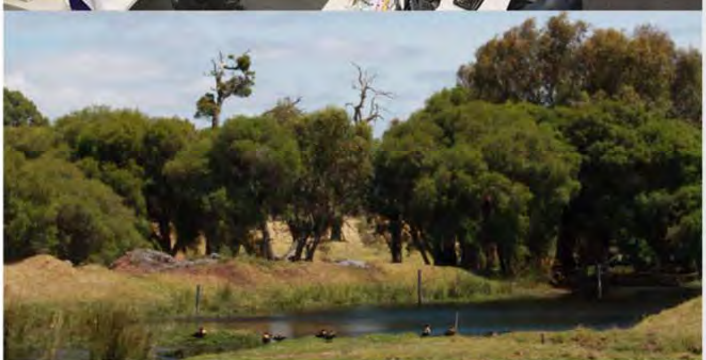
NorthLinkWA

Perth-Darwin National Highway






Preliminary Acid Sulfate Soil Investigation

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Prepared by:

Coffey Environments Australia Pty Ltd
Suite 2, 53 Burswood Road
Burswood WA 6100 Australia
t: +61 8 9269 6200 f: +61 8 9269 6299

ABN: 65 140 765 902
coffey.com

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ABBREVIATIONS AND UNITS

Term	Definition
%S	percentage sulfur
AASS	actual acid sulfate soil
AHD	Australian height datum
ALS	ALS Limited
ASS	acid sulfate soil
CC	conservation category
COC	chain of custody
Coffey	Coffey Environments Australia Pty Ltd
CRS	chromium reducible sulfur
CS	contaminated sites
DEC	Department of Environment and Conservation
DER	Department of Environment Regulation
DOTE	Department of the Environment
DOW	Department of Water
DPAW	Department of Parks and Wildlife
GHD	GHD Pty Ltd
GIS	geographic information system
Golder	Golder Associates
ha	hectare
ID	identification
km	kilometre
m	metre
mbgl	metres below ground level
mm	millimetre
MRWA	Main Roads Western Australia
MU	multiple use
NA	net acidity
PASS	potential acid sulfate soil
PCB	polychlorinated biphenyl

Term	Definition
PDNH	Perth–Darwin National Highway
QA	quality assurance
QC	quality control
RE	resource enhancement
RL	reduced level
SPOCAS	suspension peroxide oxidised combined acidity sulfur
SPOS	sulfidic peroxide oxidisable sulfur
TAA	titratable actual acidity
TGS	Tonkin Grade Separations
TPA	titratable peroxide acidity
TSA	titratable sulfur acidity
UWPCA	underground water pollution control area
WA	Western Australia
WC	Water Corporation

1 INTRODUCTION

1.1 Background

NorthLink WA has been commissioned by Main Roads Western Australia (MRWA) to undertake a preliminary investigation into the potential presence of acid sulfate soils (ASS) that may be encountered as part of the proposed Perth–Darwin National Highway (PDNH).

This report has been produced to inform the scoping for a detailed intrusive ASS investigation. Through consideration of the project scope and ASS risk profile of the project area, the preliminary ASS investigation will assess whether a risk-based approach may be appropriate in investigating and managing potential ASS (PASS) that may exist. The preliminary ASS investigation is designed to satisfy 'Step 1: Desktop Assessment and Site Inspection' of the Department of Environment and Conservation (DEC) (2013) Identification and Investigation of Acid Sulfate Soils and Acidic Landscapes.

1.2 Project overview

NorthLink WA comprises two constituent projects:

- PDNH – a new 37 km highway link between the junction of Reid Highway/Tonkin Highway and Great Northern Highway/Brand Highway at Muchea.
- Tonkin Grade Separations (TGS) – the grade separation of the intersections of Tonkin Highway with Collier Road, Morley Drive and Benara Road, together with associated works.

The PDNH is located within the City of Swan and the Shire of Chittering and extends from the Reid Highway and Tonkin Highway interchange in the City of Swan, north for 37 km to the Great Northern Highway and Brand Highway interchange in the Shire of Chittering. The PDNH passes through the suburbs of Malaga, Bennett Springs, Ballajura, Cullacabardee, Whiteman, Ellenbrook, Bullsbrook and Muchea. The location of the proposed alignment is presented in Figure 1.

1.3 Objectives

With a view towards supporting the client's project assessment under the *Environmental Protection Act 1986*, the objectives of the preliminary ASS investigation are as follows:

- Develop a preliminary understanding of the potential existence of ASS within the project area.
- Assess how the proposed development may interact with the presence of ASS and what risk this may pose to the environment and human health.
- With consideration to the outcomes of the preliminary ASS investigation, provide recommendations for intrusive investigations to further investigate potential risks to the environment and human health.

1.4 Scope of work

In order to meet the objectives outlined above, the following activities were undertaken:

- Review of the Department of Environment Regulation (DER) ASS Risk Map online database.
- Review of information supplied regarding the proposed development, in particular any ground or groundwater disturbance elements.
- Use of Geographic Information Systems (GIS) to identify any inferred ASS areas within conceptual design coordinates.
- Site inspection by qualified personnel.
- Targeted preliminary soil sampling at six inferred higher risk area locations to gain a preliminary understanding of site geological conditions.
- Collation and assessment of this information in relation to potential ASS risk.
- Preparation of a report describing the above findings.

The desktop assessment and site inspection were undertaken in accordance with guidelines presented in Identification and Investigation of Acid Sulfate Soils and Acidic Landscapes (DEC, 2013).

2 CONSTRUCTION METHODOLOGY

The NorthLink project is broken down into the PDNH and Tonkin Grade Separations constituents. The PDNH involves the construction of a 37 km link connecting Tonkin Highway to Brand Highway and Great Northern Highway at Muchea.

The Tonkin Grade Separations will involve the widening of Tonkin Highway to six lanes and grade separations at the intersections of Tonkin Highway with Collier Road, Morley Drive and Benara Road. It is understood that the first stage project scope includes:

- A single point interchange with Collier Road grade separated over Tonkin Highway.
- A roundabout at the intersection with Morley Drive.
- A bridge taking Benara Road over Tonkin Highway with no connections (flyover).

At this stage Coffey does not have any confirmed details of proposed excavation areas, depths or methods. It is expected that further details will be confirmed following the finalisation of the design stage and appointment of contractors.

2.1 Earthworks

Based on the information supplied, it is expected that the majority of earthworks will involve the importation of fill material to raise the proposed road above existing ground level. This is consistent with existing major roads such as Tonkin and Great Northern Highways, which run through similar topographical conditions.

The depth of excavations across the alignment have not been confirmed, though is expected to be generally shallow <1 metres below ground level (mbgl), if required, for the majority of the alignment. The creation of borrow/cut areas are likely in order to decrease the volume of fill importation required. Indicative information provided by the client suggests that borrow areas could be as deep as 4 mbgl. Other deep excavations may be required during the installation of foundations, ground anchors and approach embankments for grade separations and any bridges/water crossings.

2.1.1 Topsoil stripping

For the purpose of this project, topsoil is defined as material within the top 300 mm of the soil profile containing vegetative matter. Due to the highly organic nature of topsoil in low-lying areas, the geotechnical suitability of this material may be uncertain. Stripping of topsoil and reuse for rehabilitation purposes may be required at certain locations.

2.1.2 Clearing

Topsoil may be disturbed when clearing machinery traverse the site and during clearing, especially where root extraction or grading is undertaken. Although the likelihood of PASS presence in these surficial soils may be relatively low, there is a risk of prolonged exposure of disturbed topsoil to the air during vegetation clearance.

2.2 Dewatering

The scale of dewatering required relates to the depth of excavation and local groundwater levels. It is currently unknown if and to what extent dewatering will be required during the construction program.

Locations which are most likely to require dewatering are associated with deeper excavations e.g. foundations for bridges at grade separations.

As a number of seasonal watercourse crossings are likely to be required, the installation of culverts and/or bridges may require dewatering to facilitate their construction/installation. The monitoring of water quality in nearby wetlands should also be considered to ensure they are not impacted.

2.2.1 Licences

If significant dewatering is required, appropriate Licences such as a Section 5C Licence to Take Groundwater and Section 26D Licence to Construct or Alter a Groundwater Well under the *Rights in Water and Irrigation Act 1914* should be obtained. The construction and use of groundwater abstraction bores for construction water may also require the aforementioned licenses. If dewatering and/or abstraction requirements are minimal in volume and duration, an exemption may be requested.

3 ACID SULFATE SOILS

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 Reduced Level (RL) 5 m above 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 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 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 following:

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

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

3.1 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.

3.1.1 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 dissolving metals into toxic forms (generally pH <3.5).

3.1.2 Habitat degradation

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

3.1.3 Poor plant productivity

ASS has the 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.
- Stunting of roots producing water stress.

Under strongly acid conditions the activity of important soil micro-organisms is reduced, in particular fungi, bacteria and actinomycetes. Nutrient availability is also reduced for the following: nitrogen, phosphorous, potassium, sulfur, calcium, magnesium, boron, copper, zinc and molybdenum. Nutrient availability of aluminium and iron could be increased to potentially toxic levels.

In addition to the potential impacts identified above, long-term impacts may result in the dying off of some species and colonisation by species more resistant to the acid conditions. If surface water remains acidic over time, nutrient cycling will be reduced because of the reduced activity of soil micro-organisms which are normally concentrated in the topsoil.

3.2 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 ASS have contributed to the failure of bridges, culverts and other structures.

3.3 Human health

The location of ASS often coincides with high population density areas along coastlines and associated with fertile, alluvial soils. While the impacts of ASS on the environment are often the focus on management efforts, the connection to human health is not always given as detailed consideration (Powel & Ahern, 1999).

The disturbance and oxidation of ASS are widely recognized as having the potential to directly impact soil, water and biota. Negative impacts on the environment may have implications to human health, including the following:

- Increased mobility of potentially toxic elements in water used for drinking, irrigation, aquaculture or recreation.
- Acid dust mobilised during ploughing and construction activities may cause dermatitis and eye irritation.
- Acidified coastal wetlands can provide predator-free breeding grounds for mosquitos that transmit arboviruses e.g. Ross River.
- Reduced crop yields.

4 ENVIRONMENTAL SETTING

4.1 Land use and vegetation

Heddle et al. (1980) have described and mapped vegetation complexes of the Darling System at a broad floristic scale of 1:250,000 (as recognised by Diels, 1906; and Gardner, 1942). The vegetation complex mapping is based on data collected from literature, ground surveys, road traverses and aerial photographs and is related to the landforms, soils and climatic conditions.

The TGS alignment is generally within an easement consisting of verges which run alongside the existing Tonkin Highway. Adjacent land use is predominantly commercial/industrial south of Broun Avenue, then changing to low density residential dwellings to the northern extent of the TGS.

The southern extent of the PDNH predominantly overlies cleared, vacant land with occasional industrial, residential land use and bushlands or wetlands. South of Hepburn Avenue, adjacent land use is mainly low density residential with occasional industrial/commercial facilities. North of Hepburn Avenue, the PDNH alignment traverses privately owned farm land/rural residential, bushland, State Government and Federal land extending beyond the Metropolitan boundary.

4.2 Environmental receptors

4.2.1 Wetlands

Wetlands on the Swan Coastal Plain have been classified under the Department of Parks and Wildlife (DPAW) *Geomorphic Wetlands Database* based on the characteristics of landform and water permanence. DPAW has assigned wetland management categories based on their ecological, hydrological and geomorphological significance, taking into account the degree of disturbance that had occurred. The three Wetland Management Categories on the Swan Coastal Plain can be summarised as follows:

- Conservation Category (CC) – wetlands that support a high level of ecological attributes and functions (generally having intact vegetation and natural hydrological processes), or that have a reasonable level of functionality and are representative of wetland types that are rare or poorly protected.
- Resource Enhancement (RE) – wetlands that have been modified (degraded) but still support substantial ecological attributes (wetland dependant vegetation covering more than 10%) and functions (hydrological properties that support wetland dependent vegetation and associated fauna), and have some potential to be restored to the Conservation management category. Typically, such wetlands still support some elements of the original native vegetation and hydrological function.
- Multiple Use (MU) – wetlands that are assessed as possessing few remaining ecological attributes and functions. While such wetlands can still play an important role in regional or landscape ecosystem management, including water management, they are considered to have low intrinsic ecological value. Typically, they have very little or no native vegetation remaining (less than 10%).

According to DPAW's Geomorphic Wetlands Swan Coastal Plain Dataset, approximately 31 wetlands occur within or immediately adjacent to the study area and seven CC and RE wetlands occur in close proximity to the study area (Figure 2). The list of wetlands located within, and in proximity to the study area is provided in Appendix A.

4.2.2 Bush Forever sites

The Bush Forever Strategy is a ten year strategic plan which formally commenced in 2000 to protect approximately 51,200 ha of regionally significant bushland within approximately 290 Bush Forever Sites, representing a target of at least 10% of each of the original 26 vegetation complexes of the Swan Coastal Plain (Government of Western Australia, 2000). There are 13 Bush Forever sites located within 1 km of the study area. Flora and fauna studies are currently underway to assess the environmental significance of bushland and any potential impacts of the project.

4.3 Topography and hydrology

The PDNH is generally of low relief or gently undulating topography, generally between 30 to 60 m AHD, gently increasing in elevation from south to north. Surface water is expected to follow the natural and created features of the landscape, with the majority of water likely to infiltrate surficial sandy soils with surface and subsurface flows towards low lying features e.g. wetlands or streams.

The majority of the TGS has been highly modified by roads and commercial infrastructure, typically between 20 to 30 m AHD. Surface water across the TGS is expected to flow into stormwater drainage systems and drainage sumps. Infiltration is expected to occur next to roads which have been graded towards grass verges. Elevations across the alignment and surrounding area are presented in Figure 3.

4.4 Geology

The study area passes through gently undulating terrain associated with the Bassendean Dunes and Pinjarra Plain. Small sections of the study area cross narrow alluvial streams and low-lying marshlands generally associated with interdunal swales within the Bassendean Dunes (GHD, 2013). Geological mapping from the Geological Survey of Western Australia (Gozzard, 1986) is presented in Figure 4.

Soils across the PDNH are typically expected to consist of Bassendean Sands overlying Guildford Clays. Bassendean Sands typically consist of white to grey quartz sand, with minor fines content and negligible clay content. They are recognized by the DER as being of particular concern regarding ASS, as they are devoid of carbonate minerals and may contain highly reactive pyrite. Low lying areas are likely to accumulate alluvial sediments with varying organic content and may contain peaty material.

The TGS portion shares a similar geology, predominantly comprising of Bassendean Sands from the Bassendean and Southern River sandplains. The Southern River sandplains consist of low sand dunes, with iron and humus podzols, peats and clays occurring in low lying areas.

4.5 Hydrogeology

The study area is a part of the Gnangara Mound, a major shallow groundwater resource which provides a significant portion of drinking water supply for the Perth region. The Gnangara groundwater system draws water from the unconfined superficial aquifer as well as underlying semi-confined and confined Mesosoic aquifers (Davidson, 1995). The majority of the PDNH lies within the Gnangara Underground Water Pollution Control Area (UWPCA) and have been classified as Priority 1 control areas. As such, these areas are subject to the requirements of a groundwater protection policy to ensure the long-term protection of groundwater used for public drinking water supplies (Water Corporation, 2007).

Superficial aquifers typically comprise Bassendean Sands overlying Guildford Formation and Ascot Formation. The Mesozoic aquifers are predominantly limestone, sandstones and sands in varying proportions. The Mesozoic aquifers are often confined but hydraulically connected to the superficial aquifers.

Groundwater flows radially from the crest of the Gnangara mound between Muchea and Lake Pinjar, eventually discharging into the Indian Ocean, Swan River and Ellen Brook. In a localized context, groundwater flow is expected to conform to significant topographical features, flowing towards interspersed surface water bodies and low lying areas, with a general influence from the regional flownet. Depth to groundwater is largely related to topography, with the shallowest depth to groundwater found in the low lying areas.

Groundwater across the PDNH alignment is expected to be relatively shallow, frequently shallower than 2 mbgl. The occurrence of a perched groundwater table may also occur where underlying clays, peat or iron-cemented sands create a confining layer. Field data indicates that groundwater was encountered as shallow as 0.15 mbgl near the Brand Highway Link Road (Golder, 2014).

Based on information from the Perth Groundwater Atlas (DOW, 2014), depth to groundwater across the TGS is mostly around 10 mbgl when excluding unnatural topography, such as existing grade separations. However, field data suggests that groundwater may be significantly shallower, having been encountered in groundwater wells at approximately 1.4 mbgl near the Benara Road interchange and 2.3 mbgl near Reid Highway (Golder, 2014). The shallowest depth to groundwater along the TGS is towards the south, towards the Swan River and the north where the alignment traverses interdunal depressions.

4.6 ASS risk mapping

Based on the published mapping (DEC, 2010) approximately 53 ha of the alignment is described as Class 1 (high to moderate risk of ASS within 3 m of the natural soil), while approximately 720 ha is considered Class 2 (moderate to low risk of ASS). The DEC risk map for the entire project area is presented in Figure 5, and indicates the remainder of the project has no known ASS risk (approximately 287 ha).

The risk mapping for ASS is considered consistent with the published geological mapping, as ASS is generally associated with areas where organic material has accumulated in a saturated, anoxic environment, allowing the formation of sulfide minerals which can subsequently release acidity when oxidised.

5 ENVIRONMENTAL RISK ASSESSMENT

It is recognised that environmental conditions across the length of the alignment vary greatly. To create a thorough, yet efficient investigation program it is proposed that a targeted sampling program should be undertaken based primarily on the environmental risk posed by acid generation risk and the proximity to sensitive receptors. The following risk assessment has been developed with reference to the Water Corporation Acid Sulfate Soil and Dewatering Management Strategy (Parsons Brinkerhoff, 2007) and principles of the DEC (2013) Identification and Investigation of Acid Sulfate Soils and Acidic Landscapes.

The Water Corporation Management Strategy is considered a useful guidance document for preliminary investigations, as it provides a risk based approach to the assessment of substantial linear projects. However, the DEC Guidelines outline the detailed investigation and management requirements to meet legislative approval.

5.1 Project risk

Determining an appropriate level of assessment requires a clear understanding of both the project scope and environmental setting. As the project design and construction methodology are still in early stages, the following assumptions have been made to determine the overall project risk:

- Project duration is greater than three months.
- Volume of excavation is greater than 1,000 m^3.
- Depth of excavation may be greater than 10 mbgl due to the expected drilling depths for pile foundations at bridges and other structures.

Based on the aforementioned assumptions and the known environmental conditions across the alignment, including; distance to sensitive receptors, sensitivity of environmental receptors and beneficial groundwater use, the project is determined to have a **'High Project Risk Level'** in accordance with Table 3.1 of the Water Corporation (WC) Acid Sulfate Soil and Dewatering Management Strategy (Parsons Brinkerhoff, 2007), as presented below in Table 1.

Table 1 Project risk level assignment

Project factors	Project risk level		
	Low	Medium	High
Duration of project	Less than 1 month	1–3 months	Greater than 3 months
Volume of excavation	Less than 100 m^3	100 m^3–1000 m^3	Greater than 1000 m^3
Depth of excavation	Less than 3 mbgl	3–10 mbgl	Greater than 10 mbgl
Depth to groundwater	Depth to groundwater > depth of excavation	Depth of Excavation < 3 m below depth to groundwater	Depth of excavation > 3 m below depth to groundwater
Distance to sensitive receptors	Greater than 500 m	200–500 m	Less than 200 m

Project factors	Project risk level		
	Low	Medium	High
Sensitivity of environmental receptors	Unclassified water body	Multiple use	Environmental Protection Policy or Conservation Category
Beneficial use of groundwater resource	Irrigation or lower quality	Priority 3 resource	Priority 1/2 resource

Water Corporation Acid Sulfate Soil and Dewatering Management Strategy (Parsons Brinkerhoff, 2007).

The overall risk is determined by the highest factor risk to which two or more risk factors have been allocated. The interpreted risk factors for this assessment are denoted by grey shading.

It is also noted that a dewatering risk assessment will need to be undertaken to determine the scope of field investigations, when dewatering details are known.

5.2 Risk of acid sulfate soil occurrence

The potential for acid sulfate soil occurrence is assessed primarily through the ASS risk mapping as detailed in Section 4.6. However, key indicators such as topography and hydrology, geology, hydrogeology, wetlands and vegetation should also be taken into consideration when determining the risk of acid sulfate soil occurrence. A review of available information, including soil analytical results outlined in Section 7 has been undertaken with reference to the WC Acid Sulfate Soil and Dewatering Management Strategy (Parsons Brinkerhoff, 2007). Table 2 presents the ASS occurrence risk classification criteria adopted to provide a simplified, tailored risk assessment.

Table 2 ASS occurrence risk

Site elevation	Geology	Wetland classification	Groundwater depth	ASS risk mapping	ASS occurrence risk
>20 m AHD	Limestone Calcareous sand Sand of colluvial origin Sand derived from limestone	None	>10 mbgl	Low to no risk	Low
5–20 m AHD Risk	Sand of eolian origin Silt or Clay of colluvium origin	Multiple use	<5–10 mbgl	Class 2 (Moderate to low risk)	Medium
<5 m AHD	Peat and peaty sand Silt of lacustrine origin	Resource enhanced or Conservation category	<5 mbgl	Class 1 (High to moderate risk)	High

Water Corporation - Acid Sulfate Soil and Dewatering Management Strategy (Parsons Brinkerhoff, 2007)

The assessment suggests that 215 ha (20%) of the alignment are considered Low Risk, 613 ha (57%) Medium Risk and 232 ha (21%) are considered High Risk, when taking into consideration the likelihood of ASS presence and proximity to sensitive receptors. Figure 6 displays the risk classification results over the alignment.

5.3 Risk of acid generation

The risk of acid generation is dependent on the nature of site soils and the extent and duration over which they are disturbed. To accurately determine the nature of soils which may be disturbed during the project, the details of soil disturbance including depth of excavations and dewatering requirements must be used to guide field investigations. The risk of acid generation can be determined following detailed soil and groundwater (if required) investigations and used to develop appropriate management strategies in accordance with DEC 2011 treatment and management of soils and water in acid sulfate soil landscapes (DEC, 2011).

Bassendean Sands are specifically recognized by the DER as a potentially problematic acid-generating substrate. They typically have a very low pH buffering capacity and are known to contain microscopic framboidal pyrites which are highly reactive, making them prone to acidification even after relatively short exposure periods.

5.4 Dewatering risk

It is recommended that a dewatering risk assessment be undertaken to consider the potential for the oxidation of ASS. The initial risk is dependent on factors such as duration of dewatering, depth of drawdown and proximity to the nearest sensitive receptors e.g. wetlands.

To ensure an appropriate risk assessment and determine management strategies during dewatering, pre-construction groundwater investigations and hydrogeological modelling should be undertaken. The scope of groundwater investigations required for dewatering purposes should be designed to broadly characterise groundwater quality along the alignment and predict groundwater drawdown impacts. The objectives of dewatering investigations should include the following:

- Establish a baseline water quality data-set for groundwater and surface water which may be impacted by dewatering activities.
- Determine the likely quality of dewatering effluent.
- Determine appropriate dewatering and disposal methods.
- Enable the prediction of dewatering volumes.
- Enable prediction of groundwater drawdown and radius of influence.

6 SOIL ASSESSMENT

6.1 Site inspection

'Step 1: Desktop Assessment and Site Inspection' of DEC (2013) Acid Sulfate Soils Guideline Series: Identification and Investigation of Acid Sulfate Soils and Acidic Landscapes suggests that in all cases, a site inspection should be undertaken to support the findings of the desktop assessment. The site inspection should include, as a minimum:

- Visual assessment of topography and geomorphology.
- Visual assessment of surface water and hydrology.
- Visual assessment of prevalent plant communities.
- Examination of surface soils and the soil profile.

Due to the conceptual/design nature of the proposed development and large project area, detailed examination of the sub-surface soil profile did not form part of the site inspection. Photographs from the site inspection are presented in Appendix B and observations relevant to ASS are summarised as follows:

- The majority of the site has been cleared for infrastructure or pastoral land.
- Surface soils encountered were consistent with the regional lithology (e.g. Bassendean Sands) (see Plate 1).
- Soils in low lying portions of the site were found to be waterlogged, dark-grey in colour (see Plate 2), containing some organic material and geologically recent (i.e. alluvial sands/sediments).
- Groundwater is relatively shallow along the alignment, being encountered between 1.4 mbgl and 0.3 mbgl in the hand augered boreholes. However, sampling locations were mostly located in low-lying areas or near water bodies.
- The occurrence of perched aquifers is likely in low-lying areas.
- Vegetation in the project area generally ranges from banksia/eucalypt woodlands in higher relief areas, to waterlogging tolerant vegetation such as sedges and melaleucas (see Plate 5 and Plate 6) across the PDNH.
- Vegetation appeared to be generally healthy in low-lying areas and did not show any signs of significant stress.
- A number of surface water bodies and creek lines were noted within the proposed alignment.
- An inspection of wetlands/sumplands and creeks found in the northern portion of the project area found the soils to be silty/sandy dark grey (Plate 2). No evidence of PASS or AASS such as extensive iron staining, unusually clear or milky blue-green water or oily looking iron bacteria scum, was noted.
- No evidence of AASS was noted such as sulfurous odours, corroded shell, jarosite deposits, or iron oxide mottling in surface encrustations.

6.2 Soil sampling

Six preliminary soil sampling locations were selected along the alignment to target 'high risk' areas based on DER ASS risk mapping, wetlands and water bodies along the extent of the alignment. Consideration was also given in placing sampling points where excavation may be required (e.g. bridges), or where water-course crossings and/or dewatering may occur due to shallow groundwater. Initially, seven locations were selected to provide a backup location. As all of the primary locations were accessible, location SP3 was not sampled. Furthermore, provisional location SP3 does not correspond to any bridges or significant water crossings. Sampling locations are displayed in Figure 6.

Soil sampling was undertaken on 16 to 17 September 2014, utilising a 75 mm diameter hand auger to obtain samples. Locations were sampled from surface to depths ranging from 0.75 mbgl (SP7) to the target depth of 2 mbgl. At locations where the target depth was not reached, shallower termination was due to continual borehole collapse beneath the groundwater level. The soil profile was logged and samples were collected at 0.25 m intervals to the base of the soil bore, in accordance with DEC (2013) guidelines. Soil borelogs are included in Appendix C.

Note: Whilst there was an allowance to collect samples at discrete soil layers if encountered between the sampling intervals, this was not required based on the homogeneity of the underlying soils encountered.

Samples were placed in clearly labelled ziplock bags with the air excluded, and placed in an esky with ice while on site before being couriered directly to Australian Laboratory Services (ALS) laboratory in Malaga. Chain of Custody (CoC) and Sample Receipt Advices are included in Appendix D. Quality Control (QC) sampling comprised the collection of duplicate samples at a minimum rate of one per 20 samples.

6.3 Soil sample analysis

All samples (35 primary samples in total) were analysed at the laboratory for pH_F and pH_{FOX} for comparative purposes. Following a review of the field test results, 12 samples were selected (i.e. 34% of the total number of samples) for analysis via the Suspension Peroxide Oxidised Combined Acidity Sulfur (SPOCAS) method by ALS. The SPOCAS method was selected for analysis to determine the organic, sulfidic and metal-associated acidity present within the soil. SPOCAS analysis was selected as the laboratory acid base accounting method on the basis that site lithology was observed to be sand-rich. Laboratory results and assessment against the nominated criteria is summarised in Table A.

The SPOCAS method provides a standard approach that allows comparison between the acid and sulfur trails. This method provides measurements of potassium chloride pH (pHKCl), oxidation pH (pHOX), peroxide oxidisable sulfur (SPOS) and Titratable Sulfur Acidity (TSA, which is calculated from Titratable Peroxide Acidity, TPA, minus Titratable Actual Acidity, TAA). A detailed overview of the SPOCAS laboratory analysis methods and data interpretation is provided in Ahern et al (2004). Laboratory certificates of analysis are provided in Appendix E.

A comparison of the acidity concentrations determined using the acid trail (via Titratable Peroxide Acidity, TPA) and sulfur trail (via SPOS) can provide useful information on the source of acidity in the sample. Some acid soils have high TPA concentrations while the SPOS value may be below the action limit; this may reflect organic acidity or acidity from oxidation and/or titration of metal-containing compounds (i.e. iron, aluminium or manganese compounds). While this acidity is commonly not rapidly released into the environment in the short-term, it should not be immediately dismissed as being of no consequence (Ahern et al, 2004). TPA is generally not included in the assessment of net acidity (NA) for ASS; however, it should be considered in the assessment as it indicates a source of soil acidity which is independent of sulfur acidity.

The laboratory results are used to calculate the Net Acidity (NA) of a sample, which is used to characterise the current state and acid producing potential of the soil. NA values are calculated by adding results representing the soil's potential acidity to results representing existing or actual acidity (if any is present). The potential acidity is represented by SPOS values (for SPOCAS suite) and CRS (for CRS suite), and existing acidity is represented by TAA values in appropriate units. The pHKCl of a sample is used to determine the NA equation, which varies for samples with alkaline pH (NA = potential acidity), near neutral pH (NA = actual + potential acidity), and acid pH (NA = actual + potential + retained acidity). Consistent with DER guidance, the acid neutralising capacity of the soil is not included (DEC, 2013). Note that acidity results may be reported in either acidity units or percentage sulfur (%S) units, and that for the purposes of calculating NA, all components must be in the same units. For the purposes of the discussion in this report, results will be discussed in %S units.

6.4 Soil assessment criteria

The results of initial pH tests (pH_F and pH_{FOX}) are considered to give an indication of samples which may represent ASS material. The DER 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, 2013).

The DER's Action Criterion for preparation of an ASS management plan is a NA of 0.03%S (DEC, 2013), for projects where more than 1,000 tonnes of soil will be disturbed. Where any of the components of the NA equation are above this value, the NA will also exceed the Action Criterion. In the absence of a specific ASS action criterion for Bassendean Sands which are acknowledged as exhibiting extremely poor buffering capacity combined with highly reactive pyrite, where NA is reported at less than 0.03%S, consideration should be given to reported pH oxidation and detectable sulfur content in determining appropriate ASS management. This is particularly relevant to the disturbance of such soils in close vicinity to sensitive receptors such as CC wetlands and the Gnangara mound UWPCA.

7 RESULTS

7.1 Field testing

A total of 35 primary soil samples were recovered and subjected to field testing. The analytical results were compared to DER ASS indicators (DEC, 2013) and the following conclusions were drawn:

- One sample had a pH_F of less than or equal to 4 (SP4/1.0 mbgl).
- Six samples (17%) had a pH_{FOX} of less than 3 (lowest value 2.4).
- Two samples had a change in pH greater than 3 pH units (largest change 3.6).

The ASS field test data suggests the likely presence of ASS horizons at the site, particularly PASS based on low pH_{FOX} results at locations SP4, SP6 and SP7. These samples were all associated with Bassendean Sands. Locations SP6 and SP7 were noted as having high organic content.

7.2 Laboratory analysis

A total of 12 primary samples were analysed via SPOCAS, based on the preliminary pH_F and pH_{FOX} results. The samples selected for SPOCAS analysis were done on the basis that they were considered to be representative of:

- The main soil types encountered during intrusive investigations.
- The different coloured and textured quartz sands encountered.
- Soils that exhibited the greatest difference between pH_F and pH_{Fox} values.
- Soils profiles within the zone of groundwater fluctuation.

Details of the soil samples selected for quantitative testing are provided in Table A.

Based on the calculated NA values using the appropriate NA equation, three primary samples (25% of the samples tested) have a calculated net acidity above the 0.03%S Action Criterion. The NA results range from <0.02%S to 0.13%S. A summary of the sample locations and depths where the 0.03%S criterion were exceeded is provided in Table A.

Considerable total peroxide acidity (TPA) was recorded in six samples (50% of the samples tested). The TPA results ranged from <0.005%S to 1.08%S. While there is not criterion for TPA content, this helps to identify the presence of organic sulfide and/or metals which may interfere with net acidity values.

7.3 QA/QC assessment

Duplicate analyses were undertaken as part of the laboratory's internal quality assurance procedures. The laboratory quality control report is included within Appendix F. All quality control samples were within acceptable limits.

8 DISCUSSION

Preliminary soil sampling identified the typical lithology to be grey quartz sands representative of the regionally occurring Bassendean Sands. Underlying clays and coffee rock horizons, though not specifically encountered, are expected regionally at varying depths. Surficial soils were noted to contain appreciable organic content, particularly in low-lying areas where alluvial silts and peat may be encountered. Based on the results of the indicative sampling completed, soils containing net acidity above the DER criterion of 0.03%S have been identified. It is therefore foreseeable that some soils requiring management may be disturbed as part of the project, and further investigation is required to characterise and delineate the presence of ASS.

Topsoil stripping and reuse is likely, including respreading on batters. For the purpose of this project, topsoil is defined as material within the top 300 mm of the soil profile containing vegetative matter. Topsoils in WA are recognised as being naturally acidic in nature, though present a relatively low risk/ability to release metals and metalloids into the soil profile and induce acid generating reactions. The revised Identification and Investigation of Acid Sulfate Soils and Acidic Landscapes (DEC, 2013) suggest that if topsoils have an in situ pH (pH_F) > 5.0 then neutralisation treatment is not required.

Bassendean Sands, which are expected across the vast majority of the alignment, contain single crystal and framboidal aggregates of sub-micron-sized pyrites. They generally have very low clay content and therefore, extremely poor acid-buffering capacity. Soil column studies undertaken by DEC demonstrated that a sulfur content less than 0.03%S in Bassendean Sands can produce a soil pH_{FOX} of <3. In the absence of a revised trigger value for Bassendean Sands, where a Chromium reducible sulfur (CRS) value is less than 0.03%S and field pH_{FOX}<3, the soil should be considered ASS, therefore requiring treatment as if it had an inorganic sulfur content of 0.03%S (DEC, 2012).

SPOCAS analysis indicates that while SPOS values may be below the net acidity criterion, they still contain an appreciable TPA. This may reflect organic acidity, but it may also reflect acidity from oxidation and/or titration of iron-containing or manganese-containing compounds. This is recognised by the DER in Western Australia, particularly in regards to Bassendean Sands and coffee rock formations. Various aluminium-containing compounds may also contribute to this acidity. Whether or not there is any appreciable potential sulfidic acidity (i.e. any significant CRS or SPOS result) this acidity may be present. Although this acidity is often not rapidly released in the short term, it is often released into the environment over a longer period and so should not be dismissed as being of no consequence.

9 IMPACT MINIMISATION STRATEGY

9.1 Investigation strategy

A targeted, risk-based soil and groundwater investigation is recommended to characterise and delineate the potential for ASS disturbance along the alignment. When details of excavation depths, locations and likely dewatering requirements are confirmed they should be used as a guide to determine appropriate sampling locations in accordance with the Identification and Investigation of Acid Sulfate Soils and Acidic Landscapes (DEC, 2013).

Initial liaison with the DER may be beneficial to ensure the sampling program developed meets their approval. Given the large scale of the project and heterogeneous tendencies of soils across portions of the alignment, a somewhat reduced sampling and analysis program may be sufficient to meet the necessary DER approvals.

Beyond the general considerations for ASS investigations, the following project specific guidance should be considered in developing the sampling and analysis program:

- Initially delineating the areas requiring/not requiring investigation in accordance with DER guidelines and obtaining confirmation from the DER.
- Incorporation of CRS analysis in soils with considerable organic content (e.g. topsoil) to rule out interference from organic sulfides.
- A SPOCAS/CRS detection limit of 0.005%S is recommended for all sandy soils analysed.
- Seasonal background water quality monitoring in areas proposed for dewatering. This assessment should include inherent groundwater buffering capacity and indicators of previous ASS disturbance.
- Monitoring of water quality in adjacent surface water bodies should be considered to ensure they are not adversely impacted. Sound background monitoring data is crucial in assessing this.
- Groundwater monitoring locations should be selected taking into consideration public abstraction bores if applicable.

9.2 Management principles

Avoidance and minimization of ASS disturbance is the preferred approach to ASS management during the project. However, it is expected that a project of this scale is likely to require excavation into natural soils exceeding 1,000 m^3 and some dewatering may also be required. Where avoiding the disturbance of ASS is not reasonably practical, typical management techniques include the following:

- Neutralisation (e.g. mechanical mixing of Aglime or other neutralizing agent).
- Strategic reburial beneath the permanent water table or other water body.
- Hydraulic separation of pyrite from soil.

9.3 Management strategies

To minimise potential impacts through the duration of the project, the following strategies should be considered for implementation:

- Preference should be given to spread footings where sands are deemed suitable to support structures at upgrade interchanges.
- Given the shallow nature of groundwater, timing major works during summer may considerably reduce groundwater impacts and/or dewatering requirements.
- Selecting dewatering methods which minimise the radius of influence in confirmed ASS areas e.g. well-point spears.
- Regardless of the scale of dewatering activities in areas of known or likely ASS occurrence, an acid sulfate soil and dewatering management plan should be prepared and implemented to ensure the environment is managed responsibly.

10 CONCLUSIONS AND RECOMMENDATIONS

Based on the outcomes of the preliminary ASS investigation, the following conclusions are made:

- At the current stage, details of ground and/or groundwater disturbing activities are still in development.
- The project is highly likely to trigger a number of regulatory criteria which necessitate further investigation e.g. soil disturbance of >100 m^3 of soil in high ASS risk areas or dewatering in moderate ASS risk areas.
- Preliminary investigations identified sandy soils exceeding the DER net acidity criterion of 0.03%S at SP6 (stream crossing near Neaves Road) and SP7 (lowland/wetland near Brand Highway).
- ASS is likely to be present in soils underlying the project alignment. Areas of particular concern include:
  - Watercourse crossings.
  - Low-lying areas and wetlands.
  - Light grey to grey sands typical of 'Bassendean Sands.'
  - Silty or peaty soils typically found in low lying areas or wetlands.
  - Iron-cemented organic rich sands (coffee rock).
- Given the shallow depth to groundwater and surface water bodies in close proximity to the alignment, consideration should be given to assessing the inherent buffering capacity and acidification risk of groundwater and surface water if potentially impacted.

Based on the above conclusions, the following recommendations are made:

- Following further design and the definition of likely soil disturbance, a detailed ASS investigation should be carried out in accordance with the DEC (2013) Identification and Investigation of Acid Sulfate Soils and Acidic Landscapes to determine the nature and extent of ASS likely to be disturbed.
- The detailed ASS investigation should be undertaken prior to ground disturbing and/or groundwater disturbing activities and give particular consideration to:
  - Characterising the nature and extent of ASS which may be disturbed by project works.
  - Groundwater and surface water quality and acidification risk.
- Pending the outcomes of the detailed ASS investigation, an ASS and/or dewatering management plan should be developed (if required).

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12 STATEMENT OF LIMITATIONS

(Please see over the page)

Important information about your **Coffey** Environmental Report

Introduction

This report has been prepared by Coffey for you, as Coffey's client, in accordance with our agreed purpose, scope, schedule and budget.

The report has been prepared using accepted procedures and practices of the consulting profession at the time it was prepared, and the opinions, recommendations and conclusions set out in the report are made in accordance with generally accepted principles and practices of that profession.

The report is based on information gained from environmental conditions (including assessment of some or all of soil, groundwater, vapour and surface water) and supplemented by reported data of the local area and professional experience. Assessment has been scoped with consideration to industry standards, regulations, guidelines and your specific requirements, including budget and timing. The characterisation of site conditions is an interpretation of information collected during assessment, in accordance with industry practice,

This interpretation is not a complete description of all material on or in the vicinity of the site, due to the inherent variation in spatial and temporal patterns of contaminant presence and impact in the natural environment. Coffey may have also relied on data and other information provided by you and other qualified individuals in preparing this report. Coffey has not verified the accuracy or completeness of such data or information except as otherwise stated in the report. For these reasons the report must be regarded as interpretative, in accordance with industry standards and practice, rather than being a definitive record.

Your report has been written for a specific purpose

Your report has been developed for a specific purpose as agreed by us and applies only to the site or area investigated. Unless otherwise stated in the report, this report cannot be applied to an adjacent site or area, nor can it be used when the nature of the specific purpose changes from that which we agreed.

For each purpose, a tailored approach to the assessment of potential soil and groundwater contamination is required. In most cases, a key objective is to identify, and if possible quantify, risks that both recognised and potential contamination pose in the context of the agreed purpose. Such risks may be financial (for example, clean up costs or constraints on site use) and/or physical (for example, potential health risks to users of the site or the general public).

Limitations of the Report

The work was conducted, and the report has been prepared, in response to an agreed purpose and scope, within time and budgetary constraints, and in reliance on certain data and information made available to Coffey.

The analyses, evaluations, opinions and conclusions presented in this report are based on that purpose and scope, requirements, data or information, and they could change if such requirements or data are inaccurate or incomplete.

This report is valid as of the date of preparation. The condition of the site (including subsurface conditions) and extent or nature of contamination or other environmental hazards can change over time, as a result of either natural processes or human influence. Coffey should be kept appraised of any such events and should be consulted for further investigations if any changes are noted, particularly during construction activities where excavations often reveal subsurface conditions.

In addition, advancements in professional practice regarding contaminated land and changes in applicable statues and/or guidelines may affect the validity of this report. Consequently, the currency of conclusions and recommendations in this report should be verified if you propose to use this report more than 6 months after its date of issue.

The report does not include the evaluation or assessment of potential geotechnical engineering constraints of the site.

Interpretation of factual data

Environmental site assessments identify actual conditions only at those points where samples are taken and on the date collected. Data derived from indirect field measurements, and sometimes other reports on the site, are interpreted by geologists, engineers or scientists to provide an opinion about overall site conditions, their likely impact with respect to the report purpose and recommended actions.

Variations in soil and groundwater conditions may occur between test or sample locations and actual conditions may differ from those inferred to exist. No environmental assessment program, no matter how comprehensive, can reveal all subsurface details and anomalies. Similarly, no professional, no matter how well qualified, can reveal what is hidden by earth, rock or changed through time.

The actual interface between different materials may be far more gradual or abrupt than assumed based on the facts obtained. Nothing can be done to change the actual site conditions which exist, but steps can be taken to reduce the impact of unexpected conditions.

For this reason, parties involved with land acquisition, management and/or redevelopment should retain the services of a suitably qualified and experienced environmental consultant through the development and use of the site to identify variances, conduct additional tests if required, and recommend solutions to unexpected conditions or other unrecognised features encountered on site. Coffey would be pleased to assist with any investigation or advice in such circumstances.

Recommendations in this report

This report assumes, in accordance with industry practice, that the site conditions recognised through discrete sampling are representative of actual conditions throughout the investigation area. Recommendations are based on the resulting interpretation.

Should further data be obtained that differs from the data on which the report recommendations are based (such as through excavation or other additional assessment), then the recommendations would need to be reviewed and may need to be revised.

Report for benefit of client

Unless otherwise agreed between us, the report has been prepared for your benefit and no other party. Other parties should not rely upon the report or the accuracy or completeness of any recommendation and should make their own enquiries and obtain independent advice in relation to such matters.

Coffey assumes no responsibility and will not be liable to any other person or organisation for, or in relation to, any matter dealt with or conclusions expressed in the report, or for any loss or damage suffered by any other person or organisation arising from matters dealt with or conclusions expressed in the report.

To avoid misuse of the information presented in your report, we recommend that Coffey be consulted before the report is provided to another party who may not be familiar with the background and the purpose of the report. In particular, an environmental disclosure report for a property vendor may not be suitable for satisfying the needs of that property's purchaser. This report should not be applied for any purpose other than that stated in the report.

Interpretation by other professionals

Costly problems can occur when other professionals develop their plans based on misinterpretations of a report. To help avoid misinterpretations, a suitably qualified and experienced environmental consultant should be retained to explain the implications of the report to other professionals referring to the report and then review plans and specifications produced to see how other professionals have incorporated the report findings.

Given Coffey prepared the report and has familiarity with the site, Coffey is well placed to provide such assistance. If another party is engaged to interpret the recommendations of the report, there is a risk that the contents of the report may be misinterpreted and Coffey disowns any responsibility for such misinterpretation.

Data should not be separated from the report

The report as a whole presents the findings of the site assessment and the report should not be copied in part or altered in any way. Logs, figures, laboratory data, drawings, etc. are customarily included in our reports and are developed by scientists or engineers based on their interpretation of field logs, field testing and laboratory evaluation of samples. This information should not under any circumstances be redrawn for inclusion in other documents or separated from the report in any way.

This report should be reproduced in full. No responsibility is accepted for use of any part of this report in any other context or for any other purpose or by third parties.

Responsibility

Environmental reporting relies on interpretation of factual information using professional judgement and opinion and has a level of uncertainty attached to it, which is much less exact than other design disciplines. This has often resulted in claims being lodged against consultants, which are unfounded. As noted earlier, the recommendations and findings set out in this report should only be regarded as interpretive and should not be taken as accurate and complete information about all environmental media at all depths and locations across the site.

Tables

TABLE A
SOIL ANALYTICAL RESULTS - SPOCAS SUITE
NORTHLINK ASS INVESTIGATION
SEPTEMBER 2014
ENAUPERT04483AA

coffey

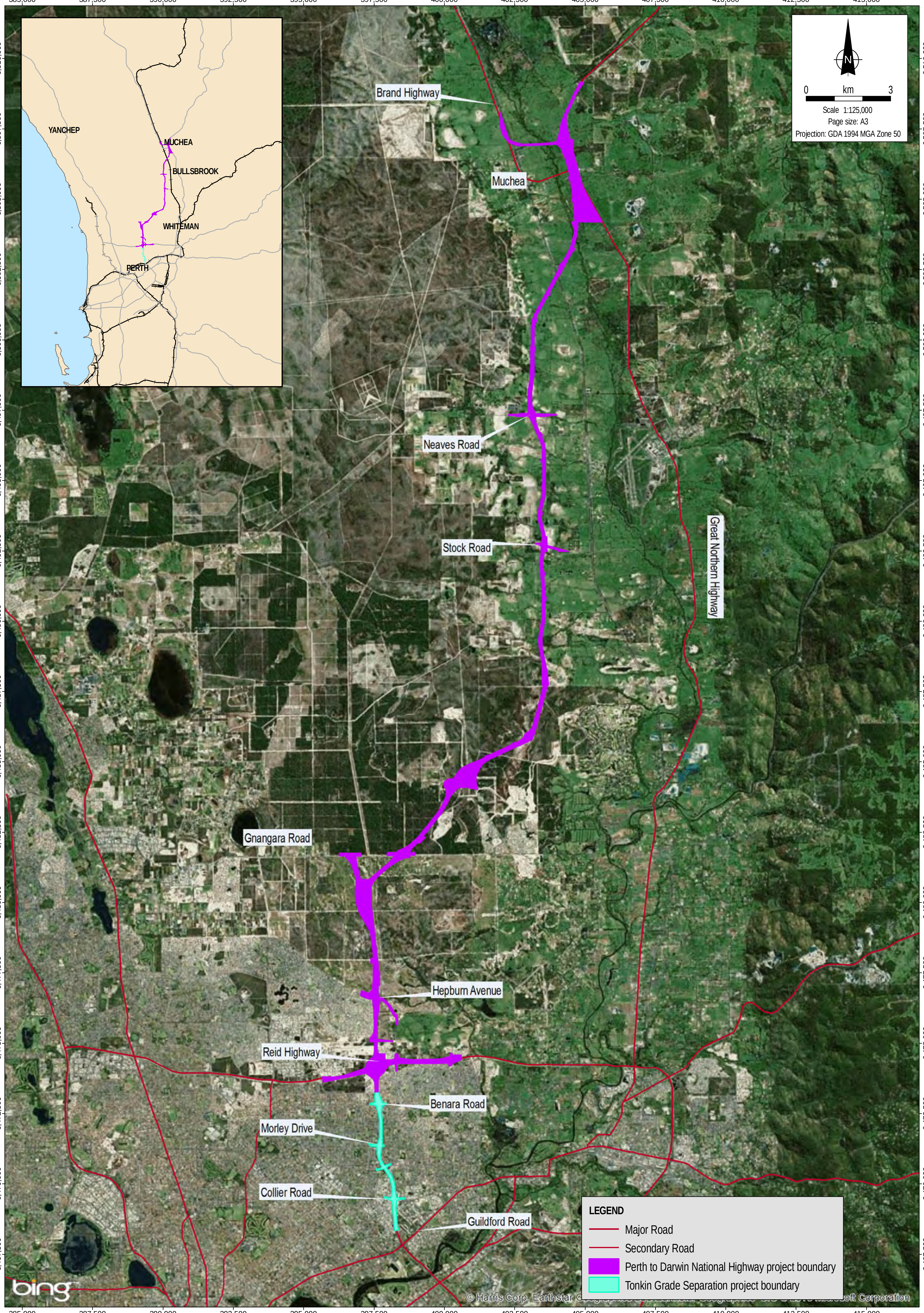
Field ID	Soil Log	Sampled Date	Lab Report Number	Sample Depth	pH (Field)	pH (FOX)	Δ pH(Field) - pH (FOX)	Reaction Rating	pH (KCl)	pH (Ox)	sulfidic - Titratable Actual Acidity (TAA)	sulfidic - Titratable Peroxide Acidity (TPA)	sulfidic - Titratable Sulfidic Acidity (TSA)	Peroxide Oxidisable Sulfur (SPOS)	Net Acidity (Excluding ANC)	sulfidic - Acid Reacted Calcium	sulfidic - Acid Reacted Magnesium
					Laboratory Field pH Test				Lab pH		SPOCAS						
					pH Units	pH Units	pH Units	-	pH Unit	pH Unit	% PYRITE S	% PYRITE S	% PYRITE S	% S	%S	% S	%S
LOR					0.1	0.1	0.1	-	-	-	0.005	0.005	0.005	0.005	0.02	0.005	0.005
DER ASS Criteria					**<4**	**<3**	**>3**	-	**<6**	**<6**	**0.03**	**NV**	**NV**	**0.03**	**0.03**	**NV**	**NV**
SP1	Silty SAND: fine grained, well sorted, grey/black, dry	16/09/2014	EP1407514	0	**5.5**	**3.6**	**1.9**	**Slight**	-	-	-	-	-	-	-	-	-
	SAND: medium grained, poorly sorted, grey, dry	16/09/2014	EP1407514	0.25	**5.9**	**3.7**	**2.2**	**Moderate**	-	-	-	-	-	-	-	-	-
		16/09/2014	EP1407514	0.5	**5.6**	**3.1**	**2.5**	**Moderate**	**7.6**	**6.3**	<0.005	<0.005	<0.005	**0.008**	<0.02	**0.006**	<0.005
	Becoming medium to coarse grained	16/09/2014	EP1407514	0.75	**6.1**	**5**	**1.1**	**Slight**	-	-	-	-	-	-	-	-	-
	Silty SAND: fine to medium grained, well sorted, dark brown, moist	16/09/2014	EP1407514	1	**6.8**	**5**	**1.8**	**Slight**	-	-	-	-	-	-	-	-	-
	Wet	16/09/2014	EP1407514	1.25	**6.9**	**5**	**1.9**	**Slight**	**6.6**	**5.1**	<0.005	<0.005	<0.005	**0.01**	<0.02	**0.009**	<0.005
		16/09/2014	EP1407514	1.5	**7**	**5.3**	**1.7**	**Slight**	-	-	-	-	-	-	-	-	-
		16/09/2014	EP1407514	1.75	**7**	**5**	**2**	**Slight**	-	-	-	-	-	-	-	-	-
SP2	Silty SAND: fine to medium grained, well sorted, dark grey, some organics, dry	16/09/2014	EP1407514	0	**5.9**	**4.1**	**1.8**	**Moderate**	-	-	-	-	-	-	-	-	-
		16/09/2014	EP1407514	0.25	**5.4**	**3.6**	**1.8**	**Moderate**	**5.4**	**3**	**0.02**	**0.11**	**0.09**	**0.01**	**0.03**	**0.006**	<0.005
	SAND: fine to medium grained, grey, dry	16/09/2014	EP1407514	0.5	**5.3**	**3.9**	**1.4**	**Moderate**	-	-	-	-	-	-	-	-	-
	Moist	16/09/2014	EP1407514	0.75	**5.2**	**4.1**	**1.1**	**Moderate**	-	-	-	-	-	-	-	-	-
	Becoming medium to coarse grained	16/09/2014	EP1407514	1	**5.3**	**4.7**	**0.6**	**Slight**	-	-	-	-	-	-	-	-	-
	Wet	16/09/2014	EP1407514	1.25	**5.3**	**4.6**	**0.7**	**Slight**	**6.2**	**4**	<0.005	<0.005	<0.005	**0.006**	<0.02	<0.005	<0.005
SP4	Silty SAND: fine grained, black, some peat, organic matter and roots, moist	16/09/2014	EP1407514	0	**5.3**	**3.4**	**1.9**	**Moderate**	-	-	-	-	-	-	-	-	-
	SAND: medium grained, well sorted, brown, moist	16/09/2014	EP1407514	0.25	**4.7**	**3.1**	**1.6**	**Slight**	-	-	-	-	-	-	-	-	-
		16/09/2014	EP1407514	0.5	**4.5**	**3.3**	**1.2**	**Slight**	-	-	-	-	-	-	-	-	-
	Wet	16/09/2014	EP1407514	0.75	**4.2**	**3.2**	**1**	**Slight**	-	-	-	-	-	-	-	-	-
		16/09/2014	EP1407514	1	**3.9**	**2.9**	**1**	**Slight**	**6.4**	**3.7**	<0.005	<0.005	<0.005	<0.005	<0.02	<0.005	<0.005
		16/09/2014	EP1407514	1.25	**4.2**	**3.4**	**0.8**	**Slight**	-	-	-	-	-	-	-	-	-
	Becoming fine to coarse grained	16/09/2014	EP1407514	1.5	**4.1**	**2.6**	**1.5**	**Slight**	**6.3**	**3.7**	<0.005	<0.005	<0.005	<0.005	<0.02	<0.005	<0.005
SP5	Silty SAND: fine to medium grained, well sorted, dark grey, some organics, dry	17/09/2014	EP1407514	0	**6.4**	**4.4**	**2**	**Slight**	**6.2**	**3**	**0.006**	**0.16**	**0.15**	**0.008**	<0.02	<0.005	<0.005
	SAND: fine to medium grained, well-sorted, grey, some silt fines, dry	17/09/2014	EP1407514	0.25	**5.8**	**4.1**	**1.7**	**Slight**	-	-	-	-	-	-	-	-	-
		17/09/2014	EP1407514	0.5	**5.2**	**3.7**	**1.5**	**Slight**	**6.4**	**3.4**	<0.005	<0.005	<0.005	<0.005	<0.02	<0.005	<0.005
	Moist	17/09/2014	EP1407514	0.75	**4.7**	**3.6**	**1.1**	**Slight**	-	-	-	-	-	-	-	-	-
	Becoming fine to coarse grained	17/09/2014	EP1407514	1	**4.6**	**3.7**	**0.9**	**Slight**	-	-	-	-	-	-	-	-	-
	Wet	17/09/2014	EP1407514	1.25	**4.4**	**3.8**	**0.6**	**Slight**	-	-	-	-	-	-	-	-	-
SP6	Silty SAND: fine to medium grained, poorly sorted, black, high organic content, moist	16/09/2014	EP1407514	0	**4.9**	**2.8**	**2.1**	**Moderate**	**4.9**	**2.5**	**0.08**	**1.08**	**1**	**0.04**	**0.13**	**0.009**	<0.005
	SAND: medium grained, poorly sorted, grey-brown, some organics, wet	16/09/2014	EP1407514	0.25	**4.7**	**3**	**1.7**	**Moderate**	**5**	**2.5**	**0.04**	**0.44**	**0.39**	**0.02**	**0.06**	**0.005**	<0.005
		16/09/2014	EP1407514	0.5	**4.8**	**3.2**	**1.6**	**Slight**	-	-	-	-	-	-	-	-	-
		16/09/2014	EP1407514	0.75	**4.8**	**3.4**	**1.4**	**Slight**	-	-	-	-	-	-	-	-	-
		16/09/2014	EP1407514	1	**4.8**	**3.5**	**1.3**	**Slight**	-	-	-	-	-	-	-	-	-
SP7	Silty SAND: Brown, high organic matter, wet	17/09/2014	EP1407514	0	**6.4**	**2.8**	**3.6**	**Extreme**	**5.6**	**3.3**	**0.04**	**0.21**	**0.17**	**0.04**	**0.08**	<0.005	<0.005
	Clayey SAND: well sorted, light brown/yellow, low plasticity, wet	17/09/2014	EP1407514	0.25	**5.6**	**2.4**	**3.2**	**Strong**	**6.4**	**3.6**	<0.005	**0.01**	**0.01**	**0.01**	<0.02	<0.005	<0.005
	Becoming light brown	17/09/2014	EP1407514	0.5	**5.1**	**2.7**	**2.4**	**Strong**	-	-	-	-	-	-	-	-	-
Quality Control																	
SB7 0.0m		17/09/2014	EP1407514	0	**6.4**	**2.8**	**3.6**	**Extreme**	**5.6**	**3.3**	**0.04**	**0.21**	**0.17**	**0.04**	**0.08**	<0.005	<0.005
QC1 (Duplicate of SB7 0.0m)					**6.5**	**3**	**3.5**	**Extreme**	-	-	-	-	-	-	-	-	-
RPD %		SB7 0.0m : QC1			2%	7%	3%	-	-	-	-	-	-	-	-	-	-
SB5 1.0m		17/09/2014	EP1407514	1	**4.6**	**3.7**	**0.9**	**Slight**	**6.2**	**3**	**0.006**	**0.16**	**0.15**	**0.008**	<0.02	<0.005	<0.005
QC2 (Duplicate of SB5 1.0m)					**4.6**	**3.5**	**1.1**	**Slight**	-	-	-	-	-	-	-	-	-
RPD %		SB5 1.0m : QC2			0%	6%	20%	-	-	-	-	-	-	-	-	-	-

Notes
LOR = Limit of Reporting (method detection limit)
SB = Soil bore
ID = Identification
% S = Percentage sulfur
# = RPD unable to be calculated due to both results reported below LOR
- = Analysis not requested
NV = No guideline value

Investigation Levels:
DER (2013) Acid Sulfate Soil Guideline Series - Identification and Investigation of Acid Sulfate Soils and Acidic Landscapes.

1.2	Values in **Bold** exceed the LOR
77	RPDs in **Red and Bold** exceed the acceptable limit
Result	Values in highlighted cells and bold exceed the DER ASS Criteria

Figures



Source & Notes
Roads from MRWA.
Aerial imagery from Bing Online.

NorthLinkWA coffey

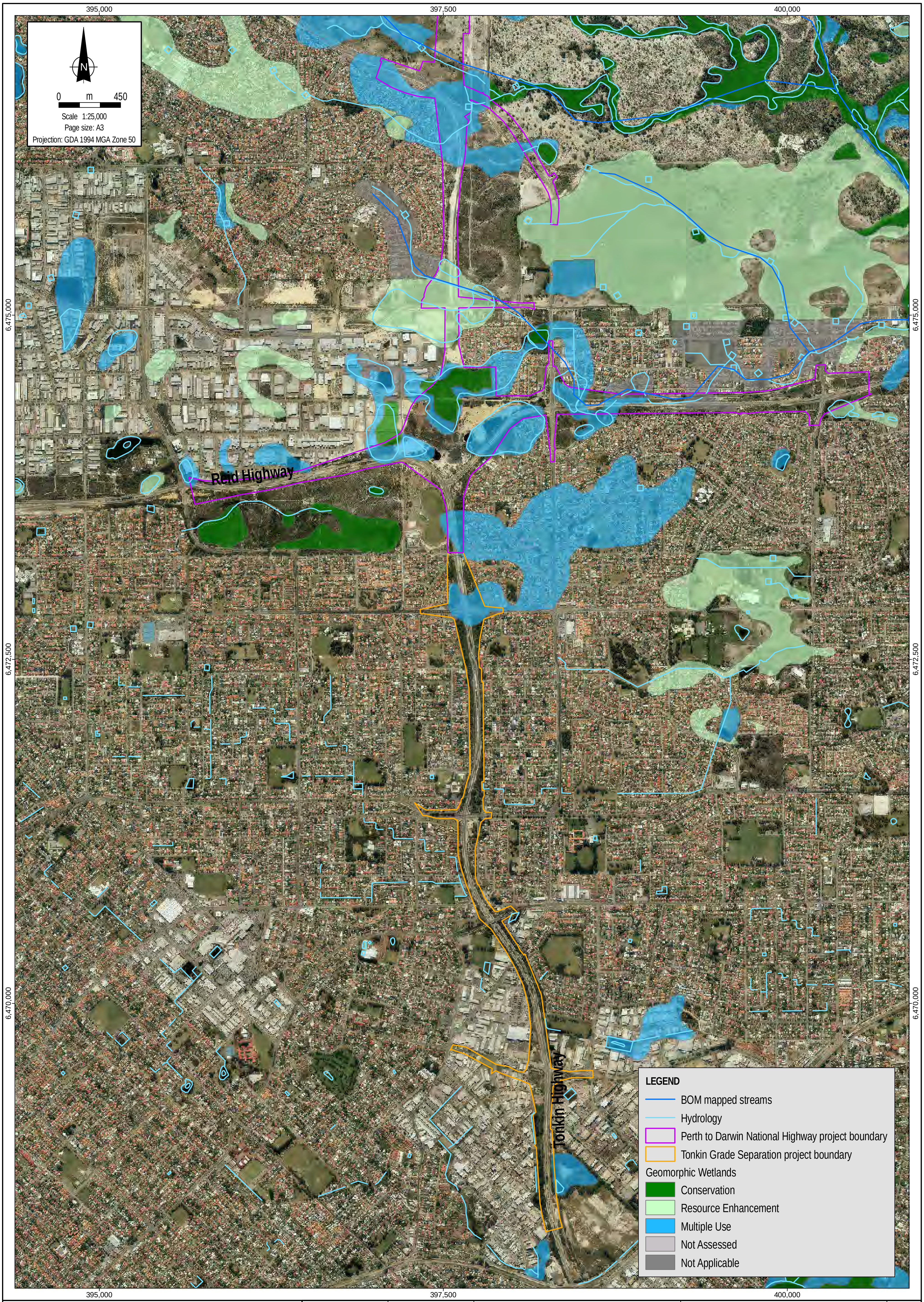
Date: 27.01.2015
MXT: 4483AA_18_GIS011_1
File Name: 4483AA_18_F001_GIS

Main Roads WA

Preliminary Acid Sulfate Soils Investigation

Site Location

Figure No: 1



Source & Notes
Geomorphic wetlands Swan Coast Plain mapping from DPAW (January 2015).
Mapped streams from BOM.
Roads and hydrology from MRWA.
Aerial imagery from Landgate (August 2014).

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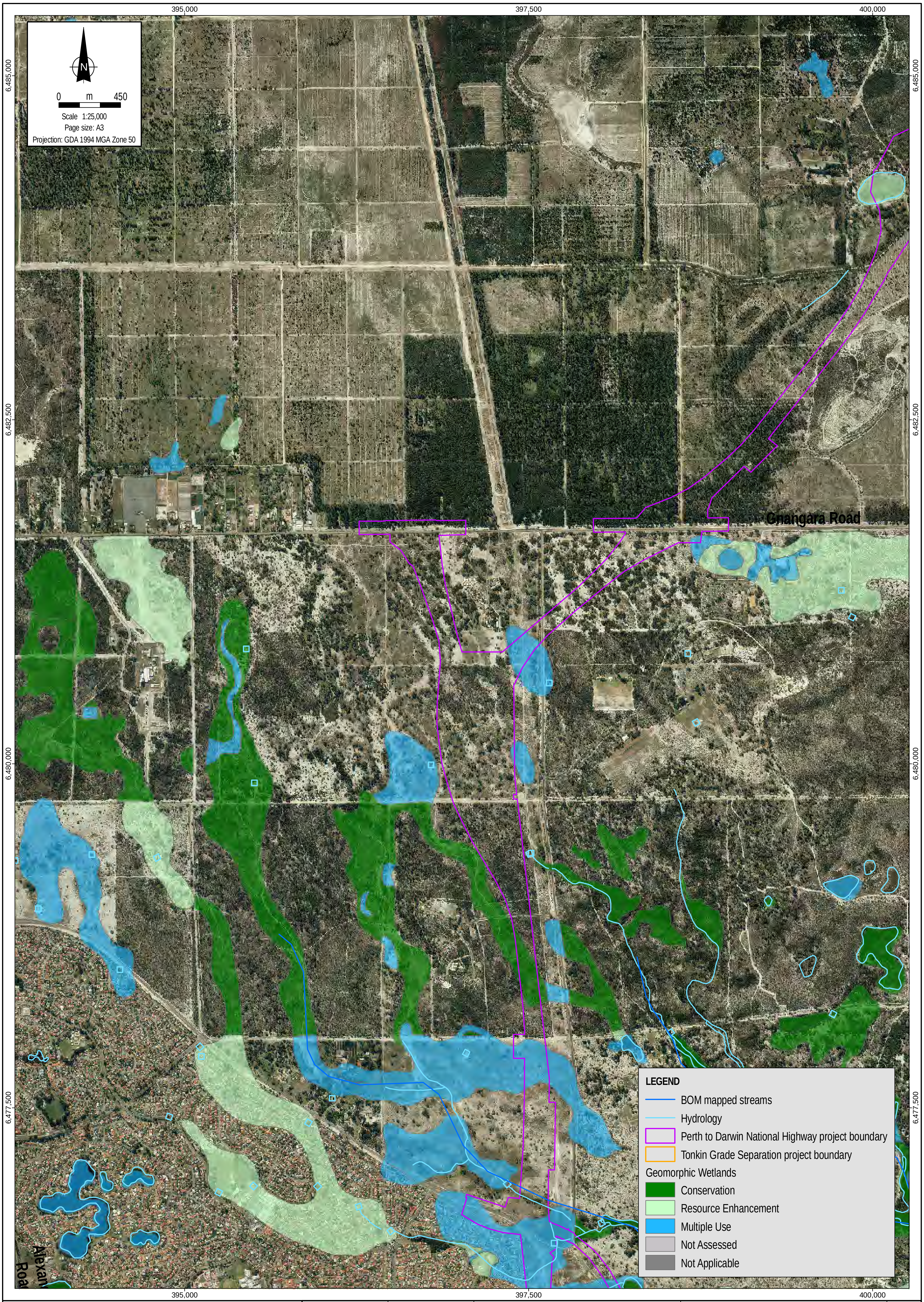
Date:	27.01.2015
MXT:	4483AA_18_GIS013_1
File Name:	4483AA_18_F002A_GIS

Main Roads WA

Preliminary Acid Sulfate Soils Investigation

Geomorphic wetlands

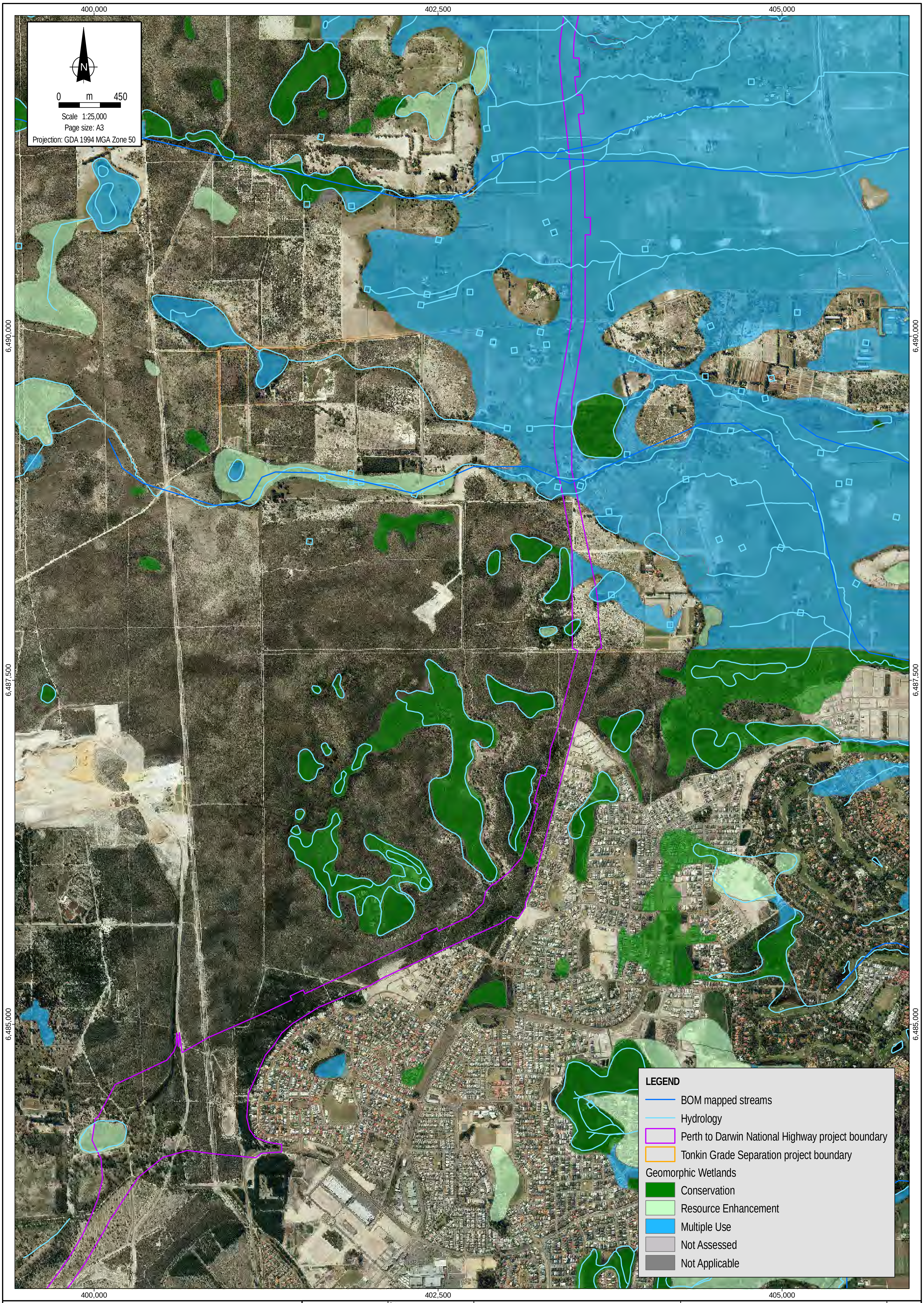
Figure No: 2A



Source & Notes
Geomorphic wetlands Swan Coast Plain mapping from DPAW (January 2015).
Mapped streams from BOM.
Roads and hydrology from MRWA.
Aerial imagery from Landgate (August 2014).

NorthLinkWA | coffey

Date: 27.01.2015	Main Roads WA	Geomorphic wetlands	Figure No: 2B
MXT: 4483AA_18_GIS013_1			
File Name: 4483AA_18_F002B_GIS	Preliminary Acid Sulfate Soils Investigation		



Source & Notes
Geomorphic wetlands Swan Coast Plain mapping from DPAW (January 2015).
Mapped streams from BOM.
Roads and hydrology from MRWA.
Aerial imagery from Landgate (August 2014).

NorthLinkWA | coffey

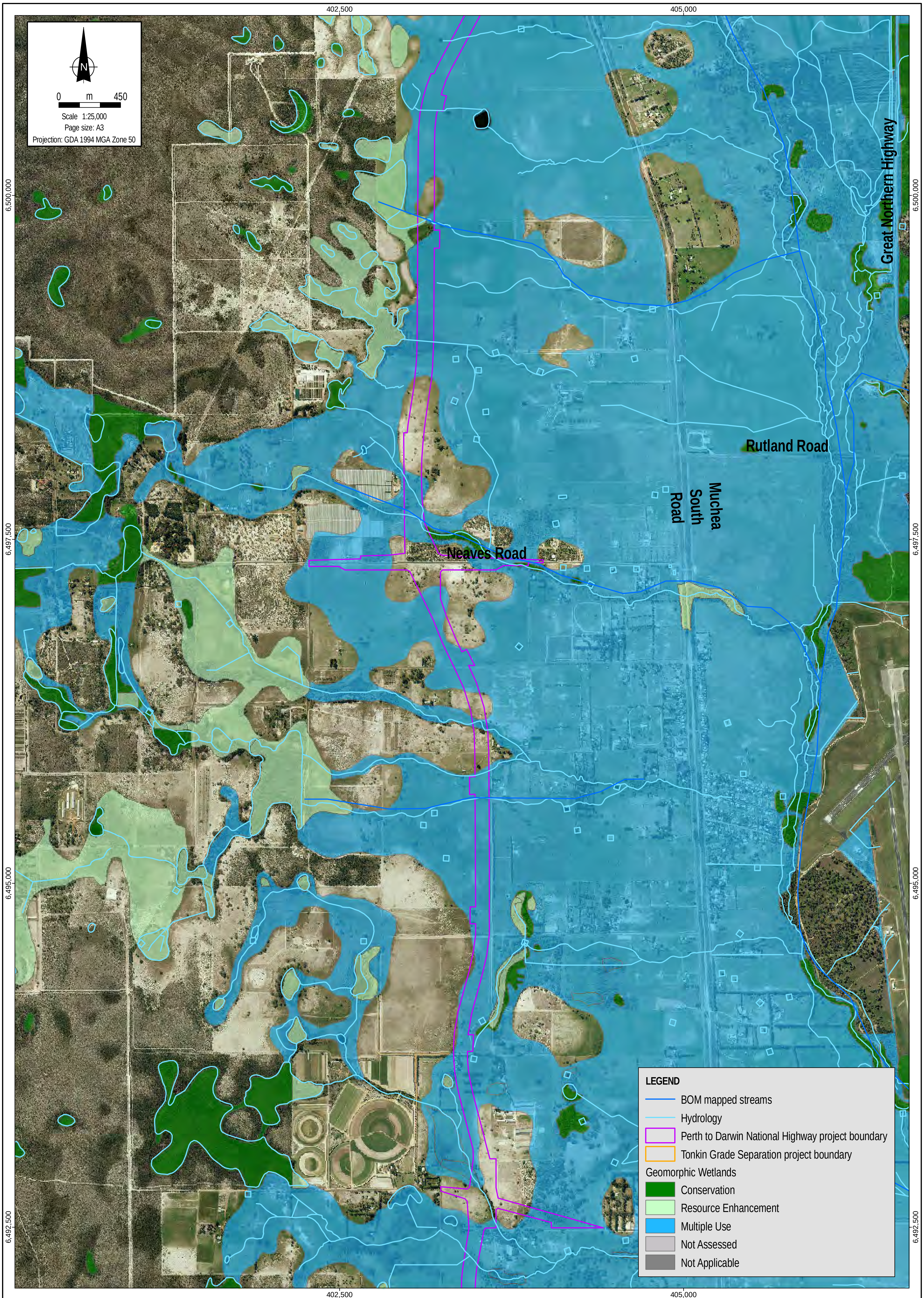
Date:	27.01.2015
MXT:	4483AA_18_GIS013_1
File Name:	4483AA_18_F002C_GIS

Main Roads WA

Preliminary Acid Sulfate Soils Investigation

Geomorphic wetlands

Figure No: 2C



Source & Notes
Geomorphic wetlands Swan Coast Plain mapping from DPAW (January 2015).
Mapped streams from BOM.
Roads and hydrology from MRWA.
Aerial imagery from Landgate (August 2014).

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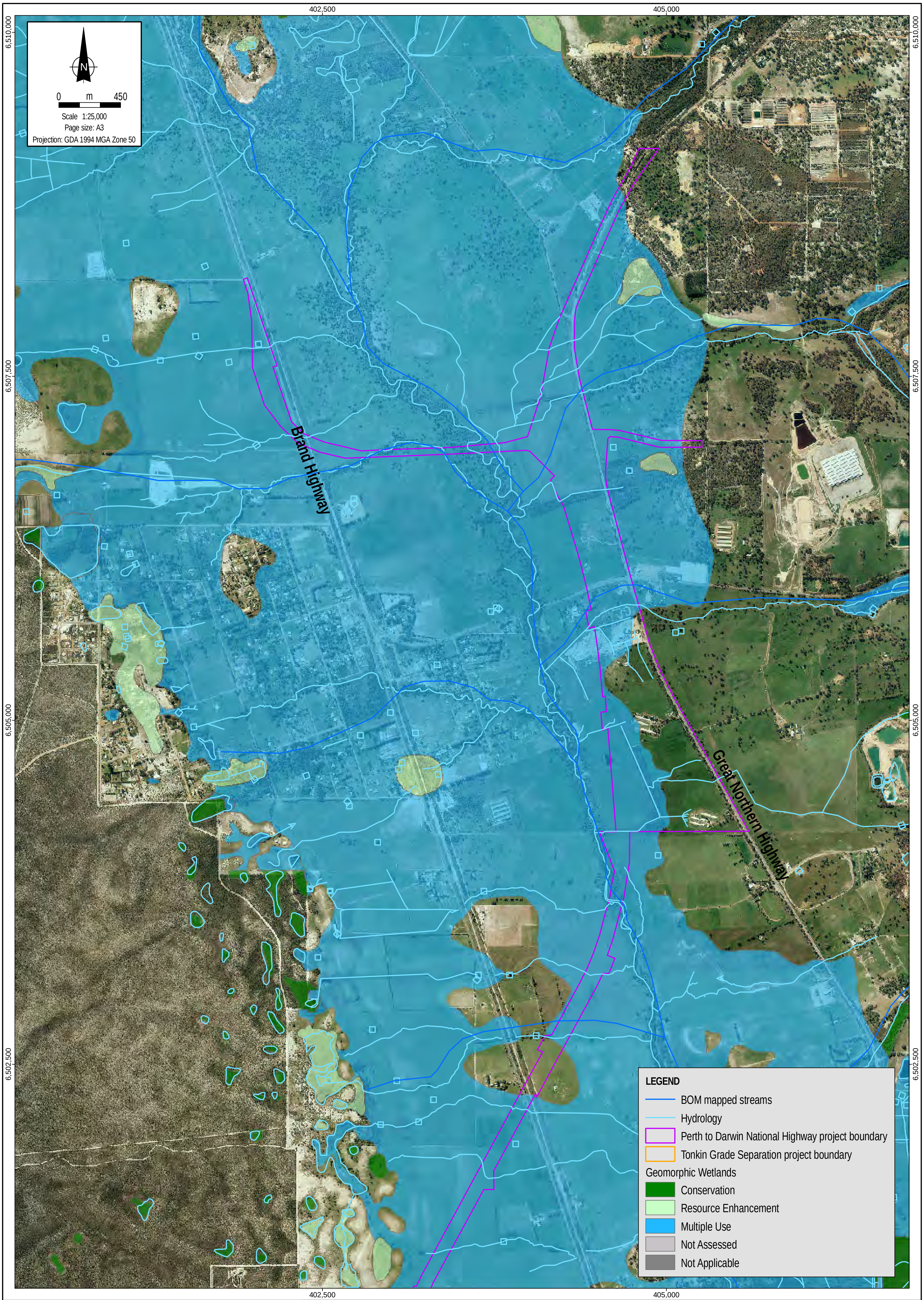
Date:	27.01.2015
MXT:	4483AA_18_GIS013_1
File Name:	4483AA_18_F002D_GIS

Main Roads WA

Preliminary Acid Sulfate Soils Investigation

Geomorphic wetlands

Figure No: 2D



Source & Notes
Geomorphic wetlands Swan Coast Plain mapping from DPAW (January 2015).
Mapped streams from BOM.
Roads and hydrology from MRWA.
Aerial imagery from Landgate (August 2014).

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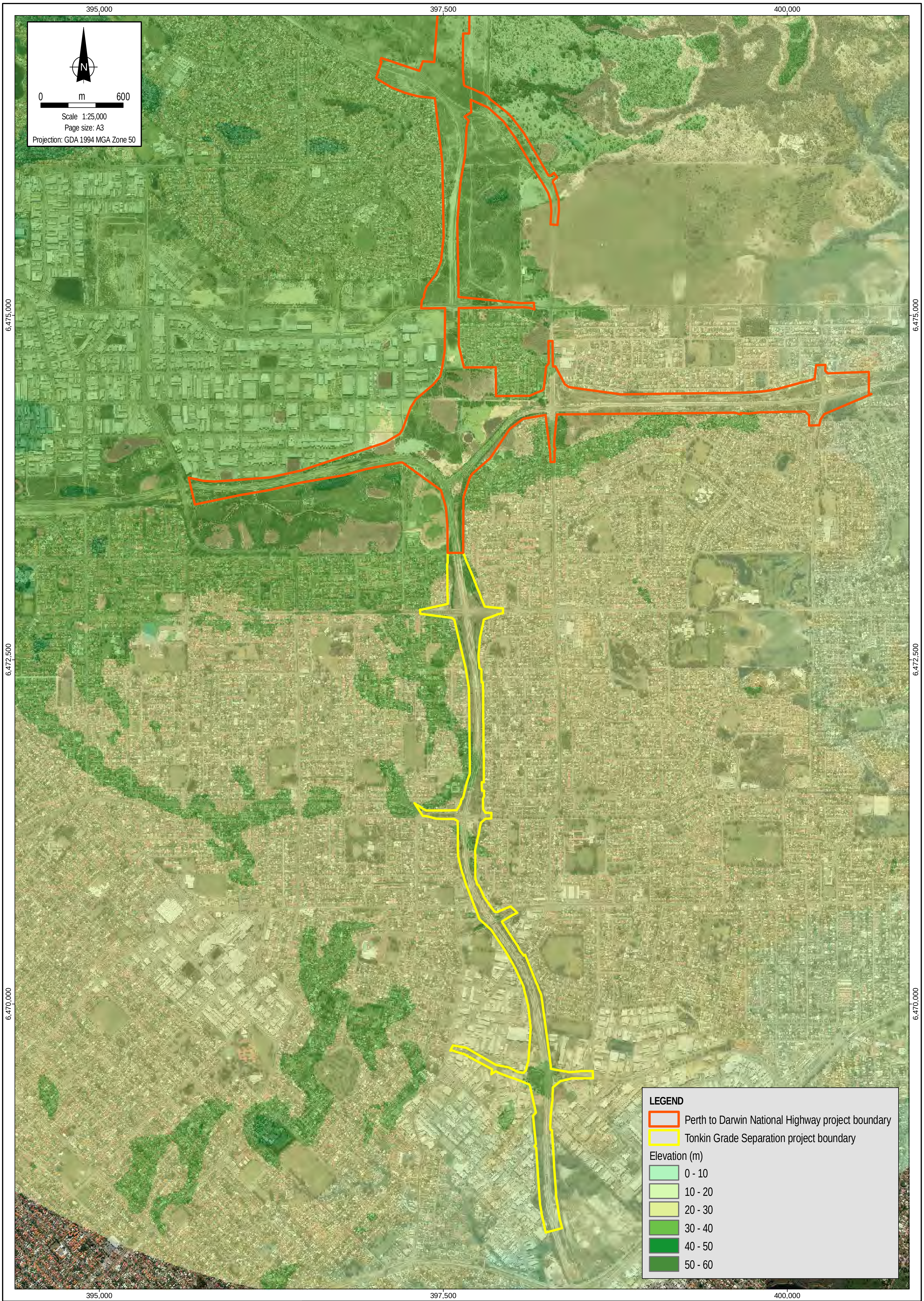
Date: 27.01.2015
MXT: 4483AA_18_GIS013_1
File Name: 4483AA_18_F002E_GIS

Main Roads WA

Preliminary Acid Sulfate Soils Investigation

Geomorphic wetlands

Figure No: 2E



Source & Notes
Dem data from MRWA.
Aerial imagery from Landgate.

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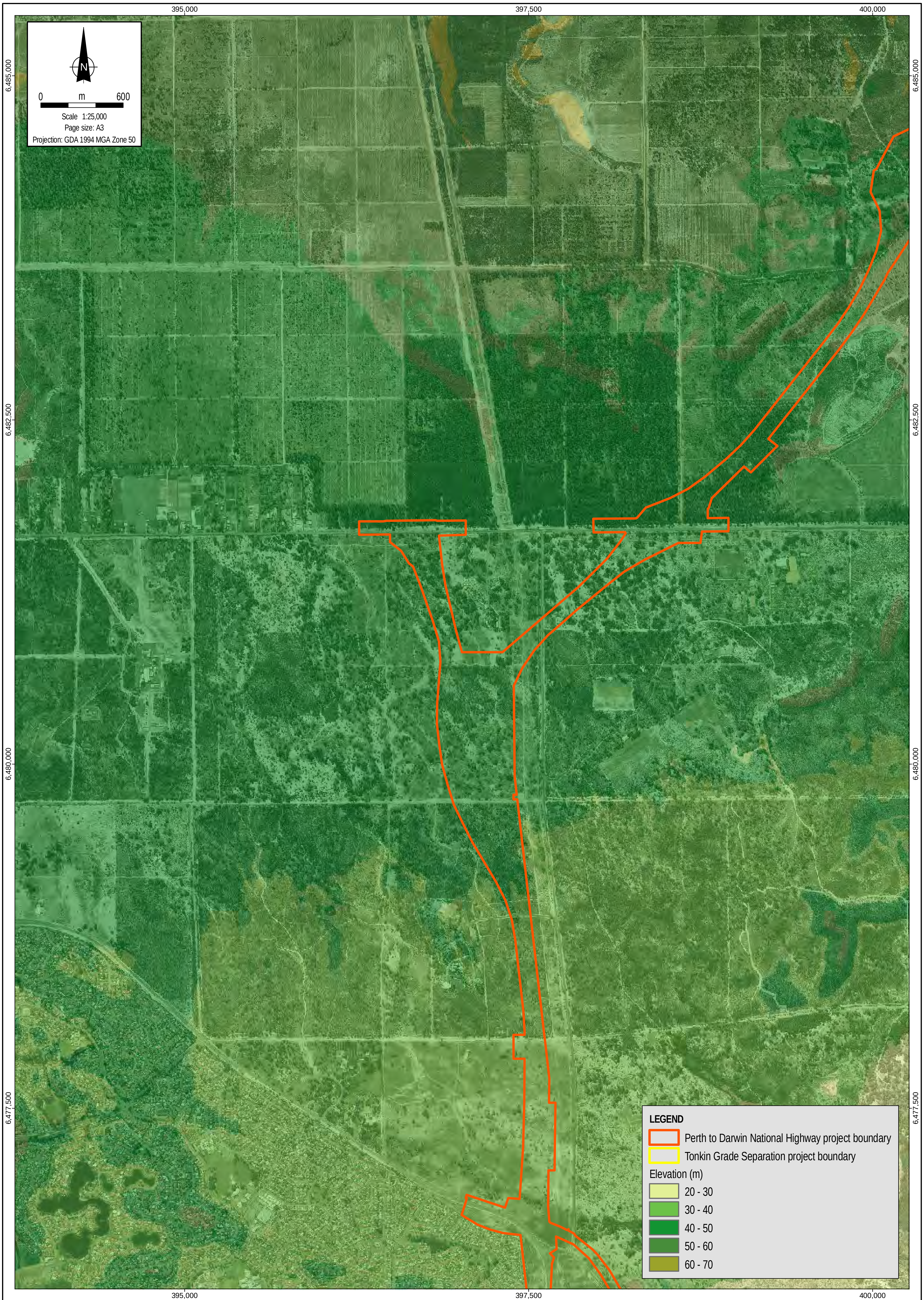
Date: 27.01.2015
MXT: 4483AA_18_GIS006_1
File Name: 4483AA_18_F003A_GIS

Main Roads WA

Preliminary Acid Sulfate Soils Investigation

Elevation

Figure No: 3A



Source & Notes
Dem data from MRWA.
Aerial imagery from Landgate.

NorthLinkWA | coffey

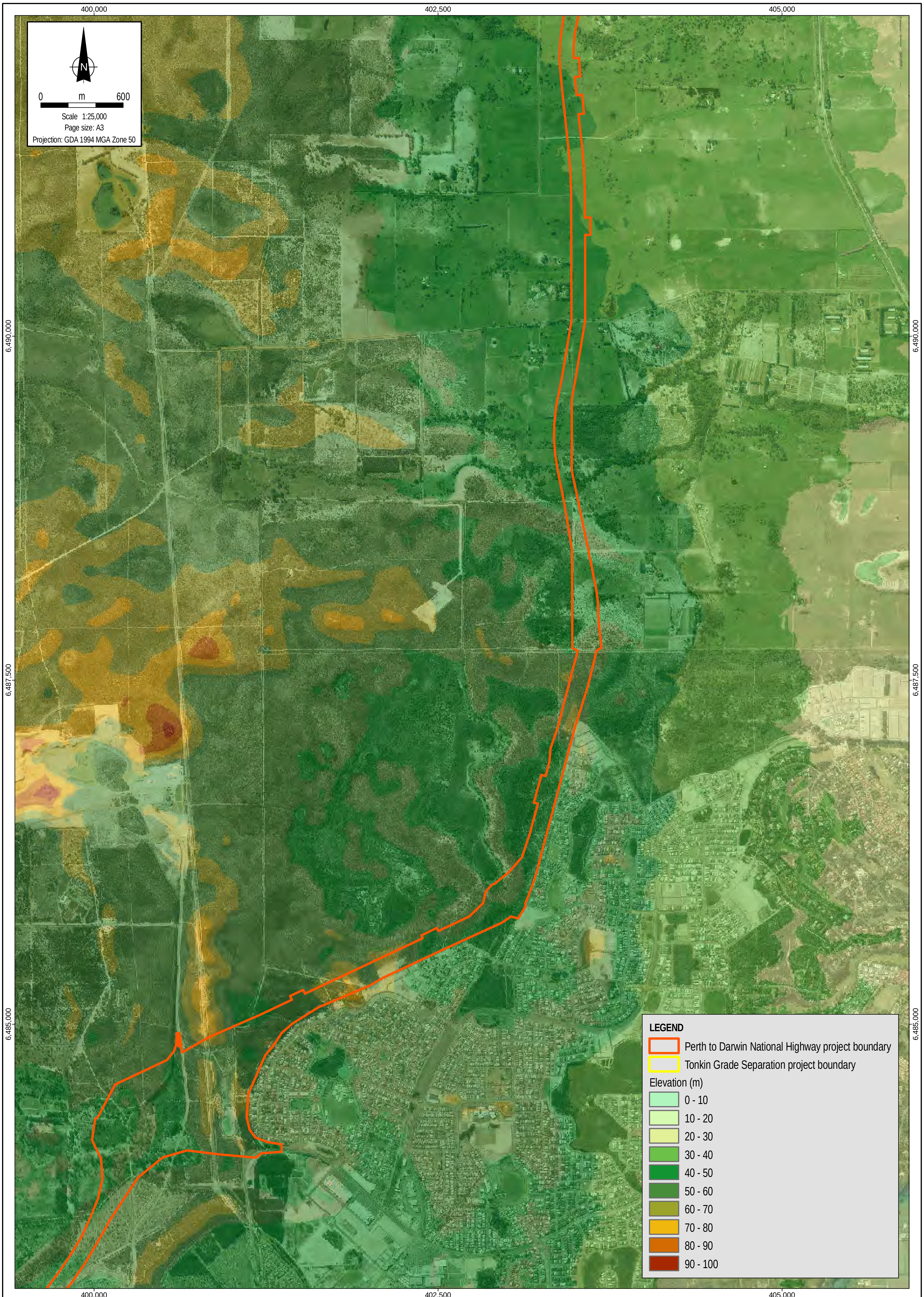
Date:	27.01.2015
MXT:	4483AA_18_GIS006_1
File Name:	4483AA_18_F003B_GIS

Main Roads WA

Preliminary Acid Sulfate Soils Investigation

Elevation

Figure No: 3B



Source & Notes
Dem data from MRWA.
Aerial imagery from Landgate.

NorthLinkWA coffey

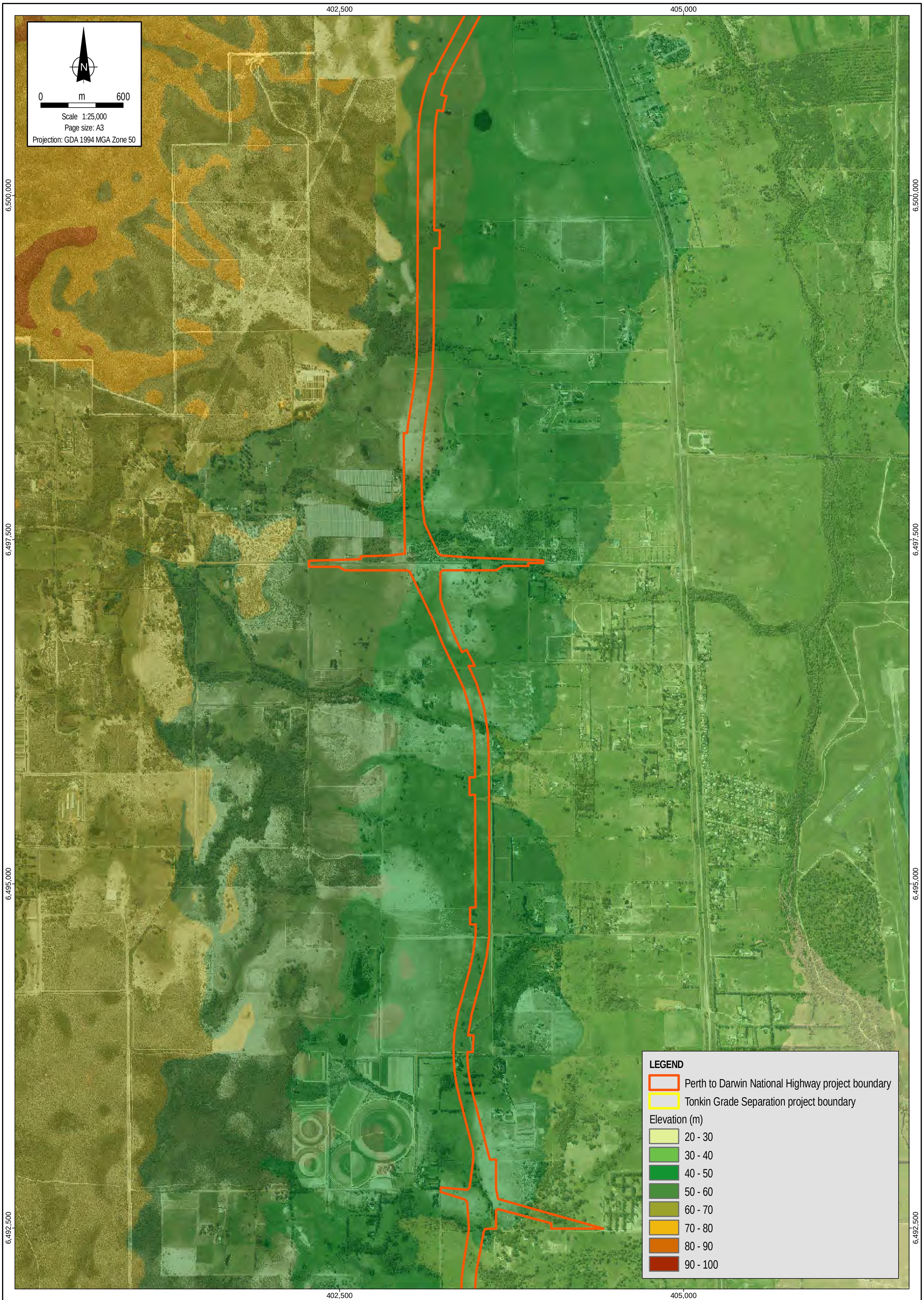
Date: 27.01.2015
MXT: 4483AA_18_GIS006_1
File Name: 4483AA_18_F003C_GIS

Main Roads WA

Preliminary Acid Sulfate Soils Investigation

Elevation

Figure No: 3C



Source & Notes
Dem data from MRWA.
Aerial imagery from Landgate.

NorthLinkWA coffey

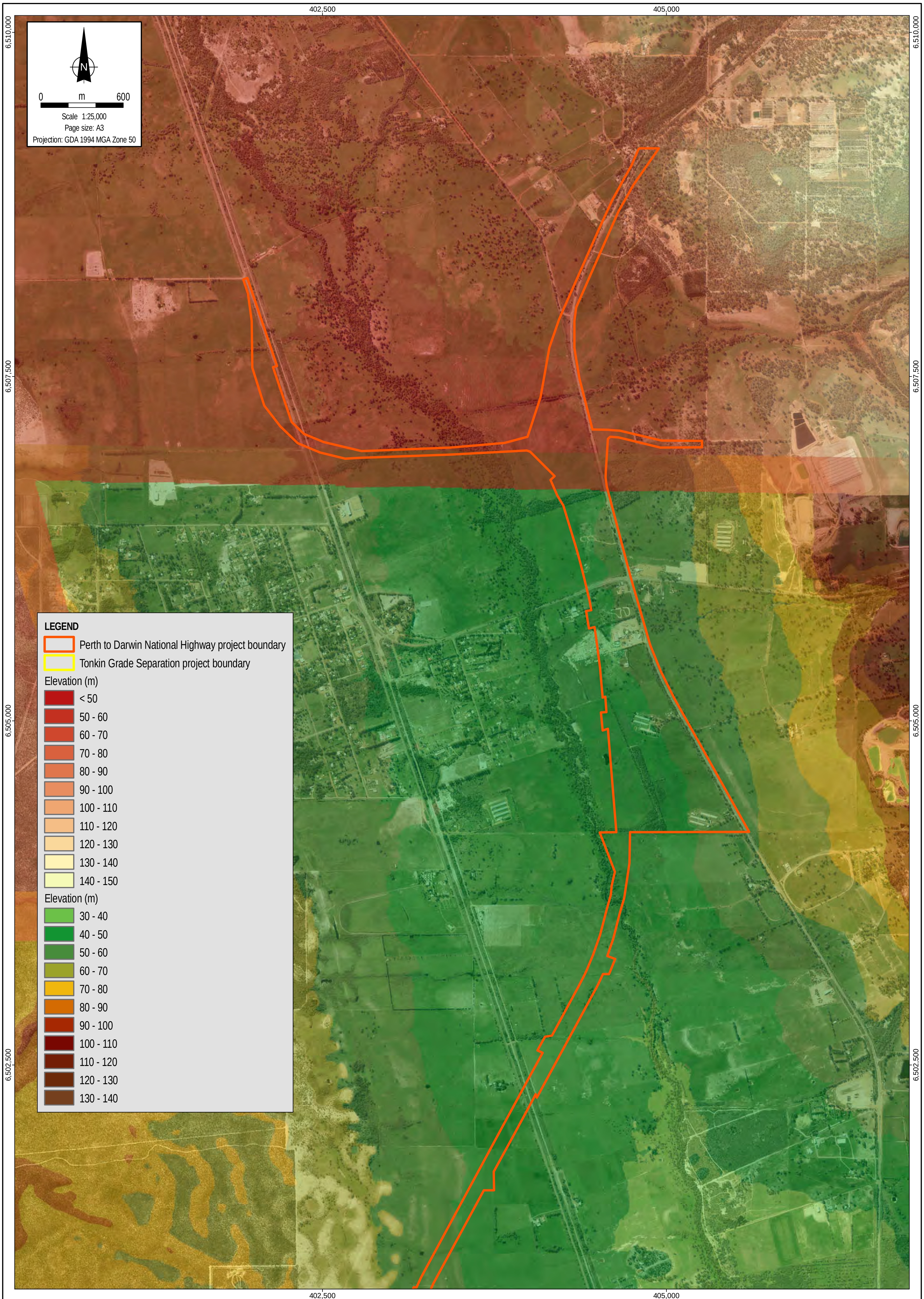
Date:	27.01.2015
MXT:	4483AA_18_GIS006_1
File Name:	4483AA_18_F003D_GIS

Main Roads WA

Preliminary Acid Sulfate Soils Investigation

Elevation

Figure No: 3D



Source & Notes
Dem data from MRWA.
Aerial imagery from Landgate.

NorthLinkWA coffey

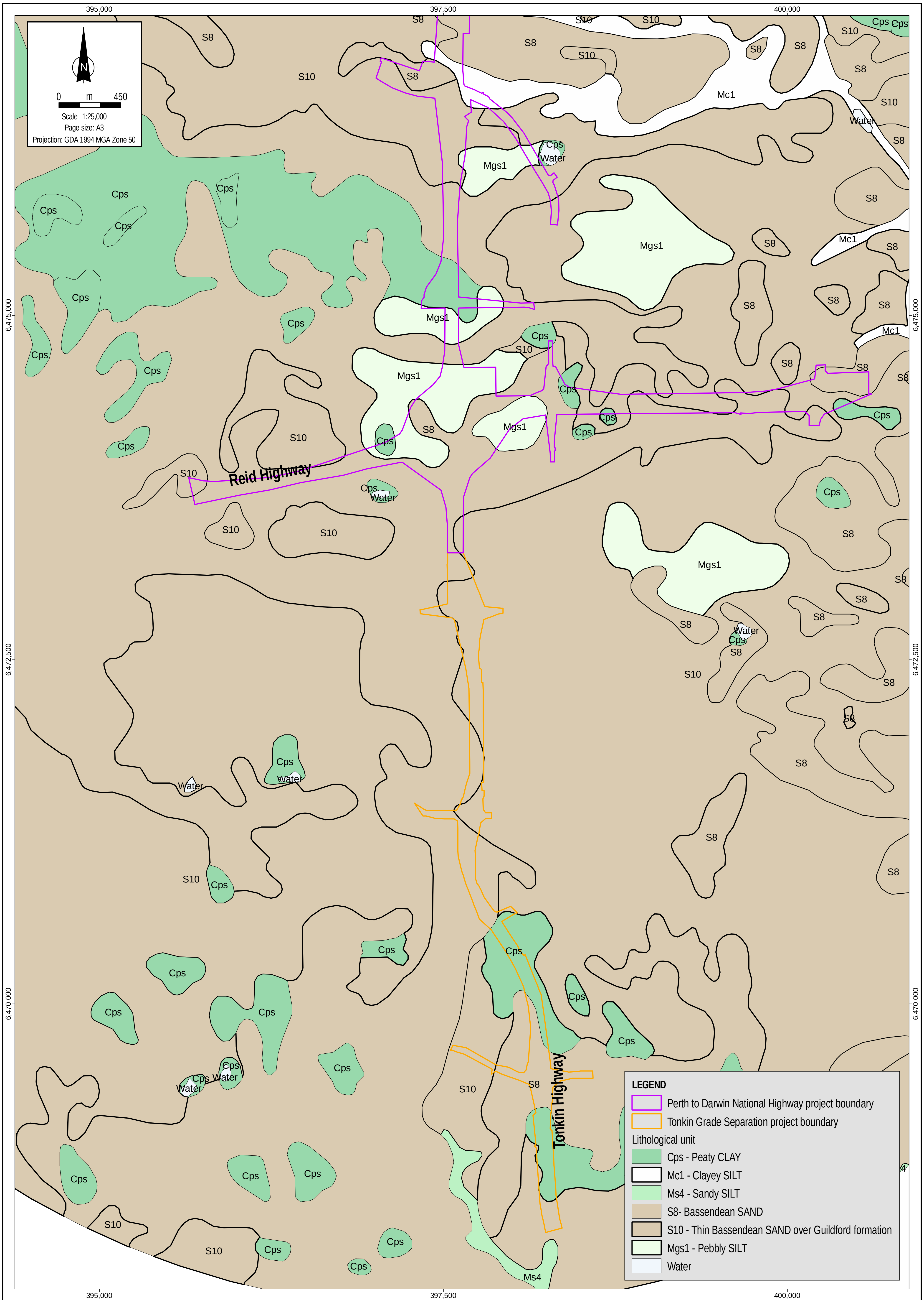
Date: 27.01.2015
MXT: 4483AA_18_GIS006_1
File Name: 4483AA_18_F003E_GIS

Main Roads WA

Preliminary Acid Sulfate Soils Investigation

Elevation

Figure No: 3E



Source & Notes
GSWA Geological maps (Perth Metropolitan Region Env. Geol.Series) 1982 and 1986.
Roads from MRWA.

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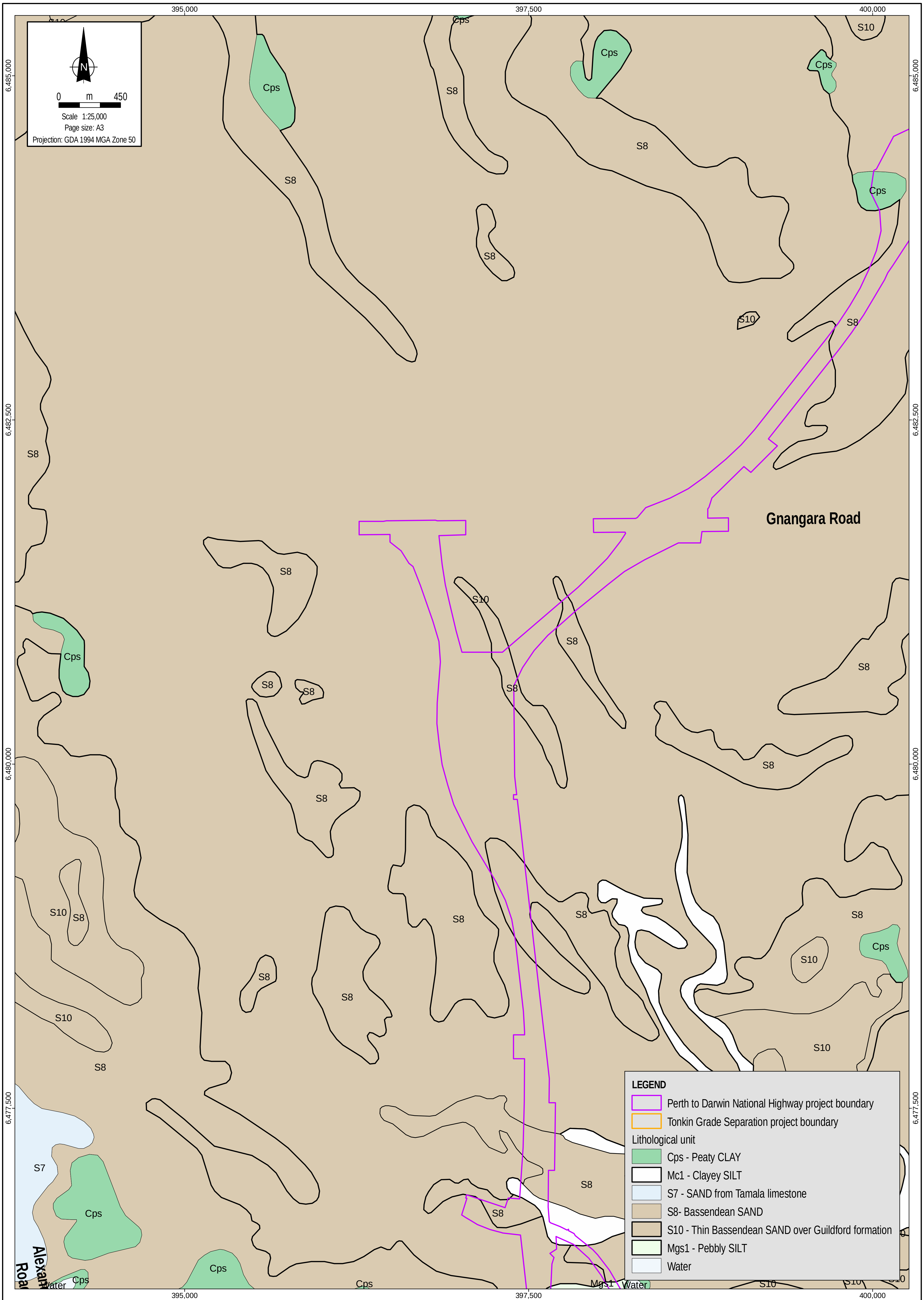
Date: 27.01.2015
MXT: 4483AA_18_GIS002_1
File Name: 4483AA_18_F004A_GIS

Main Roads WA

Preliminary Acid Sulfate Soils Investigation

Geology

Figure No: 4A



Source & Notes
GSWA Geological maps (Perth Metropolitan Region Env. Geol.Series) 1982 and 1986.
Roads from MRWA.

NorthLinkWA

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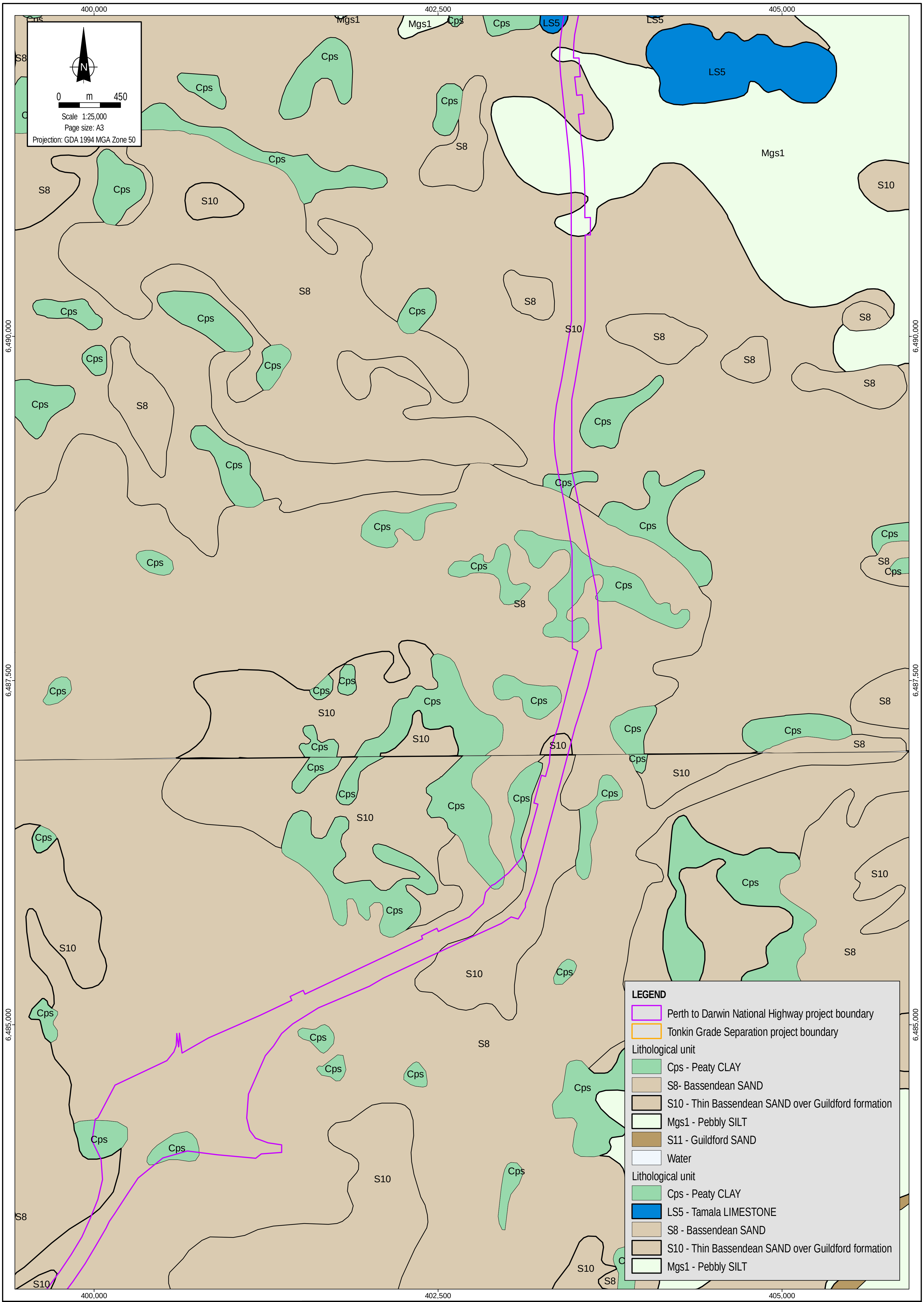
Date:	27.01.2015
MXT:	4483AA_18_GIS002_1
File Name:	4483AA_18_F004B_GIS

Main Roads WA

Preliminary Acid Sulfate Soils Investigation

Geology

Figure No: 4B



Source & Notes
GSWA Geological maps (Perth Metropolitan Region Env. Geol.Series) 1982 and 1986.
Roads from MRWA.

NorthLinkWA

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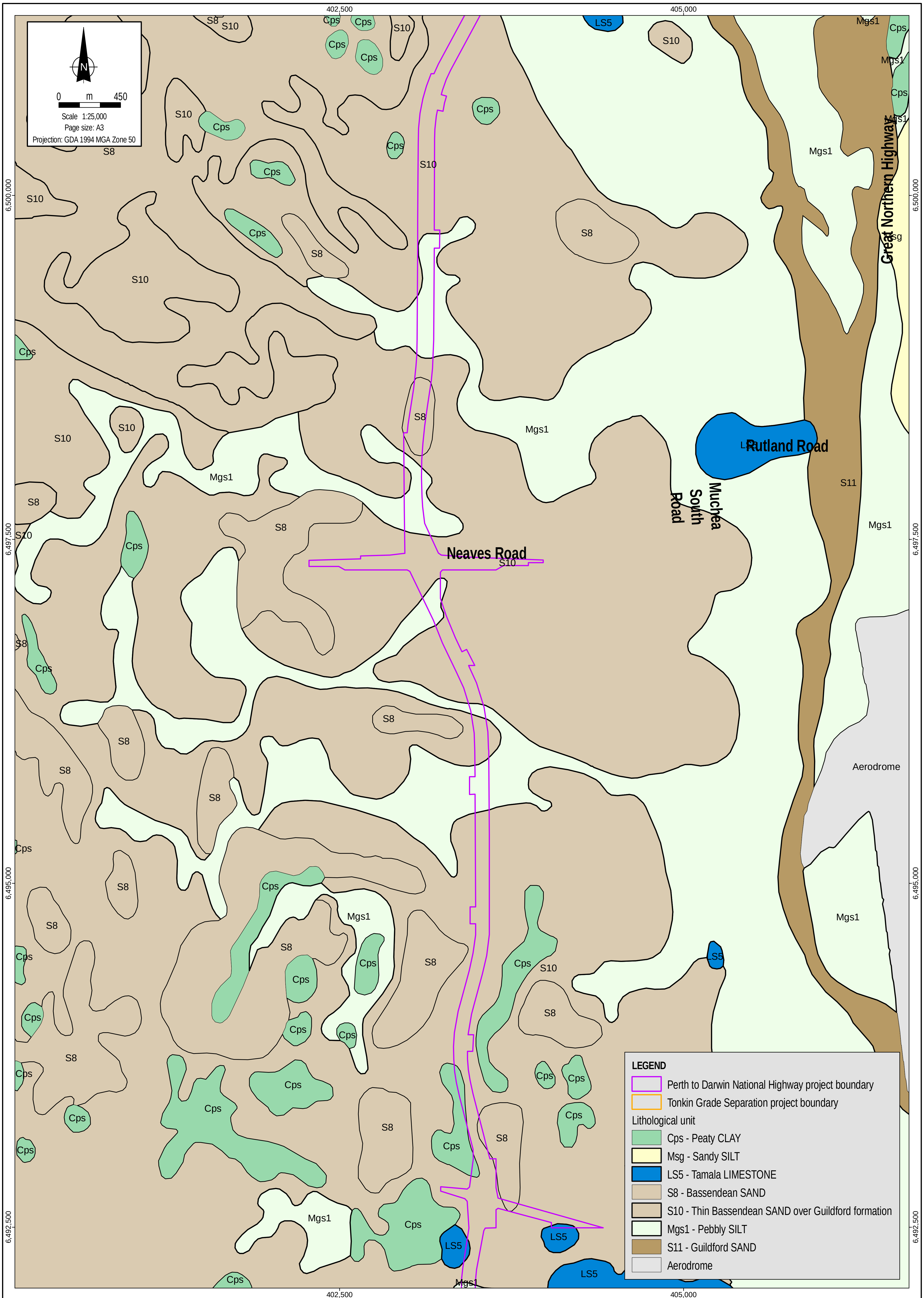
Date: 27.01.2015
MXT: 4483AA_18_GIS002_1
File Name: 4483AA_18_F004C_GIS

Main Roads WA

Preliminary Acid Sulfate Soils Investigation

Geology

Figure No: 4C



Source & Notes
GSWA Geological maps (Perth Metropolitan Region Env. Geol.Series) 1982 and 1986.
Roads from MRWA.

NorthLinkWA

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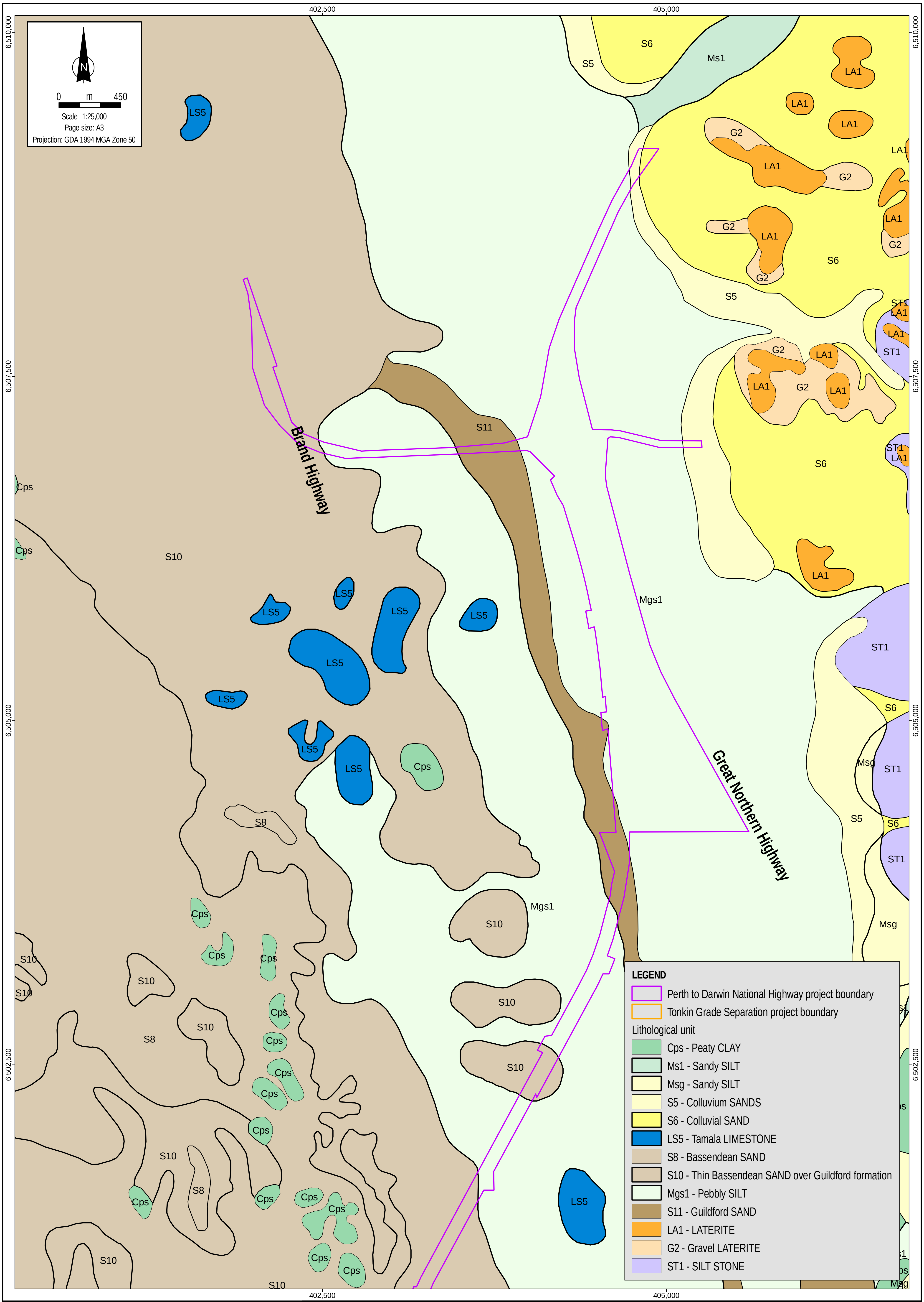
Date: 27.01.2015
MXT: 4483AA_18_GIS002_1
File Name: 4483AA_18_F004D_GIS

Main Roads WA

Preliminary Acid Sulfate Soils Investigation

Geology

Figure No: 4D



Source & Notes
GSWA Geological maps (Perth Metropolitan Region Env. Geol.Series) 1982 and 1986.
Roads from MRWA.

NorthLinkWA

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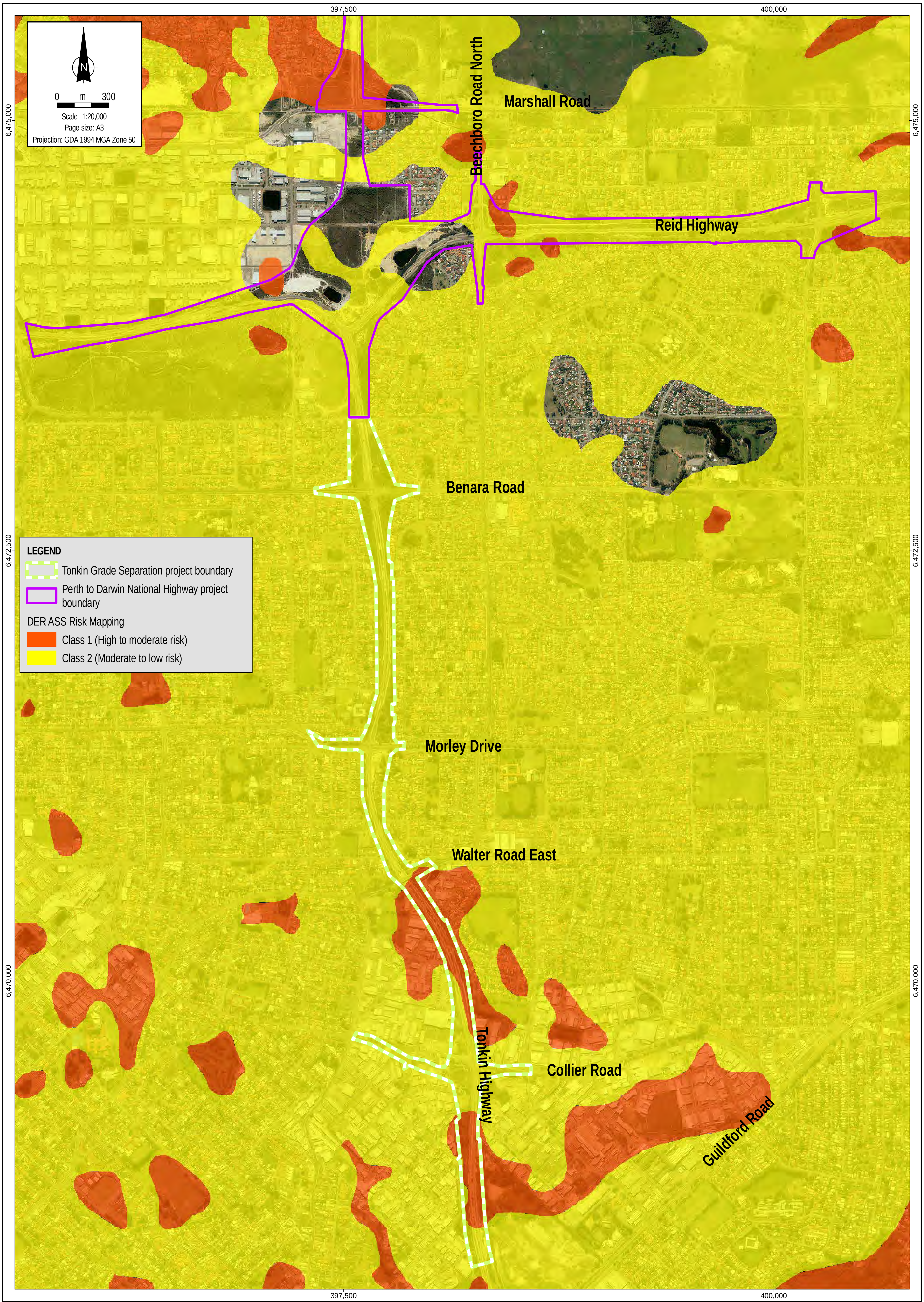
Date: 27.01.2015
MXT: 4483AA_18_GIS002_1
File Name: 4483AA_18_F004E_GIS

Main Roads WA

Preliminary Acid Sulfate Soils Investigation

Geology

Figure No: 4E



Source & Notes
DER ASS Riak Mapping from DER.
Cadastre from MRWA (August 2014)
Aerial imagery from Landgate (August 2014)

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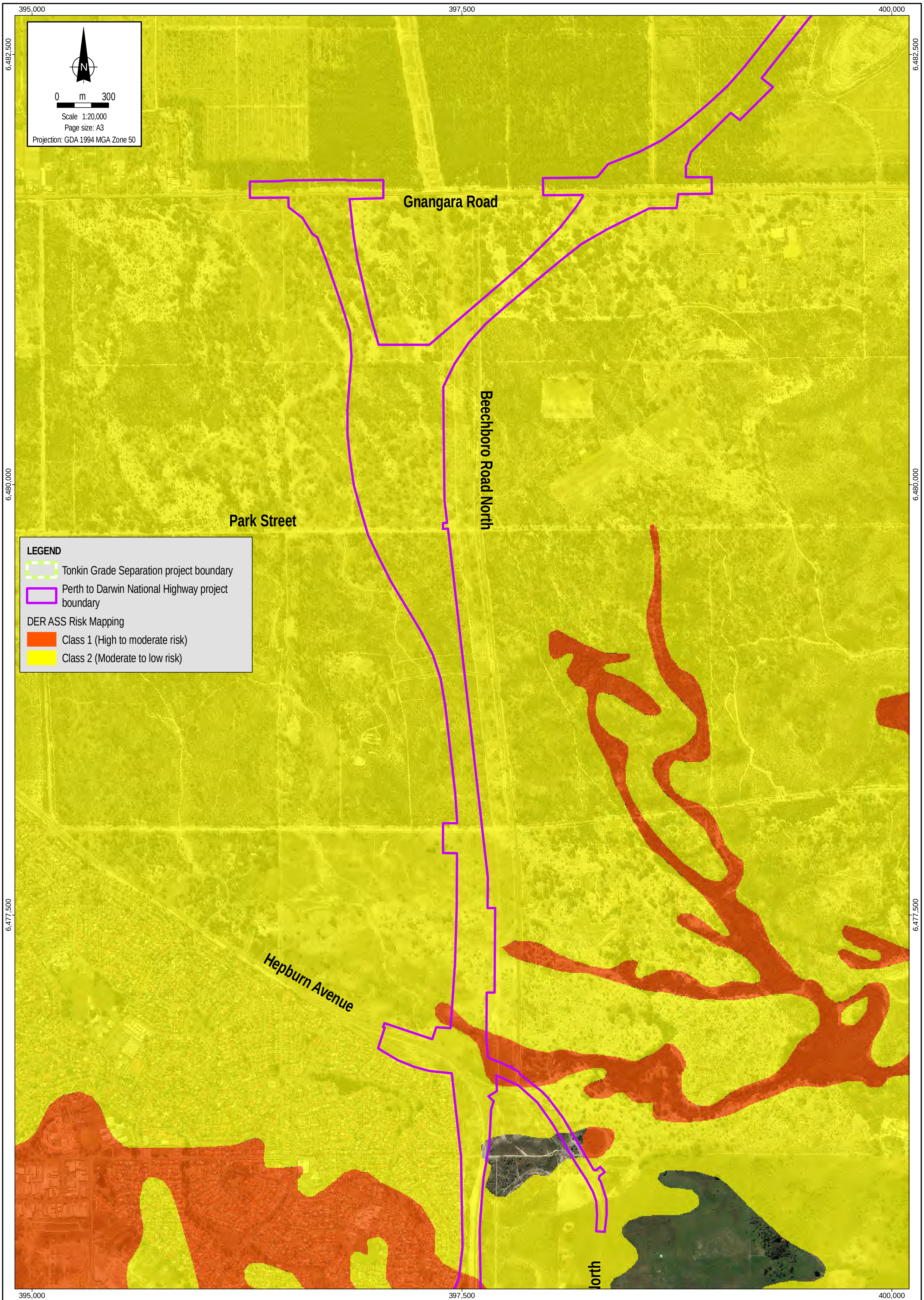
Date: 27.01.2015	Main Roads WA	DER Acid Sulfate Soils Risk Mapping	Figure No: 5A
MXT: 4483AA_18_GIS009_2	Preliminary Acid Sulfate Soils Investigation		
File Name: 4483AA_18_F005A_GIS			



Source & Notes
DER ASS Riak Mapping from DER.
Cadastre from MRWA (August 2014)
Aerial imagery from Landgate (August 2014)

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Date: 27.01.2015 MXT: 4483AA_18_GIS009_2 File Name: 4483AA_18_F005B_GIS	Main Roads WA Preliminary Acid Sulfate Soils Investigation	DER Acid Sulfate Soils Risk Mapping	Figure No: 5B