Acid Sulfate Soils Investigation
Learmonth Pipeline Fabrication Facility

Prepared for:

Subsea 7

December 2018

Prepared by:

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LEARMONTH PIPELINE BUNDLE PROJECT
ACID SULFATE SOIL INVESTIGATION

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Final Report	Gert du Plessis	Spencer Shute	7 December 2018

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1. INTRODUCTION

1.1 PROJECT BACKGROUND AND OBJECTIVES

The Learmonth Pipeline Fabrication Facility (the Proposal) involves the construction and operation of a new pipeline fabrication facility adjacent to the western shoreline of Exmouth Gulf, at Learmonth, approximately 35 km south of the Exmouth townsite (Figure 1). The proposed facility will allow the construction and launching of pipeline Bundles for the offshore oil and gas industry. A pipeline Bundle, used in the development of offshore gas fields, co-locates a number of services within a single pipeline, which is constructed onshore before being launched and towed offshore to the field under development.

The proposal includes the construction of a fabrication shed, where the Bundles will be constructed, a storage area where the Bundle materials will be stored prior to use, and two approximately 10 km long Bundle tracks along which each Bundle will be constructed and then launched (Figure 2). A Bundle launchway, crossing the beach and extending into the shallow subtidal area, will facilitate the launch of each Bundle.

The Proposal was referred to the Western Australian Environmental Protection Authority (EPA) by Subsea 7 on 23 October 2017. On 20 November 2017 the EPA determined the project required formal assessment with the level of assessment set as Public Environmental Review (PER), with an eight week public review period. An Environmental Scoping Document (ESD) was prepared by the EPA to define the form, content, timing and procedure of the Environmental Review Document (ERD) which takes the form of a PER. The ESD outlines the preliminary key environmental factors, other environmental factors and work requirements for completion of the ERD.

The proposal has the potential to impact soil, surface water or groundwater quality following the exposure or disturbance of acid sulfate soils.

Scale: 1:300000
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Air Photo: ESRI Satellite

0 5 10 km

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Figure 1

Locality Map

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0 0.5 1 1.5 km

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Figure 2

Site Plan

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1.2 DETAILS OF DEVELOPMENT

The proposal includes the construction of a fabrication shed, where the Bundles will be constructed, a storage area where the Bundle materials will be stored prior to use, and two approximately 10 km long Bundle tracks along which each Bundle will be constructed and then launched. A Bundle launchway, crossing the beach and extending into the shallow subtidal area, will facilitate the launch of each Bundle.

Shallow excavation will be required for the pipeline fabrication shed footings, along sections of the Bundle track (predominantly for cuts through elevated dune features) and to facilitate construction of the Bundle launchway. Indicated depths of disturbance of soils are expected to be less than one metre.

1.3 SITE HISTORY

The majority of the site remains undeveloped. Cape Seafarms Pty Ltd proposed to develop a 120 ha onshore prawn farm at Heron Point including a total footprint of 250 ha. The project was recommended for approval by the EPA (EPA Bulletin 854) and was approved via Ministerial Statement 456 on 27 August 1997. Initial earthworks were undertaken but the project has since been abandoned. An examination of aerial imagery suggests that up to approximately 170 ha of the onshore footprint have been disturbed following initial earthworks for the Cape Seafarms project.

1.4 RELEVANT POLICY AND GUIDANCE

MBS Environmental has taken into consideration relevant policy and guidance in the design and completion of the ASS sampling program and the consideration of potential impacts associated with the proposal.

A summary of the policy and guidance relevant to Terrestrial Environmental Quality, and how these have been considered, is presented in Table 1.

Table 1: Policy and Guidance to Relevant Terrestrial Environmental Quality

Policy/Guidance	Consideration for Proposal
Environmental Factor Guideline – Terrestrial Environmental Quality (EPA 2016)	Referred to in the determination of data requirements to support the development of the PER.
Identification and Investigation of Acid Sulfate Soils and Acidic Landscapes (DER 2015a)	Referred to in the assessment and identification of acid sulfate soils.
Treatment and Management of Soil and Water in Acid Sulfate Soil Landscapes (DER 2015b)	Referred to in the treatment and management of identified acid sulfate soils as well as groundwater.
Acid sulfate soil risk maps (DWER 2016)	Referred to in the selection of sampling locations.

1.5 ACID SULFATE SOILS AND ASS RISK MAPS

Acid sulfate soils (ASS) are naturally occurring soils, sediments and peats that contain iron sulfides that are generally found in a layer of waterlogged soil or sediment in low-lying land bordering the coast, estuarine, saline or freshwater wetlands throughout Western Australia (DER 2015a).

ASS are benign in an anoxic state and do not pose a significant risk to human or environmental health. However, when these soils are disturbed by dewatering/groundwater pumping or exposed to air, they can oxidise and produce sulfuric acid, iron precipitates and concentrations of heavy metals. Disturbing ASS has the potential to cause significant environmental and economic impacts.

Desktop mapping published by Department of Water and Environmental Regulation (DWER) (formerly Department of Environmental Regulation (DER)) identified portions of the Site are mapped as Class 1 'High to Moderate' risk of ASS within 3 m of the natural soil surface (DWER 2016). A portion of the development area along the coast is also mapped as Class 2: 'Moderate to Low' risk of ASS within 3 m of natural soil surface with 'High to Moderate' risk of ASS beyond 3 m (DWER 2016). These areas correspond generally with supratidal mud flats. Where mapped, the surrounding landscape is mostly 'High to Moderate' risk of ASS with small strips of areas of 'Moderate to Low' risk within 3 m of the natural soil surface (DWER 2016). Risk mapping in relation to the Project development area and sampling locations are discussed in Section 5.1.

2. SCOPE OF WORK

The ESD included Terrestrial Environmental Quality under 'Other Factors or Matters'. The required work for this factor is as follows:

- Provide details of chemical and diesel storage, and power generation and management measures, including contingencies in the event of a spill, to ensure that contamination of land does not occur.
- Provide details on the presence of acid sulfate soils within the proposal area, and if present details of proposed management measures to be implemented during construction to minimise impacts to terrestrial environmental quality (EPA 2018).

This report documents the work completed to determine the potential for acid sulfate soils (ASS) presence and/or disturbance within the proposal area. Specifically, MBS Environmental completed the following scope of work as part of the acid sulfate soils investigation:

- Desktop review of acid sulfate soil risk according to Department of Water and Environment Regulation (DWER) in the vicinity of the project. This included a desktop investigation of acid sulfate soil risk within the project envelope as per DWER (2016) mapping and selection of potential sampling locations.
- Site visit by an experienced MBS Environmental Scientist to collect samples along the project disturbance footprint where there is a high risk of acid sulfate soils within three metres from ground level.
- Submission of collected samples to a NATA accredited laboratory.
- Interpretation of laboratory results and preparation of a report presenting the findings from the acid sulfate soils investigation.

3. SITE CONDITIONS AND SURROUNDING ENVIRONMENT

3.1 SITE AND SURROUNDING ENVIRONMENT

The Project is located on the coastal plains within a minor syncline between Cape Range in the west and Rough Range in the southeast. Within the main project footprint, which is east of Minilya-Exmouth Road, the site surface geology is typically residual sand plains forming longitudinal dunes, with intertidal flats (calcareous clay, silt and sand) and supratidal flats (calcareous clay, silt and sand with authigenic gypsum and salt) identified in the far northeast of the Project area along the coastal fringes (GSWA 1980).

The site lies within the Carnarvon bioregion and the Cape Range subregion of the Eremaean Botanical province (360 Environmental 2018). As it is in an arid zone with a desert climate, there is no assured growth season. The landscape from north to south exhibits:

- Dry spinifex grassland (Triodia and Plectrachne) in the north where summer rainfall peaks,
- Deserts with intermittent rainfall, and;
- Low Acacia-Eucalyptus woodlands receiving evenly distributed rains.

Site vegetation consists of samphire and saltbrush low shrubs, Bowgada low woodland on sandy ridges and plains, Snakewood shrubs on clay flats and tree to shrub steppe over hummock grasslands between red sand dune fields (GHD 2018). Photographs of the surrounding landscape was taken during the ASS investigation (19 September 2018) and shown in Plate 1 and Plate 2.

Plate 1: Site Photograph of Surrounding Landscape – Low Shrub/Grassland

Plate 2: Site Photograph of Surrounding Landscape – Low Shrubland/Grassland with Isolated Eucalypts

No residential areas are located close to the Project area and the only major land cover modifications close to the site includes Learmonth Airport, Learmonth RAAF Base and Exmouth-Minilya Highway.

3.2 TOPOGRAPHY AND SURFACE DRAINAGE

The elevation of the Proposal area ranges from about 25 m Australian Height Datum (AHD) at the inland (southern) end to 0 m AHD at the coast and generally slopes from the south west end to the north east (GHD 2018). The majority of the Proposal area is characterised by a series of parallel network dunes and residual sand plains made up of red brown to yellow quartz sand. The dunes are approximately 5 m in height and are stabilised by light vegetation comprising grasses and small shrubs. The site appears to drain internally, with a coastal dune preventing discharge to the ocean (GHD 2018). Whilst limited data is available to determine water infiltration rates, some areas (mainly within the northern portion of the project envelope) have been classified as swamps according to Bureau of Meteorology methodology likely to have low infiltration rates (GHD 2018).

The floodplain has very few defined flow paths based on aerial imagery and available topographical data, making it difficult to determine exact surface water catchment boundaries. The catchment areas draining to the proposed infrastructure were mapped by GHD using CatchmentSim (Version 3.5) and shown in Figure 3 (GHD 2018). Three catchment areas are evident from Figure 3 with the following associated areas:

- Catchment A – 108.3 km^2.
- Catchment B – 36.9 km^2.
- Catchment C – 59.8 km^2.

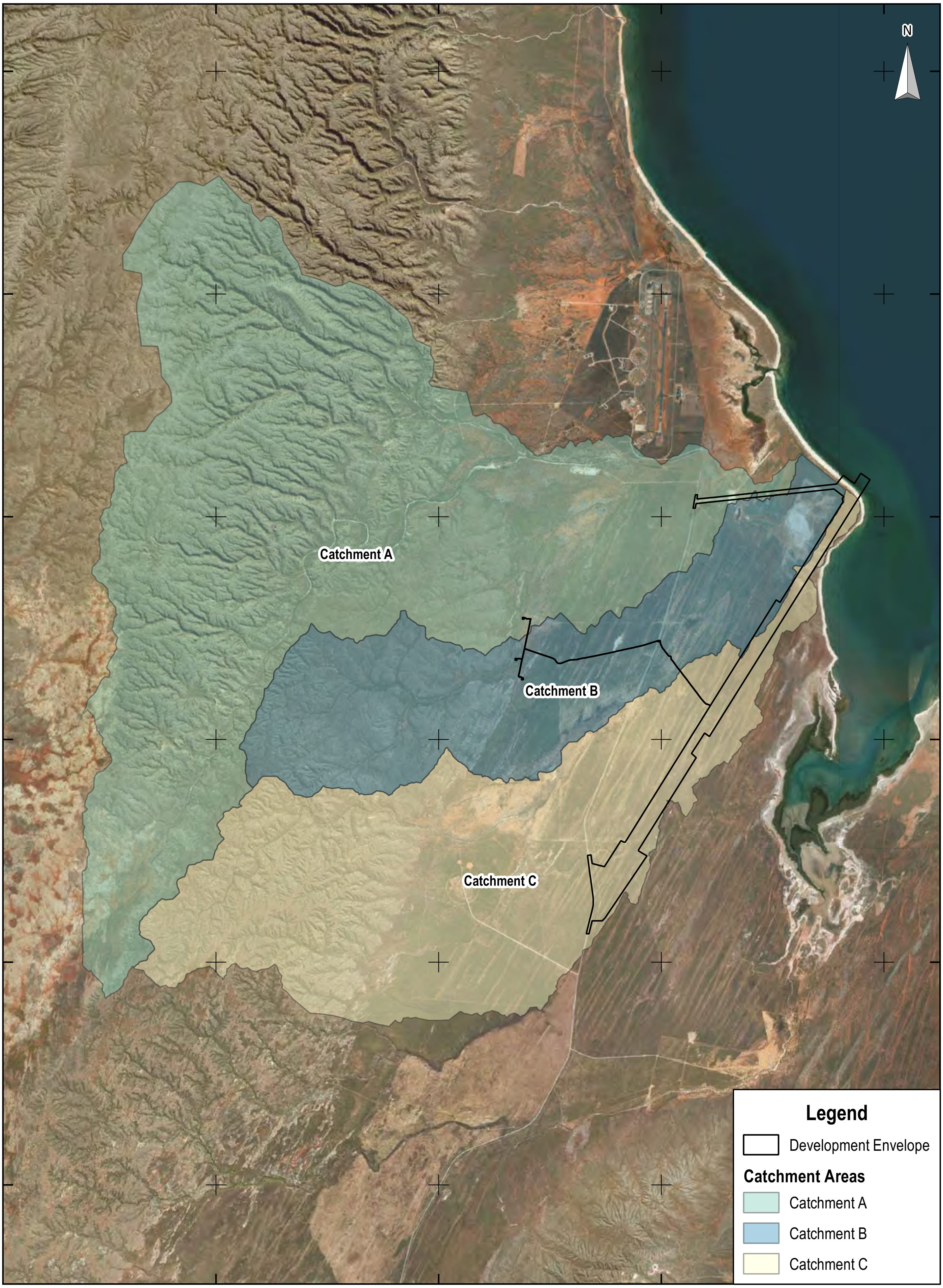
Catchment A drains to the access road, whereas Catchment B and C drain toward the access road, fabrication facility and the bundle track alignment. Whilst the catchments are large, the average rainfall in the area is low and therefore the waterways are ephemeral in nature with no baseline flow (GHD 2018). The area is also at high risk of flooding because of (Elliot *et al.* 2012):

- High intensity events, and/or

- When impacted by a series of rainfall events resulting in a high catchment antecedent moisture condition, and/or
- If bushfires have reduced vegetation cover, and/or
- If discharges are constrained at the catchment outlet by a coastal dune.

3.3 INDICATORS OF AASS OR PASS

The Project site has remained largely undisturbed (Section 1.2) with no indications of any AASS. The ASS investigation considered risk mapping (DWER 2016) for indications of any PASS material and targeted the sampling regime towards higher risk areas (See Section 1.5 and 5.1).



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Aerial Photo Date: ESRI Satellite

0 1 2 3 4 km

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Figure 3

Catchment Areas

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4. GEOLOGY AND HYDROGEOLOGY

4.1 GEOLOGICAL MAPPING

Surface geology was mapped at a scale of 1:100 000 and identified three surface geology profiles within the Heron Point area (GSWA 2008):

- Dunes 38496: Dunes, sandplain with dunes and swales; may include numerous interdune claypans; residual and Aeolian sand with minor silt and clay; Aeolian red quartz sand, clay and silt in places gypsiferous; yellow hummocky sand.
- Estuarine and delta deposits 38489: Coastal silt and evaporate deposits; estuarine, lagoonal, and lacustrine deposits.
- Colluvium 38491: Colluvium, sheetwash, talus: gravel piedmonts and aprons over and around bedrock; clay-silt-sand with sheet and nodular kankar; alluvial and Aeolian sand-silt-gravel in depressions and broad valleys in Canning Basin; local calcrete, reworked laterite.

4.2 SOIL STRATIGRAPHY

The Department of Agriculture and Food WA (DAFWA) Soil Subsystems mapping indicates that the Littoral System and the Cardabia System occur in the Heron Point area (DAFWA 2012):

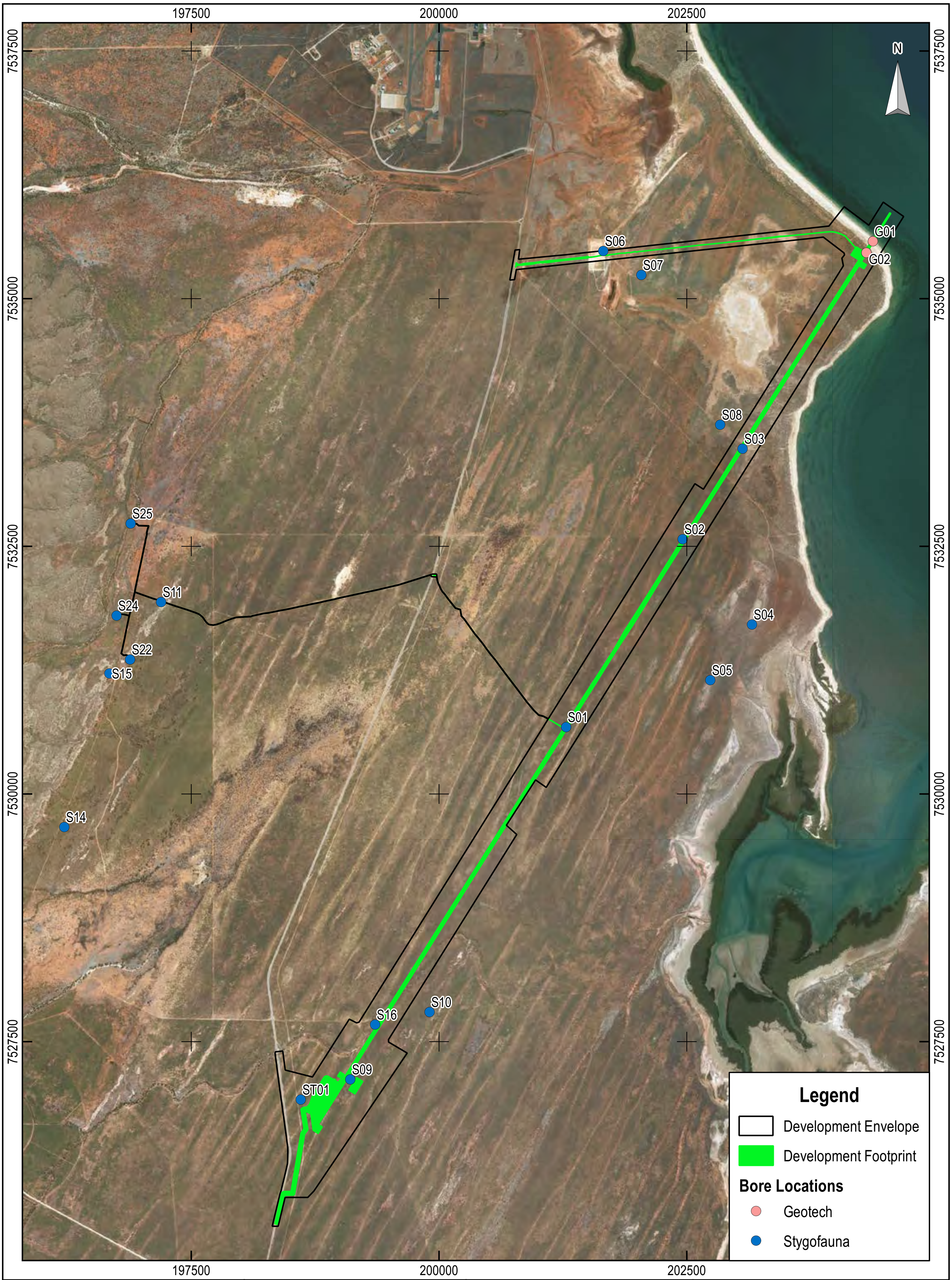
- Littoral System (204Li): Bare coastal mudflats (unvegetated), samphire flats, sandy islands, coastal dunes and beaches, supporting samphire low shrublands, sparse acacia shrublands and mangrove forests. The major soil type in this System is expected to be tidal soil (80%) and to a lesser extent salt lake soil (10%).
- Cardadia System (204Ca): Undulating sandy plains with linear dunes, minor limestone plains and low rises, supporting mainly soft spinifex hummock grasslands with scattered acacia shrublands and mangrove forests. The major soil type in this System is expected to be red deep sand (85%) and to a lesser extent red shallow sand (10%).

Review of the 'Yanrey-Ningaloo' (Learmonth) 1:250, 000 geological maps indicates the geology of the Site mainly comprises of longitudinal network dunes and residual sandplains comprised of red brown to yellow quartz sand (GHD 2017).

The Proposal area crosses areas of beach and coastal dunes closer to the coast that contain some quartzrose calcerenite bedrock and areas of supratidal flats containing mixes of mud and silt where regularly inundated and calcareous clay, silt and sand with some deposits of gypsum and salt where the inundation is more sporadic (GHD 2017).

Boreholes were installed and soil profiles logged as part of stygofauna and geotechnical investigations within the Project in August 2018 (GHD 2018). Their locations are shown in Figure 4. Soil profiles in boreholes in relatively close proximity to current sampling locations of the acid sulfate soils investigation (Section 5.1) exhibited the following characteristics:

- Sand from 0 to 1 metres below ground level (mBGL) – red, poorly sorted loamy and clayey sand.
- Predominantly indurated/cemented layers of sandstone and limestone underlying sand strata to termination depth of the borehole. Sandstone was described as weakly cemented with increasing red clay content at depth. Limestone cement was described as moderately cemented with sub-angular platy fragments.



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Air Photo: ESRI Satellite

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Figure 4

Bore Hole Locations

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4.3 HYDROGEOLOGY AND WATER QUALITY

4.3.1 Regional Hydrogeology

With reference to surface geology, it is inferred that minor sandstone and calcarenite underlie the surface sands, with a succession of limestone beneath. A regionally important aquifer exists between the sandstone and limestone units and is currently utilised for Exmouth Town water supply, Learmonth RAAF base water supply and various stock and domestic supply bores (GHD 2018).

Groundwater flow within the limestone aquifer is generally eastwards, from the Cape Range (groundwater recharge source) towards the Exmouth Gulf where it discharges. Local groundwater flow patterns are likely to be significantly affected by karstic features. The high permeability of the limestone aquifer allows for a large saline interface, known to extend up to 5 km inland (GHD 2018). It is noted that the saltwater wedge coincides with, and is controlled by, the presence of highly transmissive karstic features, leading to supply bores which are sensitive to over-pumping (GHD 2018).

4.3.2 Groundwater Levels and Quality

Boreholes constructed in August 2018 as part of the stygofauna investigation were surveyed and sampled in October 2018 by 360 Environmental.

The following was noted with respect to groundwater levels (GHD 2018):

- The greatest depth to groundwater was recorded in western bores, which were located west of Minilya-Exmouth Road (e.g. offsite). Levels recorded ranged from 22 to 32 mBGL with an elevation of approximately 1.6 m AHD (Australian Height Datum).
- Groundwater occurred closest to surface in bores located closest to the coast. Groundwater levels up to 1.5 mBGL were recorded for these bores with an elevation less than 0.5 mAHD.
- In the main fabrication area, groundwater was encountered at depths between 12 and 17 mBGL depending on location.

Sampling of groundwater was undertaken by 360 Environmental on selected bores to demonstrate baseline groundwater quality at the site. A summary of monitoring results are provided in tabular form in Appendix F and monitoring report provided in Appendix G of the GHD (2018) report. Groundwater quality results indicated the following:

- Two distinct groundwater signatures were found:
  - Hypersaline groundwater in bores located within the main project footprint.
  - Fresh to slightly brackish groundwater in western (i.e. offsite) bores, which represented the proposed groundwater supply area.
- Hypersaline groundwater found within the main project area had salinity concentrations (as total dissolved solids (TDS)) ranging from 46,900 to 73,700 mg/L. High salinity in the project area was attributed to the likely concentration of salts in areas of tidal flats.
- Fresh to slightly brackish groundwater found in western bores (offsite) had salinity concentrations ranging from 887 to 1,120 mg/L TDS. This signature was very similar to Exmouth Town Water Supply water.
- In general, the salinity concentration decreased with increasing distance from the coast inland (i.e. becomes fresher).
- Low concentrations of nutrients and biological components indicate that site wide groundwater is un-impacted by its current use for sheep grazing.

5. SAMPLING AND ANALYSIS PLAN AND SAMPLING METHODOLOGY

5.1 SAMPLE TEST PIT LOCATIONS

Seven sampling locations were selected within the project envelope and one location outside the project envelope (Figure 5). ASS risk mapping (DWER 2016), and the proposed layout of infrastructure, was used as a guide to determine the ASS investigation sites. The data obtained from the construction of the stygofauna monitoring bores also informed the location of the ASS investigation sites. Sample locations were chosen where the project envelope intersected areas of 'high ASS risk within 3 m of surface'. Acid sulfate soil risk mapping for the Pilbara Coastline (DWER-053) was used (DER 2016).

5.2 SAMPLING LOCATION AND DENSITY JUSTIFICATION

The number of sample locations was based on guidance provided in the Identification and Investigation of Acid Sulfate Soils and Acidic Landscapes (DER 2015a) document. The total area of disturbance was estimated to be less than 1 hectare (ha) within areas mapped as high ASS risk, which in the DER (2015a) guidance document required a minimum of four sampling locations. Seven sampling locations were selected within the project envelope and one location outside the project envelope, which satisfies the DER (2015a) sampling density requirement.

5.3 SAMPLING METHODOLOGY

Test pits were dug using a Hitachi 5 tonne excavator along previously cleared tracks (no additional disturbance). Soil was excavated in approximately 0.25 m increments and stockpiled alongside the test pit. Samples were collected either from the test pit walls or from stockpiles where entry to the test pit was unsafe. Manual hand augering was used in locations where there were access issues for the excavator.

5.3.1 Field Equipment

Field equipment used during the ASS investigation is provided in Table 2.

Table 2: ASS Soil Sampling Equipment

Equipment Type	List of Equipment
Data recording	Soil field data sheet.
	Laboratory Chain of Custody form.
	Permanent marker, biro pens.
	GPS.
	Camera.
	Measuring tape.
Sampling	Trowel.
	Hand auger.
Sampling containers	Plastic zip-lock bags
Storage and transport	Insulated container (esky) with frozen ice bricks.
Safety equipment	PPE (long sleeved clothing, steel capped safety boots, sunscreen, gloves, field hat, and safety glasses clear and smoked).
	First aid kit.
	Bottled water.

5.3.2 Field Methodology

Test pits were excavated, soil profiles logged and photographed, samples collected and submitted to a NATA accredited laboratory (MPL Envirolab) in accordance with DER (2015a) guidance.

The following sampling methodology was utilised:

- Dig test pits with excavator on cleared tracks within the project envelope using preselected sampling locations as guidance.
- Measure depth of excavation, log and take photographs of the soil profile and record details/photograph the surrounding landscape. Indicate a depth to groundwater (where applicable).
- Record GPS coordinates of final sampling locations.
- Collect samples from trench or spoil. Samples were collected every 0.25 m or where there was a change in strata. Where the excavator had access issues, samples were collected using a hand-auger. Shells were removed from collected samples to prevent overestimation of neutralising capacity as per DER 2015a.
- Samples were collected, photographed, made air-tight by excluding air in ziplock bags and immediately placed in esky with frozen ice bricks. Samples were frozen in a freezer overnight and submitted to the laboratory the following day accompanied by the completed Chain of Custody.

Figure 5: Sampling Locations

6. QUALITY ASSURANCE AND QUALITY CONTROL (QA/QC)

6.1 SAMPLE LOGS AND CHAIN OF CUSTODY FORMS

A total of 24 samples, including five duplicates, were collected and submitted for laboratory analysis. Field log sheets and Chain of Custody documentation are presented in Appendix 1.

6.2 LABORATORY PROGRAM

The laboratory program consisted of analysing for the following parameters as part of a standard 'Chromium Reducible Sulfur Suite' (CRS suite):

- Field pH (pH_F) and peroxide pH (pH_{FOX}).
- Chromium reducible sulfur (S_{CR}).
- Potassium chloride pH (pH_{KCl}).
- Titratable actual acidity (TAA).
- Net acid soluble sulfur (SNAS) if pH is less than 4.5 or Acid Neutralisation Capacity (ANC) if pH is greater than 6.5.

All samples were initially screened for pH_F and pH_{FOX}. A reduced (targeted) number of samples were then selected for the CRS suite based on the pH_F and pH_{FOX} results. This laboratory program is in line with the guidance document 'Identification and Investigation of Acid Sulfate Soils and Acidic Landscapes' (DER 2015a) and considered appropriate for the current study. Sample integrity was maintained by keeping the samples frozen during transit to the laboratory.

6.3 FIELD QUALITY ASSURANCE

Field duplicate sampling was undertaken every five samples to verify the reproducibility of sampling techniques in the field and analytical techniques in the laboratory. Field duplicate sampling comprised the collection of five duplicate samples. These were submitted to MPL Envirolab for the same analyses as the primary samples:

- DUP1 as a duplicate of sample ASS2 0.25 – 0.40 m.
- DUP2 as a duplicate of sample ASS4 0.25 – 0.50 m.
- DUP3 as a duplicate of sample ASS6 1.00 – 1.25 m.
- DUP4 as a duplicate of sample ASS8 0.80 – 1.10 m.
- DUP5 as a duplicate of sample ASS8 1.10 – 1.30 m.

The Relative Difference Percentage (RPD) was calculated for each primary and duplicate sample laboratory results to verify reproducibility of the sampling technique and presented in Table 3. The original laboratory report is presented in Appendix 2. All field RPD values were within the general criteria of 30% (NEPC 2013) for suitable replicate analysis and hence also the general criteria for field soil replicates of 50% RPD (AS 4482.1-2005).

Table 3: Calculated RPDs for Field Duplicate Samples

Sample ID	pH_F	pH_{FOX}	pH_{KCl}	TAA (% w/w S)	S_{CR} (% w/w)	ANC (moles H^+/t)	Net Acidity (% w/w S)
ASS2 0.25-0.40m	8.6	6.7	N/A	N/A	N/A	N/A	N/A
DUP1	8.6	6.7	N/A	N/A	N/A	N/A	N/A
RPD (%)	<1	<1	-	-	-	-	-
ASS4 0.25-0.50m	8.6	6.9	N/A	N/A	N/A	N/A	N/A
DUP2	8.9	6.9	N/A	N/A	N/A	N/A	N/A
RPD (%)	3.4	<1	-	-	-	-	-
ASS6 1.00-1.25m	8.7	6.6	9.7	<0.01	<0.005	1,600	<0.005
DUP3	8.8	6.6	9.6	<0.01	<0.005	1,300	<0.005
RPD (%)	1.1	<1	1.0	<1	<1	20.7	<1
ASS8 0.80-1.10m	8.2	6.4	N/A	N/A	N/A	N/A	N/A
DUP4	8.2	6.6	N/A	N/A	N/A	N/A	N/A
RPD (%)	<1	3.1	-	-	-	-	-
ASS8 1.10-1.30m	8.5	6.6	N/A	N/A	N/A	N/A	N/A
DUP5	8.3	6.6	N/A	N/A	N/A	N/A	N/A
RPD (%)	2.4	<1	-	-	-	-	-

N/A = Not Analysed

6.4 LABORATORY QUALITY ASSURANCE

Laboratory duplicates were analysed to verify the reproducibility of the analytical technique within the laboratory on prepared samples. Laboratory duplicates were analysed at a rate of 1 in every 10 samples or part thereof (Appendix 2) for a total of three duplicates based on the total number of samples submitted (24 samples). Calculated RPDs from this data is presented in Table 4. The laboratory acceptance criteria for duplicate laboratory samples is within 50% for results greater than 10 times the laboratory limit of reporting (LOR) and higher for results less than the laboratory LOR (AS 4482.1-2005 and MPL 2018 criteria – Appendix 2). All results were within these acceptance criteria.

Table 4: Calculated RPDs for Laboratory Duplicate Samples

Sample ID	pH_F	pH_{FOX}
ASS1 0-0.25m	8.3	6.7
ASS1 0-0.25m (laboratory dup)	8.5	6.9
RPD (%)	2.4	2.9
ASS6 1.00-1.25m	8.8	6.6
ASS6 1.00-1.25m (laboratory dup)	8.7	6.6
RPD (%)	1.1	<1
DUP2	8.9	6.9
DUP2 (laboratory dup)	8.8	7.0
RPD (%)	1.1	1.4

6.5 QA/QC DATA EVALUATION

All tabulated results for field duplicate RPDs (Section 6.3 – Table 3) and laboratory duplicate RPDs (Section 0 – Table 4) fall within the acceptance criteria of the laboratory (MPL Envirolab) and more stringent generic criteria of the NEPC (30% RPD). Based on this, it is considered that the reported results are of an acceptable quality upon which to draw reliable conclusions regarding presence of ASS in the samples collected.

7. ACID SULFATE SOIL ASSESSMENT CRITERIA

7.1 ACID SULFATE SOIL METHODOLOGY

The following is a brief introduction to laboratory methods and terminology ASS. The reader should refer to the glossary of technical terms (Section 12), Australian Standard AS4969-2008 and ISO Standard 14388-1:2014 for further information.

The aim of quantitative laboratory testing for ASS is to estimate the net potential for acid formation if the soil is disturbed and allowed to oxidise by exposure to atmospheric oxygen. ASS methods are a form of acid base accounting as used in acid metalliferous drainage (AMD) procedures for waste rock, but are tailored specifically for soils where the concentrations of sulfides are normally lower, significant levels of organics are often present and other forms of acidity (collectively called retained acidity) are more common.

Pyrite forms naturally under reduced oxygen (anaerobic) conditions in soils and sediment from biological reduction of sulfate to sulfide by sulfate reducing bacteria (SRB). Anaerobic conditions for the generation of pyrite occur in areas of waterlogging and organic rich soils and sediments such as swamps and wetlands. When exposed by physical disturbance or a lowering of the water table, the pyrite reacts with oxygen and water to produce acidity (H^+) according to the chemical equation:

$$4FeS_2 + 15O_2 + 14H_2O \rightarrow 4Fe(OH)_3 + 16H^+ + 8SO_4^{2-}$$

Oxidation of one mole of pyrite will produce two moles of sulfuric acid or alternatively, 30.6 kg of sulfuric acid will be produced by oxidation of one tonne of ASS containing 1% by weight of sulfur. This potential acidity will be in addition to any existing acidity already in the sample but can also be counter acted by any acid neutralising capacity (ANC) present or added to the soil. In acid base accounting terms for ASS the net potential for acid production (net acidity) is defined as:

Net Acidity = Existing Acidity + Potential Acidity – Acid Neutralising Capacity (ANC)

These parameters are normally expressed in units of %S w/w, kg H_2SO_4/t (Australian Standards) or moles H^+/t (ISO Standard 14388-1:2014). For consistency, this report will use %S; to express as moles H^+/t, multiply %S by 623.7.

7.1.1 Existing Acidity

Existing acidity is the sum of actual acidity (measured as titratable actual acidity (TAA)) and what in ASS terminology is called retained acidity. Actual acidity (TAA) is a direct measure of acidity by titration which includes previously released sulfuric acid from oxidation, acid released by hydrolysis of Fe(III) and Al(III) ions and organic acidity (primarily organic fulvic and humic acids). Retained acidity is released more slowly and is caused by hydrolysis of sulfate minerals such as jarosite ($KFe_3(OH)_6(SO_4)_2$) and alunite ($KAl_3(OH)_6(SO_4)_2$) as indicated by the following equation for alunite:

$$KAl_3(OH)_6(SO_4)_2 + 3H_2O \rightarrow 3Al(OH)_3 + K^+ + 3H^+ + 2SO_4^{2-}$$

Jarosite and alunite are themselves commonly formed as oxidation products of ASS – i.e. previous oxidation. Retained acidity (as sulfur), can only be measured after extraction in dilute hydrochloric acid to fully dissolve these poorly soluble minerals and is done if the pH_{KCl} is less than 4.5. Organic acidity (measured as part of TAA), although not strictly part of a sulfur acid base accounting system, normally occurs in combination with sulfide based potential acidity and is important as soil disturbance can significantly increase the levels of organic acidity causing widespread lowering of pH levels and subsequent dissolution of environmentally significant metals such as aluminium and arsenic. Disturbance related organic acidity should be managed in the same way as ASS material.

7.1.2 Potential Acidity

The two approaches to measurement of potential acidity are different laboratory simulations of the amount of sulfur which is present in the form of sulfide minerals that could oxidise to form sulfuric acid. The first is the Suspension Peroxide Oxidation Combined Acidity and Sulfate (SPOCAS) suite and in particular determination of peroxide oxidisable sulfur (S_{POS}) as a measure of potential acidity. The other is the chromium reducible sulfur (CRS) suite which involves determination of chromium reducible sulfur (denoted as S_{CR}) as the measure of potential acidity from sulfide oxidation. The CRS method was used in this study and is described below.

The CRS procedure has less parameters than the SPOCAS suite and relies on the direct measurement of sulfides using the chromium reducible sulfur (S_{CR}) method. Terms measured or calculated as part of the CRS suite include:

- Chromium reducible sulfur (S_{CR}).
- Titratable actual acidity (TAA).
- Measurement of ANC (direct titration with acid to pH 4.5).

The CRS suite is simpler but tends to underestimate potential acidity – but is preferred for high organic material samples as it is not affected by organic forms of sulfur.

7.1.3 Adopted ASS Classification Criteria

Classification of ASS potential is based on net acidity result calculated from either the SPOCAS or CRS suite and the texture/clay content of the soil. Note that the existing ANC of the soil is normally measured as part of the ASS investigation but is considered unreliable in predicting field results i.e. actual net acidity. Thus the action criteria for Western Australia are based on net acidity ignoring ANC where:

Net Acidity = Existing Acidity + Potential Acidity

For this project, the texture based action criteria for 'sands to loamy sands (<5% clay)' of 0.03 %S w/w net acidity (DER 2015a) was adopted in combination with the measured pH_{KCl} based on a review of all laboratory and field results to indicate actual acid sulfate soils (AASS) where present. A combined ASS classification scheme based on net acidity and pH_{OX} determinations is presented in Table 5.

Table 5: Adopted ASS Classification Criteria

Acid Sulfate Soil Classification	Net Acidity (%S)	pH_{KCl}	pH_{FOX}
Non Acid Sulfate Soil (NASS)	<0.03	>4.5	>3
Potentially Acid Sulfate Soil (PASS)	≥0.03	>4.5	<3
Actual Acid Sulfate Soil (AASS)	≥0.03	<4.5	<3

Net acidity (%S) for classification was calculated from the CRS suite.

8. RESULTS AND DISCUSSION

8.1 FIELD OBSERVATIONS

No locations within the proposed disturbance area indicated field visual signs of AASS or PASS. Location ASS8 indicated minor mottling at two depths, however ASS8 is outside the disturbance footprint.

8.2 SCREENING ASSESSMENT RESULTS

All samples recorded circum-neutral to alkaline pH_F and pH_{FOX} values and indicated that no samples were AASS (pH_{KCl} < 4 or 4.5) or PASS (pH_{FOX} < 4 or in particular < 3).

8.3 LABORATORY RESULTS

Laboratory results are for soil samples are collated in Table 6 and raw laboratory reports provided in Appendix 2. Soil profile descriptions for each of the sampling locations inspected is presented with photographs in Appendix 3.

The following is noted for soil and landscape characteristics within the project envelope:

- Frequent outcropping of limestone or other siliceous rock (e.g. sandstone).
- Surface soils range from light brown fine sand to silty and loamy sands. Shells were frequently observed within topsoils.
- Subsoils were generally light to medium brown loams (brown/red in deeper soils). Sample location ASS8 (outside the project envelope) was an exception to other sampling locations in that the subsoil type was predominantly clay, grading from grey/blue (with yellow and orange mottling) to cream coloured clay near and below groundwater. No limestone/sandstone indurated layer was encountered at this location (ASS8) and was the only location where groundwater was observed.
- Depth of excavation was limited by refusal from cemented/indurated layers (calcrete/silcrete hardpan layers). Only two locations achieved excavated depths of greater than 1m (e.g. ASS6 and ASS8). These locations were further away from limestone outcrops/hills compared to other sampling locations.

Results from laboratory analysis (CRS suite) of soils indicated the following (Table 6):

- Field pH (pH_F) values were alkaline ranging from 8.2 to 9.0, which indicated that no soils were AASS. This is also confirmed by the potassium chloride pH (pH_{KCl}) values which were slightly higher (more alkaline) and ranged from 9.1 to 9.9.
- Peroxide pH (pH_{FOX}) measured after reaction with a strong oxidising agent was circum-neutral to alkaline and ranged from 6.4 to 9.0. Additionally all S_{CR} results were less than the laboratory limit of reporting of 0.005% w/w and indicate the absence of any sulfides capable of producing acid conditions. All results thus indicate the absence of AASS/PASS and all soils were NASS.
- The measured ANC was high and variable, ranging from 0.67 to 11% w/w indicating capacity to neutralise acidity. It should be noted that some bias could have been introduced by the presence of shells which were not completely removed during sampling.
- Net acidity calculated from the sum of the total existing and potential acidity was less than 0.005% w/w and well below DER (2015a) criteria.

8.4 ASS CLASSIFICATION RESULTS

All soils were classified NASS based on results presented in Section 8.2 and Table 6.

Table 6: Laboratory Test Results

Sample	Location	Depth (mBGL)		Soil Description	Depth to Water	pHF	pHFOX	Delta pH	Reaction Rate	pH KCl	SKCl	SCR	SHCl	TAA	ANCBT	Fineness Factor	SNAS	Net Acidity	Net Acidity without ANCE
		From	To		mBGL	pH Units	pH Units	pH Units	-	pH units	%S	%S	%S	%S	%S		%S	%S	%S
Assessment Criteria (DER 2015a)					-	4	3 or 4	1				0.03		0.03				0.03	
ASS1: 201756.53 mE / 7535449.31 mN																			
ASS1 0-0.25m	ASS1	0	0.25	Light brown silty sand		8.3	6.7	1.6	Medium										
ASS2: 201823.20 mE / 7535458.78 mN																			
ASS2 0-0.25m	ASS2	0	0.25	Light brown loamy sand; quite moist		8.6	6.8	1.8	Medium										
ASS2 0.25-0.4m	ASS2	0.25	0.40	Light brown/grey clay loam with medium brown mottling		8.6	6.7	1.9	Low	9.6	NT	<0.005	NT	<0.01	5.7	1.5	NT	<0.005	<0.005
ASS4: 203328.11 mE / 7535616.86 mN																			
ASS4 0-0.25m	ASS4	0	0.25	Light brown loamy sand		8.6	6.8	1.8	Low										
ASS4 0.25-0.5m	ASS4	0.25	0.50	Medium brown/red loamy sand		8.6	6.9	1.7	Low	9.7	NT	<0.005	NT	<0.01	2.9	1.5	NT	<0.005	<0.005
ASS5: 203542.51 mE / 7535631.69 mN																			
ASS5 0-0.25m	ASS5	0	0.25	Light brown silty sand		8.7	7.0	1.7	Medium										
ASS6: 203064.28 mE / 7533499.07 mN																			
ASS6 0-0.25m	ASS6	0	0.25	Light brown to medium brown sandy loam; fine light brown sand at surface		8.8	6.8	2.0	Medium										
ASS6 0.25-0.5m	ASS6	0.25	0.50	Uniform profile - medium brown silty/sandy loam; increasing moisture content with depth; sand becomes coarser at depth		8.6	6.8	1.8	Low										
ASS6 0.5-0.75m	ASS6	0.50	0.75			8.8	6.7	2.1	Low	9.9	NT	<0.005	NT	<0.01	3.1	1.5	NT	<0.005	<0.005
ASS6 0.75-1.00m	ASS6	0.75	1.00			9.0	6.6	2.4	Low	9.7	NT	<0.005	NT	<0.01	0.92	1.5	NT	<0.005	<0.005
ASS6 1.00-1.25m	ASS6	1.00	1.25			8.8	6.6	2.2	Low	9.6	NT	<0.005	NT	<0.01	2.6	1.5	NT	<0.005	<0.005
ASS7: 203434.02 mE / 7535635.28 mN																			
ASS7 0-0.3m	ASS7	0	0.30	Light brown loamy sand		8.7	6.9	1.8	Medium										
ASS7 0.3-0.5m	ASS7	0.30	0.50	Medium brown/red loamy sand		8.7	9.0	-0.3	Medium										
ASS8: 201685.51 mE / 7535543.15 mN																			
ASS8 0-0.15m	ASS8	0	0.15	Medium brown loamy sand; quite moist		8.2	6.6	1.6	Medium										
ASS8 0.15-0.8m	ASS8	0.15	0.80	Grey/blue moist clay loam with yellow/orange mottling		8.3	6.7	1.6	Medium	9.4	NT	<0.005	NT	<0.01	2.7	1.5	NT	<0.005	<0.005
ASS8 0.8-1.1m	ASS8	0.80	1.10	Grey/blue/yellow clay		8.2	6.4	1.8	Low	9.1	NT	<0.005	NT	<0.01	0.67	1.5	NT	<0.005	<0.005
ASS8 1.1-1.3m	ASS8	1.10	1.30	Light grey/brown clay		8.5	6.6	1.9	Low	9.5	NT	<0.005	NT	<0.01	11	1.5	NT	<0.005	<0.005
ASS8 1.3-1.8m	ASS8	1.30	1.80	Light brown/cream clays - saturated zone; blue/grey mottling mixed through	1.8	8.2	6.6	1.6	Low										

9. RISK ASSESSMENT

Based on the findings of field observations and laboratory test work there is no indicated risk of acid sulfate soils presence or disturbance within the excavated/investigated depths of the project envelope. All soil samples recorded less than reportable values for net acidity and were subsequently classified NASS. Although the investigation could not characterise soils to 1 mBGL and below for many sampling locations due to refusal, soil profile logs (Section 4.2, GHD 2018) indicate that the cemented layers of calcareous sandstone and limestone at these depths continue well below this (greater than 12 mBGL for boreholes located in close proximity to sampling locations). As such these deeper calcareous sandstone/limestone profiles are by their nature and definition have no acid sulfate potential. The minimal shallow disturbance across the project envelope for footings and levelling of expected depth less than one metre (where such depth of soil actually exists), have no considered potential to cause acid generation and risk to the environment.

10. CONCLUSIONS AND RECOMMENDATIONS

Assessment of 24 soil samples as part of an ASS investigation indicated the following:

- Soils within the project envelope were characterised as light brown silty sands grading to darker medium brown loamy sands. Soil profiles comprised shallow colluvium over siliceous hardpan (limestone or sandstone).
- Results from laboratory analysis indicated no detectable concentrations of chromium reducible sulfur (S_{CR} < 0.005% w/w) or net acidity (<0.005% w/w) for any samples analysed.
- All soil samples were classified NASS.

Based on the findings of this investigation there is no identified risk of disturbing any acid sulfate soils during proposed site works. This investigation has assumed that the area of excavation within high ASS risk area (DWER mapping) will not exceed 1 ha and that excavations will not exceed a depth of 1 m. A limitation to the sampling program was shallow refusal to excavations due at presence of calcareous hardpan/limestone. Hence depths deeper strata to 1 m (and below) could not be characterised for most sampling locations. However, stygofauna borehole logs indicated limestone rich cemented layers continue from these refusal depths to well below the proposed excavation depths and present (due to highly alkaline nature of the material), no considered risk of acid formation/acid sulfate soils.

No limitations due to potential for disturbance of ASS materials are hence indicated for the project as proposed.

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12. GLOSSARY OF TECHNICAL TERMS

Term	Explanation
Action criteria	The critical net acidity values (expressed as % pyrite sulfur or the equivalent moles H+/t) for different soil texture groups and sizes of soil disturbance that trigger the need for ASS management.
alunite	A hydrated aluminium potassium sulfate mineral, formula $KAl_3(SO_4)_2(OH)_6$. It is an analogue of jarosite where aluminium has replaced iron and can hydrate to aluminium hydroxide and release soluble free acidity. It is thus a source of stored or 'retained' acidity.
Actual acidity	The soluble and exchangeable acidity already present in the soil, often as a result of previous oxidation of sulfides. It is measured in the laboratory using the TAA method but does not include the less soluble acidity (i.e. residual acidity) held in minerals such as alunite and jarosite.
ANC	Acid Neutralising Capacity. A measure of a soil's inherent ability to buffer acidity and resist the lowering of the soil pH.
Anoxic	Depleted of dissolved oxygen.
ASS	Acid Sulfate Soils.
CRS	Chromium Reducible Sulfur. A measurement of reactive sulfide sulfur normally applied to acid sulfate soils using reaction with metallic chromium and hydrochloric acid to liberate hydrogen sulfide gas which is trapped and then measured by iodometric titration. The approach of calculating net acidity using the chromium reducible sulfur method to determine potential sulfidic acidity. It is combined with a decision process based on pH_{KCl} to determine the other components of the acid-base accounting (TAA, ANC).
circum-neutral pH	pH value near 7.
EC	Electrical conductivity. A measurement of solution salinity. Conversion: 1,000 µS/cm = 1 dS/m = 1 mS/cm
Existing acidity	The acidity already present in acid sulfate soils, usually as a result of oxidation of sulfides, but which can also be from organic material or hydrolytic acid releasing ions (Fe and Al). Existing acidity is the sum of actual acidity and retained acidity.
Fineness factor	A factor applied to the amount of ANC material required to neutralise the acid potential due to the poor reactivity of coarser carbonate or other acid neutralising material. The minimum factor is 1.5 for finely divided pure agricultural lime (calcium carbonate), but may be as high as 3.0 for coarser shell material.
Jarosite	A hydrated iron potassium sulfate mineral, formula $KFe_3(SO_4)_2(OH)_6$. It can hydrate to iron (III) hydroxide and release soluble free acidity. It is thus a source of stored or 'retained' acidity. Jarosite is often distinguished by its yellow colouration among dark sediments exposed to oxygen. A sodium form is known as natrojarosite.
laterite	Highly weathered soils/subsoils developed by extensive leaching of iron and aluminium rich parent rocks in tropical climates to leave soils rich in iron and aluminium oxides/hydroxides.
Net acidity	Result obtained after accounting for all forms of soil acidity and neutralising capacity. Net acidity = Potential acidity + Existing acidity – (ANC/Fineness Factor)
pH_F	pH field of a 1:2 soil:water paste
pH_{FOX}	pH field after addition of a few drops of strong oxidant (hydrogen peroxide).
pH_{KCl}	pH in a 1M potassium chloride solution (laboratory measured).
pH_{OX}	pH in a peroxide oxidised suspension as per the SPOCAS method (laboratory measured).
Potential acidity	The latent acidity in ASS that can be generated if the sulfide minerals present are fully oxidised to generate sulfuric acid. It is estimated by measurement of S_{POS} (SPOCAS Suite)

Term	Explanation
	or SCR (Chromium Suite).
pyrite	Iron (II) sulfide, FeS_2. Pyrite is the most common sulphide minerals and the major acid forming mineral oxidising to produce sulfuric acid
Retained acidity	The less available fraction of existing acidity which is not measured by TAA and is due to hydrolysis of relatively insoluble minerals such alunite and jarosite.
S_{CR}	The symbol often given to the result from the chromium reducible sulfur method i.e. CRS.
SPOCAS	An acronym for suspension peroxide combined acidity and sulfur method a combination of decision tree approach and analytical methods to allow estimation of net acidity.
TAA	Titratable actual acidity. Used in both the SCR and SPOCAS suites it determines the present soil acidity by titration with sodium hydroxide after extraction in potassium chloride.
TPA	Titratable peroxide acidity. The acidity by titration following peroxide digestion in the SPOCAS method.

APPENDICES

APPENDIX 1: CHAIN OF CUSTODY FORM AND FIELD LOGS

PA ASS1 & PA ASS2.

ASS Field Sampling Log

Project: Subsea7 Pipe Bundle Project - ASS Investigation	Date: 19 September 2018
	Project Code: SUB7ST
Sampled by: G. du Plessis	1tsp. soil paste with DI water (pHf) or pH adjusted 30%H2O2 left 20 min (pHfox)

Sample ID	Site Name	Description (incl. colour & texture)	Depth (m)	pH_F	pH_{FOX}	Reaction*	Comments
ASS1 0.25m		Light brown silty sand surface					ASS1 0-0.25m.
		Refusal at 0.25m.					
	Cemented	Indurated layer of limestone.					
		Ferruginous boulders/rocks within.					
							ASS2 0-0.25m.
ASS2 0.25		light brown loamy sand					"Peanut rock"
		Moderate moisture					
		Seashells observed.					
0.25-0.4m.							ASS2 0.25-0.40m (DUP1)
		Grades to clay loam (light brown/grey with brown mottling)					
	rounded siliceous pebbles.	- No seashells					
		- Increased moisture					
		- more 'plastic' indicative of clay content					
		- Refusal at 0.4m limestone cement.					

* Reaction: L = slight effervescence; M = moderate; H = vigorous; X = volcanic/very vigorous

0744
-22.26
114.10537
HD 4m
"A103"

waypt: "A102"
Lat 22.260815°
Long 114.106189°

General Obs
- Low lying area
- Dense small shrubland
- Seashells observed at surface.
- Limestone outcrop on road.

* Elevation 5m.

ASS 4 WP A105 AHD 4m
Lat: 22.259594
Long: 114.121454

Pit ASS 3 No pit - Refusal at 0.15m. WP. A104 Lat: 22.259716
Long: 114.119754
AHD = 3m

ASS Field Sampling Log

Project: Subsea7 Pipe Bundle Project - ASS Investigation	Date: 19 September 2018
	Project Code: SUB7ST
Sampled by: G. du Plessis	1tsp. soil paste with DI water (pHf) or pH adjusted 30%H2O2 left 20 min (pHfox)

Sample ID	Site Name	Description (incl. colour & texture)	Depth (m)	pH_F	pH_{FOX}	Reaction*	Comments
ASS 4	0-0.25m.	Light brown loamy sand					ASS ~~3~~ 4 0-0.25m.
	0.25m - 0.6m	~~Dark~~ Med. brown/red loamy sand.					ASS 4 0.25-0.5m ("DUP2")
		Refusal at 0.6m. Indurated/cemented limestone.					~~ASS 4 0.5-0.6m.~~
ASS 7	0-0.3m	light brown loamy sand					Pit ASS 7 - WP A106 Lat 22.257426 Long 114.122487 AHP 4m. NEW
	0.3-0.5	Med. brown/red loamy sand.					ASS 7 0-0.3m
		Refusal at 0.5m. Indurated/cemented limestone or rock.					ASS 7 0.3-0.5m.

* Reaction: L = slight effervescence; M = moderate; H = vigorous; X = volcanic/very vigorous

General Obs.

- Low lying flat area.
- Surrounded by dunes/hills
- Dense small shrubs
- Medium trees immediately adjacent to dunes.

Pit ASS 2

I.F.? Seen in

- "Peanut" rock mined at quarries
- Sometimes up to 8m thick.

Ass 5 WP A107 Lat 22.259477 Long 114.123535 AHD 3m.

ASS Field Sampling Log

MBS Environmental	Project: Subsea7 Pipe Bundle Project - ASS Investigation	Date: 19 September 2018
		Project Code: SUB7ST
	Sampled by: G. du Plessis	1tsp. soil paste with DI water (pHf) or pH adjusted 30%H2O2 left 20 min (pHfox)

Sample ID	Site Name	Description (incl. colour & texture)	Depth (m)	pH_F	pH_{FOX}	Reaction*	Comments
	0-0.3	Light brown ~~Silty~~ silty sand					ASS 5 0-0.25m.
		Refusal at 0.3m.					
		Purple/white chips coming from indurated layer.					

* Reaction: L = slight effervescence; M = moderate; H = vigorous; X = volcanic/very vigorous

General Obs

- Area more vegetated with yellow grassland
- Low lying area.

ASS 6   WP A108   Lat: 22.278637   Long: 114.118804   4WD 4m.

ASS Field Sampling Log

Project: Subsea7 Pipe Bundle Project - ASS Investigation	Date: 19 September 2018
	Project Code: SUB7ST
Sampled by: G. du Plessis	1tsp. soil paste with DI water (pHf) or pH adjusted 30%H2O2 left 20 min (pHfox)

Sample ID	Site Name	Description (incl. colour & texture)	Depth (m)	pH_F	pH_{FOX}	Reaction*	Comments
	0-0.25m	Light brown to med.					ASS 6 0-0.25
		brown sandy loam					0.25-0.5
		fine sand at surface					~~0.75~~-0.5 0.75
							0.75-1.00
	0.25-1.25	Uniform profile.					1.00-1.25
		Med. brown silty					
		Sand/loam					
		Moisture content					Dup 3 = ASS 6 1.00-1.25
		increasing with					
		depth.					
		Sand becomes					
		coarser with depth.					

* Reaction: L = slight effervescence; M = moderate; H = vigorous; X = volcanic/very vigorous

pH ASS8 : NP A19 Lat : 22.259955 Long : 114.105517 AHD 4m.

ASS Field Sampling Log

Project: Subsea7 Pipe Bundle Project - ASS Investigation	Date: 19 September 2018
	Project Code: SUB7ST
Sampled by: G. du Plessis	1tsp. soil paste with DI water (pHf) or pH adjusted 30%H2O2 left 20 min (pHfox)

Sample ID	Site Name	Description (incl. colour & texture)	Depth (m)	pH_F	pH_{FOX}	Reaction*	Comments
	0-0.15	quite moist med. brown loamy sand					
	~~0-0.25~~	~~Quite moist loamy~~					
	0.15-0.8	Grey/blue moist clay loam					Yellow/Orange mottling
	0.8-1.1	Grey/blue/Yellow clay					Jarosite suspicion.
	1.1-1.3	~~Cream~~ Light grey/brown clay					
	1.3-1.8	Wet cream clays.					Blue/grey clay mottles
	1.8 +	Refusal + water. Friable rock.					
						samples	ASS 8 0-0.15
							ASS8 0.15-0.8
							ASS8 0.8-1.1
							ASS8 1.1-1.3
							ASS8 1.3-1.8
							DUP 4 = ASS8 0.8-1.1
							DUP 5 = ASS8 1.1-1.3

* Reaction: L = slight effervescence; M = moderate; H = vigorous; X = volcanic/very vigorous

WWTF 1 AI 10 ~~Lat~~ Lat : 22.335951 Long : 114.079128 AHD 17m

ASS Field Sampling Log

MBS Environmental – environmental and water resource consultants

Project: Subsea7 Pipe Bundle Project - ASS Investigation	Date: 19 September 2018
	Project Code: SUB7ST
Sampled by: G. du Plessis	1tsp. soil paste with DI water (pHf) or pH adjusted 30%H2O2 left 20 min (pHfox)

Sample ID	Site Name	Description (incl. colour & texture)	Depth (m)	pH_F	pH_{FOX}	Reaction*	Comments
	Surface Sample (0-200)	Light brown Silty Sand					
		Friable aggregates					
		Vegetation mainly spinifex with scattered mulga. Trees isolated.					
		Termite ~~mo~~ mounds ~~exist~~ observed.					

* Reaction: L = slight effervescence; M = moderate; H = vigorous; X = volcanic/very vigorous

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Chain of Custody Documentation

MBS Environmental
4 Cook Street, West Perth, WA 6005

Project: Subsea7 Pipe Bundle (page 1 of 4)
Project Code: SUB7ST

Send Report to: gduplessis & mnorth@mbsenvironmental.com.au
Send Invoice to: dsims@mbsenvironmental.com.au
Turnaround Time: Standard

Lab ID	Sample ID	Matrix	Date	Container Type	Container Preservative	pH_F + pH_{FOX}	CRS Suite	TP + PSI	Comments
1	ASS1 0-0.25m	SOIL	19/9/18			✓			See attached analysis requirements (page 4)
2	ASS2 0-0.25m					✓			
3	ASS2 0.25-0.4m					✓			
4	ASS4 0-0.25m					✓			Hold samples
5	ASS4 0.25-0.5m					✓			for analysis of
6	ASS5 0-0.25m					✓			CRS Suite on
7	ASS6 0-0.25m					✓			selected once
8	ASS6 0.25-0.5m					✓			results issued
9	ASS6 0.5-0.75m					✓			for pHF/pHFOX
10	ASS6 0.75-1.00m					✓			
11	ASS6 1.00-1.25m					✓			
12	ASS7 0-0.3m					✓			
13	ASS7 0.3-0.5m					✓			
14	ASS8 0-0.15m					✓			
15	ASS8 0.15-0.8m					✓			
16	ASS8 0.8-1.1m					✓			
17	ASS8 1.1-1.3m					✓			
18	ASS8 1.3-1.8m					✓			
19	WWTF1							✓	
20	DUP1					✓			
21	DUP2					✓			
22	DUP3					✓			

Relinquished By:	G. du Plessis	Received By:	SB	Lab Use
Date:	20-Sep-18	Date:	20/9	Cooler Seal:
Time:		Time:	1500	Cooler Temperature:

empl Laboratories
ENVIROLAB GROUP
Job No.- 216274
Date Rec- 20/9
Time Rec- 1500
Rec By- SB
TAT Req - SAME 1/2/3/STD
Temp - cool/ambient
Cooling - Ice / Ice pack / None
Security Seal - Yes / No

Chain of Custody Documentation

MBS Environmental
4 Cook Street, West Perth, WA 6005

Project: Subsea7 Pipe Bundle (page 2 of 4)
Project Code: SUB7ST

Send Report to: gduplessis & mnorth@mbsenvironmental.com.au
Send Invoice to: dsims@mbsenvironmental.com.au
Turnaround Time: Standard

Lab ID	Sample ID	Matrix	Date	Container Type	Container Preservative	$pH_F + pH_{FOX}$	CRS Suite	TP + PSI								Comments
23	DUP 4	SOIL	19/9/18			✓										See attached analysis requirements (page 4)
4	DUP5	SOIL	19/9/18			✓										

Relinquished By: G. du Plessis
Date: 20-Sep-18
Time:

Received By:
Date:
Time:

Lab Use
Cooler Seal:
Cooler Temperature:

APPENDIX 2: LABORATORY ANALYSIS REPORTS

Envirolab Services (WA) Pty Ltd trading as MPL Laboratories
ABN 53 140 099 207
16-18 Hayden Court Myaree WA 6154
ph 08 9317 2505 fax 08 9317 4163
lab@mpl.com.au
www.mpl.com.au

CERTIFICATE OF ANALYSIS 216274

Client Details

Client	MBS Environmental
Attention	Gert Du Plessis
Address	4 Cook Street, WEST PERTH, WA, 6005

Sample Details

Your Reference	**SUB7ST**
Number of Samples	24 soils
Date samples received	20/09/2018
Date completed instructions received	20/09/2018
Location	Subsea 7 Pipe Bundle

Analysis Details

Please refer to the following pages for results, methodology summary and quality control data.

Samples were analysed as received from the client. Results relate specifically to the samples as received.

Results are reported on a dry weight basis for solids and on an as received basis for other matrices.

Report Details

Date results requested by	28/09/2018
Date of Issue	28/09/2018

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Results Approved By
Joshua Lim, Operations Manager
Stacey Hawkins, Acid Soils Supervisor

Authorised By

Todd Lee, Laboratory Manager

sPOCAS field test						
Our Reference		216274-1	216274-2	216274-3	216274-4	216274-5
Your Reference	UNITS	ASS1 0.0.25m	ASS2 0-0.25m	ASS2 0.25-0.4m	ASS4 0-0.25m	ASS4 0.25-0.5m
Date Sampled		19/09/2018	19/09/2018	19/09/2018	19/09/2018	19/09/2018
Type of sample		Soil	Soil	Soil	Soil	Soil
Date prepared	-	20/09/2018	20/09/2018	20/09/2018	20/09/2018	20/09/2018
Date analysed	-	21/09/2018	21/09/2018	21/09/2018	21/09/2018	21/09/2018
pH_F (field pH test)*	pH Units	8.3	8.6	8.6	8.6	8.6
pHFOX (field peroxide test)*	pH Units	6.7	6.8	6.7	6.8	6.9
Reaction Rate*	-	Medium	Medium	Low	Low	Low

sPOCAS field test						
Our Reference		216274-6	216274-7	216274-8	216274-9	216274-10
Your Reference	UNITS	ASS5 0-0.25m	ASS6 0-0.25m	ASS6 0.25-0.5m	ASS6 0.5-0.75m	ASS6 0.75-1.00m
Date Sampled		19/09/2018	19/09/2018	19/09/2018	19/09/2018	19/09/2018
Type of sample		Soil	Soil	Soil	Soil	Soil
Date prepared	-	20/09/2018	20/09/2018	20/09/2018	20/09/2018	20/09/2018
Date analysed	-	21/09/2018	21/09/2018	21/09/2018	21/09/2018	21/09/2018
pH_F (field pH test)*	pH Units	8.7	8.8	8.6	8.8	9.0
pHFOX (field peroxide test)*	pH Units	7.0	6.8	6.8	6.7	6.6
Reaction Rate*	-	Medium	Medium	Low	Low	Low

sPOCAS field test						
Our Reference		216274-11	216274-12	216274-13	216274-14	216274-15
Your Reference	UNITS	ASS6 1.00-1.25m	ASS7 0-0.3m	ASS7 0.3-0.5m	ASS8 0-0.15m	ASS8 0.15-0.8m
Date Sampled		19/09/2018	19/09/2018	19/09/2018	19/09/2018	19/09/2018
Type of sample		Soil	Soil	Soil	Soil	Soil
Date prepared	-	20/09/2018	20/09/2018	20/09/2018	20/09/2018	20/09/2018
Date analysed	-	21/09/2018	21/09/2018	21/09/2018	21/09/2018	21/09/2018
pH_F (field pH test)*	pH Units	8.8	8.7	8.7	8.2	8.3
pHFOX (field peroxide test)*	pH Units	6.6	6.9	9.0	6.6	6.7
Reaction Rate*	-	Low	Medium	Medium	Medium	Medium

sPOCAS field test						
Our Reference		216274-16	216274-17	216274-18	216274-20	216274-21
Your Reference	UNITS	ASS8 0.8-1.1m	ASS8 1.1-1.3m	ASS8 1.3-1.8m	DUP1	DUP2
Date Sampled		19/09/2018	19/09/2018	19/09/2018	19/09/2018	19/09/2018
Type of sample		Soil	Soil	Soil	Soil	Soil
Date prepared	-	20/09/2018	20/09/2018	20/09/2018	20/09/2018	20/09/2018
Date analysed	-	21/09/2018	21/09/2018	21/09/2018	21/09/2018	21/09/2018
pH_F (field pH test)*	pH Units	8.2	8.5	8.2	8.6	8.9
pHFOX (field peroxide test)*	pH Units	6.4	6.6	6.6	6.7	6.9
Reaction Rate*	-	Low	Low	Low	Low	Medium

sPOCAS field test				
Our Reference		216274-22	216274-23	216274-24
Your Reference	UNITS	DUP3	DUP4	DUP5
Date Sampled		19/09/2018	19/09/2018	19/09/2018
Type of sample		Soil	Soil	Soil
Date prepared	-	20/09/2018	20/09/2018	20/09/2018
Date analysed	-	21/09/2018	21/09/2018	21/09/2018
pH_F (field pH test)*	pH Units	8.8	8.2	8.3
pHFOX (field peroxide test)*	pH Units	6.6	6.6	6.6
Reaction Rate*	-	Low	Low	Low

Miscellaneous Inorg - soil		
Our Reference		216274-19
Your Reference	UNITS	WWTF1
Date Sampled		19/09/2018
Type of sample		Soil
Date prepared	-	20/09/2018
Date analysed	-	27/09/2018
Phosphorus Buffer Index		100
Total Phosphorus	mg/kg	120

Moisture		
Our Reference		216274-19
Your Reference	UNITS	WWTF1
Date Sampled		19/09/2018
Type of sample		Soil
Date prepared	-	20/09/2018
Date analysed	-	27/09/2018
Moisture	%	0.70

Chromium Suite						
Our Reference		216274-3	216274-5	216274-9	216274-10	216274-11
Your Reference	UNITS	ASS2 0.25-0.4m	ASS4 0.25-0.5m	ASS6 0.5-0.75m	ASS6 0.75-1.00m	ASS6 1.00-1.25m
Date Sampled		19/09/2018	19/09/2018	19/09/2018	19/09/2018	19/09/2018
Type of sample		Soil	Soil	Soil	Soil	Soil
Date analysed	-	26/09/2018	26/09/2018	26/09/2018	26/09/2018	26/09/2018
pH_{kcl}	pH units	9.6	9.7	9.9	9.7	9.6
TAA	moles H^+/t	<5	<5	<5	<5	<5
S_{KCl}	%w/w S	NT	NT	NT	NT	NT
Chromium Reducible Sulfur	%w/w	<0.005	<0.005	<0.005	<0.005	<0.005
ANC_{BT}	% $CaCO_3$	18	9.0	9.6	2.9	8.1
S_{HCl}	%w/w S	NT	NT	NT	NT	NT
s-TAA	%w/w S	<0.01	<0.01	<0.01	<0.01	<0.01
a-Chromium Reducible Sulfur	moles H^+/t	<5	<5	<5	<5	<5
a-ANC_{BT}	moles H^+/t	3,500	1,800	1,900	570	1,600
s-ANC_{BT}	%w/w S	5.7	2.9	3.1	0.92	2.6
Fineness Factor		1.50	1.50	1.50	1.50	1.50
S_{NAS}	%w/w S	NT	NT	NT	NT	NT
a-S_{NAS}	moles H^+/t	NT	NT	NT	NT	NT
s-SNAS	%w/w S	NT	NT	NT	NT	NT
s-Net Acidity	%w/w S	<0.005	<0.005	<0.005	<0.005	<0.005
a-Net Acidity	moles H^+/t	<5	<5	<5	<5	<5
Liming rate	kg $CaCO_3$/t	<0.75	<0.75	<0.75	<0.75	<0.75
s-Net Acidity without ANCE	% w/w S	<0.005	<0.005	<0.005	<0.005	<0.005
a-Net Acidity without ANCE	moles H^+/t	<5	<5	<5	<5	<5
Liming rate without ANCE	kg $CaCO_3$/t	<0.75	<0.75	<0.75	<0.75	<0.75

Chromium Suite					
Our Reference		216274-15	216274-16	216274-17	216274-22
Your Reference	UNITS	ASS8 0.15-0.8m	ASS8 0.8-1.1m	ASS8 1.1-1.3m	DUP3
Date Sampled		19/09/2018	19/09/2018	19/09/2018	19/09/2018
Type of sample		Soil	Soil	Soil	Soil
Date analysed	-	26/09/2018	26/09/2018	26/09/2018	26/09/2018
pH $_{kcl}$	pH units	9.4	9.1	9.5	9.6
TAA	moles H^+/t	<5	<5	<5	<5
S_{KCl}	%w/w S	NT	NT	NT	NT
Chromium Reducible Sulfur	%w/w	<0.005	<0.005	<0.005	<0.005
ANC_{BT}	% $CaCO_3$	8.4	2.1	34	6.5
S_{HCl}	%w/w S	NT	NT	NT	NT
s-TAA	%w/w S	<0.01	<0.01	<0.01	<0.01
a-Chromium Reducible Sulfur	moles H^+/t	<5	<5	<5	<5
a-ANC_{BT}	moles H^+/t	1,700	420	6,800	1,300
s-ANC_{BT}	%w/w S	2.7	0.67	11	2.1
Fineness Factor		1.50	1.50	1.50	1.50
S_{NAS}	%w/w S	NT	NT	NT	NT
a-S_{NAS}	moles H^+/t	NT	NT	NT	NT
s-SNAS	%w/w S	NT	NT	NT	NT
s-Net Acidity	%w/w S	<0.005	<0.005	<0.005	<0.005
a-Net Acidity	moles H^+/t	<5	<5	<5	<5
Liming rate	kg $CaCO_3$/t	<0.75	<0.75	<0.75	<0.75
s-Net Acidity without ANCE	% w/w S	<0.005	<0.005	<0.005	<0.005
a-Net Acidity without ANCE	moles H^+/t	<5	<5	<5	<5
Liming rate without ANCE	kg $CaCO_3$/t	<0.75	<0.75	<0.75	<0.75

Method ID	Methodology Summary
INORG-008	Moisture content determined by heating at 105 deg C for a minimum of 12 hours.
INORG-063	pH- measured using pH meter and electrode. Soil is oxidised with Hydrogen Peroxide or extracted with water. Based on section H, Acid Sulfate Soils Laboratory Methods Guidelines, Version 2.1 - June 2004.
INORG-064	Suspension Peroxide Oxidation Combined Acidity and Sulphate (SPOCAS) using ASSMAC guidelines.
INORG-068	Chromium Reducible Sulfur - Hydrogen Sulfide is quantified by iodometric titration after distillation to determine potential acidity. Based on Acid Sulfate Soils Laboratory Methods Guidelines, Version 2.1 - June 2004.
METALS-020	Metals in soil and water by ICP-OES.

QUALITY CONTROL: sPOCAS field test					Duplicate				Spike Recovery %	
Test Description	Units	PQL	Method	Blank	#	Base	Dup.	RPD	[NT]	[NT]
Date prepared	-			20/09/2018	1	20/09/2018	20/09/2018		[NT]	[NT]
Date analysed	-			21/09/2018	1	21/09/2018	21/09/2018		[NT]	[NT]
pH_F (field pH test)*	pH Units		INORG-063	[NT]	1	8.3	8.5	2	[NT]	[NT]
pHFOX (field peroxide test)*	pH Units		INORG-063	[NT]	1	6.7	6.9	3	[NT]	[NT]

QUALITY CONTROL: sPOCAS field test					Duplicate				Spike Recovery %	
Test Description	Units	PQL	Method	Blank	#	Base	Dup.	RPD	[NT]	[NT]
Date prepared	-			[NT]	11	20/09/2018	20/09/2018		[NT]	[NT]
Date analysed	-			[NT]	11	21/09/2018	21/09/2018		[NT]	[NT]
pH_F (field pH test)*	pH Units		INORG-063	[NT]	11	8.8	8.7	1	[NT]	[NT]
pHFOX (field peroxide test)*	pH Units		INORG-063	[NT]	11	6.6	6.6	0	[NT]	[NT]

QUALITY CONTROL: sPOCAS field test					Duplicate				Spike Recovery %	
Test Description	Units	PQL	Method	Blank	#	Base	Dup.	RPD	[NT]	[NT]
Date prepared	-			[NT]	21	20/09/2018	20/09/2018		[NT]	[NT]
Date analysed	-			[NT]	21	21/09/2018	21/09/2018		[NT]	[NT]
pH_F (field pH test)*	pH Units		INORG-063	[NT]	21	8.9	8.8	1	[NT]	[NT]
pHFOX (field peroxide test)*	pH Units		INORG-063	[NT]	21	6.9	7.0	1	[NT]	[NT]

QUALITY CONTROL: Miscellaneous Inorg - soil					Duplicate				Spike Recovery %	
Test Description	Units	PQL	Method	Blank	#	Base	Dup.	RPD	LCS-1	[NT]
Date prepared	-			20/09/2018	[NT]	[NT]	[NT]	[NT]	20/09/2018	[NT]
Date analysed	-			27/09/2018	[NT]	[NT]	[NT]	[NT]	27/09/2018	[NT]
Phosphorus Buffer Index				[NT]	[NT]	[NT]	[NT]	[NT]	96	[NT]
Total Phosphorus	mg/kg	10	METALS-020	<10	[NT]	[NT]	[NT]	[NT]	100	[NT]

QUALITY CONTROL: Chromium Suite					Duplicate				Spike Recovery %	
Test Description	Units	PQL	Method	Blank	#	Base	Dup.	RPD	LCS-1	[NT]
Date analysed	-			26/09/2018	11	26/09/2018	26/09/2018		26/09/2018	[NT]
pH_{kcl}	pH units		INORG-064	[NT]	11	9.6	9.7	1	102	[NT]
TAA	moles H^+/t	5	INORG-064	[NT]	11	<5	<5	0	106	[NT]
S_{KCl}	%w/w S	0.005	INORG-064	[NT]	11	NT	NT		[NT]	[NT]
Chromium Reducible Sulfur	%w/w	0.005	INORG-068	[NT]	11	<0.005	<0.005	0	98	[NT]
ANC_{BT}	% $CaCO_3$	0.01	INORG-068	[NT]	11	8.1	8.1	0	100	[NT]
S_{HCl}	%w/w S	0.005	INORG-068	[NT]	11	NT	NT		[NT]	[NT]
s-TAA	%w/w S	0.01	INORG-068	[NT]	11	<0.01	<0.01	0	[NT]	[NT]
a-Chromium Reducible Sulfur	moles H^+/t	5	INORG-068	[NT]	11	<5	<5	0	[NT]	[NT]
a-ANC_{BT}	moles H^+/t	5	INORG-068	[NT]	11	1600	1600	0	[NT]	[NT]
s-ANC_{BT}	%w/w S	0.01	INORG-068	[NT]	11	2.6	2.6	0	[NT]	[NT]
Fineness Factor			INORG-064	[NT]	11	1.50	1.50	0	[NT]	[NT]
S_{NAS}	%w/w S	0.005	INORG-068	[NT]	11	NT	NT		[NT]	[NT]
a-S_{NAS}	moles H^+/t	5	INORG-064	[NT]	11	NT	NT		[NT]	[NT]
s-SNAS	%w/w S	0.01	INORG-064	[NT]	11	NT	NT		[NT]	[NT]
s-Net Acidity	%w/w S	0.005	INORG-064	[NT]	11	<0.005	<0.005	0	[NT]	[NT]
a-Net Acidity	moles H^+/t	5	INORG-064	[NT]	11	<5	<5	0	[NT]	[NT]
Liming rate	kg $CaCO_3$/t	0.75	INORG-068	[NT]	11	<0.75	<0.75	0	[NT]	[NT]
s-Net Acidity without ANCE	% w/w S	0.005	INORG-064	[NT]	11	<0.005	<0.005	0	[NT]	[NT]
a-Net Acidity without ANCE	moles H^+/t	5	INORG-064	[NT]	11	<5	<5	0	[NT]	[NT]
Liming rate without ANCE	kg $CaCO_3$/t	0.75	INORG-064	[NT]	11	<0.75	<0.75	0	[NT]	[NT]

Result Definitions

NT	Not tested
NA	Test not required
INS	Insufficient sample for this test
PQL	Practical Quantitation Limit
<	Less than
>	Greater than
RPD	Relative Percent Difference
LCS	Laboratory Control Sample
NS	Not specified
NEPM	National Environmental Protection Measure
NR	Not Reported

Quality Control Definitions

Blank	This is the component of the analytical signal which is not derived from the sample but from reagents, glassware etc, can be determined by processing solvents and reagents in exactly the same manner as for samples.
Duplicate	This is the complete duplicate analysis of a sample from the process batch. If possible, the sample selected should be one where the analyte concentration is easily measurable.
Matrix Spike	A portion of the sample is spiked with a known concentration of target analyte. The purpose of the matrix spike is to monitor the performance of the analytical method used and to determine whether matrix interferences exist.
LCS (Laboratory Control Sample)	This comprises either a standard reference material or a control matrix (such as a blank sand or water) fortified with analytes representative of the analyte class. It is simply a check sample.
Surrogate Spike	Surrogates are known additions to each sample, blank, matrix spike and LCS in a batch, of compounds which are similar to the analyte of interest, however are not expected to be found in real samples.

Australian Drinking Water Guidelines recommend that Thermotolerant Coliform, Faecal Enterococci, & E.Coli levels are less than 1cfu/100mL. The recommended maximums are taken from "Australian Drinking Water Guidelines", published by NHMRC & ARMC 2011.

Laboratory Acceptance Criteria

Duplicate sample and matrix spike recoveries may not be reported on smaller jobs, however, were analysed at a frequency to meet or exceed NEPM requirements. All samples are tested in batches of 20. The duplicate sample RPD and matrix spike recoveries for the batch were within the laboratory acceptance criteria.

Filters, swabs, wipes, tubes and badges will not have duplicate data as the whole sample is generally extracted during sample extraction.

Spikes for Physical and Aggregate Tests are not applicable.

For VOCs in water samples, three vials are required for duplicate or spike analysis.

Duplicates: >10xPQL - RPD acceptance criteria will vary depending on the analytes and the analytical techniques but is typically in the range 20%-50% – see ELN-P05 QA/QC tables for details; <10xPQL - RPD are higher as the results approach PQL and the estimated measurement uncertainty will statistically increase.

Matrix Spikes, LCS and Surrogate recoveries: Generally 70-130% for inorganics/metals; 60-140% for organics (+/-50% surrogates) a

In circumstances where no duplicate and/or sample spike has been reported at 1 in 10 and/or 1 in 20 samples respectively, the sample volume submitted was insufficient in order to satisfy laboratory QA/QC protocols.

When samples are received where certain analytes are outside of recommended technical holding times (THTs), the analysis has proceeded. Where analytes are on the verge of breaching THTs, every effort will be made to analyse within the THT or as soon as practicable.

Where sampling dates are not provided, Envirolab are not in a position to comment on the validity of the analysis where recommended technical holding times may have been breached.

Measurement Uncertainty estimates are available for most tests upon request.

APPENDIX 3: PIT DESCRIPTIONS AND SITE PHOTOGRAPHS

Site	ASS1	**GPS Coordinates**	50H	201756	mE	Page 1 of 8
				7535449	mN	
Locality	Learmonth	**Date**	19-Sep-18		**Time**	8:52

Vegetation and Landscape

Slope:	Slight slope (2°) trending west. Elevation 5 mAHD.
Vegetation:	Dense small shrubland.
Landscape:	Limestone outcrop on access roads. Generally low/flat lying area.

Pit Notes

Horizon	*Description*
0 - 0.25m	Light brown silty sand. Surface evident of limestone outcrop.
0.25m +	Refusal - siliceous cemented layer (suspect limestone). Mixed ferruginous cobbles in siliceous cement.
Sample Register	ASS1 0-0.25m

Photo 1: Pit Profile

Photo 2

Site	ASS2	**GPS Coordinates**	50H	201823	mE	
				7535458	mN	
Locality	Learmonth	**Date**	19-Sep-18		**Time**	9:05

Vegetation and Landscape	
Slope:	Slight slope (2°) trending west. Elevation 5 mAHD.
Vegetation:	Dense small shrubland.
Landscape:	Limestone outcrop on access roads. Generally low/flat lying area.

Pit Notes

Horizon	*Description*
0 - 0.25m	Light brown loamy sand with moderate moisture. Shells observed mixed throughout soil.
0.25 - 0.40m	Light brown/grey clay loam with brown mottling. No shells observed in soil. Higher moisture and clay content compared to surface 0.25m horizon.
0.40m +	Refusal - siliceous cemented layer (suspect limestone).
Sample Register	

Photo 1: Pit Profile

Site	ASS4	**GPS Coordinates**	50H	203328	mE	Page 4 of 8
				7535616	mN	
Locality	Learmonth	**Date**	19-Sep-18		**Time**	10:27

Vegetation and Landscape

Slope:	Flat lying area (no slope). Elevation 4 mAHD.
Vegetation:	Dense small shrubland on flat plains. Medium sized trees limited to dunes/hills.
Landscape:	Surrounded by small dune systems and limestone hills.

Pit Notes

Horizon	*Description*
0 - 0.25m	Light brown loamy sand.
0.25 - 0.60m	Medium brown/red loamy sand.
0.60m +	Refusal - siliceous cemented layer (suspect limestone).
Sample Register	ASS4 0-0.25m ASS4 0.25-0.50m DUP2 (ASS4 0.25-0.50m)

Photo 1: Pit Profile

Photo 2: Landscape

Site	ASS5	GPS Coordinates	50H	203542	mE	Page 5 of 8
				7535631	mN	
Locality	Learmonth	**Date**	19-Sep-18		**Time**	11:11

Vegetation and Landscape	
Slope:	Low lying area (no slope). Elevation 3 mAHD.
Vegetation:	Small shrubland with yellow flowers prominent in this area.
Landscape:	Flat grass plain. Dune systems and limestone hills in the distance.

Pit Notes

Horizon	*Description*
0 - 0.30m	Light brown silty sand.
0.30m +	Refusal - cemented layer (purple/white chips indicative of sandstone/limestone cap).
Sample Register	ASS5 0-0.25m

Photo 1: Pit Profile

Photo 2: Landscape

Site	ASS6	**GPS Coordinates**	50 H	203064	mE	Page 6 of 8
				7533499	mN	
Locality	Learmonth	**Date**	19-Sep-18		**Time**	13:14

Vegetation and Landscape

Slope:	Generally flat lying area (no slope). Elevation 4 mAHD.
Vegetation:	Cleared area, no vegetation. Vegetation surrounding sampling location is predominantly grassland and small shrubs.
Landscape:	Flat lying area.

Pit Notes

Horizon	*Description*
0 - 0.25m	Light brown to medium brown sandy laom. Fine sand at surface.
0.25 - 1.25m	Uniform profile - medium brown silty sand/loam. Moisture content increasing with depth and texture becoming coarser with depth.
1.25m +	Refusal - cemented layer. Unable to identify indurated layer (sampling by auger).
	Sampling by auger - excavator not able to access this sampling location.

Sample Register	ASS6 0-0.25m ASS6 0.25-0.50m ASS6 0.50-0.75m ASS6 0.75-1.00m ASS6 1.00-1.25m	DUP3 (ASS6 1.00-1.25m)

Photo 1: Samples

Site	ASS7	**GPS Coordinates**	50H	203434	mE	Page 7 of 8
				7535635	mN	
Locality	Learmonth	**Date**	19-Sep-18		**Time**	10:42

Vegetation and Landscape

Slope:	Flat lying area (no slope). Elevation 4 mAHD.
Vegetation:	Dense small shrubland on flat plains. Medium sized trees limited to dunes/hills.
Landscape:	Surrounded by small dune systems and limestone hills.

Pit Notes

Horizon	*Description*
0 - 0.30m	Light brown loamy sand.
0.30 - 0.50m	Medium brown/red loamy sand.
0.50m +	Refusal - siliceous cemented layer (suspect limestone).
Sample Register	ASS7 0-0.30m ASS7 0.30-0.50m

Photo 1: Pit Profile

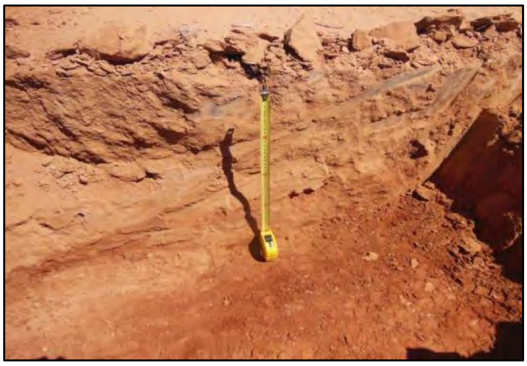

Photo 2: Landscape

Site	ASS8	**GPS Coordinates**	**50H**	201685	mE	Page 8 of 8
				7535543	mN	
Locality	Learmonth	**Date**	19-Sep-18		**Time**	14:05

Vegetation and Landscape

Slope:	Flat area (no slope).
Vegetation:	Scattered small shrubs. Adjacent to dense grass and shrubland.
Landscape:	Previously cleared area - flat plain.

Pit Notes

Horizon	*Description*
0 - 0.15m	Quite moist medium brown loamy sand.
0.15 - 0.80m	Grey/blue clay loam (moist) with yellow/orange mottling.
0.80 - 1.10m	Grey/blue clay with yellow mottling.
1.30 - 1.80m	Waterlogged - cream coloured clay with blue/grey clay mottling.
1.80m +	Refusal and groundwater interception - friable aggregates mixed with cream clays.

Sample Register	ASS8 0-0.15m ASS8 0.15-0.80m ASS8 0.80-1.10m ASS8 1.10-1.30m ASS8 1.30-1.80m	DUP4 (ASS8 0.80-1.10m) DUP5 (ASS8 1.10-1.30m)

Photo 1: Pit Profile

Photo 2: Landscape