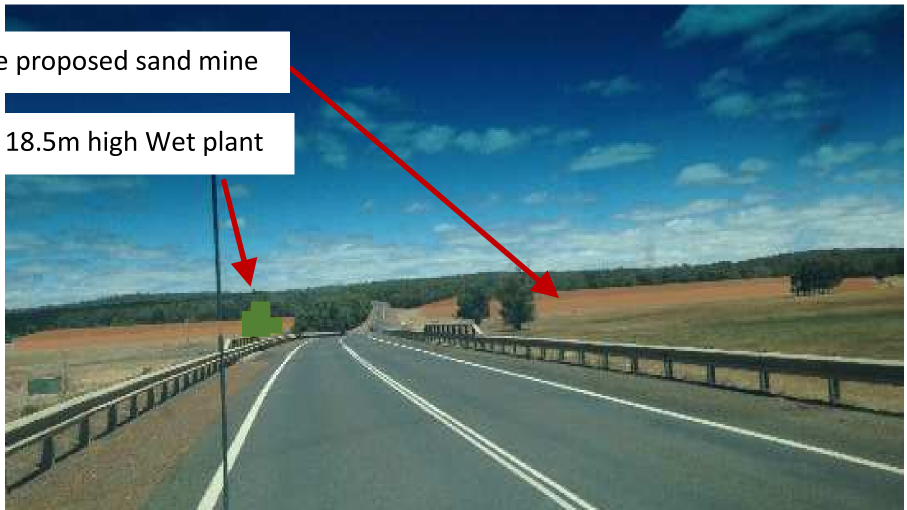
Visual impression of proposed earth bund

Visual impression of a shade cloth privacy screen

LOCATION F.

The viewshed from this location heading south along Sues Road is likely to have some visual impact on the scenic values of the Whicher Scarp for the passing motorist, an item which the Department of Parks and Wildlife have identified as part of their PER Public Comment submission. In the opinion of the author the presence of earth mounds and active earthworks in place of agricultural lands for the 3 year period of the proposal is not considered a significant intrusion on the overall landscape of the vicinity for a passing motorist and also given the near proximity of other mining operations in the region.

It is likely that some interest may be taken by the public at this vantage with regards to tourism and a general interest in mining.



LOCATION G.

Given the speed of passing motorists and the dense vegetation adjacent the roadway leading up to the proposed mine, the visual impact is considered to be low as it would only be viewed for a number of seconds.

6. SUMMARY AND CONCLUSION.

The proposed mineral sands mine at this location has the potential to be visible from some of the surrounding properties and segments of Sues Road. The landscape is relatively flat in nature and consists of open agricultural lands.

Proposed earth bunds at the perimeter of the mine may not entirely provide visual screening of the mine simply due to the angle of trajectory between the operations and identified vantage points, however with consideration to proposed earth bunds and strategic placement of privacy screening, these visual impacts are likely to be reduced to that of being non-significant to the regional permanent and transient community.

The planting of vegetation is likely to have minimal benefit due to the three year life expectancy of the mine. It is suggested that the proponents of the proposed sand mine continue to liaise with the neighbouring landowners to coordinate the most effective areas for the implementation of a reasonable screening solution.

APPENDIX 11 PER AMENDMENTS

APPENDIX 11-A UPDATED CHART 3-1 – FLOW CHART OF MINING OPERATIONS

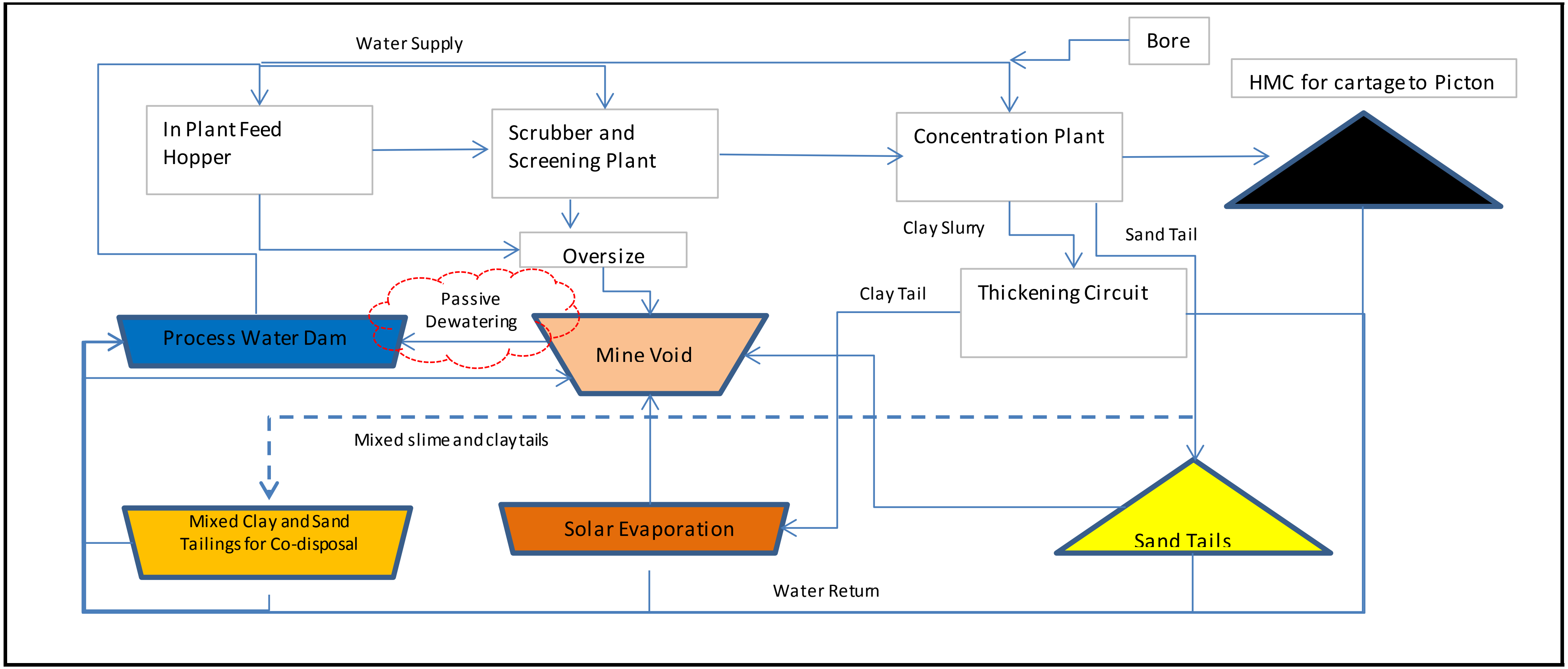


Figure 3-1 from PER

Updated to show return water from Mine Void into Process Water Pond (Changes clouded by red dashed line)

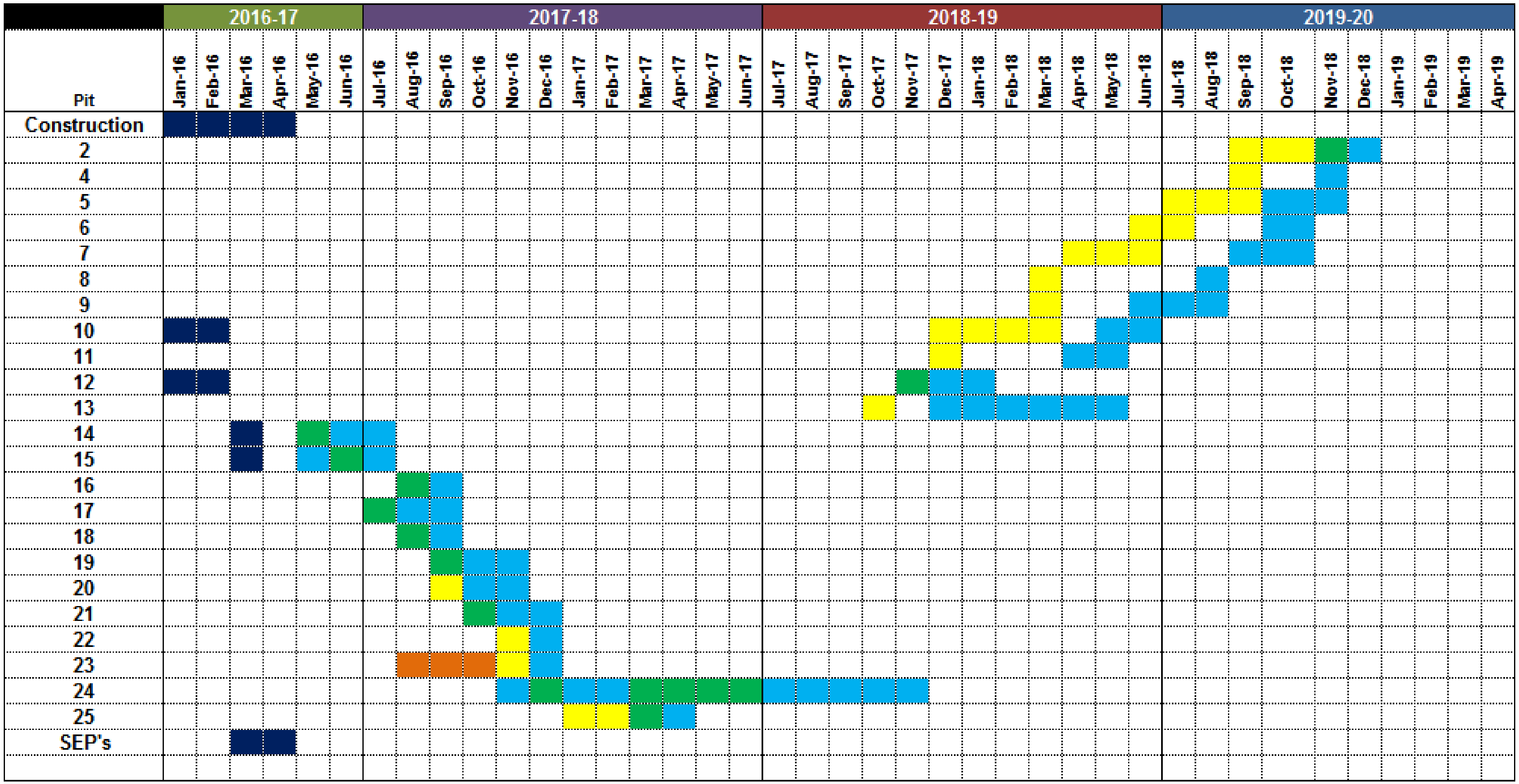
APPENDIX 11-B UPDATED TABLE 3-3 – MINING SCHEDULE

PROPOSED MINING SCHEDULE
YOONGARILLUP PROJECT

Dated: Worksheet Updated 25/06/2015

LEGEND

- Construction
- Realign SuesRd
- Overburden
- Ore
- Ore & Overburden

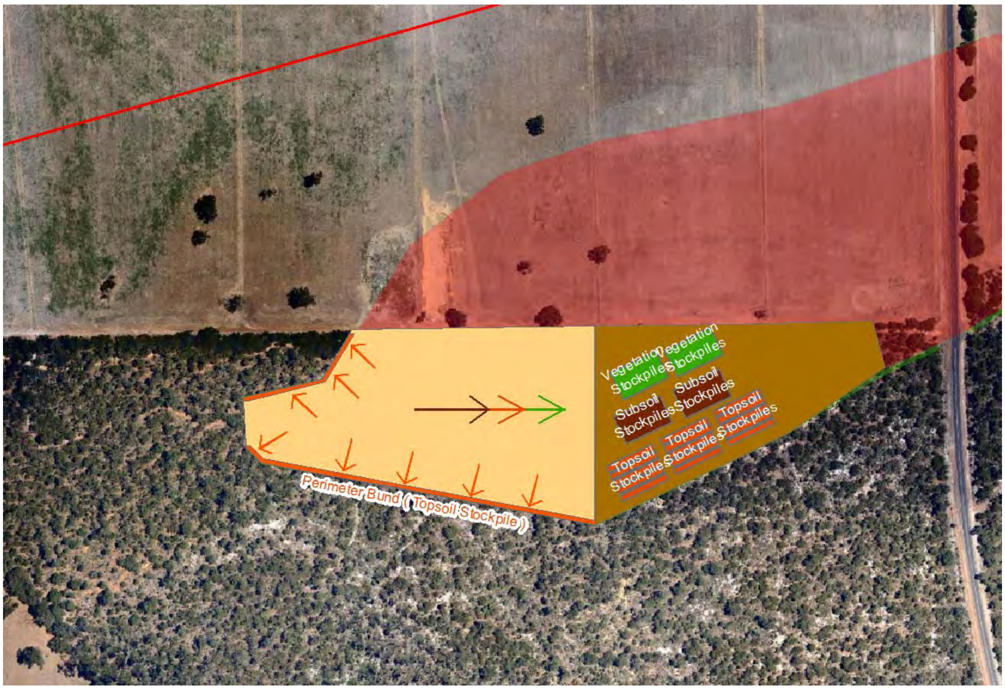


APPENDIX 11-C UPDATED SECTION 3.7.2 – MINING OF STATE FOREST SUB-AREA

3.7.2 Mining of State Forest Sub-Area

As mining nears completion in the Haddon West sub-area (block 22), stripping of dieback free vegetation from the State Forest sub-area will commence within block 25 and block 24 from west to east (refer to Figure 1-2 for mine block locations). Mining in the State Forest sub-area will be undertaken such that topsoil and subsoil material will be able to be stockpiled within the State Forest sub-area, so as to minimise the ingress of weeds from the paddock areas. Dieback and weed management protocols will be employed during clearing and stripping operations within the State Forest sub-area. Mining will then continue using the same techniques as the Haddon West and Haddon East sub-areas, with progressive backfilling occurring as mining progresses towards the east.

PLATE 3-2: PROPOSED MANAGEMENT OF TOPSOIL IN STATE FOREST SUB-AREA



1. State Forest Sub-Area Cleared, Vegetation stockpiled in eastern half of State Forest sub-area
2. Topsoil and Subsoil removed from western side of State Forest sub-area, stockpiled on eastern side.
3. Western side of State Forest sub-area mined and backfilled

4. After backfill has stabilised, Subsoil and Topsoil respread over western side
5. Vegetation relocated from eastern side to western side
6. Topsoil and Subsoil removed from eastern side, stockpiled on western side
7. Eastern side of State Forest sub-area mined and backfilled
8. After backfill has stabilised on eastern side, subsoil and topsoil respread over eastern side
9. Revegetation works will be undertaken as soon as is practicable after the respread of topsoil

APPENDIX 11-D UPDATED SECTION 8.2.1 – WATER BALANCE

8.2.1 Water Balance

The simple site water balance was developed to establish a monthly water balance for the life of mine (PB, 2014c). The wet concentration plant processing operations have the highest demand for water; based on an average mining rate of 200TPH, a net water demand of 180TPH per 200TPH of ore is required over the life of mine. This equates to a water demand of 4.32 megalitres (ML) per day, approximately 131ML per month and approximately 1577ML (1.6GL/yr).

Water will be drawn directly from the PWP. The main inputs of water to the PWP will include:

- Recycled process water;
- Groundwater inflows pumped from the active mining cells (i.e. pit dewatering);
- Site runoff from impervious areas, including access road, building / structures and hardstands;
- Direct rain that falls over the surface of the PWP;
- Abstraction from production bores screened in the Yarragadee aquifer.

The outputs from the PWP are:

- Use of water in the wet concentration plant process;
- Evaporation.

The PWP will be constructed to hold a maximum of 113ML, but will operate at 80% capacity. This will allow 21 days of water demand to be held at any time during the life of mine, therefore water will be secure for this period at all times.

Based on the simple water balance (PB, 2014c) (Appendix 8-D), the net water demand for the proposal can be up to 129ML per month and therefore, even during a wet year, groundwater will be required to supplement the net water demand. During dry years nearly all of the water demand will have to be sourced from groundwater because any rainfall that occurs during these months will be lost to evaporation (PB,2014c).

Doral propose to supplement direct rainfall and pit inflow water sources with groundwater sourced from the Yarragadee aquifer. The simple water balance (PB,2014c) states that a pumping rate of 50L/s is sufficient to meet the unmet water demands for the proposal. This equates to 1.6 GL/year. Doral propose to secure water for the Proposal through the legislative instruments of the RIWI Act. An application for a licence to abstract 1.6GL/year from the Yarragadee aquifer has been submitted to the DoW.

APPENDIX 11-E UPDATED SECTION 10.5 - NOISE

- Spraying HMC stockpiles at the mine with water if they dry to the extent dust generation occurs. HMC stockpiles generally have a moisture content of between 5-9% and are not vulnerable to the adverse effects of strong winds causing dust;
- The co-disposal of sand tails and clay tails into pit backfill areas. This homogenous mixing increases the average particle size and reduces the potential for dust generation;
- When and where necessary, spraying with water or other dust suppression measures (e.g. emulsion spray, erection of wind barriers) is employed;
- Employ routine maintenance and housekeeping practices to ensure that waste materials in and around the mine voids and infrastructure do not accumulate and lead to the generation on unacceptable airborne particulates.

To monitor impacts of dust on vegetation, regular monitoring of vegetation health in adjacent undisturbed vegetation within the State Forest sub-area will occur as per the Flora and Vegetation Management Plan.

10.4.5 Predicted Environmental Outcomes

Implementation of dust control measures will minimise dust generation. Monitoring of dust emissions will be conducted to ensure non-compliance with the Licence are acted upon. Doral is confident that with the above measures in place, the EPA objective to ensure that emissions do not adversely affect environmental values or the health, welfare and amenity of people and land uses can be achieved.

10.5 NOISE

10.5.1 EPA Objectives

To protect the amenity of nearby residents from noise impacts resulting from activities associated with the proposal by ensuring the noise levels meet statutory requirements and acceptable standards.

10.5.2 Noise Regulations

Environmental noise is regulated by the EP Act, through the implementation of the *Environmental Protection (Noise) Regulations 1997*.

No noise limits apply for the construction period, as per Regulation 13(2), as long as construction work is carried out between 0700 hours and 1900 hours on any day which is not a Sunday or public holiday if the occupier of the premises, shows that:

(a) The construction work was carried out in accordance with control of environmental noise practices set out in Section 4 of AS 2436: 2010 Guide to Noise and Vibration Control on Construction, Maintenance and Demolition sites;

(b) The equipment used on the premises was the quietest reasonably available.

Noise limits for mining on residences (noise sensitive premises) are listed in Table 10-2 as assigned by *Environmental Protection (Noise) Regulations 1997*, Part 2 Division 1 Regulation 8 (3) Table 1.

TABLE 10-2: ASSIGNED NOISE LIMITS AS PER EP(NOISE) REGULATIONS 1997

TYPE OF PREMISES RECEIVING NOISE	TIME OF DAY	ASSIGNED LEVEL (dB)		
		$L_{A\ 10}$	$L_{A\ 1}$	$L_{A\ max}$
Noise Sensitive premises: highly sensitive area	Mon-Sat 0700 – 1900	45+	55+	65+
	Sun & Pub Hol. 0900 - 1900	40+	50+	65+
	All Days 1900 – 2200	40+	50+	55+
	Mon - Sat 2200 – 0700	35+	45+	55+
	Sun & Pub Hol. 2200 – 0900	35+	45+	55+

+ influencing factor

Influencing factors vary from residence to residence depending on the surrounding land use. Traffic flows on roads in the vicinity of the proposed mine site are insufficient for any of the roads to be classified as either major or secondary roads and therefore no transport factors apply. Influencing factor ranging from 0.05 dB to 0.83 dB were calculated for the noise sensitive receptors for this proposal. These calculated values were rounded to 0 dB and 1 dB according to the Regulations. Influencing factors were found to apply at R2 and R3, with an influencing factor of 1dB being applied to both residences.

TABLE 10-3: NOISE LIMITS AT RECEIVING LOCATIONS

CLOSEST RESIDENTS	INFLUENCING FACTOR dB	ASSIGNED NOISE LEVELS (L_{A10}) in dB(A)		
		Day	Evening	Night
R2 and R3	1	46	41	36
Others	0	45	40	35

10.5.3 Findings of Noise Investigations

SVT Engineering Consultants (SVT) was commissioned by Doral to carry out a noise impact assessment for the Proposal (SVT, 2015). An acoustic model was developed to predict noise levels at 16 noise sensitive premises for day and night time operations under both worst-case and calm metrological conditions. The assessment was based on the proposed location of fixed plant and mobile equipment according to the proposed mine schedule, sound power levels of the fixed plant and mobile equipment as measured when operational at the Dardanup Mine, and with consideration of likely wind conditions. A copy of the noise assessment report is contained in Appendix 10-A.

Six operating scenarios were assessed as shown in Table 10-4, which includes one construction scenario and five mining scenarios. Scenario 1 refers to the pre-mine establishment phase which is restricted to day time activity only. Scenarios 2, 3 and 4 are applicable to mining pits west of Sues Road (Haddon West and State Forest sub-areas). Scenarios 5 and 6 refer to mining pits east of Sues Road

(Haddon East and Piggott sub-areas). Mining scenarios are applicable to both day and night time activity.

TABLE 10-4: OPERATING SCENARIOS CONSIDERED IN THE ACOUSTIC MODEL

PHASE	SCENARIO	OPERATING TIME	LIKELY COMMENCEMENT
Pre-mine establishment	1	Day	From June 2015 to Sept 2015
Mining	2	Day/Night	December 2015
Mining	3	Day/Night	May 2016
Mining	4	Day/Night	September 2016
Mining	5	Day/Night	February 2018
Mining	6	Day/Night	April 2018

A summary of the worst-case noise levels at each residence under the six scenarios is presented in Table 10-5. A 5dB tonality penalty was applied where required depending on the dominating noise sources.

TABLE 10-5: WORST-CASE NOISE LEVELS (DB(A)) AT EACH RESIDENCE PER SCENARIO

CLOSEST RESIDENCES	S1	S2		S3		S4		S5		S6	
	Day	Day	Night	Day	Night	Day	Night	Day	Night	Day	Night
R1	31.8	24.3	24.8	31.5	26.3	32.0	26.0	26.8	24.7	27.2	22.5
R2	***53.2****	32.9	33.1	***45.2****	31.2	***45.1****	34.0	31.1	28.9	33.4	30.0
R3	***49.3****	32.4	32.7	37.3	30.4	37.7	31.6	31.3	28.8	32.9	30.3
R4	26.9	21.4	22.0	25.1	21.3	25.6	18.5	20.7	16.9	22.9	16.9
R5	29.3	26.9	27.4	27.9	25.0	28.6	22.3	24.1	20.6	26.3	20.7
R6	31.3	29.9	30.3	31.9	30.4	31.4	25.7	27.5	24.1	29.7	24.1
R7	26.5	27.1	27.6	27.7	26.8	29.2	25.9	30.2	22.8	31.2	23.0
R8	29.8	31.3	31.7	31.2	30.4	33.1	29.7	38.3	27.9	38.2	28.8
R9	27.7	29.0	29.4	29.0	28.2	31.0	27.4	36.6	25.4	36.7	27.9
R10	27.2	28.3	28.7	28.4	27.5	30.4	26.7	37.1	24.6	37.3	28.6
R11	26.7	30.3	30.8	30.2	29.7	31.1	28.6	36.3	27.0	36.4	30.8
R12	21.2	20.3	20.7	21.3	20.4	23.7	20.1	29.5	19.2	26.9	23.1
R13	22.9	23.3	23.9	23.7	22.9	26.4	22.1	30.1	19.2	30.7	22.9
R14	26.2	26.9	27.4	27.4	26.5	29.1	25.9	30.7	22.7	31.5	23.0
R15	26.1	26.7	27.3	27.3	26.5	28.9	25.7	30.2	22.5	31.1	22.7
R16	24.7	25.1	25.6	25.7	24.9	27.4	24.1	28.4	20.8	29.5	21.0

*Values adjusted for tonality (5dB penalty)

TABLE 10-6: COMPLIANCE ASSESSMENT WORST-CASE NOISE LEVEL EXCEEDANCES FOR MINING SCENARIO

Closest Residence	Assigned Noise Levels db(A)	Worst-Case Noise Levels (dBA) DAYTIME				
		Scenario				
		2	3	4	5	6
R1	45	24.3	31.5	32.0	26.8	27.2
R2	46	32.9	***45.2***	***45.1***	31.1	33.4
R3	46	32.4	37.3	37.7	31.3	32.9
R4	45	21.4	25.1	25.6	20.7	22.9
R5	45	26.9	27.9	28.6	24.1	26.3
R6	45	29.9	31.9	31.4	27.5	29.7
R7	45	27.1	27.7	29.2	30.2	31.2
R8	45	31.3	31.2	33.1	38.3	38.2
R9	45	29.0	29.0	31.0	36.6	36.7
R10	45	28.3	28.4	30.4	37.1	37.3
R11	45	30.3	30.2	31.1	36.3	36.4
R12	45	20.3	21.3	23.7	29.5	26.9
R13	45	23.3	23.7	26.4	30.1	30.7
R14	45	26.9	27.4	29.1	30.7	31.5
R15	45	26.7	27.3	28.9	30.2	31.1
R16	45	25.1	25.7	27.4	28.4	29.5

TABLE 10-7: COMPLIANCE ASSESSMENT WORST-CASE NOISE LEVEL EXCEEDANCES FOR MINING SCENARIO

Closest Residence	Assigned Noise Levels db(A)	Worst-Case Noise Levels (dBA) NIGHT-TIME				
		Scenario				
		2	3	4	5	6
R1	35	24.8	26.3	26.0	24.7	22.5
R2	36	33.1	31.2	34.0	28.9	30.0
R3	36	32.7	30.4	31.6	28.8	30.3
R4	35	22.0	21.3	18.5	16.9	16.9
R5	35	27.4	25.0	22.3	20.6	20.7
R6	35	30.3	30.4	25.7	24.1	24.1
R7	35	27.6	26.8	25.9	22.8	23.0
R8	35	31.7	30.4	29.7	27.9	28.8
R9	35	29.4	28.2	27.4	25.4	27.9
R10	35	28.7	27.5	26.7	24.6	28.6
R11	35	30.8	29.7	28.6	27.0	30.8
R12	35	20.7	20.4	20.1	19.2	23.1
R13	35	23.9	22.9	22.1	19.2	22.9
R14	35	27.4	26.5	25.9	22.7	23.0
R15	35	27.3	26.5	25.7	22.5	22.7
R16	35	25.6	24.9	24.1	20.8	21.0

TABLE 10-8: COMPLIANCE ASSESSMENT WORST-CASE NOISE LEVEL EXCEEDANCES FOR MINING SCENARIO

RESIDENCE	PERIOD	NOISE LIMIT (dB(A))	SCENARIO COMPLIES?				
			2	3	4	5	6
R1	Monday to Friday 0700 to 1900	45	YES	YES	YES	YES	YES
R2		46	YES	YES	YES	YES	YES
R3		46	YES	YES	YES	YES	YES
R4 – R8		45	YES	YES	YES	YES	YES
R9		45	YES	YES	YES	YES	YES
R10		45	YES	YES	YES	YES	YES
R11		45	YES	YES	YES	YES	YES
R12		45	YES	YES	YES	YES	YES
R13		45	YES	YES	YES	YES	YES
R14-R16		45	YES	YES	YES	YES	YES
R1	Monday to Friday 1900 to 2200	40	YES	YES	YES	YES	YES
R2		41	YES	YES	YES	YES	YES
R3		41	YES	YES	YES	YES	YES
R4 – R8		40	YES	YES	YES	YES	YES
R9		40	YES	YES	YES	YES	YES
R10		40	YES	YES	YES	YES	YES
R11		40	YES	YES	YES	YES	YES
R12		40	YES	YES	YES	YES	YES
R13		40	YES	YES	YES	YES	YES
R14-R16		40	YES	YES	YES	YES	YES
R1	Monday to Friday 2200 To 0700	35	YES	YES	YES	YES	YES
R2		36	YES	YES	YES	YES	YES
R3		36	YES	YES	YES	YES	YES
R4 – R8		35	YES	YES	YES	YES	YES
R9		35	YES	YES	YES	YES	YES
R10		35	YES	YES	YES	YES	YES
R11		35	YES	YES	YES	YES	YES
R12		35	YES	YES	YES	YES	YES
R13		35	YES	YES	YES	YES	YES
R14-R16		35	YES	YES	YES	YES	YES

RESIDENCE	PERIOD	NOISE LIMIT (dB(A))	SCENARIO COMPLIES?				
			2	3	4	5	6
R1	Sundays and Public Holidays 0900 to 1900	45	YES	YES	YES	YES	YES
R2		46	YES	YES	YES	YES	YES
R3		46	YES	YES	YES	YES	YES
R4 – R8		45	YES	YES	YES	YES	YES
R9		45	YES	YES	YES	YES	YES
R10		45	YES	YES	YES	YES	YES
R11		45	YES	YES	YES	YES	YES
R12		45	YES	YES	YES	YES	YES
R13		45	YES	YES	YES	YES	YES
R14-R16		45	YES	YES	YES	YES	YES
R1	Sundays and Public Holidays 1900 to 2200	40	YES	YES	YES	YES	YES
R2		41	YES	YES	YES	YES	YES
R3		41	YES	YES	YES	YES	YES
R4 – R8		40	YES	YES	YES	YES	YES
R9		40	YES	YES	YES	YES	YES
R10		40	YES	YES	YES	YES	YES
R11		40	YES	YES	YES	YES	YES
R12		40	YES	YES	YES	YES	YES
R13		40	YES	YES	YES	YES	YES
R14-R16		40	YES	YES	YES	YES	YES
R1	Sundays and Public Holidays 2200 To 0900	35	YES	YES	YES	YES	YES
R2		36	YES	YES	YES	YES	YES
R3		36	YES	YES	YES	YES	YES
R4 – R8		35	YES	YES	YES	YES	YES
R9		35	YES	YES	YES	YES	YES
R10		35	YES	YES	YES	YES	YES
R11		35	YES	YES	YES	YES	YES
R12		35	YES	YES	YES	YES	YES
R13		35	YES	YES	YES	YES	YES
R14-R16		35	YES	YES	YES	YES	YES

10.5.4 Assessment of Potential Impacts

The Development Envelope is primarily pastoral farmland and State Forest. Sixteen (16) closest noise sensitive premises were selected for detailed assessment of noise impacts. R13 represents a receiver standing on the top floor of a two-storey house while the others are the receivers of single-storey houses. Figure 10-2 shows the location of 15 of the 16 receptors modelled. R16, not shown in Figure

10-2, is located approximately 220 m north-east of R15. Figure 1 from SVT(2015) shows the location of all 16 residences modelled.

Initial analysis and assessment of noise at the proposed Yoongarillup Mineral Sands Project predicted non-compliance with the noise regulations (Appendix 10-B) however, a review of mining methodologies, including a review of the plant fleet and location of noise bunds was undertaken as part of the revised modelling presented in SVT (2015) (Appendix 10-A). The revised noise assessment predicts compliance to the EP(Noise) Regulations under all operating conditions at all noise sensitive receptors located surrounding the proposal.

Some of the changes that were included in the revised noise assessment include:

- Additional noise bunding to be constructed within the paddock areas west of Sues Road;
- Use of Carry Graders instead of a Dozer for topsoil and subsoil stripping operations within Pits 24 and 25;
- Construction of a temporary noise bund (utilising topsoil material) within Pit 24;
- A 6.5m high noise barrier to be constructed on the western edge of Pit 25;
- The construction of a 5.5m high noise bund along the north and eastern edge of Pit 2;
- The construction of a temporary noise bund, 2.5m high within Pits 7 and 8;

10.5.5 Management Measures and Performance Standards

Although the revised noise modelling predicts compliances with the EP(Noise) Regulations during the mining phase of the proposal, management measures are still proposed to be implemented to ensure noise emissions are the lowest that are practicable to be achieved.

During the pre-mine establishment phase, all construction work will be carried out in accordance with *AS 2436-2010 Guide to Noise and Vibration Control on Construction, Maintenance and Demolition Sites* with the quietest noise equipment feasible.

A Noise Management Plan will be prepared for the mine and will be included in Doral's EMS. The objective of the Noise Management Plan will be to maintain the amenity of neighbouring residences during mining operations. The Noise Management Plan will include noise management strategies and control measures to reduce noise levels to below noise limits.

In addition to the construction of noise bunds and barriers as outlined in SVT(2015) (Appendix 10-A), , the following management strategies, which are successfully implemented at the Dardanup Mine, will be implemented for the Proposal:

- Selecting quieter bulldozer or front end loader;
- Installing silencers to reduce exhaust noise of the bulldozer and front end loader;
- Ensuring that no overburden fleet or ore fleet will operate simultaneously in the same mining block at any one time;
- Restricting the operation of machinery relative to worst case weather conditions on Sundays and Public holidays to minimise potential noise impacts;
- Restricting the operation of ancillary machinery (water cart and grader) to only one in operation at a time and operate during day-time only;

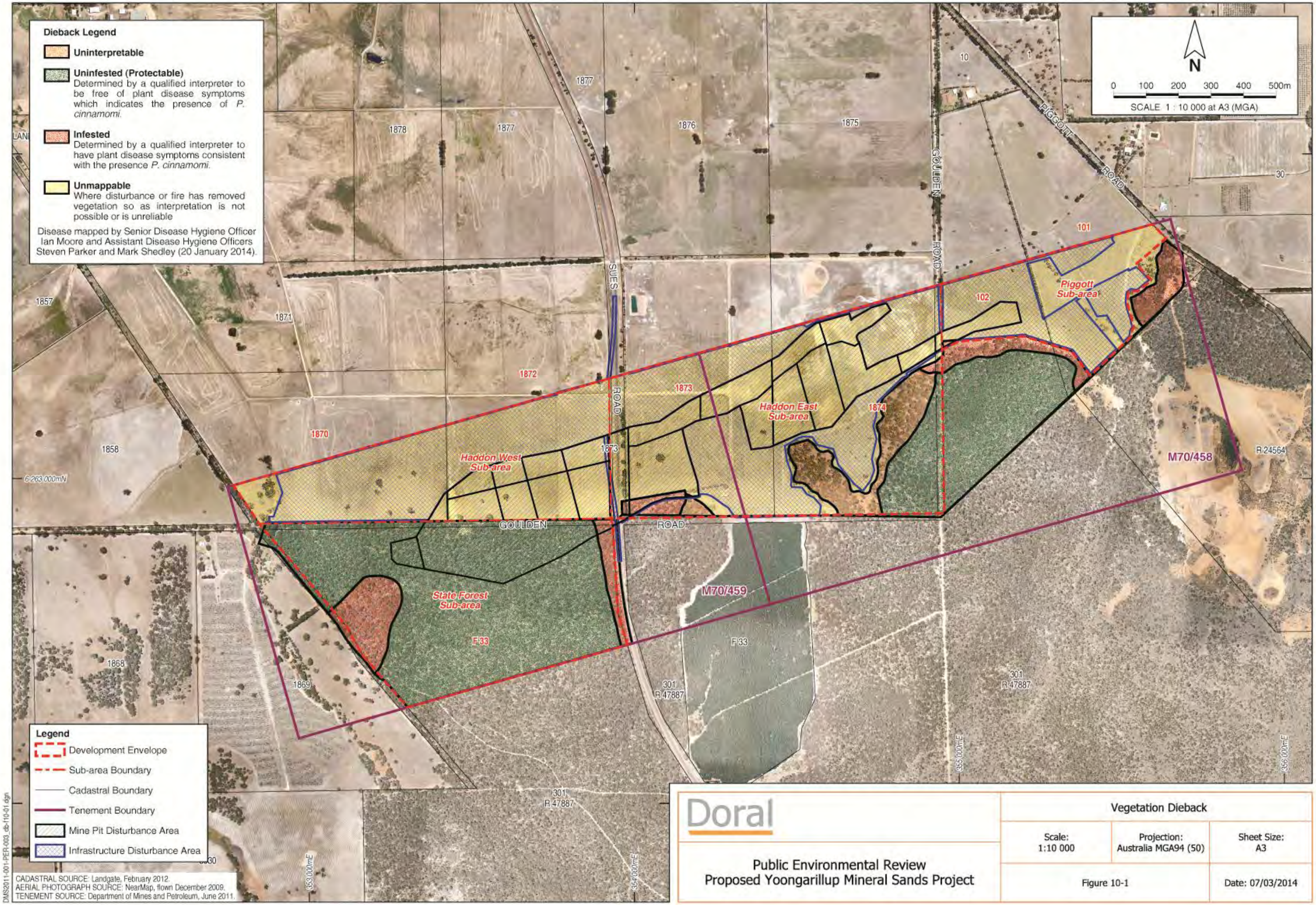
- Establishing preventative maintenance schedules for all vehicles, fixed plant and mobile equipment;
- Educating employees and contractors on the importance and requirements for noise management prior to commencing work on the mine, as part of the site induction process;
- Maintaining ongoing effective dialogue with nearby residents to ensure noise impacts are communicated to Doral to allow for rapid resolution;
- Continuing to implement an effective public comment and complaint communication system to ensure all concerns are received, recorded and acted upon.
- Seeking to establish amenity agreements with adjacent landholders.

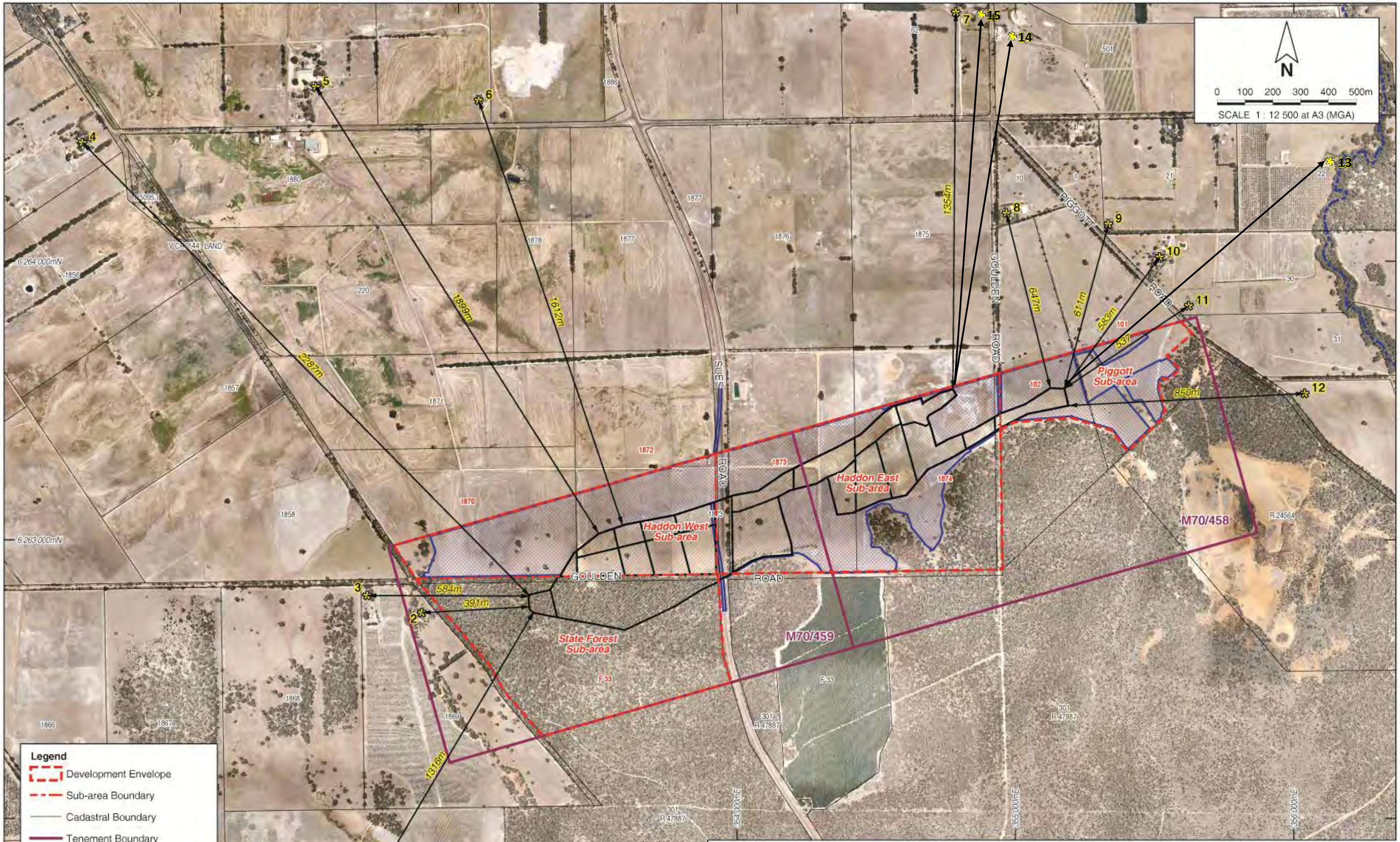
If noise limits are exceeded after the above management strategies are implemented, the following contingency actions will be implemented:

- Attenuation of machinery where practicable;
- Temporary relocation of the mining fleet to alternate mining pit to ensure compliance with respect to worst case scenario wind conditions;
- Temporary shutdown of relevant (noise generating) operations to ensure compliance during persistent wind conditions;
- Investigate and implement methods to reduce noise emissions in accordance with best practice.

10.5.6 Predicted Environmental Outcomes

Doral are experienced at managing noise impacts associated with mineral sands mine sites. Noise levels associated with mining will be controlled as described above. Effective implementation of these noise management strategies will ensure noise emissions from the operations comply with the Noise Regulations. Therefore it is expected that the environmental objective for this matter can be met.


Dieback Legend
Uninterpretable
Uninfested (Protectable)
Determined by a qualified interpreter to be free of plant disease symptoms which indicates the presence of P. cinnamomi.
Infested
Determined by a qualified interpreter to have plant disease symptoms consistent with the presence P. cinnamomi.
Unmappable
Where disturbance or fire has removed vegetation so as interpretation is not possible or is unreliable
Disease mapped by Senior Disease Hygiene Officer Ian Moore and Assistant Disease Hygiene Officers Steven Parker and Mark Shedley (20 January 2014).
N
0 100 200 300 400 500m
SCALE 1 : 10 000 at A3 (MGA)
PIGGOTT ROAD
GOULDEN ROAD
SUES ROAD
Piggott Sub-area
Haddon East Sub-area
Haddon West Sub-area
State Forest Sub-area
M70/458
M70/459
F 33
301 R 47887
R 24564
Legend
Development Envelope
Sub-area Boundary
Cadastral Boundary
Tenement Boundary
Mine Pit Disturbance Area
Infrastructure Disturbance Area
CADASTRAL SOURCE: Landgate, February 2012.
AERIAL PHOTOGRAPH SOURCE: NearMap, flown December 2009.
TENEMENT SOURCE: Department of Mines and Petroleum, June 2011.
DMS2011-001-PER-003_db-f10-01.dgn
Doral
Public Environmental Review
Proposed Yoongarillup Mineral Sands Project
Vegetation Dieback
Scale: 1:10 000
Projection: Australia MGA94 (50)
Sheet Size: A3
Figure 10-1
Date: 07/03/2014



Doral

Public Environmental Review
Proposed Yoongarillup Mineral Sands Project

Location of Nearest Residences		
Scale: 1:12 500	Projection: Australia MGA94 (50)	Sheet Size: A3
Figure 10-2		Date: 28/04/2014

APPENDIX 11-F NEW SECTION – SECTION 16 - REFERENCES

16 REFERENCES

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APPENDIX 11-G PER APPENDIX 16B - OFFSET STRATEGY

Yoongarillup Mineral Sands Project

Offsets Strategy

Prepared for
Doral Mineral Sands
by Strategen

June 2015

STRATEGEN
environmental consultants

Yoongarillup Mineral Sands Project

Offsets Strategy

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June 2015

Limitations

Scope of services

This report ("the report") has been prepared by Strategen Environmental Consulting Pty Ltd (Strategen) in accordance with the scope of services set out in the contract, or as otherwise agreed, between the Client and Strategen. In some circumstances, a range of factors such as time, budget, access and/or site disturbance constraints may have limited the scope of services. This report is strictly limited to the matters stated in it and is not to be read as extending, by implication, to any other matter in connection with the matters addressed in it.

Reliance on data

In preparing the report, Strategen has relied upon data and other information provided by the Client and other individuals and organisations, most of which are referred to in the report ("the data"). Except as otherwise expressly stated in the report, Strategen has not verified the accuracy or completeness of the data. To the extent that the statements, opinions, facts, information, conclusions and/or recommendations in the report ("conclusions") are based in whole or part on the data, those conclusions are contingent upon the accuracy and completeness of the data. Strategen has also not attempted to determine whether any material matter has been omitted from the data. Strategen will not be liable in relation to incorrect conclusions should any data, information or condition be incorrect or have been concealed, withheld, misrepresented or otherwise not fully disclosed to Strategen. The making of any assumption does not imply that Strategen has made any enquiry to verify the correctness of that assumption.

The report is based on conditions encountered and information received at the time of preparation of this report or the time that site investigations were carried out. Strategen disclaims responsibility for any changes that may have occurred after this time. This report and any legal issues arising from it are governed by and construed in accordance with the law of Western Australia as at the date of this report.

Environmental conclusions

Within the limitations imposed by the scope of services, the preparation of this report has been undertaken and performed in a professional manner, in accordance with generally accepted environmental consulting practices. No other warranty, whether express or implied, is made.

Client: Doral Mineral Sands

Report Version	Revision No.	Purpose	Strategen author/reviewer	Submitted to Client	
				Form	Date
Draft Report	A	Client review	C Roberts, M Brook, R Banks	Electronic	12/01/15
Final Draft Report	B	Client review	C Roberts, R Banks	Electronic	16/01/15
Final Report	0	Issued for use	C Roberts	Electronic	21/01/15
Revised Final Report	C	Issued for use	C Roberts	Electronic	5/02/15
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1. Introduction

1.1 Background

Doral Mineral Sands Pty Ltd (Doral) proposes to extract ore from the strand of heavy mineral deposit known as the Yoongarillup Mineral Sands Deposit (the Proposal) located within Mining Tenements M70/0458 and M70/0459. The Proposal is located approximately 17 km southeast of Busselton (Figure 1).

Approximately 4 million tonnes (Mt) of ore will be extracted from the deposit to produce 256 000 t of heavy mineral concentrate (HMC). Ore from the deposit will be mined progressively via a series of open-cut pits using dry mining techniques. Mining will be staged in order to minimise the area of disturbance at any one time. The life of the mine is expected to be three years, including an initial pre-mine establishment phase and three mining phases. Rehabilitation and mine closure will be implemented at the cessation of mining; this phase is likely to take up to five years.

The Proposal requires disturbance of up to 95.71 ha (Disturbance Footprint) within a Development Envelope of 152 ha (Figure 2). Within the Development Envelope 8.90 ha of the disturbance is located in part of State Forest No. 33, which has previously undergone partial clearing and has since revegetated (excluding an area of 0.22 ha which remains cleared). The majority of the disturbance area (86.81 ha) is located on previously cleared land currently used for agricultural activities. For the purposes of this report, the area of native vegetation (8.68 ha) within State Forest No. 33 that is required to be cleared for the Proposal is referred to as the State Forest sub-area.

Doral commissioned Strategen to prepare an Offset Strategy for the Proposal. This strategy has been prepared based on advice from Doral in respect to the impact mitigation measures implemented and proposed offset measures.

1.2 Environmental Approvals

The Proposal was referred to the Environmental Protection Authority (EPA) under s 38 of the *Environmental Protection Act 1986* (EP Act) on 22 March 2012. On 27 August 2012, the EPA determined the level of assessment for the Proposal as Public Environmental Review (PER) with a four week public review period (Assessment No. 1938). The Yoongarillup Mineral Sands Project PER (Doral 2014) was submitted to the EPA and subject to public review. The public comment period closed on 17 November 2014.

Doral referred the proposal to the Australian Government Department of Sustainability, Environment, Water, Population and Communities (DSEWPaC; now Department of the Environment [DotE]) on 24 August 2012 as it has the potential to affect Matters of National Environmental Significance (MNES) defined under the *Environment Protection and Biodiversity Act 1999* (EPBC Act). On 26 September 2012, the DSEWPaC determined the proposed action is a ‘Controlled Action’ (EPBC Reference 2012/6521) and requires assessment by PER under the bilateral agreement with the State of Western Australia. The Proposal is being assessed under the intergovernmental bilateral agreement between the Commonwealth of Australia and the State of Western Australia under s 47 of the EPBC Act.

1.3 Purpose and scope

The offset strategy has been prepared to address residual impacts to environmental values relevant to the State as assessed by the EPA and MNES as assessed by the DotE.

The residual environmental impacts of the Proposal, after consideration of other mitigation measures to be applied, are expected to be:

1. Clearing of up to 8.68 ha of very good to excellent condition native vegetation and fauna habitat within State Forest including 8.22 ha of the Priority 1 Ecological Community 'Central Whicher Scarp Jarrah woodland' (Floristic Community Type 1 [FCT 1]).
2. Clearing of up to 8.68 ha of foraging, roosting and breeding habitat for *Caloyptorhynchus baudinii* (Baudin's Black-Cockatoo [BBC]), *Calyptorhynchus latirostris* (Carnaby's Black-Cockatoo [CBC]) and *Calyptorhynchus banksii naso* (Forest Red-tailed Black-Cockatoo [FRBC].

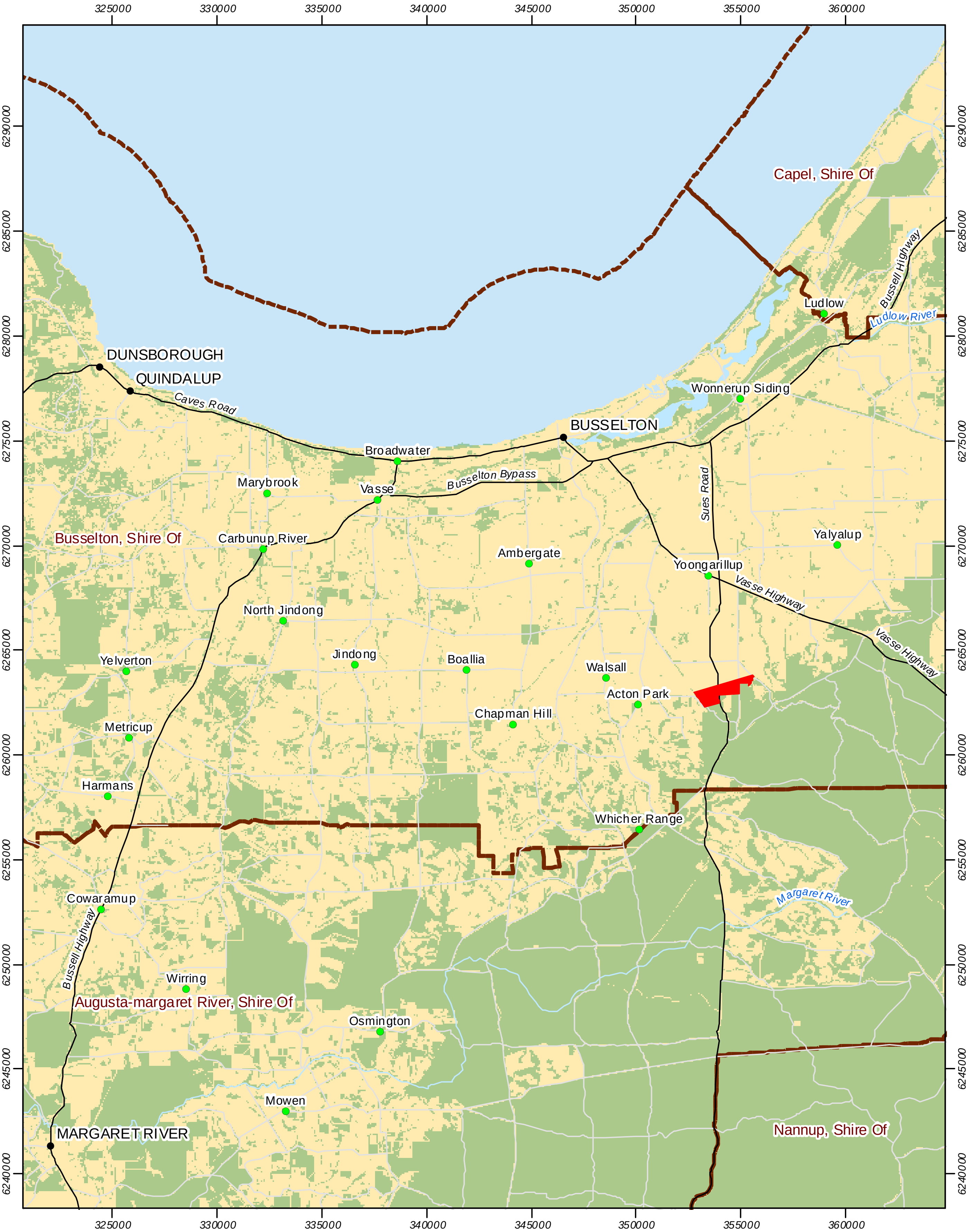
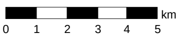


Figure 1 Regional location

Scale 1:250,000 at A4



Coordinate System: GDA 1994 MGA Zone 50
Note that positional errors may occur in some areas
Date: 15/01/2015
Author: JCrute
Source: Topography: Geoscience Australia 2011.

Legend

- Town
- Place name
- Major road
- Minor road
- River
- Water areas
- Proposed Yoongarillup Mineral Sands Project
- Shire boundaries
- Native vegetation

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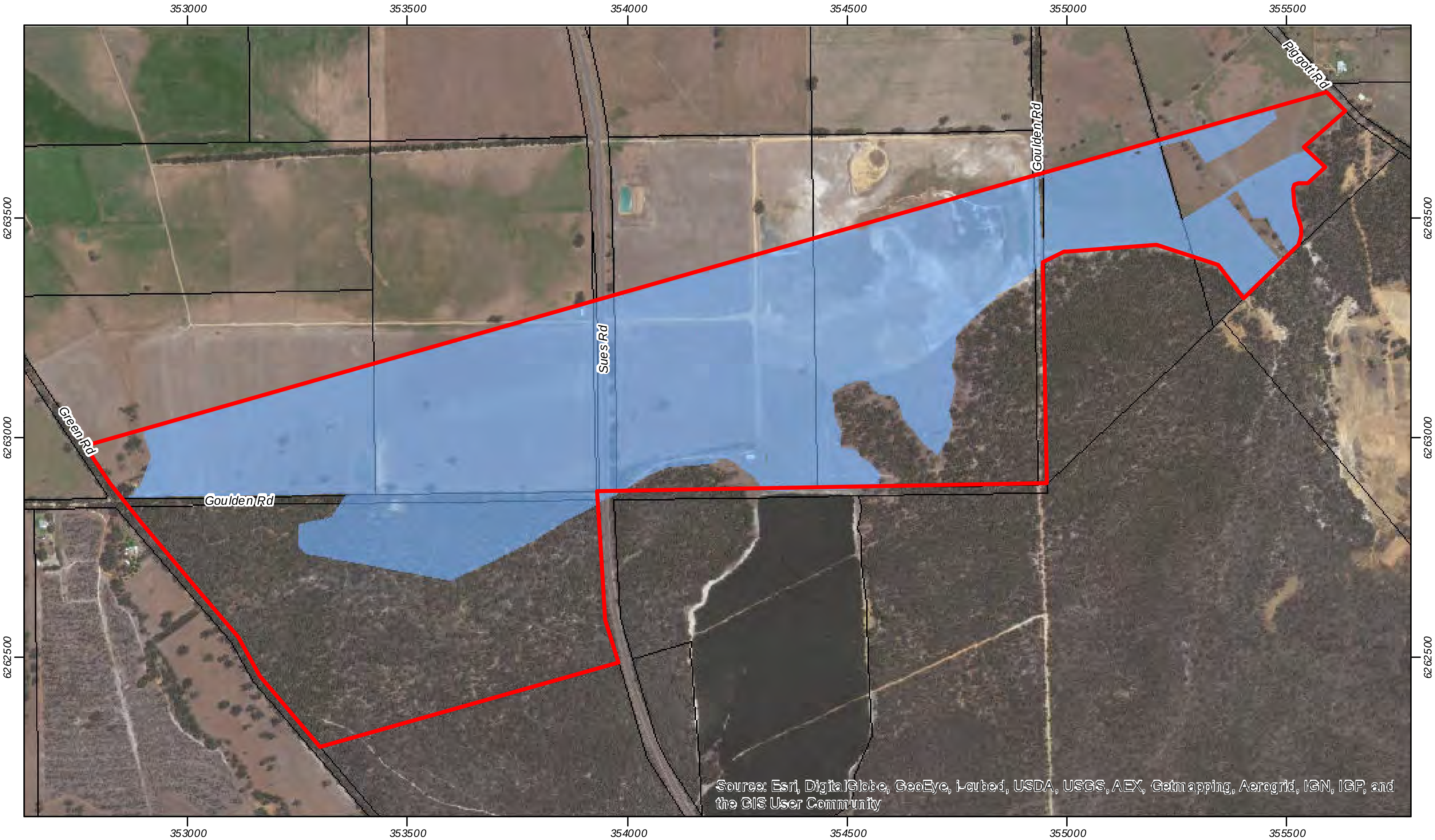

Figure 2: Development Envelope

Scale 1:12,000 at A4

0 50 100 150 200 250 m

N

Coordinate System: GDA 1994 MGA Zone 50

Note that positional errors may occur in some areas

Date: 15/01/2015

Author: JCrute

Source: Aerial image: ESRI online, approx. 2010. Mine layout: Client 2015.

Legend

- Development Envelope
- Disturbance Footprint
- Existing cadastre

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2. Offset framework

2.1 Regulatory framework

Consideration of environmental offsets is required by both the WA State Government and Australian Government to ensure a proposal results in net environmental benefit. Where a proposal is being assessed in parallel under the EP Act and the EPBC Act, agencies will endeavour to align offset requirements.

2.2 Policy framework

Where a significant residual environmental impact has been identified, both the WA Government and the Australian Government have policies regarding offsets (DSEWPaC 2012a, Government of Western Australia 2011, EPA 2011, EPA 2014).

2.2.1 EPA offsets policy

Offsets are used to compensate for residual environmental impacts and are designed to achieve long-term outcomes, building on existing conservation programs and initiatives. Where a significant residual environmental impact has been identified, the WA Government Environmental Offsets Policy 2011 (Offsets Policy) seeks to ensure that environmental offsets are applied in a transparent manner to engender certainty and predictability, while acknowledging that there are some environmental values that are not readily replaceable (Government of Western Australia 2011).

When considering proposed environmental offsets, the EPA is guided by the following principles as outlined in the Offsets Policy:

- environmental offsets will only be considered after avoidance and mitigation options have been pursued
- environmental offsets are not appropriate for all projects
- environmental offsets will be cost-effective, as well as relevant and proportionate to the significance of the environmental value being impacted
- environmental offsets will be based on sound environmental information and knowledge
- environmental offsets will be applied within a framework of adaptive management
- environmental offsets will be focussed on longer term strategic outcomes (Government of Western Australia 2011).

2.2.2 WA Government Environmental Offsets Guidelines

The WA Government has recently released the WA Government Environmental Offsets Guidelines (Offset Guidelines) that is intended to complement the Offsets Policy by clarifying the determination and application of environmental offsets in Western Australia (Government of Western Australia 2014). The Offsets Guidelines outline the methodology for determining an appropriate offset by identifying the key elements that should be considered to ensure that decisions made on environmental offsets are consistent and accountable under the EP Act.

The Offset Guidelines outline the framework for consideration of offsets required under the environmental approvals process, including demonstrated application of the mitigation measures and assessment of the residual impacts in relation to relevant EPA environmental factors (Government of Western Australia 2014). The provision of offsets is the final mitigation option available to help manage significant adverse environmental impacts.

2.2.3 Australian Government policy

The Environmental Offsets Policy (EPBC Act Policy) (DSEWPaC 2012a) defines two types of offsets

- **direct offsets**: measures that have on-ground, tangible benefits that improve the viability of the protected matter
- **other compensatory measures**: any other measure that contributes to the overall conservation outcome of the protected matter.

Principles guiding the EPBC Act Policy are that offsets:

1. Deliver an overall conservation outcome.
2. Be efficient, effective, transparent, proportionate, scientifically robust and reasonable.
3. Be built around direct offsets but may include indirect (i.e. compensatory) offsets.
4. Be of a size and scale proportionate to the impacts being offset.
5. Be in proportion to the level of statutory protection that applies to the affected species or community.
6. Effectively manage the risks of the offset not succeeding.
7. Be able to be readily measured, monitored, audited and enforced.

Australian Government policy specifies direct offsets should make up at least 90% of the required offset package (DSEWPaC 2012a). However, deviation from this 90% will be considered where it can be demonstrated that there will likely be a greater benefit to the protected matter through increasing the proportion of indirect offsets or where scientific uncertainty is so high that it is not possible to determine a direct offset likely to benefit the protected matter.

3. Residual impacts

This section summarises impact assessment and mitigation measures relevant to the assessment of offsets (additional detail is available in the PER and associated appendices). Significant residual impacts on environmental values require the implementation of an environmental offset to compensate for those impacts and to achieve a net environmental benefit. The following section summarises the significant residual environmental impacts identified in the PER resulting from unavoidable requirements of the Proposal.

The assessment of residual impacts has been structured as follows:

- description of environmental value (Section 3.1)
- mitigation measures (Section 3.2)
- summary of residual impacts (Section 3.3)
- significance of residual impacts on environmental values (Section 3.4)

An Environmental Offsets Reporting Form for the Proposal is presented in Appendix 1. While this structure has been presented in terms of WA EPA requirements, Section 3.1.3 outlines the relevant Australian Government MNES and Section 3.3 concludes on the likely residual impact to MNES.

3.1 Clearing the State Forest sub-area

3.1.1 Whicher Scarp Landform

The Proposal requires clearing of 8.68 ha of native vegetation within the State Forest sub-area which is located on the Whicher Scarp soil-landscape system. Environmental Protection Bulletin No. 6 'The values of the Whicher Scarp' (EPA 2009) state that the Whicher Scarp is a distinct and naturally restricted landform with diverse flora containing local 'biodiversity hotspots'. The EPA (2009) recognises the significance of the natural values of the Whicher Scarp across a range of biodiversity characteristics at the genetic, species and community levels and the small overall extent of the Whicher Scarp environments. The landform is approximately 21 000 ha in area of which 46% (approximately 9200 ha) remains naturally vegetated leading to unusual relictual habitats of plant communities and flora. Of the remaining area, 64% (approximately 5800 ha) is on public lands with the majority of this managed by Department of Parks and Wildlife (Parks and Wildlife) within nine forest areas. Clearing for the Proposal represents 0.09% (i.e. 8.68 ha of 9200 ha) of the remaining vegetation within the Whicher Scarp landform.

The vegetation within the State Forest sub-area contains populations of conservation significant flora, including *Daviesia elongata* subsp. *elongata* (Vulnerable under the EPBC Act, Threatened under the WC Act), two Priority listed species, *Conospermum paniculatum* (P3) and *Acacia semitrullata* (P4), and the regionally significant flora *Jacksonia sp. Whicher (G.J. Keighery 9953)*, *Hemiphora bartlingii* and *Petrophile serruriae*. The majority of the vegetation within the State Forest sub-area was rated as very good or excellent and so is considered valuable by the community and /or government (EPA 2006).

The vegetation is considered of high value to several fauna species of conservation significance, local significance and three species of reptile occurring in that habitat as a rare assemblage.

3.1.2 Priority Ecological Community

The Proposal requires clearing of 8.22 ha of the Priority 1 Ecological Community, FCT C1 which represents approximately 11% of the known mapped extent of this Priority Ecological Community (PEC). This estimate however is likely to be conservative given that it is possible that more surveys of the Whicher Scarp, particularly on coloured sands, are likely to identify more FCT C1 vegetation (Ecoedge 2015).

3.1.3 Matters of National Environmental Significance

The Proposal has the potential to significantly affect the following MNES protected under Part 3 of the EPBC Act:

- listed Threatened species and communities (sections 18 and 18A of the EPBC Act).

The Proposal requires clearing of a total of 8.68 ha (110 habitat trees [i.e. >50 cm DBH]) of black cockatoo (CBC, BBC and FRBC) foraging, roosting and potential breeding habitat. Of the 110 habitat trees, 10 trees contain hollows of sufficient size for use by black cockatoos for breeding purposes (i.e. hollows with entrances of ~>12 cm) and one night roosting site. The remaining trees represent potential breeding habitat.

3.2 Mitigation measures

In accordance with the hierarchy of on-site mitigation measures presented in the Offset Guidelines, the Proposal includes mitigation measures to avoid, minimise and rectify impacts prior to the application of environmental offsets. The mitigation measures for each residual impact are described in Table 1.

3.3 Summary of residual impacts

The significant residual environmental impacts of the Proposal, after consideration of other mitigation measures to be applied, are expected to be:

1. Short to medium term impact of loss of 8.68 ha of native vegetation with high natural biodiversity, which supports a number of conservation flora and fauna species.
2. An associated medium term loss of 8.68 ha of potential foraging, roosting and breeding habitat for black cockatoos. Longer-term impacts would be reduced over time through achievement of targets for forage and nesting species return in rehabilitation.
3. Longer-term impact on local biodiversity from possible permanent change in biodiversity of the area subject to clearing. This may include a change in species composition and vegetation structure resulting from rehabilitated ecosystems not fully resembling the pre-mining state.

The residual impacts listed above include a significant impact to black cockatoos (Endangered or Vulnerable under EPBC Act), all of which are MNES. In addition, the following species are also proposed to be considered specifically in the offsets strategy:

- *Daviesia elongata* subsp. *elongata* (Vulnerable under EPBC Act)
- Priority flora species affected by Proposal and FCT C1.

The proposed clearing of six individuals of *Daviesia elongata* subsp. *elongata* represents only 0.59% of the estimated population of 1016 mature plants and is not expected to have a significant impact on this species. However; from a regional perspective, this species is restricted to a relatively small geographical area and the clearing impacts on 6 of the 7 known occurrences of this species within the State Forest sub-area. Appropriate management actions will be developed in consultation with Parks and Wildlife to mitigate the potential impact on this species. This species and a number of Priority Flora species directly affected by the Proposal contribute to the inherent high biodiversity values of the area and would be further considered in proposed offsets.

After the application of mitigation measures, other impacts of the Proposal are not expected to be significant. However, the offset package is expected to provide benefits to other environmental values affected by the Proposal.

Table 1: Summary of mitigation measures and residual impacts

Environmental Value	Applicable legislation	Impact Mitigation			Residual impact
		Avoid	Minimise	Rehabilitate	
Black cockatoo habitat	EPBC Act listed species (Section 18 and 18A) Wildlife Conservation Act 1950, Schedule 1 species Clearing principle (b)	The original Proposal footprint comprised up to 20 ha of black cockatoo habitat. This has been reduced to 8.68 ha under the current Proposal. Cleared land will be used for the Proposal where possible, i.e. infrastructure disturbance areas are located on previously cleared land. Progressive mining and rehabilitation, including associated void backfill practices, restrict many activities to the mining areas avoiding unnecessary clearing in high value areas.	Clearing will be the minimum necessary for the safe construction and operation of the Proposal. Temporary duration of the Proposal. The proposed mining schedule has been developed to minimise the disturbance time associated with mining within the State Forest sub-area. Revegetation will commence as soon as practicable following extraction of the ore through progressive backfilling of the mine void and replacement of overburden, subsoil and topsoil. Mine operations would follow a staged sequence such that the net extent of clearing and mining impacts at any point in time is minimised. Sand and clay materials (tailings) separated during the processing phase would be returned to the mine void, minimising impacts to the form of the post-mining landscape. Replacement of topsoil and use of locally collected seed in rehabilitation works.	Cleared area within the State Forest sub-area will be revegetated with suitable habitat species. Topsoil would be removed prior to mining, and stockpiled (< 18 months where possible) for return to the same or nearby areas.	Clearing of 8.68 ha of black cockatoo habitat

Environmental Value	Applicable legislation	Impact Mitigation			Residual impact
		Avoid	Minimise	Rehabilitate	
Whicher Scarp soil landscape system including a PEC	Wildlife Conservation Act 1950, subsection (2) of section 23F Clearing principle (a) and (c)	The original Proposal footprint comprised up to 20 ha native vegetation on the Whicher Scarp soil landscape system including PEC FCT A1 and PEC FCT C1. The current proposal footprint comprises a reduced area of FCT C1 (8.22 ha) and has removed the impact on FCT A1. Cleared land will be used for the Proposal where possible, i.e. infrastructure disturbance areas are located on previously cleared land. Progressive mining and rehabilitation, including associated void backfill practices, restrict many activities to the mining areas avoiding unnecessary clearing in high value areas.	Clearing will be the minimum necessary for the safe construction and operation of the Proposal. Temporary duration of the Proposal. The proposed mining schedule has been developed to minimise the disturbance time associated with mining within the State Forest sub-area. Revegetation will commence as soon as practicable following extraction of the ore through progressive backfilling of the mine void and replacement of overburden, subsoil and topsoil. Mine operations would follow a staged sequence such that the net extent of clearing and mining impacts at any point in time is minimised. Sand and clay materials (tailings) separated during the processing phase would be returned to the mine void, minimising impacts to the form of the post-mining landscape. Replacement of topsoil and use of locally collected seed in rehabilitation works.	Cleared area within the State Forest sub-area will be revegetated with suitable habitat species. Topsoil would be removed prior to mining, and stockpiled (< 18 months where possible) for return to the same or nearby areas.	Clearing of 8.68 ha of vegetation within the Whicher Scarp soil-landscape system including 8.22 ha of the Priority 1 Ecological Community FCT C1

3.4 Significance of residual impacts on environmental values

The staged mining and rehabilitation program would ensure that the significant residual impacts are largely transitional, and not permanent. The exception to this may be the longer-term changes in species composition and vegetation structure resulting from rehabilitation not returning the identical pre-existing state. Revegetation of the State Forest sub-area will commence as soon as practicable following extraction of the ore through progressive backfilling of the mine void and replacement of overburden, subsoil and topsoil. Progressive rehabilitation will ensure that time-dependency of returning the Proposal site to a functioning ecosystem is minimised.

Given consideration to the scale, and the transitional and temporary nature of the expected residual impact on the environmental values, Doral does not consider there to be any significant adverse impacts to environmental values from the proposal. Furthermore, together with the offsets package to be negotiated as discussed in the following section, Doral believes that there would be a ‘net environmental benefit’ resulting from implementation of the Proposal, in accordance with EPA goals. This is considered sufficient to limit application of a presumption of unacceptability of the Proposal.

4. Environmental offset strategy

This offset strategy has been developed following consultation with Parks and Wildlife and DotE based on the principles set out in the Offset Guidelines and EPBC Act Policy (DSEWPaC 2012a). Consultation has included meetings, telephone conversations and site visits to the Proposal site and proposed offset site.

The quality value of habitat to be cleared and the proposed offset has been determined using the DotE document *How to use the offsets assessment guide* (DSEWPaC 2012c), which requires three elements of habitat quality to be assessed and their relative importance for each MNES to be determined. The basis for the quality values used in the offset calculations is outlined in Appendix 2.

The summary of the assessment and components of the offsets package have also been qualitatively defined and are detailed in Table 2. An EPA environmental offsets reporting form has been prepared for the Proposal and is provided in Appendix 1.

It is intended that this offsets strategy will be provided to the EPA at the time of submission of the Summary and Response to Public Submissions on the PER. Doral commit to the development of a more detailed offset strategy following acceptance of this strategy and granting of State and Federal approval for the Proposal. The finalised offset strategy will identify the preferred offset package and will include further information on the land acquisition process, financial obligations and ongoing management requirements.

Doral believes that there would be a ‘net environmental benefit’ resulting from implementation of the Proposal, in accordance with EPA goals. This is considered sufficient to limit application of a presumption of unacceptability of the Proposal.

Doral intend to use land acquisition as its primary method for providing a direct offset for the Proposal supplemented by the restoration of degraded lands and on-going land management of these areas to improve the quality of habitat. The offset package (summarised in Table 2 and detailed in Section 5) focuses on the residual impacts identified in Section 3. Doral, through investigating available options and consultation with Parks and Wildlife, have identified that there is a limited area of privately held native vegetation on the Whicher Scarp available for purchase.

In the event that either of the offset options outlined below are not progressed then Doral will engage with the Office of the Environmental Protection Authority (OEPA), Parks and Wildlife and DotE to identify and secure suitable alternative land, of equivalent size and value that meets the requirements of the WA and Australian Government Offsets Policies.

Table 2: Offset Assessment

Existing environment/impact				Significant residual impact	Offset calculation methodology				
	Avoid and Minimise	Rehabilitation type	Likely rehabilitation success		Type	Risk	Likely offset success	Time lag	Offset quantification
8.68 ha of potential foraging, roosting and potential breeding habitat for black cockatoo species.	Refer to Table 1.	8.90 ha of disturbance will be revegetated with the species suitable as foraging, roosting and breeding habitat for black cockatoo species.	Seed stock will be retained during disturbance significantly enhancing the likely success of rehabilitation. Lee et al (2013) has demonstrated that mine site rehabilitation is able to provide foraging resources for all three species of black cockatoos within eight years. It is estimated that for the majority of the habitat trees to be cleared, a time lag of approximately 50-65 years from the time of rehabilitation/planting is undertaken before habitat values equivalent to those lost will be replaced. However, the habitat trees with hollows with larger entrances (~>12cm) are likely to be many years older given that it takes in the order of 130-200 years for a habitat tree to mature sufficiently.	Temporary disturbance to up to 8.68 ha of foraging, roosting and potential breeding habitat for black cockatoos. Expected to return equivalent foraging habitat within ten years.	Land acquisition – offset site has been identified for purchase.	Low – land to be ceded to Parks and Wildlife.	Value to black cockatoo species can be defined through acquisition, rehabilitation and protection of additional areas of habitat and rehabilitation and management within the State Forest sub-area.	<u>Acquisition of land</u> – no time lag <u>and</u> <u>Rehabilitation of land</u> – Rehabilitation of disturbance area within 50-65 years to achieve no net loss.	Total offset of 26 ha of land acquisition, rehabilitation and habitat protection. The area of land acquisition/rehabilitation was determined using the DotE offset calculator.
					Revegetation of cleared agricultural areas and State Forest sub-area.	Low – land to be ceded to Parks and Wildlife.			

Existing environment/impact				Significant residual impact	Offset calculation methodology				
	Avoid and Minimise	Rehabilitation type	Likely rehabilitation success		Type	Risk	Likely offset success	Time lag	Offset quantification
8.68 ha of vegetation within the Whicher Scarp soil-landscape system including 8.22 ha of a PEC (FCT C1).	Refer to Table 1.	8.90 ha of disturbance will be rehabilitated. Vegetation in rehabilitated areas will have similar values as surrounding natural systems.	A detailed Rehabilitation Management Plan will be prepared outlining the measures to be implemented to significantly enhance rehabilitation success. Some of the measures to be implemented include: • retention of seed stock during disturbance • re-establishment of functional soil profiles including replacement of subsoil and topsoil • deep ripping of compacted areas • weed management • dieback management. Doral is committed to adopting best practice rehabilitation methods from the wider mining industry including utilising available expertise gained from similar rehabilitation projects. Doral has been undertaking rehabilitation and revegetation works at its Dardanup and Burekup West operations since 2009, in accordance with the Rehabilitation Management Plan and Mine Closure Plan approved by the DMP. At its existing operations, Doral operates under an Environmental Management System in line with the requirements of the Australian/New Zealand Standard AS/NZS ISO 14001:1996. The established Environmental Management Framework will ensure that the proposed Yoongarillup Mineral Sand Mine will have established and proven processes and procedures in place at the time of commencement.	Temporary disturbance of 8.68 ha of vegetation within the State Forest sub-area. The primary focus of the rehabilitation plan will be to revegetate the area to represent the vegetation types found prior to clearing. However; there may be longer-term changes in species composition and vegetation structure resulting from rehabilitation not returning the identical pre-existing state.	Land acquisition – offset site has been identified for purchase. Revegetation of cleared agricultural areas and State Forest sub-area.	Low – Doral will purchase and implement improvement/ rehabilitation programs. Upon successful implementation of these programs, Doral will offer the land to Parks and Wildlife for incorporation into the Whicher National Park Low – land to be ceded to Parks and Wildlife.	Value to FCT C1 can be defined through acquisition, rehabilitation and protection of additional areas of habitat and rehabilitation and management within State Forest No. 33.	Acquisition of land – no time lag and Rehabilitation of land – Rehabilitation of disturbance area within 50-65 years to return ecosystem to as close as possible to pre-existing state.	Total offset of 26 ha of land acquisition, rehabilitation and habitat protection. The area of land acquisition/rehabilitation was determined using the DotE offset calculator.

5. Proposed Environmental Offset Packages

Doral have investigated two potential offset packages, outlined in the following section, to compensate for residual environmental impacts resulting from the Proposal.

5.1 Offset Package 1

5.1.1 Direct offset

Table 3 provides the objectives and description of offset package 1 – acquisition of part of and subsequent transfer of land to the State. The direct offset package would comprise approximately 16 ha of native vegetation and 3 ha of cleared agricultural land that will be rehabilitated.

The calculation of offset quantum has been based on the native vegetation to be purchased representing at least 'good' condition. As such, the calculation of the offset has assumed a start quality of 6, a future quality of 5 and a future quality with the offset of 7.

This offset aims to compensate for the residual impact associated with the loss of vegetation including PEC FCT C1 and the loss of breeding, roosting and foraging habitat for black cockatoo species. The offset property would be within 50 km of the Disturbance footprint.

Table 3: Protection and improvement of remnant native vegetation comprising habitat for black cockatoos in surrounding land

Objective	Description
Protect habitat for black cockatoo species by removing or reducing threatening processes	Acquisition of this land and implementation of a rehabilitation management plan will: • protect habitat used for foraging by all three species of black cockatoo • protect potential habitat used for breeding by all three species of black cockatoo • improve condition of the habitat through management programs including feral and pest animal management, weed control, monitoring of fauna species and management for forest hygiene.
Revegetate existing cleared agricultural land to restore habitat for black cockatoo species	Acquisition of this land and revegetation of existing cleared land will: • provide habitat used for foraging and breeding by all three species of black cockatoo.

Conservation of habitat is consistent with the definition of a direct offset in accordance with the Offsets Policy (EPA 2011) and the EPBC Environmental Offsets Policy (DSEWPaC 2012a). The proposed offset is expected to result in the protection of additional lands or the enhancement and management of current lands within the conservation estate. Protection of habitat is also consistent with the principles of the *Baudin's and Forest Red Tailed Black-Cockatoo Recovery Plan (2007–2016)* (DEC 2007) and *Carnaby's Cockatoo* (Calyptorhynchus latirostris) *Recovery Plan* (DEC 2012).

The land proposed for acquisition is currently privately owned agricultural land, and is therefore at risk of future clearance as part of agricultural activities. Ceding of the land to the State for conservation purposes will prevent potential agricultural activities in this area, as well as provide for active management of threats including forest pathogens (such as dieback, which alters structure and reduces diversity), introduced animals and pests (such as kangaroos, which are currently impacting vegetation condition) and weeds. The long-term security and conservation of the offset will be ensured as the property is to be vested with Parks and Wildlife and managed for conservation.

Doral will provide ongoing active management of these areas prior to handover of the land to the State with the aim of improving vegetation condition. The implementation of management measures including fencing to exclude kangaroos, subjecting the vegetation to prescribed burning and mechanically disturbing bare areas is expected to result in an increase in species richness and plant cover.

Implementation of the management program will commence following acquisition of the land by Doral.

Rehabilitation of the existing cleared area will focus on the establishment of black cockatoo foraging habitat (Eucalypts and proteaceous shrubs) plus Marri for hollow creation in the long-term.

Additionally, this offset will protect habitat for all impacted fauna species recorded in the area. The site is connected to larger areas of native vegetation, including the Whicher National Park, which will minimise edge effects on these existing areas.

5.1.2 Indirect offset

Doral would undertake surveys outside of the Proposal area to provide further information on the known extent of conservation significant vegetation communities that may be impacted by the Proposal (i.e. FCT C1). This survey program would focus on areas previously identified by Ecoedge as likely to contain FCT C1 (Ecoedge 2015) and will be developed in consultation with Parks and Wildlife.

5.1.3 Implementation of the Offset package

Implementation of the land acquisition process and development of the revegetation program will commence immediately following approval and setting of conditions by both the State and Australian Governments and the various phases are summarised in Table 4 with anticipated timeframes.

Table 4: Proposed implementation plan for the Offset Package 1

Implementation Stage	Timeframe for Completion
Obtain written confirmation from landowner that they are willing to sell identified land. Subdivision of purchased land.	Immediately following State and Federal approval of the Proposal. Subdivision process to commence upon obtaining written confirmation from landowner that land will be sold to Doral
Undertake additional surveys outside of the Proposal area to provide further information on the known extent of the vegetation community FCT C1.	Within three months of gaining approval.
Site assessment by Parks and Wildlife – determination of characteristics for conservation and site management requirements.	Within three months of gaining approval.
Development of a Revegetation and Rehabilitation Management Plan for the site.	Within six months of gaining approval.
Implementation of a Revegetation and Rehabilitation Management Plan.	Within twelve months of gaining approval.
Commence revegetation of the disturbed areas of the site.	Works will commence as soon as is practicable after the backfilling of mine voids, reconstruction of the soil profile and respread of topsoil materials.
Subdivision of offset area to enable transfer of land titles to the State of WA and management responsibilities for the site to Parks and Wildlife.	On fulfilment of completion criteria.

A detailed Revegetation and Rehabilitation Management Plan will be developed within six months of gaining approval. The plan will detail the various phases of revegetation and rehabilitation including the following aspects of the work program:

- desired target ecosystems to be achieved
- proposed seed mixes and plant species to be utilised in revegetation works
- proposed resourcing to be made available for the completion of the revegetation and rehabilitation works
- indicative timeframes for completion of revegetation and rehabilitation works
- plans for evaluation and reporting of revegetation and rehabilitation success including desired species richness and fauna utilisation of the site to be achieved.

Revegetated areas (existing pastoral land and State Forest sub-area) and rehabilitated vegetation will require on-going management to ensure the objectives and completion criteria are met. While there will be further detail in the Revegetation and Rehabilitation Management Plan, at present, management actions are envisaged to cover the following land management aspects:

- stock exclusion
- fencing
- weed management
- feral and pest animal management
- fire management
- protection of growing seedlings and young plants from feral (and native) animals
- assessment of restoration success through vegetation and fauna presence assessments post-restoration.

The detailed plan will be provided to Parks and Wildlife to seek advice and as an interested stakeholder.

In the event that the acquisition of the identified land is not possible, due to failed negotiations with the landowner, Doral will pursue Offset Package 2, described below.

5.2 Offset Package 2 (Alternative to Offset Package 1)

5.2.1 Description of direct offset

Table 5 provides the objectives and description of offset package 2 – provision of significant funds to the State for the acquisition and management of black cockatoo foraging and breeding habitat and vegetation of high biodiversity value near to the Proposal area.

Doral commit to undertaking a fauna assessment of the site to determine the value as black cockatoo habitat. This offset aims to compensate for the residual impact associated with the loss of vegetation including the loss of breeding, roosting and foraging habitat for black cockatoo species.

Table 5: Protection and improvement of remnant native vegetation habitat for black cockatoos in surrounding land

Objective	Description
Protect habitat for black cockatoo species by removing or reducing threatening processes	Acquisition of this land and implementation of a rehabilitation management plan will: • protect potential habitat used for foraging, roosting and breeding by all three species of black cockatoo • improve condition of the potential habitat through management programs including feral animal species and weed control, monitoring of fauna species and management for forest hygiene.
Protect vegetation with high biodiversity value	Acquisition of this land and implementation of a rehabilitation management plan will: • protect vegetation with high biodiversity value • improve condition of the habitat through management programs implemented by Parks and Wildlife, e.g. feral animal species and weed control, introduction of a fire regime and management for forest hygiene.

Conservation of habitat is consistent with the definition of a direct offset in accordance with the Offsets Policy (EPA 2011) and the EPBC Environmental Offsets Policy (DSEWPaC 2012a). The proposed offset is expected to result in the protection of additional lands or the enhancement and management of current lands within the conservation estate. The offset is not likely to be directly related to the environmental value being impacted (i.e. PEC FCT C1) given the limited available area of PEC FCT C1 in privately held land and so is not considered to fulfil the 'like for like' requirement. However, the site will be selected to provide high quality foraging, roosting and breeding habitat for black cockatoos and vegetation with high biodiversity value. Protection of habitat is also consistent with the principles of the *Baudin's and Forest Red Tailed Black-Cockatoo Recovery Plan (2007–2016)* (DEC 2007) and *Carnaby's Cockatoo* (Calyptorhynchus latirostris) *Recovery Plan* (DEC 2012).

Purchase of this land by the State for conservation purposes will prevent potential clearing activities within this area, as well as provide for active management of threats including forest pathogens (such as dieback, which alters structure and reduces diversity), introduced animals and weeds. The long-term security and conservation of the offset will be ensured as the property is to be vested with Parks and Wildlife and managed for conservation.

Doral will provide funding to Parks and Wildlife for the active management of these areas with the aim of improving vegetation condition.

5.2.2 Implementation of the Offset package

Implementation of the offset package will commence immediately following approval and setting of conditions by both the State and Federal Governments and the various phases are summarised in Table 6 with anticipated timeframes. Funding requirements for the purchase and management of the land will be determined in consultation with Parks and Wildlife following State and Federal approval of the Proposal.

Table 6: Proposed implementation plan for the Offset Package 2

Implementation Stage	Timeframe for Completion
Obtain written confirmation from Parks and Wildlife that they have identified a suitable offset area.	Immediately following State and Federal approval of the Proposal.
Site assessment by Parks and Wildlife – determination of characteristics for conservation and site management requirements.	Within three months of gaining approval.
Site assessment by a fauna specialist to determine black cockatoo habitat values of the site.	Within three months of gaining approval.
Provision of funding to Parks and Wildlife.	Prior to clearing State Forest sub-area.

6. Reporting

All environmental offsets required as part of approvals under WA legislation are now made public via the WA Environmental Offsets Register. Progress of environmental offsets are tracked via the register as actions listed as 'complete' or 'not complete'. For projects approved under Part IV of the EP Act, the Offsets Register is administered by the OEPA. Once a Statement is issued, the OEPA will upload the relevant details into the register. The offsets 'condition milestones' are based on the conditions in the Statement. The 'implementation milestones' (if required) are generally based on actions in your Offsets Strategy.

Doral currently submits an Annual Environmental Report (AER) to the DMP that reports on progress in operating their mines and implementing progressive rehabilitation. Monitoring of progressive rehabilitation undertaken at the offset site will be described in detail within the AER. Doral will be required to provide an annual report (or as required in accordance with the Statement) to the OEPA detailing the progress of the strategy or as a result of an action arising from a Statement condition. Updating the register to reflect the progress of the strategy is the responsibility of the OEPA.

Progress reporting to Parks and Wildlife is also anticipated to be required as part of ceding the land to the State.

7. References

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Appendix 1
EPA environmental offsets reporting form

Environmental Protection Authority

GOVERNMENT OF WESTERN AUSTRALIA

Environmental offsets reporting form

See *EPA Guidance Statement No. 19: environmental offsets - biodiversity*

Please note that the EPA may request additional information.

Section A: Administrative information
1. Proposal or scheme name: Yoongarillup Mineral Sands Project
2. Summary of proposal or scheme: Doral Minerals Sands Pty Ltd proposes to extract ore from the strand of heavy mineral deposit known as the Yoongarillup Mineral Sands Deposit located within Mining Tenements M70/0458 and M70/0459. The Proposal is located approximately 17 km southeast of Busselton. Ore from the deposit will be mined progressively via a series of open-cut pits using dry mining techniques. Mining will be staged in order to minimise the area of disturbance at any one time. The life of the mine is expected to be three years, including an initial pre-mine establishment phase and three mining phases. Rehabilitation and mine closure will be implemented at the cessation of mining; this phase is likely to take up to five years. The proposal footprint totals 95.71 ha including 8.68 ha of native vegetation located within State Forest No. 33.
Section B: Type of environmental asset (s) – State whether Critical or High Value, describe the environmental values and attributes
The proposed site is considered a 'high value' environmental asset as per definitions given in EPA (2006) as the proposal footprint constitutes vegetation with high biodiversity values and habitat for three species of listed threatened black cockatoos (Carnaby's Black Cockatoo, Baudin's Black Cockatoo and Forest Red-tailed Black Cockatoo). The following is a summary of environmental assets for the proposal footprint: • high levels of natural biodiversity, including significant flora and fauna located in State Forest No. 33 within the Whicher Scarp soil-landscape system • a total of 8.68 ha (110 habitat trees [i.e. >50 cm DBH]) of black cockatoo foraging, roosting and potential breeding habitat will be impacted by the proposal. Of the 110 habitat trees, 10 trees contain hollows of sufficient size for use by black cockatoos for breeding purposes (i.e. hollows with entrances of ˜>12 cm) • 8.22 ha of the Priority 1 ecological community (PEC), FCT 1 • populations of conservation significant flora, including *Daviesia elongata* subsp. *elongata* (Vulnerable under the EPBC Act, Threatened under the WC Act), two Priority listed species, *Conospermum paniculatum* (P3) and *Acacia semitrullata* (P4), and the regionally significant flora *Jacksonia sp. Whicher (G.J. Keighery 9953)*, *Hemiphora bartlingii* and *Petrophile serruriae* • it is rated as very good to excellent condition where "vegetation that is good to excellent condition, is considered valuable by the community and /or government" (EPA 2006) • it is considered of high value to several fauna species of conservation significance, local significance and three species of reptile occurring in that habitat as a rare assemblage.
Section C: Significant impacts (describe the significant adverse environmental impacts related to the proposal or scheme before mitigation measures are applied)
Clearing of 8.68 ha of vegetation in State Forest No. 33 within the Whicher Scarp soil-landscape system. Loss of 8.22 ha of the PEC FCT C1. Loss of some potential habitat and known locations of conservation significant flora including the EPBC Act listed (Vulnerable) *Daviesia elongata* subsp. *elongata* and a number of Priority flora species. Loss of 8.68 ha of black cockatoo foraging, roosting and potential breeding habitat. Potential introduction and spread of invasive weed species and the plant pathogen *Phytophthora cinnamomi* (Dieback).
Section D: Mitigation measures (describe all measures to Avoid, Minimise, Rectify and Reduce)

Avoid

It is difficult to avoid the majority of the area of impact, as the Proposal is restricted to areas in which the mineral resources are located. Doral has conducted comprehensive minerals exploration activities in order to establish a proposal footprint with minimal potential for environmental impacts. There is flexibility in placement of infrastructure to avoid areas of higher environmental value.

Mining infrastructure would be located in already disturbed areas.

Progressive mining and rehabilitation, including associated void backfill practices, restrict many activities to the mining areas avoiding unnecessary clearing in high value areas.

Minimise

Mine operations would follow a staged sequence such that the net extent of clearing and mining impacts at any point in time is minimised.

Doral would develop a rigorous internal clearing and stripping permits system to ensure clearing is minimise to that necessary and authorised.

Temporary duration of the Proposal. The proposed mining schedule has been developed to minimise the disturbance time associated with mining within the State Forest sub-area. Sand and clay materials (tailings) separated during the processing phase would be returned to the mine void, minimising impacts to the form of the post-mining landscape.

Replacement of topsoil and use of locally collected seed in rehabilitation works.

Rectify/Reduce

Long-term impacts would be reduced through the rehabilitation of all land affected by the Proposal. Doral would implement a Mine Closure plan in accordance with the DMP and EPA Guidelines for Preparing Mine Closure Plans (DMP & EPA 2011). This would include the definition of a final land use for the proposal footprint, development of completion criteria, and specific rehabilitation strategies for the management of significant flora and fauna species and communities.

Doral would also implement environmental management plans to reduce impacts to key environmental assets.

Topsoil would be removed prior to mining, and stockpiled (< 18 months where possible) for return to the same or nearby areas.

Doral would develop specific rehabilitation criteria to increase the potential for conservation significant flora and fauna species to be successfully returned to the rehabilitated mine site. For example, Doral would ensure all species considered likely to be foraging species for black cockatoos are returned to a specified density in rehabilitation works. For Threatened and Priority flora taxa, Doral would develop strategies for the establishment of these species and monitor compliance against the targets identified in rehabilitation areas.

Section E: Significant residual impacts (describe all the significant adverse residual impacts that remain after all mitigation attempts have been exhausted)

1. Short to medium term impact of loss of 8.68 ha of native vegetation with high natural biodiversity, which supports a number of conservation flora and fauna species.
2. An associated medium term loss of 8.68 ha of potential foraging, roosting and breeding habitat for black cockatoos. Longer-term impacts would be reduced over time through achievement of targets for forage and nesting species return in rehabilitation.
3. Longer-term impact on local biodiversity from possible permanent change in biodiversity of the area subject to clearing. This may include a change in species composition and vegetation structure resulting from rehabilitated ecosystems not fully resembling the pre-mining state.

Risks presented to the conservation status of FCT C1 are addressed in the offsets package.

The residual impacts listed above include a significant impact to three species of listed threatened black cockatoos (Endangered or Vulnerable under EPBC Act), all of which are MNES. In addition, the following species are also proposed to be considered specifically in the offsets strategy:

- *Daviesia elongata* subsp. *elongata* (Vulnerable under EPBC Act)
- Priority flora species affected by Proposal and FCT C1.

The proposed clearing of six individuals of *Daviesia elongata* subsp. *elongata* represents only 0.59% of the estimated population of 1016 mature plants and is not expected to have a significant impact on this species. However; from a regional perspective, this species is restricted to a relatively small geographical area and the clearing impacts on 7 of the 8 known occurrences of this species within the State Forest sub-area. This species and a number of Priority flora species directly impacted by the Proposal contribute to the inherent high biodiversity values of the area and would be further considered in proposed offsets.

Section F: Proposed offsets for each significant residual impact (identify direct and contributing offsets). Include a description of the land tenure and zoning / reservation status of the proposed offset site. Identify any encumbrances or other restrictions on the land that may impact the implementation of the proposed offset and provide evidence demonstrating how these issues have been resolved.

As offset negotiations are at a preliminary stage, and considering the components of the package carry some commercial sensitivity, a brief description of the offset concept being considered is provided below. These include a number of options of direct and indirect offsets that could be pursued. These are divided into 'primary' offsets and 'supporting' offsets.

Primary Offsets (Direct and Indirect/Contributing Components)

Acquisition of land for black cockatoo habitat and FCT C1 conservation project

This offset is based around the acquisition of land for the conservation of black cockatoo foraging, roosting and breeding habitat and vegetation of high biodiversity value near to the State Forest subarea. This land is to be acquired and managed for conservation in perpetuity through an agreement with DPaW. Acquisition of this land would be supported by funding for initial works to allow transfer to DPaW management, preparation of a Revegetation and Rehabilitation Management Plan and ongoing conservation management of the land. The proposed offset site contains black cockatoo foraging, roosting and breeding habitat and an area of vegetation that is representative of FCT C1.

This proposed offset consists of direct (conservation of land, improved management) and indirect/contributing offsets (ongoing management activities, rehabilitation, implementation of management plan, removal of threatening processes).

Acquisition of land for black cockatoo habitat and vegetation with high biodiversity value

This offset is based around the acquisition of land for the conservation of black cockatoo foraging, roosting and breeding habitat and vegetation of high biodiversity value. This land is to be acquired and managed for conservation in perpetuity through an agreement with DPaW. Acquisition of this land would be supported by funding for initial works to allow transfer to DPaW management and ongoing conservation management of the land. The offset site would be selected based on the presence of black cockatoo foraging, roosting and breeding habitat and an area of vegetation that is recognised as having high biodiversity values.

This proposed offset consists of direct (conservation of land, improved management) and indirect/contributing offsets (ongoing management activities and removal of threatening processes).

Supporting Offsets (Indirect/Contributing Only)

Regional surveys for significant vegetation communities

Doral would undertake surveys outside of the Proposal area to provide further information on the known extent of conservation significant vegetation communities that may be impacted by the Proposal (i.e. FCT C1). This survey program would focus on areas previously identified by Ecoedge as likely to contain FCT C1 (Ecoedge 2015)and will be developed in consultation with Parks and Wildlife.

Section G: Spatial data relating to offset site/s (see *EPA Guidance Statement No. 19: environmental offsets- biodiversity*, Appendix 4)

Spatial data and metadata statements would be provided to the EPA when the offsets package is finalised. This is expected to follow EPA assessment on the environmental acceptability of the project.

Section H: Relevant data sources and evidence of consultation (consultation with agencies, relevant stakeholders, community and references to sources of data / information). Include details of specific environmental, technical or other relevant advice and information obtained to assist in the formulation of the offset.

Flora and fauna surveys have been undertaken on the proposed offset site to evaluate the conservation significance of the vegetation and allow comparison with the proposal footprint. Details on the consultation undertaken so far in developing an offset package for the proposal are presented in Section 4 of the Yoongarillup Mineral Sands Project Public Environment Review.

Appendix 2
Justification of values used in the offset calculations

Assessment of habitat values within State Forest sub-area

A process of assessment was conducted to quantify habitat value within the State Forest sub-area considering the factors of site condition, site context and species stocking rate for black cockatoos. The results of this assessment are provided below.

Fauna habitat value

Habitat quality within the State Forest sub-area has been informed by the following aspects:

1. Site condition. This is the condition of a site in relation to the ecological requirements of a threatened species or ecological community. This includes considerations such as vegetation condition and structure, the diversity of habitat species present, and the number of relevant habitat features.
2. Site context. This is the relative importance of a site in terms of its position in the landscape, taking into account the connectivity needs of a threatened species or ecological community. This includes considerations such as movement patterns of the species, the proximity of the site in relation to other areas of suitable habitat, and the role of the site in relation to the overall population or extent of a species or community.
3. Species stocking rate. This is the usage and/or density of a species at a particular site. The principle acknowledges that a particular site may have a high value for a particular threatened species, despite appearing to have poor condition and/or context. It includes considerations such as survey data for a site in regards to a particular species population or, in the case of a threatened ecological community this may be a number of different populations. It also includes consideration of the role of the site population in regards to the overall species population viability or community extent.

Quantification of value

Consideration of habitat value of the State Forest sub-area from an assessment of vegetation condition, structure and extent of disturbance has been derived from Appendix 1 Table 1.

Appendix 1 Table 1: Vegetation condition within the study area (Keighery 1994)

Condition rating	Area (ha)	Description	Interpreted value (proposed habitat quality score)
Pristine	-	Pristine or nearly so; No obvious signs of disturbance	10
Excellent	5.48	>80% native flora composition; Vegetation structure intact or nearly so; Minor signs of disturbance; Non-aggressive weed species (cover <5%)	8–9
Very Good	3.20	60–80% native flora composition; vegetation structure altered in places; Obvious signs of disturbance; Weed cover/abundance 5–20%.	6–7
Good/Fair	-	40–60% native flora composition; Vegetation structure significantly altered yet retains basic structure or ability to regenerate to it; Very obvious signs of multiple disturbance; Weed cover/ abundance 20–50%.	4–5
Degraded	-	Basic vegetation structure severely impacted by disturbance; Scope for regeneration but not to a state approaching good condition without intensive management.	2–3
Completely Degraded	-	<20% native flora composition; Vegetation structure no longer intact; Extensive disturbance/modification present; Weeds are highly invasive (cover/abundance >80%).	1

Value as Carnaby's Black-Cockatoo habitat

Condition results from surveys show that vegetation structure across the majority of the State Forest sub-area was considered to be intact or nearly so (Mattiske 2012), despite being subject to partial clearing probably conducted during the period 1950-1965, grazing by kangaroos and the presence of *Pythoptora* disease in some areas. Given that the above assessment indicates the Proposal may result in temporary impact to potential foraging and breeding habitat for this species, an assessment of the site as potential habitat has also been undertaken (Appendix 1 Table 2).

Appendix 1 Table 2: Site assessment for Carnaby's Black Cockatoo habitat

Element	Criteria	Assessment	Score
Site condition	Vegetation condition	Vegetation condition was assessed by Mattiske in 2012. The State Forest sub-area was rated as 'Very Good' to 'Excellent'.	8
	Vegetation structure	Vegetation structure is a contributing factor to vegetation condition, described above. Vegetation structure across the majority of the State Forest sub-area was considered to be intact or nearly so (Mattiske 2012). The State Forest sub-area has been subject to partial clearing probably conducted during the period 1950-1965, grazing by kangaroos and is affected by the presence of Pythoptora disease in some areas.	
	Diversity of habitat species	The State Forest sub-area hosts a range of foraging species suitable for foraging by Carnaby's Black Cockatoo. 34 foraging habitat species for Carnaby's Black Cockatoo were identified by Harewood (2014b).	
	Relevant habitat features	Plant species identified within the State Forest sub-area are primarily used by Carnaby's Black-Cockatoo for foraging. *Corymbia calophylla, Eucalyptus marginata, Eucalyptus patens* and *Eucalyptus rudis,* identified during the Level 2 surveys, are also utilised for roosting (Groom 2011). *Corymbia calophylla* was the only nesting species positively identified in the State Forest sub-area, considered a high priority for planting to encourage nesting (Groom 2011). 110 habitat trees (i.e. >50 cm DBH) were identified during the Level 2 survey. Of the 110 habitat trees, 10 trees contain hollows of sufficient size for use by black cockatoos for breeding purposes (i.e. hollows with entrances of ~>12 cm) and one was identified as a night roosting site.	
Site context	Movement patterns	The species is highly mobile and displays a seasonal migratory pattern that is linked to breeding (Saunders 1980, 1990, Berry 2008 in DEC & Australian Government 2012). Breeding takes places between late July and December and most breeding occurs in the inland parts of its distribution, in areas receiving between 300–750 mm of average rainfall (Saunders 1974 in DEC & Australian Government 2012). During the non-breeding season (January to July), the majority of the birds move to the higher rainfall coastal regions of their range including the Midwest coast, Swan Coastal Plain and south coast (Saunders 1980, 1990; Berry 2008; Saunders et al. 2011; Johnstone et al 2011 in DEC & Australian Government 2012).	7
	Proximity of the site to other areas of suitable habitat	Mapping of remnant native vegetation in the area indicates similar remnant native vegetation is well-represented in the near vicinity.	

Element	Criteria	Assessment	Score
	Regional importance of site to species	The remnant vegetation within the State Forest sub-area represents potential foraging habitat for Carnaby's Black Cockatoo and there was foraging evidence attributable to this species recorded during the Level 2 surveys. 110 habitat trees (i.e. >50 cm DBH) were identified during the Level 2 survey. Of the 110 habitat trees, 10 trees contain hollows of sufficient size for use by black cockatoos for breeding purposes (i.e. hollows with entrances of ~>12 cm). However, there was no evidence of any trees being utilised for nesting. Several trees with evidence of roosting activity were observed within the Development Envelope including one tree within the State Forest sub-area. There was no direct evidence, i.e. actual black cockatoos, of the trees being used for roosting during the Level 2 fauna surveys and it is appears that the roost trees observed may only be used on a rotational basis with other roost trees in the area. Based on the results of the Level 2 fauna surveys, the small area of proposed clearing (8.68 ha) and the extensive areas of black cockatoo habitat located nearby the clearing is anticipated to only have a moderate localised impact.	
Species stocking rate	Site survey data	Botanical surveys carried out during 2011 and 2012 recorded the presence or absence of Carnaby's Black-Cockatoos (Harewood 2014b). Small flocks of Carnaby's Black Cockatoos were observed flying over the State Forest sub-area and there was evidence of foraging attributable to this species was recorded (Harewood 2014b).	7
	Regional role of the site population in overall species viability or community extent	Rather than hosting a discrete population of Carnaby's Black-Cockatoos, the site is expected to play a role in contributing foraging habitat within the wider South West region for visiting groups of the species during the autumn and winter months.	
Score			7

In summary, the site may be used as foraging and roosting habitat by Carnaby's Black-Cockatoos for part of the year due to presence of vegetation species used for foraging and existence of a roost tree. However, the site is not considered of regional importance for nesting or roosting, based on the absence of direct evidence of the utilisation of the habitat trees for these purposes (Harewood 2014b). An abundance of similar vegetation occurs in close proximity to the State Forest sub-area.

Rather than hosting a discrete population of Carnaby's Black-Cockatoos, the site is expected to play a role in contributing foraging and roosting habitat within the wider South West region for visiting groups of the species during the autumn and winter months.

Habitat quality of the State Forest sub-area for Carnaby's Black-Cockatoos has been rated as medium-high (i.e. habitat quality score of 7).

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