Appendix A (ii)

Environmental Referral, North West Infrastructure Multi User Iron Ore Export (Landside) Facility

ASS Sampling and Analysis Plan (Coffey 2011c)

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SPECIALISTS IN ENVIRONMENTAL,
SOCIAL AND SAFETY PERFORMANCE

MULTI USER IRON ORE EXPORT (LANDSIDE) FACILITY
SAMPLING AND ANALYSIS PLAN - ACID SULFATE SOILS

Prepared for:

North West Infrastructure
46 Parliament Place
West Perth WA 6005

Report Date: 25 July 2011
Project Ref: ENVIPERT02319AA

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SPECIALISTS IN ENVIRONMENTAL, SOCIAL AND SAFETY PERFORMANCE

25 July 2011

North West Infrastructure
46 Parliament Place
West Perth WA 6005

Attention: Tony Considine

Dear Tony

RE: Multi User Iron Ore Export (Landside) Facility
Sampling and Analysis Plan - Acid Sulfate Soils

Coffey Environments are pleased to provide this Sampling and Analysis Plan (SAP) for Acid Sulfate Soils (ASS) within the proposed Multi User Iron Ore Export (Landside) Facility Project. This plan should be read in the context of the Statement of Limitations attached.

For and on behalf of Coffey Environments Australia Pty Ltd

Luke Craig
Environmental Scientist

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ABBREVIATIONS

AASS	Actual Acid Sulfate Soils
AHD	Australian Height Datum
ANC	Acid neutralising capacity
ANC_{BT}	Acid neutralising capacity back titration
ANC_{E}	Acid neutralising capacity effective
ANZECC	Australian and New Zealand Environment and Conservation Council
ARMCANZ	Agriculture and Resource Management Council of Australia and New Zealand
ASS	Acid Sulfate Soils
Ca_{A}	Reacted calcium
CD	Chart Datum
Coffey	Coffey Environments
CRS	Chromium Reducible Sulfur
DEC	Department of Environment and Conservation
DoW	Department of Water
ENV	Effective neutralising value
EPA	Environmental Protection Authority
GL	Gigalitres
ha	hectares
HBI	Hot Briquetted Iron
km	kilometre(s)
m	metre(s)
m^3	Cubic metre(s)
mAHD	Meter(s) Australian Height Datum

ABBREVIATIONS

mbgl	meter(s) below ground level
mCD	meter(s) Chart Datum
Mg_A	Reacted magnesium
NATA	National Association of Testing Authorities
NWI	North West Infrastructure
NWIOA	North West Iron Ore Alliance
PASS	Potential Acid Sulfate Soils
pH_F	Field pH
pH_{OX}	Post oxidation pH
PHPA	Port Hedland Port Authority
QC	Quality Control
SAP	Sampling and Analysis Plan
S_{KCl}	Preoxidation sulfur
S_{RAS} or S_{NAS}	Residual acid soluble sulfur
SPOCAS	Suspension peroxide oxidation combined acidity and sulfur
TAA	Titratable actual acidity
TPA	Total potential acidity
TSA	Total sulfur acidity

1 INTRODUCTION

Coffey Environments was commissioned by the North West Iron Ore Alliance (NWIOA) and trading as North West Infrastructure (NWI), to prepare a Sampling and Analysis Plan (SAP) for acid sulfate soils (ASS) at the Multi-User Iron Ore Export (Landside) Facility (the project) located at Port Headland, Western Australia. The SAP has been developed as part of the Environmental Referral Document (2011a) requirements and guidance from relevant legislation and standards for the investigation and disturbance of ASS.

The SAP has been designed to fulfill Section 6.4.3 of the Environmental Referral Document for the investigation of ASS. Results of the ASS investigation shall be used to formulate management strategies that minimise the environmental impact of ASS disturbance during the construction phase of the project.

1.1 Applicable Legislation and Standards

The implementation of the project will require compliance with Western Australian legislation and regulations, Commonwealth legislation and regulations, and Department of Environment and Conservation (DEC) guidelines.

Applicable legislation and guidelines for ASS include:

- Planning Bulletin No. 64/2009 Acid Sulfate Soils (Western Australian Planning Commission, 2009).
- *Contaminated Sites Act 2003*.
- Policy Position Acid Sulfate Soils (DEC, 2006).
- *Acid Sulfate Soils Guideline Series: Identification and Investigation of Acid Sulphate Soils and Acidic Landscapes.* Perth, WA (DEC, 2009a).
- Acid Sulfate Soils Guideline Series: *Draft Treatment and Management of Soils and Water in Acid Sulfate Soil Landscapes* (DEC, 2009b).
- *National Strategy for the Management of Coastal Acid Sulfate Soils* (ANZECC/ARMCANZ 2000a).

1.2 Project Description

1.2.1 Overview

NWIOA formed in 2007 has been assigned two export berths within Port Hedland Port Authority's South West Creek in the Pilbara Region of Western Australia (Figure 1). The proposed project will provide an additional port facility at Port Hedland to receive and stockpile the product from emerging miners, specifically the various mines owned by the NWI shareholders, and load this product onto ships for delivery to customers through these berths.

The project includes the development of two berths within South West Creek to provide for the export capacity of a nominal 50 million tonnes per year, along with supportive infrastructure incorporating stackers and loaders, conveyors, stockyard, rail car dumper and rail loop (Figure 2). The current proposal stops at the southern boundary of land proposed to be vested in the Port Headland Port

Authority (PHPA). The project accommodates a combination of haematite and a lesser quantity of magnetite iron ore product, depending on shareholder requirements.

2.1.2 Key Project Characteristics

The key characteristics of the proposal includes:

- A two berth wharf and ship loading infrastructure at Stanley Point within South West Creek in the Port Hedland Inner Harbour to provide for the export capacity of 50 million tonnes per year;
- A single shiploader (long travelling, slewing, luffing);
- Overland conveyors 1800mm wide for a total of 6.2km between the stockpile area and a shiploader;
- Stockpile area enclosed within an embankment that supports the ballast, sleepers and rail for the car dumper rail loop at stockyard 2;
- Single twin cell rotary car dumper feeding to dual stacker; and
- Identification of two optional rail connections to the edge of land proposed to be vested in the PHPA (Boodarie Estate) allowing for access to rail providers.

The key characteristics of the Multi-user Iron Ore Export (Landside) Facility is provided in Table 1.

Table 1 Key Characteristics of NWI's Multi-user Iron Ore Export (Landside) Facility

Element	Description
Rail	Railway comprising: • Western rail loop on Stockyard 2 providing possible connection to FMG, BHP-B or third party provider; • Eastern rail providing a possible connection to Roy Hill Iron Ore • Twin car train unloader.
Stockyard	Stockyard 2 comprising a rail loop, 2 stackers, 1 reclaimer and stockpile area of approximately 1500 m long by 400m wide – 8 x 210000t live stockpiles
Conveyors	1800mm wide by 5.2 km overland conveyors (1.5 km and 3.7 km long respectively) from the stockyard to a transfer station located on the Eastern side of the Finucane Island access causeway. 1800mm wide by 1.0 km conveyor which runs from the overland conveyor transfer station to the berth shiploader conveyor.
Wharf	Wharf structures, two shipping berths and one ship loader at Stanley Point in South West Creek
Other infrastructure	Offices, workshops, access roads and service corridors

Element	Description
Life of project	50 years or more
Throughput	Nominal 50 million tonnes per annum
Disturbance footprint	360 ha comprising: • 214.73 ha within existing PHPA vested land; • 144.70 ha within land proposed to be vested in the PHPA.
Mangrove disturbance	2.7 ha

2 ACID SULFATE SOILS

2.1 Background

ASS are soils that contain iron sulfides (pyrite). The formation of pyrite requires the presence of iron (naturally available from sediments), sulfur (usually from seawater or sediments of marine origin) and organic matter. ASS is thus formed under specific environmental conditions. When exposed to air due to drainage or disturbance, these soils produce sulfuric acid, potentially releasing quantities of iron, aluminium and heavy metals, which may have detrimental impacts on the natural environment and infrastructure

Pyritic soils of concern on low-lying and coastal lands have mostly formed in the Holocene period, (i.e. 10,000 years ago to present day) predominantly in the 7,000 years since the last rise in sea level. It is generally considered that pyritic soils that formed prior to the Holocene period (i.e. >10,000 years ago) would already have oxidised and leached during periods of low sea level which occurred during ice ages, exposing pyritic coastal sediments to oxygen. ASS are thus found predominantly in alluvial coastal landforms lying lower than 5m Australian Height Datum (AHD), which is approximately the height of the seas during the Holocene period, and they are usually only present in unconsolidated sediments.

When ASS is exposed to air, (that is, no longer in a waterlogged anaerobic state), the iron sulfides in the soil react with oxygen and water to produce a variety of iron compounds and sulfuric acid. Consequently under the anaerobic reducing conditions maintained by permanent groundwater/surface water, the iron sulfides are stable and the surrounding soil pH is often weakly acid to weakly alkaline. Such soils, although potentially considered acidic do not pose a threat to the natural or manmade environment, provided the conditions remain constant.

Therefore ASS can broadly be divided into two broad categories namely actual ASS (AASS), which are soils in which the pyrite has already been oxidised and sulfuric acid is present in the soil, and potential ASS (PASS) where the pyrite is present but has not been oxidised. Disturbance of both AASS and PASS have the potential to release acid by;

- the reburial of AASS below the water table; and
- the oxidation of PASS and in-situ PASS (change from an anaerobic to an aerobic environment such as by excavating/dredging the soils or lowering the water table).

The release of acid can cause the degradation of both the environment and infrastructure.

2.2 Environmental Impacts

The main environmental effects of ASS disturbance are changes to surface and groundwater quality, habitat degradation and poor plant productivity. The effects will depend on the natural buffering capacity of the receiving environment and vegetation type.

2.2.1 Water Quality

The release of acid into both the surface and ground waters can significantly reduce the natural buffering capacity of the water lowering pH and dissolve metals into toxic forms (generally pH <3.5).

2.2.2 Habitat degradation

In waterway habitats drainage from AASS and PASS (upon oxidation) has the potential to cause iron precipitation that smothers vegetation and microhabitat.

2.2.3 Poor plant productivity

Potential to cause reduced plant productivity and stunted growth at low soil pH because of the following;

- toxic effects of aluminium, iron and manganese (become more available at low pH);
- deficiency in plant base minerals such as calcium, magnesium and potassium;
- low availability of nutrients;
- increased attacks by plant pathogens due to stressed growing condition;
- decrease in soil microbes, particularly those responsible for nitrogen fixation; and
- stunting of roots producing water stress.

2.3 Infrastructure Impacts

The potential impacts of any free acid on infrastructure may be severe. The uncontrolled release of acid from AASS and/or disturbed PASS can corrode infrastructure and building elements made of concrete and iron. Historically acidic conditions, associated with the disturbance of ASS have contributed to the failure of bridges, culverts and other structures.

2.4 Soil Investigation

ASS investigations designed to assess the distribution and magnitude of ASS horizons within the disturbance footprints below 5mAHD are required prior to the construction of these facilities. Table 2 outlines the DEC (2009a) recommended borehole sampling frequencies.

Table 2 DEC (2009a) Minimum number of profile sampling (boreholes or test pits) for sites involving disturbances >1000m^3 below 5mAHD

Type of Disturbance	Area of Site	Number of Sampling Locations
Non-linear	> 4 ha	2 locations/ha
Linear	Major width and volume	@ 50m intervals

Approximately 150ha of non-linear disturbance and 1.62km of linear disturbance below 5mAHD is proposed during construction. Testing at the DEC guidelines this area of disturbance would equate to over 424 sampling locations.

For large projects, the DEC accepts reduced sampling densities, if the investigation program is designed to satisfactorily characterise the various geological and geomorphological units at the site. The following SAP proposes a reduced sampling density, based on site specific ASS risk assessment derived from elevation, DEC ASS risk and detailed vegetation community mapping.

2.5 ASS Occurrence and Risk

Coffey undertook a preliminary investigation into the potential presence of ASS that may be encountered as part of the Multi-user Iron Ore Export (Landside) Facility (Coffey Environments, 2011a). The preliminary ASS investigation was designed to satisfy 'Step 1: Desktop Assessment and Site Inspection' of the DEC guidelines, *Identification and Investigation of Acid Sulfate Soils and Acidic Landscapes* (DEC, 2009a).

The preliminary investigation indicated that ASS horizons are likely to be identified in Holocene deposits situated in intertidal areas below 5mAHD. Based on published mapping (DEC 2010) approximately 895ha of the project is described as having a potentially high to moderate risk of ASS, while approximately 45ha is considered moderate to low risk of ASS within 3m of the natural soil surface. The DEC risk map for the entire project area is presented in Figure 3.

To further delineate likely ASS risk, the detailed vegetation community map (Figure 4) prepared by Woodman Environmental (2011) was reviewed for ASS indicator vegetation communities (i.e. mangroves and *Phragmites*).

Three project specific ASS risk categories were developed based on elevation below 5mAHD, broad scale DEC ASS risk mapping and the detailed vegetation community mapping. The three ASS risk categories developed for the purposes of the SAP are; high to moderate, moderate to low and likely nonASS. The areas of the project considered to have a:

- **High to moderate ASS** risk areas are defined as situated below 3mAHD and comprises of coastal vegetation communities that are ASS indicators (including but not limited to mangroves and cyanobacterial algal mats).
- **Moderate to low ASS** risk areas are defined as situated between 3mAHD and 5mAHD and comprise of floristic community types that are not usually associated with ASS (including but not limited to samphire and supratidal shrubland).

- **NonASS** risk areas are defined as situated between 3mAHD and 5mAHD and comprise of the floristic and mosaic community types nor associated with ASS (including but not limited to Acacia sp and FCT1 and FCT2).

2.6 Activities likely to disturb ASS

Four construction activities which have the potential to disturb ASS have been identified for infrastructure project. A summary of these construction activities follows.

2.6.1 Excavation (Various Activities)

A common form of disturbance is the excavation of PASS and the placement of the soils in aerobic conditions. During construction, machinery will excavate large amounts of soils potentially exposing pyrite which oxidises and, with water, forms sulfuric acid. Excavation of AASS may also accelerate the release of acid into the natural environment during handling.

In sandy ASS, high rates of oxygen diffusion into the soils allow the rapid oxidation of the pyrite. In addition, high permeability allows the ingress of water and rapid leaching of the acids. As a result, sandy soils in aerobic environments tend to release high volumes of acid in the short term, however, the acid is likely to be depleted relatively quickly. This may occur over a period of months or several years, depending on conditions.

In clayey ASS, the rate of oxidation and acid release is generally slower due to the low rates of oxygen diffusion into the soil and the low permeability of the clays. However, the very high levels of oxidisable sulfur in the ASS on this site are likely to result in greater rates of acid release over prolonged periods. Any excavation of ASS has the potential to cause environmental harm and must be strictly managed to ameliorate the risks.

Removal of geotechnically unsuitable material, boring for piles and/or the “mucking out ”of the piles in order to install anchors and general bulk and civil excavations are the main activities requiring excavation for the infrastructure project.

2.6.2 Load (Shear Failure and Heaving)

Embankments and fill structures will create loads on the underlying unconsolidated soils. The resultant fill and structural loads placed can result in shear failure in the underlying unconsolidated soils and the consequent development of upward heave of soils adjacent to the load. This is colloquially known as a ‘mud wave’. While most of the soils on the site are competent to tolerate the likely loads, the Holocene facies are likely to be of low strength and, without appropriate design, may fail and shear at some locations and create a ‘mud wave’. The upward heave of soils adjacent to the loads can raise potential ASS into aerobic conditions above the water level and allow the development of sulfuric acid. The extent of shear failure and heaving will not be known until the completion of the detailed geotechnical investigations.

Also associated with load is the subsequent consolidation of unconsolidated soils post filling. The consolidation process involves the expulsion of water from the pore spaces within the soil matrix. The pore water expelled may be acidic if the unconsolidated soil is AASS and its release can contribute to the acidification of the receiving environment and corrode susceptible items of infrastructure.

2.6.3 Surface Disturbances

Construction activities such as clearing, traffic movement and the placement and pick up of materials can cause disturbance to soil surfaces. Such disturbances can allow soils to come into direct contact with the air. Where ASS occur at the surface (i.e., supratidal flats), construction activities causing direct contact with air can potentially increase the rate of oxidation of pyritic materials in the soil and lead to acid generation. On the project site, ASS soils are likely to occur on the surface at elevations below 2mAHD.

2.6.4 Dewatering

Construction activities that require dewatering (i.e., car dumper) may expose *in situ* ASS to oxygen within the cone of groundwater depression that occurs as the water table is lowered. Exposure of *in situ* ASS to oxygen may result in the oxidation of pyrite, which produces sulfuric acid.

2.7 Potential Disturbances

The total area of the development is 6,855ha, with approximately 895ha mapped as being high risk of containing ASS. Disturbances below 5mAHD are proposed for the Wharf and Ship Loading, Conveyor Corridor, Stockyard and Car Dumper facilities. Over 150ha of non-linear disturbance and 1.62km of linear disturbance is proposed below 5mAHD.

2.7.1 Wharf and Ship Loading

The wharf and ship loading area is located in the northern-most portion of the project area. The area will be dredged as part of the Port Hedland Port Authority-led approvals and has an approximate dredge volume of 3,630,000m^3. Pile drivers will be used to drive steel piles into the ground after which a concrete and steel deck, conveyor ship loader and service access road will be constructed to form the wharf.

The proposed invert of each pile is dependent on the depth to basement rock and total dredging depth at each location. Currently, dredging is likely to occur to -19m chart datum (CD) while basement rock exists from approximately -50mCD. The entire disturbance footprint is located within the intertidal zone (mudflats and sand bars) likely to consist of Holocene horizons to depth. Mucking out of unsuitable material for tension piles may disturb up to 1,000m^3.

The PHPA referred the South West Creek Dredging and Reclamation Project, which addressed the dredging campaign and onshore disposal of dredged material associated with the development of South West Creek, to the Environmental Protection Authority (EPA) on 8 November 2010. The South West Creek Dredging and Reclamation Project has been assessed by the EPA at the level of Assessment on Referral Information (ARI), and received ministerial approval on 15 March 2011 (Ministerial Statement 859). All disturbance of ASS during the construction of the wharf and ship loading area shall be shall be undertaken by the PHPA and in accordance with their approvals and management plans.

2.7.2 Conveyor Corridor

A 6.2km long and 40m wide conveyor corridor will be constructed between the stockyard and wharf comprising an indicative surface disturbance area of 26ha and bulk excavation cut volume of 10,000m^3.

The conveyor will be constructed on an 8mAHD high earth causeway over tidal flats and minor creeks and on trestles over major tidal creeks, i.e. Salmon Creek.

Culverts will be installed beneath the earth causeway to minimise tidal flow and flood drainage impacts. Proposed culvert invert levels are approximately 3mAHD. The entire disturbance footprint is located within the middle supratidal zone (mangroves) likely to consist of Holocene horizons overlying residual soil horizons at depth.

2.7.3 Stockyard

The Stockyard is located in the northern portion of the project area with an indicative disturbance area of approximately 190ha, of which approximately 150ha is situated below 5mAHD. Areas expected to be ASS are limited to the northern and northwest portion of the site. This area is located within the upper supratidal zone (consisting of samphire shrubland and cyanobacteria mats) and is likely to consist of shallow Holocene horizons immediately overlying residual soil horizons.

The Stockyard will be built up to approximately 8mAHD, this shall involve the excavation and/or filling over of geotechnical unsuitable material. A bulk earthworks volume of over 1,000,000m^3, is anticipated for this facility.

2.7.4 Car Dumper Facility

The Car Dumper facility will be installed in the southern portion of the project area with an indicative disturbance area of 2ha. The proposed facility has an excavation depth of approximately 12m below ground level (mbgl) and bulk earthwork cut volume of 200,000m^3. The invert depth is below the water table and will require dewatering beyond 12mbgl for an estimated nine months during excavation and construction works.

The Car Dumber facility is situated below 5mAHD but has been classified as nonASS, as the mapped vegetation communities for this area associated with residual soils which have no risk of ASS. In situ ASS may be disturbed if the cone of depression lowers the water table in ASS horizons situated to the north of the site.

3 SAMPLING AND ANALYSIS PLAN

3.1 Aim and Objectives

The aim of the SAP is to determine the following:

- Distribution and magnitude of ASS in areas where disturbance is proposed;
- Baseline groundwater conditions beneath the site and groundwater susceptibility to acidification; and
- Provide adequate information so that appropriate management strategies to minimise the environmental impact during any disturbance of ASS during the infrastructure project is achieved.

The scope of the investigation is based on guidance presented in the *Identification and Investigation of Acid Sulfate Soils and Acidic Landscapes* (DEC, 2009a) for soil and water disturbances for non-linear and linear disturbances.

3.2 Proposed Soil Investigation

Due to the size of the site, it is considered appropriate to undertake a reduced soil investigation that is based on the expected ASS risk. In this regard, risk-based sampling frequencies are proposed for each of the three ASS risk categories as follows:

- **High to moderate** risk of ASS (i.e., coastal communities) shall be sampled at a rate of 2 borehole per 5 hectares for non linear and 1 borehole per 250m linear disturbance (1/5 DEC guidelines);
- **Moderate to low** risk of ASS (i.e., samphire and supratidal shrubland floristic community types) shall be sampled at a rate of 1 borehole per 10 hectares (1/20 DEC guidelines); and
- **NonASS** (i.e., *Acacia sp* and FCT1 and FCT2 the floristic and mosaic community types) shall be sampled at a rate of 1 borehole per 20 hectares (1/40 DEC guidelines).

Table 3 outlines the proposed intrusive soil investigation for ASS at the NWI's Multi-User Iron Ore Export (Landside) Facility. The investigation is based on designs and likely soil disturbances in areas below 5mAHD at the time of reporting. The borehole investigation is anticipated, at least in part, to undertaken in combination with the geotechnical investigation under the direct supervision of an Environmental Consultant.

Table 3: Proposed ASS Investigation

Infra-structure	Likely ASS Areas below 5mAHD	Estimated Area Disturbance	Proposed Boreholes	Maximum Depth [1]	Maximum Number of ASS Samples[2]	Maximum Number of Field Tests[3]	Maximum Number of Quantitative Tests[4]
Wharf and Ship Loading	□igh to moderate risk	Not applicable to the ASS SAP scope. ASS disturbance associated with this area to be managed in accordance with the South West Creek Dredging and Reclamation Project's conditions and management plans.					
Overland Conveyor	High to moderate risk	6.2km	25	3mbgl	300	300	150
Stockyard	High to moderate risk	50ha	20	3mbgl	240	240	120
	Moderate to low risk	40ha	4	2mbgl	32	32	16
	NonASS	70ha	4	2mbgl	32	32	16
Car Dumper	NonASS	2ha	1	13mbgl	26	26	6[5]

In summary, total of 54 sampling locations are proposed for the soil investigation. Indicative soil bore locations are shown in Figure 4. The proposed sampling location frequency equates to less than 15% of the DEC guidelines requirements however based on expected site characteristics, the frequencies

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[1] 2m minimum or 1m below design invert level in Holocene horizons.

2 ASS samples to be collected every 0.25m in Holocene horizons and at 0.5m interval in residual horizons.

3 pHF and pHOX testing.

4 50% of field tests. If residual soils are encountered the borehole will be terminated following the drilling and sampling of an additional 0.5m.

[5] Assumes only residual soils be encountered. Residual soils will be collected and field tested at 0.5m intervals. The six samples which indicate the highest potential of being ASS, shall be selected for CRS suite analysis to confirm their nonASS status.

proposed are considered adequate to characterise the ASS risk of the various geological and geomorphological units on site[6].

3.2.1 Soil Sampling

Where possible, drilling techniques that allow for undisturbed soil sampling (i.e., push probe and vibrocore etc) shall be employed. All boreholes shall be logged using the United Soil Classification system by experienced field personnel.

Soil sampling shall be undertaken as per DEC (2009a) guidelines. ASS samples shall be collected at 0.25m depth intervals until the termination of each borehole. Each soil sample shall be placed in clearly labelled ziplock bags with the air excluded, and placed in an esky with ice bricks while on site before being couriered to a NATA accredited laboratory for testing. Quality control (QC) sampling comprised the collection of duplicate samples at a rate of one per 20 samples.

3.3 Groundwater Investigation

3.3.1 DEC Soil Sampling Guidelines

The DEC 2009b guidelines state that groundwater modelling should be undertaken for all dewatering proposed in ASS risk areas.

Major dewatering is proposed during the construction of the Car Dumper facility. Situated at approximately 5mAHD it is unlikely that ASS horizons exist within the excavation footprint however, ASS horizons are likely in Holocene horizons located in close proximity north of the facility. Groundwater modelling and soil investigation are required to assess if the anticipated cone of depression will lower the water table where *in situ* ASS is identified. A baseline groundwater investigation is also required to assess whether the sites groundwater is or has been affected by the oxidation of sufides and its vulnerability to acidification.

3.3.2 Proposed Groundwater Investigation

No specific ASS groundwater monitoring wells are proposed for construction. The four groundwater monitoring wells installed during the hydrogeological survey shall be sampled and analysed for ASS parameters[7].

6Due to the reduced sampling location frequencies, a conservative approach may be adopted for any ASS management strategies proposed in areas delineated as ASS by the soil investigation. The investigation results may require further sampling prior to excavation and increased rates of validation sampling and testing to ensure that any treatment and management strategies proposed achieved to environmental best practise.

7 Assuming the orientation and construction of the wells are representative of the study area and are suitable for groundwater sampling.

3.3.3 Groundwater Sampling

Groundwater sampling shall be performed by experienced field personnel. Collection of samples shall be in consultation with relevant Australian Standards (Standards Australia, 1998a and 1998b). Prior to collecting groundwater samples the SWL and total depth of well shall be measured using a depth to water indicator (electrical contact gauge) from the top of the casing. The water column and purge volume shall then be calculated. Groundwater shall be collected following a three volume purge is required using a 12 volt submergible pump (or similar). Groundwater samples shall be collected directly into laboratory-supplied containers. Once collected the groundwater samples shall be placed in an esky with ice bricks while on site before being couriered to a NATA accredited laboratory for testing. The containers must be packed appropriately to ensure that there can be no damage to the integrity of the containers during transport.

Quality control (QC) sampling comprised the collection of duplicate samples at a rate of one per 20 samples.

3.4 Laboratory Testing

3.4.1 Soil Testing

The DEC (2009a) guidelines suggest that qualitative field test should be undertaken at 0.25m intervals with either quantitative SPOCAS or CRS suite analysis undertaken at 0.5m intervals.

3.4.1.1 Qualitative Testing

The field pH test is used to get comparative values of field pH field (pH_F) using distilled water and post oxidisation pH (pH_{OX}) using 30% hydrogen peroxide for the soil profile. pH field tests are indicative only and definitely not quantitative. The results of the field pH tests allows for improved selection of samples for quantitative testing.

3.4.1.2 Quantitative Testing

Acid base account approach is to be used for predicting the sulfuric Net Acidity (NA) of the samples. NA shall be calculated using the following formula:

sulfuric NA = Existing Sulfuric Acidity + Residual Sulfuric Acidity + Potential Sulfuric Acidity - Acid Neutralising Capacity (divided by a 1.5 fineness factor)

There are two laboratory suites of analytical methods which provide data for acid base accounting. These are the suspension peroxide oxidation combined acidity and sulfate (SPOCAS) and chromium reducible sulfur (CRS) suites. The suites are set out in the DEC (2009a) guidelines and are widely used in Western Australian ASS investigations and assessments. A detailed overview of these analytical suites and guidance on data interpretation are provided in Ahern et al (2004), and a summary is provided below. The suite chosen shall depend on soil characteristics inferred during the intrusive investigation, with clean sands and soils containing carbonates better quantified by the SPOCAS suite while highly organic soils (i.e., marine muds and clays) better quantified by the CRS suite.

The SPOCAS method provides a standard approach that allows comparison between the acid and sulfur trails. This method provides measurements of pH in a weak potassium chloride suspension (pH_{KCl}), titratable actual acidity (TAA), post oxidation pH using a 30% hydrogen peroxide digest (pH_{OX}), total potential acidity (TPA), peroxide oxidisable sulfur (S_{POS}) and total sulfur acidity (TSA) (which is calculated as TPA-TSA). Where SPOCAS results are assessed, the potential sulfuric acidity is measured by S_{POS}, while the existing sulfuric acidity is measured by TAA. If jarosite is present or pH_{KCl} is less than 4.5, residual acid soluble sulfur (S_{RAS} or S_{NAS}) measurements are also included into NA calculations. The SPOCAS method does not differentiate between organic and inorganic sulfur and can give false positive results, especially in highly organic soils.

The CRS method provides a direct measure of inorganic sulfur using a chromium digest. It is thus a direct measure of oxidisable sulfur and potential sulfuric acidity. The amount and nature of the actual sulfuric acidity for the sample is measured by the TAA and preoxidation sulfur (S_{KCl}) techniques respectively. Again, if jarosite is present or pH_{KCl} is less than 4.5, residual acid soluble sulfur (S_{RAS} or S_{NAS}) concentrations are included into NA calculations.

The acid neutralising capacity (ANC) of soil is defined as its ability to neutralise any acid that is produced. Significant ANC to maintain the pH above 5.5 (and preferably at or above 6.5) is commonly provided by calcium and magnesium carbonates. There are several ways to quantify the ANC of soil with the most common being the back titration method (ANC_{BT}) which is used with the CRS suite. Another method to calculate the ANC is using the reacted calcium (Ca_A) and Magnesium (Mg_A) results from the SPOCAS suite. The excess ANC (ANC_E) test which involves a titration with the HCl extract following the initial peroxide digest in the SPOCAS suite is also commonly used for calculating ANC.

Acid neutralising capacity obtained in the laboratory may not be reflective of the soils in the natural environment (*in situ* carbonates). Prior to testing, the soil samples are crushed. This increases the effective neutralising value (ENV) of carbonates present by removing any inhibiting coatings (iron oxides, gypsum) and increasing the surface area of the *in situ* carbonates. It should be noted that in accordance with Dear SE *et al* (2002), all visible fragments should be removed by hand prior to laboratory testing. Port Headland being a marine/estuarine system, the sediments below the Lowest Astronomical Tide are likely to contain significant amounts of *in situ* ANC (present as fine shell and exo skeletons). However these soils cannot be assumed to be self neutralising (i.e., ANC>NA) until the particle size distribution and reactivity is assessed. In order to offset the limitations of the laboratory ANC results and to account for particle size and reactivity of the *in situ* carbonates, all measured ANC concentrations have been divided by a Fineness Factor (FF) of 1.5.

In addition to the determination of sulfides, selected samples will be analysed for priority metals to assist in determining risk of metal mobilisation to groundwater and suitable options for material disposal if required.

3.4.2 Groundwater Testing

The laboratory tests associated with the baseline groundwater investigation for the 4 bores in accordance with the DEC ASS groundwater suite which includes:

- Water quality: pH, conductivity, total dissolved solids, chloride, sulfate, total acidity, total alkalinity;
- Nutrients: ammoniacal nitrogen, total nitrogen, filterable reactive phosphorous and total phosphorous;
- Dissolved Metals: aluminium, arsenic, cadmium, chromium, copper, iron, manganese, nickel, selenium, and zinc; and
- Total Metals: aluminium and iron.

3.5 Result Analysis

3.5.1 Soil Analysis

The results of soil field tests are considered to give an indication of samples which may represent ASS material. The DEC recommend that soils which have low pH values (pH_F of less than 4, or pH_{FOX} of less than 3), or which exhibit a significant change in pH after oxidation (as pH_F-pH_{FOX}) may indicate a soil with ASS characteristics (DEC, 2009b).

The DEC action criteria (DEC, 2009c) for preparation of an ASS Management Plan adopted for this site is a sulfuric NA of **0.03%S** or (equivalently) 18molH^+/tonne acidity or greater based on the anticipated volume of soil proposed to be disturbed being greater than 1,000 tonnes.

3.5.2 Groundwater Analysis

3.5.2.1 ASS Indicators

The DEC (2009b) specify that the following chemical indicators may indicate that groundwater is being affected by the oxidation of sulfides:

- a chloride/sulfate ratio of greater than 0.5;
- a pH of less than 5; and
- a soluble aluminium concentration of greater than 1mg/L.

In addition, the DEC (2009b) have developed indicative guidelines as to the buffering capacity of groundwater, based on a review of its alkalinity and pH. The five alkalinity categories are summarised below:

- very high alkalinity: alkalinity above 180mg/L, pH above 6.5, adequate to maintain acceptable pH;
- high alkalinity: alkalinity 60-80mg/L, pH above 6.0, adequate to maintain acceptable pH;
- moderate alkalinity: alkalinity 30-60mg/L, pH 5.5-7.5, inadequate to maintain stable, acceptable pH in areas vulnerable to acidification;
- low alkalinity: alkalinity 10-30mg/L, pH 5.0-6.0, inadequate to maintain stable, acceptable pH;
- very low alkalinity: alkalinity below 10mg/L, pH below 6.0, unacceptable pH level under all circumstances.

During dewatering monitoring programs, a target of 40mg/L for acidity is used, and so that value shall be considered as an indication of groundwater that may require management.

3.5.2.2 Irrigation Guidelines

To assess if the dewatering effluent was adequate for re-infiltrating or use as a dust suppression, monitoring results shall be compared with the Short Term Irrigation (STI) guidelines specified in the *Australian and New Zealand Guidelines for Fresh and Marine Water Quality* (ANZECC & ARMCANZ, 2000). Short term irrigation trigger values are defined by ANZECC & ARMCANZ (2000b) as follows:

The short-term trigger value is the maximum concentration (mg/L) of contaminant in the irrigation water which can be tolerated for a shorter period of time (20 years) assuming the same maximum annual irrigation loading to soil as for long term trigger value.

The loading assumptions described in Volume 3, Section 9.2.5 of ANZECC & ARMCANZ (2000b) are that the annual application of irrigation water is 1,000mm, inorganic contaminants are retained in the top 150mm of the soil profile; irrigation will continue on an annual basis for a maximum of 100 years; and soil bulk density is 1,300kg/m^3. It is considered that the assumptions used to derive the STI values are appropriate for the assessment of the reuse of groundwater onsite, although they are inherently conservative.

3.5.2.3 Ecological Guidelines

Guidelines for the protection of ecological receptors are provided in *Australian and New Zealand Guidelines for Fresh and Marine Water Quality* (ANZECC and ARMCANZ, 2000b), and adopted by DEC in *Assessment Levels for Soil, Sediment and Water* (DoE, 2003). In view of the adjacent and down-gradient estuarine areas, the guidelines for estuarine waters are considered appropriate assessment criteria for the project.

3.6 Quality Assurance

All laboratories commissioned must be accredited by NATA, for the analysis required. The internal laboratory quality control (QC) report shall included a summary of the laboratory method blank analysis, together with matrix spike results, which provide in-house quality control information. Blank results should be less than the LOR, and spike results should generally be in the range of 70 percent to 130 percent of the known spike concentration.

Laboratory QC sampling shall comprise of the collection of duplicate samples at a rate of one per 20 samples (DEC, 2009a). The precision measurement shall be determined using the relative percent difference (RPD) between the duplicate sample results. The RPD is calculated as follows: [(X1 - X2) x 100] / [(X1 + X2)/2].

Generally, it is recommended that RPD is less than 30-50 percent (Standards Australia, 2005). For the purposes of this assessment, duplicate data with concentrations above 10 times the laboratory limit of reporting (LOR) should have a RPD less than 30 percent, and duplicate data with concentrations below 10 times the LOR should have a RPD less than 50%. For example, the arsenic LOR is 5mg/kg, so duplicate data with concentrations above 50mg/kg should have a RPD below 30% and data with concentrations less than 50mg/kg should have a RPD less than 50%.

Where RPDs are outside the acceptable range, sampling procedures, laboratory analytical methods and laboratory results shall be investigated.

3.7 Reporting

A report shall be prepared detailing the findings of the soil and groundwater investigations. Reporting shall include:

Comparison of soil and groundwater analysis results with applicable assessment guidelines and trigger criteria.

Interpretation of soil and groundwater results to determine potential risks from planned works at the site.

Should ASS be identified an ASS management plan shall be prepared for inclusion in the Construction Environmental Management Plan for the project. The strategies outlined in the management plan shall be in accordance with the DEC (2009b) Treatment and Management of Soils and Water in Acid Sulfate Soil Landscapes.

4 REFERENCES

ANZECC & ARMCANZ (2000a). *National Strategy for the Management of Coastal Acid Sulphate Soils.* Australian and New Zealand Environment Conservation Council and Agriculture and Resources Management Council of Australia and New Zealand, Canberra ACT.

ANZECC and ARMCANZ (2000) *Australian and New Zealand Guidelines for Fresh and Marine Water Quality. Volume 1 The Guidelines (Chapters 1 to 7). National Water Quality Management Strategy paper No 4*, Australian and New Zealand Conservation Council (ANZECC) and Agriculture and Resource Management Council of Australia and New Zealand (ARMCANZ), Canberra, ACT.

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DEC (2009a) *Acid Sulfate Soils Guideline Series: Identification and Investigation of Acid Sulphate Soils and Acidic Landscapes*. Department of Environment and Conservation (DEC), Perth, WA.

DEC (2009b) *Acid Sulfate Soils Guideline Series: Draft Treatment and Management of Soils and Water in Acid Sulphate Soil Landscapes.* Department of Environment and Conservation (DEC), Perth, WA.

DoE (2003) *Assessment Levels for Soil, Sediment and Water.* Department of Environment (DoE), Perth, WA.

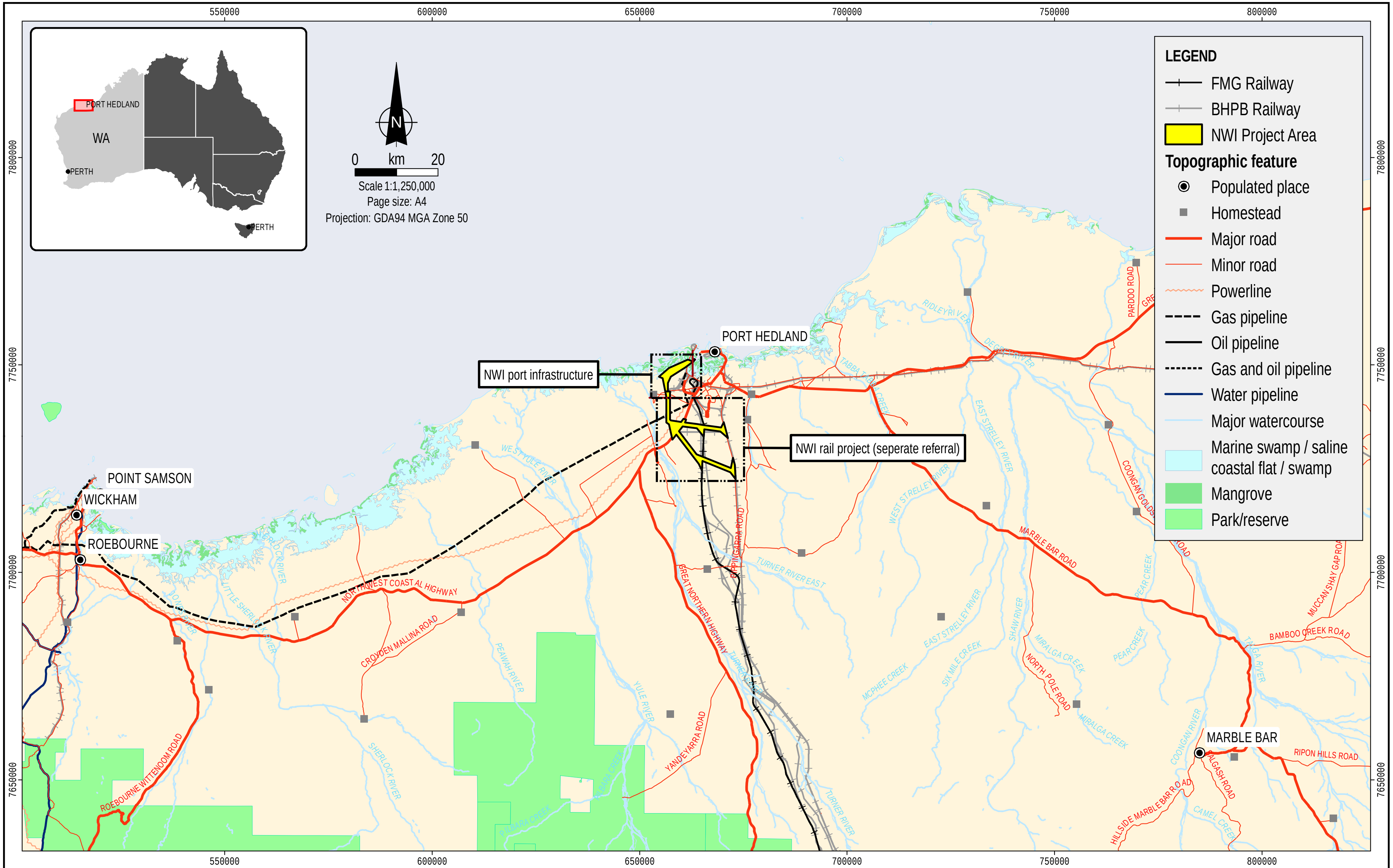
Standards Australia (1997) *Guide to the Sampling and Investigation of Potentially Contaminated Soil Part 1: Non-volatile and semivolatile compounds*. AS 4482.1-1997. Standards Australia, Homebush, NSW.

Standards Australia (1998a) *Water Quality Sampling: Part 1 Guidance on Design of Sampling Programs, Sampling Techniques and the Preservation and Handling of Samples*. *AS 5667.1:1998*. Standards Australia, Homebush, NSW.

Standards Australia (1998b) *Water Quality Sampling: Part 11 Guidance on Sampling of Groundwaters. AS 5667.11-:1998.* Standards Australia, Homebush, NSW.

Figures

Multi User Iron Ore Export (Landside) Facility - Port Headland
Sampling and Analysis Plan - Acid Sulfate Soils



Source:
Topographic data from GEODATA TOPO 250K (optimum scale 1:250,000)
NWI study area (updated by Coffey 07.01.2011) and railways from SKM

coffey environments

Date: 27.07.2011
MXD: 2319_SAPASS_GIS003_v0_2
File Name: 2319_SAPASS_F001_GIS

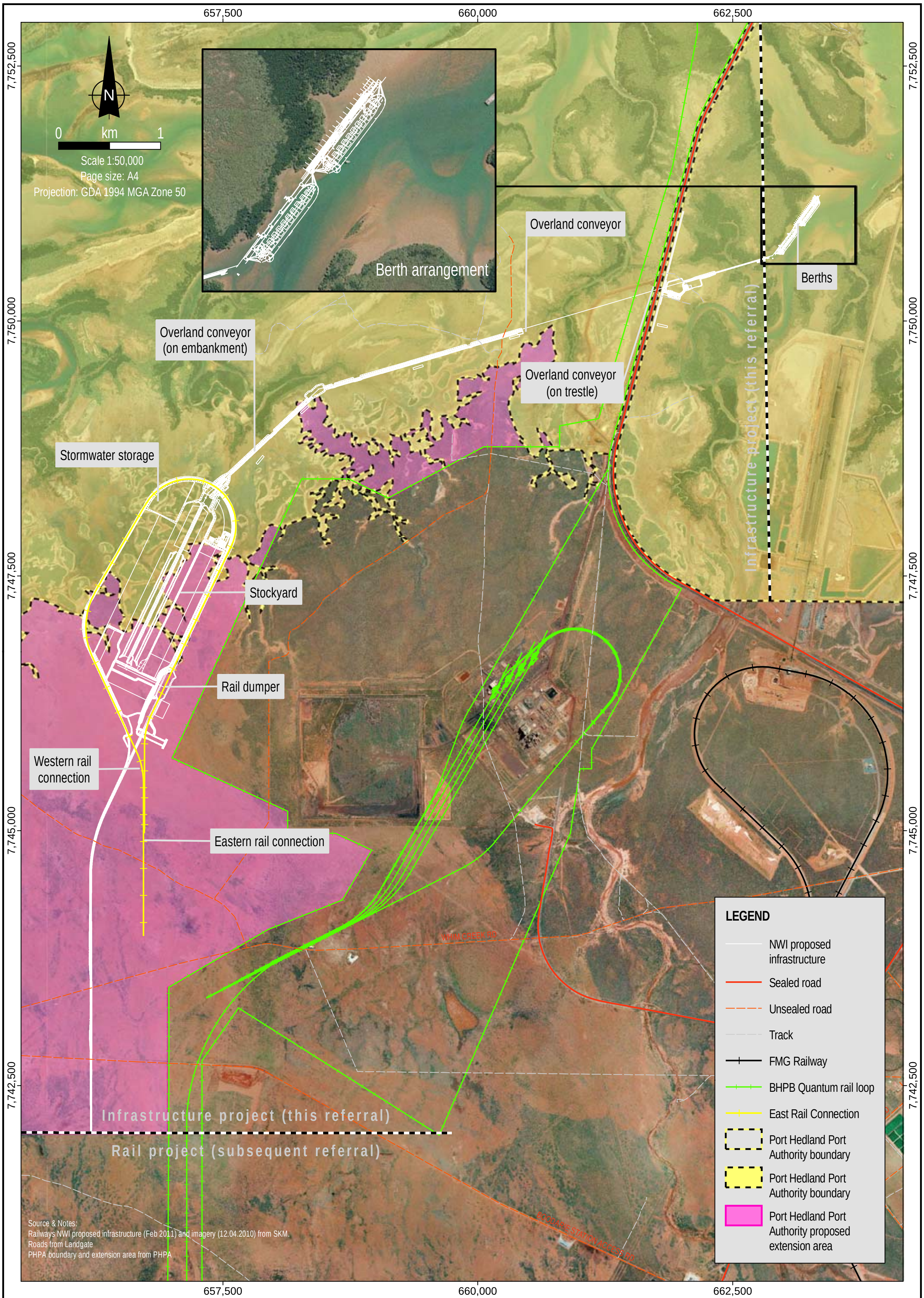
North West Infrastructure

Sampling and Analysis Plan - Acid Sulfate Soils

North West Infrastructure

Regional Location

Figure No: **1**



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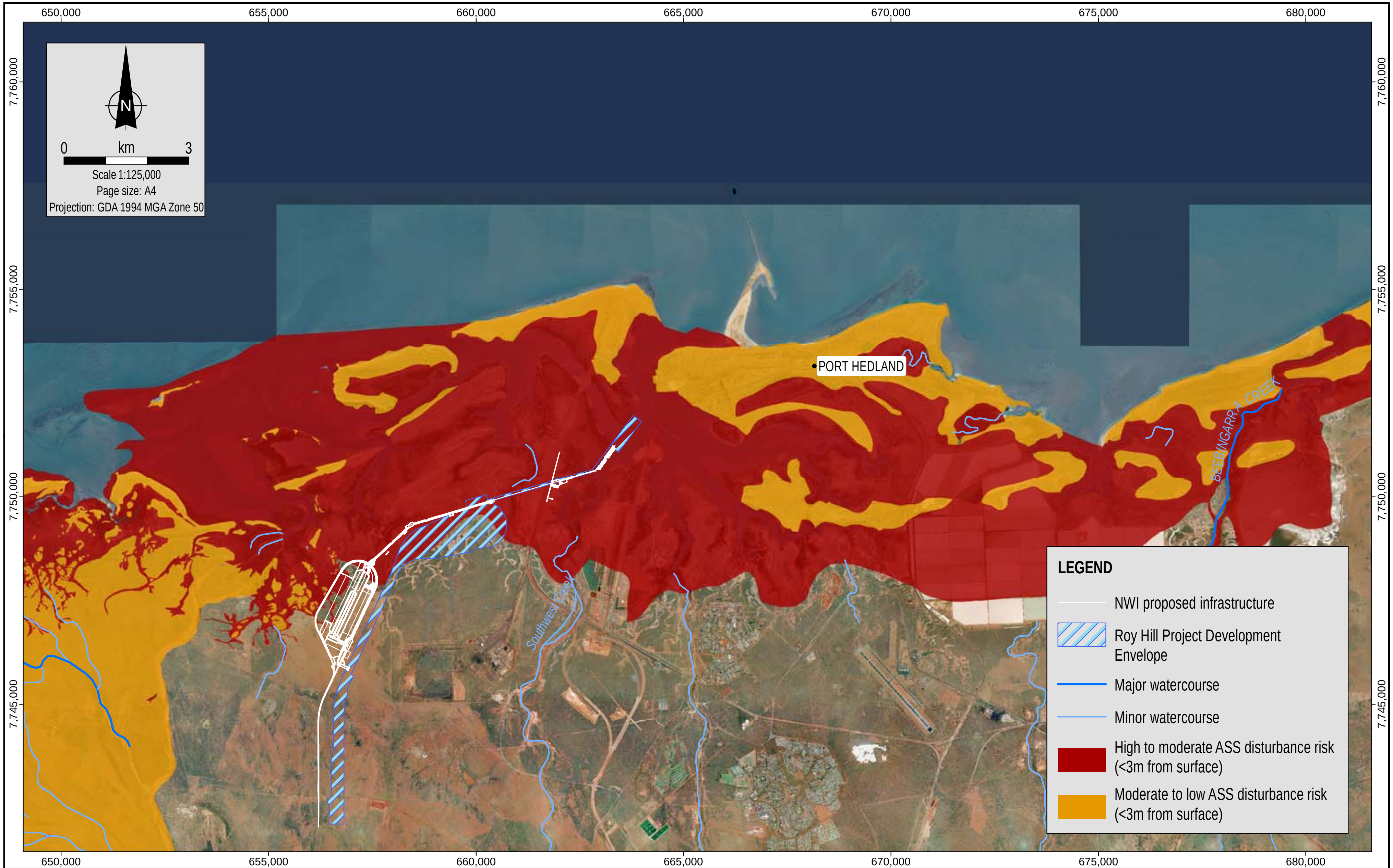
North West Infrastructure

Sampling and Analysis Plan - Acid Sulfate Soils

North West Infrastructure

Proposed Project - Boodarie Industrial Precinct

Figure No: 2



Source:
Imagery from Landgate
NWI proposed infrastructure from SKM
Watercourses from GEODATA TOPO 250K (optimum scale 1:250,000)
Acid Sulfate Soil data from DEC
Roy Hill from Roy Hill 1 Iron Ore Project Port Infrastructure Report and Recommendation of the EPA, Report 1377, December 2010.

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Date: 27.07.2011
MXD: 2319_SAPASS_GIS005_v0_2
File Name: 2319_SAPASS_F003_GIS

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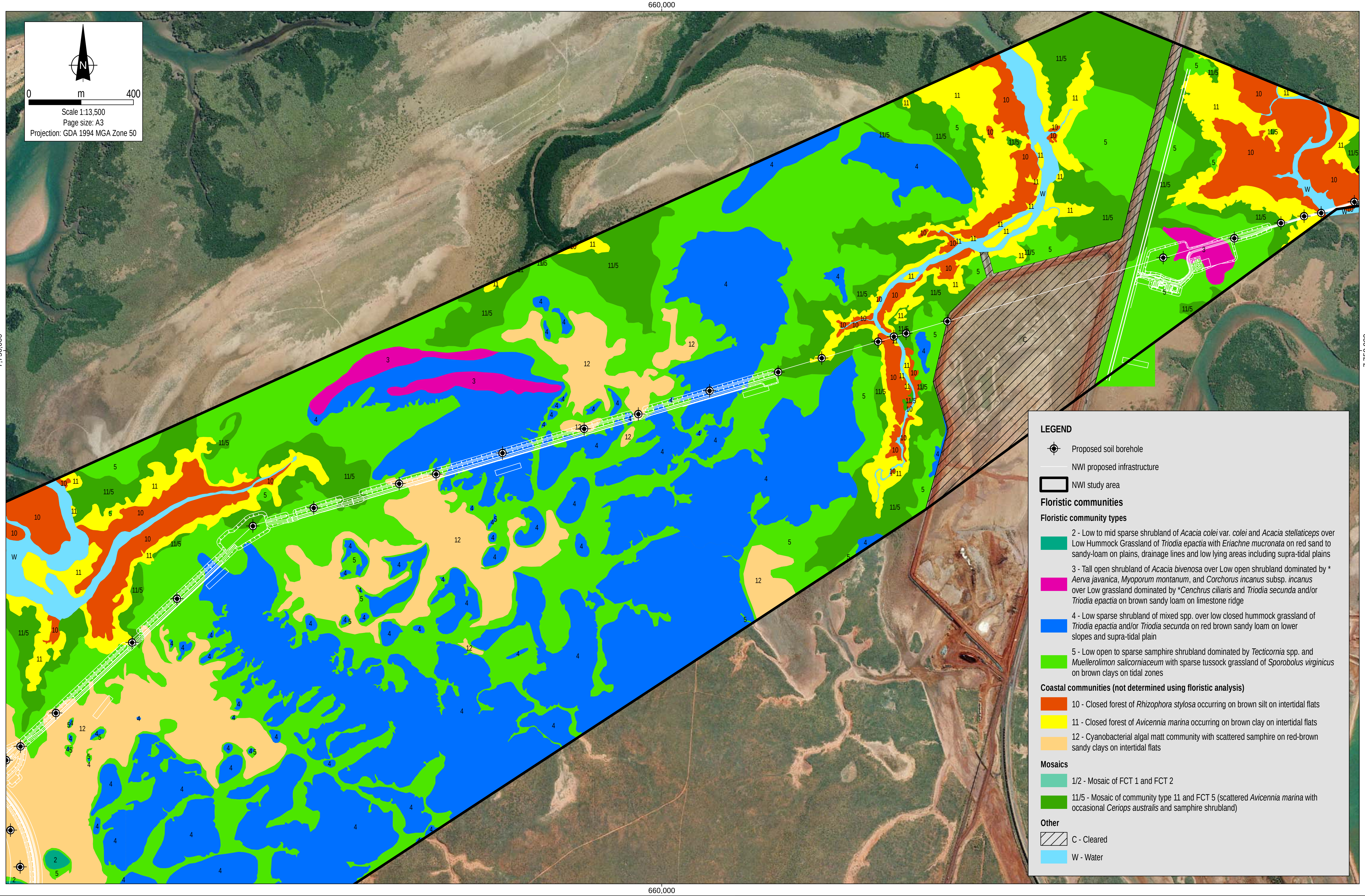
Sampling and Analysis Plan - Acid Sulfate Soils

North West Infrastructure

Acid Sulfate Soils Risk Mapping DEC

Figure No: 3



Source & Notes:
NWI project area (ammended by Coffey 07.01.2011) and imagery (12.04.2010) from SKM.
Vegetation communities and prority flora species from Woodman Environmental
Proposed soil boreholes digitised by Coffey Environments

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Date: 26.07.2011
MXT: 2319_SAPASS_GIS001_v0_2
File Name: 2319_SAPASS_F004a_GIS

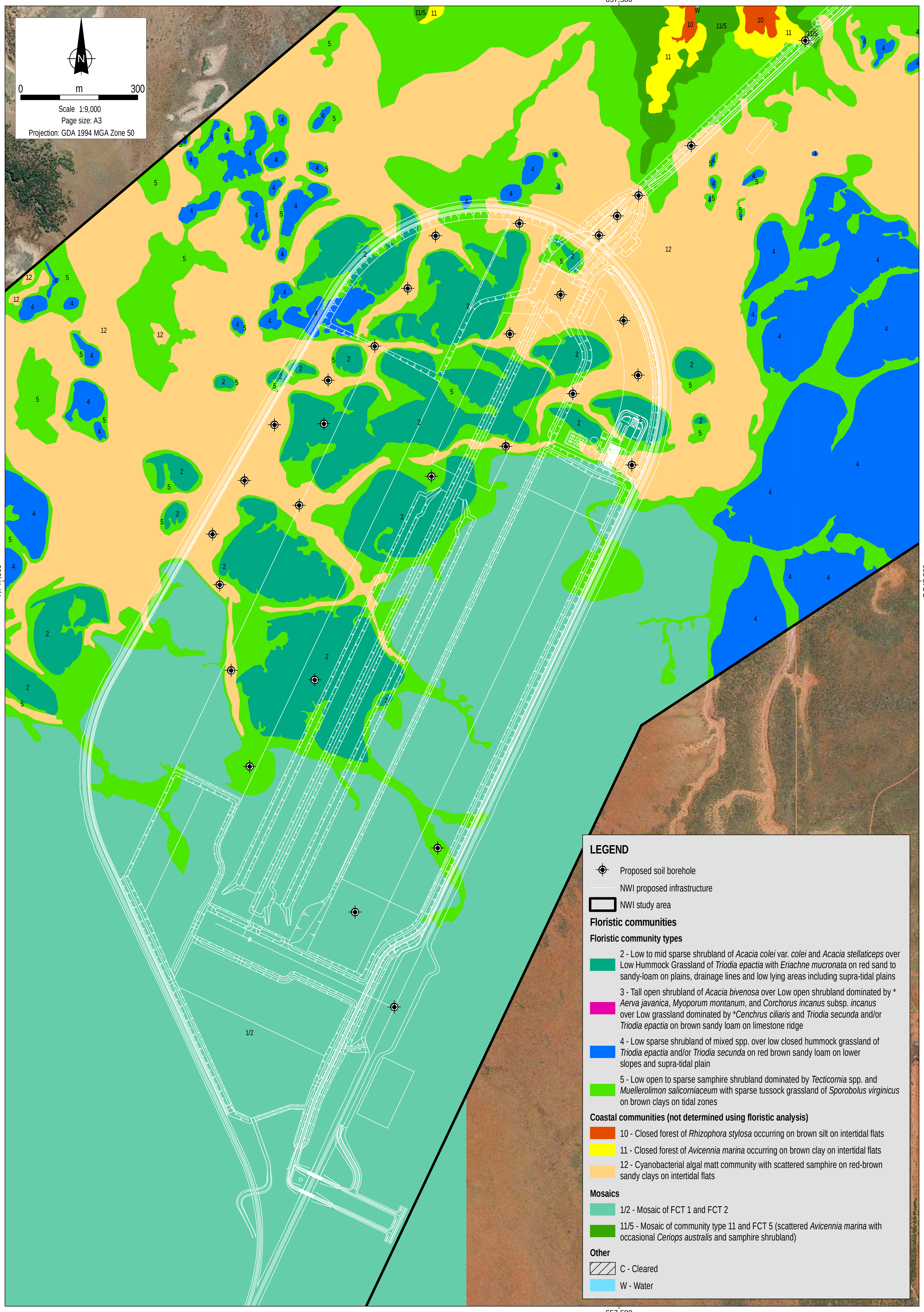
North West Infrastructure

Sampling and Analysis Plan - Acid Sulfate Soils

North West Infrastructure

Floristic vegetation types and proposed soil boreholes

Figure No: 4a



Source & Notes:
NWI project area (ammended by Coffey 07.01.2011) and imagery (12.04.2010) from SKM.
Vegetation communities and prority fora species from Woodman Environmental

coffey environments

Date:	26.07.2011
MXT:	2319 SAPASS GIS002 v0 2
File Name:	2319 SAPASS F004b GIS

North West Infrastructure
Sampling and Analysis Plan - Acid Sulfate Soils

North West Infrastructure

Floristic vegetation types and proposed soil boreholes

Figure No: 4b