GEMINI PROJECT
Site-Specific EA Application

MAGNETIC SOUTH PTY LTD
December 2020

VOLUME 3:

- Appendix G: Geochemical Assessment of Mining Waste Materials
- Appendix H: Geochemical Assessment of Coal Reject Materials
- Appendix I: Soils and Land Suitability Assessment
- Appendix J: Terrestrial Ecology Assessment

BRISBANE OFFICE
Suite 5, 1 Swann Road
Taringa, QLD 4068
P +61 7 3217 8772

CAIRNS OFFICE
PO Box 4887
Cairns, QLD 4879
P +61 7 4057 9402

E info@aarc.net.au
AARC.NET.AU

ACN. 620 818 920
ABN. 71 620 818 920

AARC Environmental Solutions Pty Ltd

Appendix G Geochemical Assessment of Mining Waste Materials

Gemini Project

Geochemical Assessment of Mining Waste Materials

Report prepared for:

Magnetic South Pty Ltd

Date: 20 September 2019
Project Number: 2017002
Document Number: R001_A

Prepared by: Dr. Alan M. Robertson
RGS Environmental Pty Ltd ATF
RGS Environmental Family Trust
123 Wynne Street
Sunnybank Hills QLD 4109
Australia

Tel/Fax: +61 7 3344 1222
Mob: +61 431 620 623
Email: alan@rgsenv.com
Webpage: http://www.rgsenv.com

LEADERS IN MINING GEOCHEMISTRY

EXECUTIVE SUMMARY

ES1 Background

Magnetic South Pty Ltd (Magnetic South) is the project proponent and the applicant for Mining Lease (ML) and Environmental Authority (EA) to develop the Gemini Coal Project (the Project), a greenfield open cut mine to produce pulverised coal injection (PCI) coal and Coking Coal products for export for steel production. The Project term is anticipated to be 25 years from grant of the ML with this term including initial construction, mine operation and rehabilitation activities.

The Project is located on EPC 881 in the Bowen Basin, Central Queensland. Located 20 km east of Bluff and 6 km west of Dingo, the tenement straddles the Capricorn Highway and the Blackwater-Gladstone rail network (**Figure 1**, **Attachment A**).

The main activities associated with the Project that are related to mining waste geochemistry include:

- Exploration activities continuing in order to support mine planning.
- Construction and operation of a Coal Handling Preparation Plant (CHPP) and coal handling facilities adjacent to the MIA (including Run-of-Mine (ROM) coal, product stockpiles and reject stockpiles [coarse and fine rejects]).
- Development and mining of mine areas (open cut pits) and out-of-pit spoil emplacements.
- Progressive placement of spoil (overburden/interburden) in:
    - Emplacements, adjacent to and near the open cut voids.
    - Mine voids, behind the advancing open cut mining operations.
- Progressive rehabilitation of waste rock emplacement areas and mined voids.
- Progressive establishment of soil stockpiles, laydown area and borrow pits (for road base and civil works). Material will be sourced from local quarries where required.
- Disposal of CHPP rejects (coarse and fine rejects) in out of pit waste rock emplacements, and in-pit behind the mining void.

Existing local and regional infrastructure, facilities and services will be used to support Project activities. These include the SunWater water distribution network, the Aurizon rail network, Ergon's electricity network, the Capricorn Highway, and Gladstone export coal terminals.

The proposed mine will target the Rangal coal measures. Up to seven seams/plies are targeted, ranging in thickness from 0.5 m to 3.0 m. The seams are impacted by faulting and seam splitting and are typically overlain by overburden ranging in depth from 45 m to 60 m.

As the mine is planned to be an open cut mine, there will be spoil generated from removal of the overburden and interburden to access to the target coal seams. This spoil will report to the overburden emplacement facility and therefore needs to be geochemically characterised. Similarly, coal and coal reject (coarse reject and tailings) likely to be generated from washing of the target coal seams at the CHPP may also report to surface storage facilities and needs to be geochemically characterised, although the geochemical characterisation of coal reject materials is the subject of a separate report (RGS, 2019).

ES2 Scope of Work

As part of the technical studies being completed for input into the environmental approvals process for the Project, RGS Environmental Pty Ltd (RGS) was commissioned by Magnetic South to complete a geochemical assessment of mining waste (overburden and interburden) materials at the Project.

The objective of the scope of work was to complete a geochemical assessment of representative samples of mining waste materials in accordance with relevant legislation, guidelines and policies and with a level of rigour consistent with the Queensland EIS approvals process. The scope of work included:

- Review of available geochemical and geological data and drill hole database (including plans, drill hole logs and drill core photographs) associated with the Project;
- Design of a geochemical assessment program, including sampling for and testing of representative overburden and potential coal reject materials within the Project boundary. The program utilised exploration drill core/drill chip samples from drilling programs;
- Coordination of the material sampling and geochemical characterisation programs;
- Geochemical characterisation of overburden from the proposed open pit area and potential coal reject material from strata in and around the target seams;
- Development of any necessary environmental management measures related to overburden and potential coal reject emplacement and rehabilitation; and
- Preparation of a Geochemical Assessment Report based on existing information, sample analyses and discussion regarding any acid and metalliferous drainage (AMD) potential or other salinity and sodicity issues related to the Project.

The outcome of completion of the above scope of work is this stand-alone technical report (suitable for inclusion as an appendix to the regulatory approvals documentation), which provides an overview of the proposed Project; a description of the sampling and geochemical testing methodology; presentation and discussion of the results and findings; and develops conclusions and recommendations.

ES3 Methodology

The sampling strategy and subsequent geochemical characterisation strategy for mining waste materials from the proposed Project was guided by Australian (DME, 1995, DEHP, 2013; and COA, 2016) and international (INAP, 2009) technical guidelines for the geochemical assessment of mining wastes. The more recent guidelines favour a risk-based approach to determine the sampling frequency at a proposed mining operation. The sampling strategy at the Project identified representative (fresh drill core/drill chip) samples of mining waste materials from the exploration drilling program.

The results of the sampling and geochemical testing program provided important information to assist with the planning and management of operational and mine closure issues. In particular, the characterisation of mine waste materials potentially intended for use in mine rehabilitation activities was completed so that the geochemical characteristics of these materials were sufficiently well understood to ensure performance according to operational and mine closure planning expectations.

A total of 70 mining waste samples were collected from three drill holes at the proposed Project. The samples represented the main overburden, interburden and potential coal reject materials likely to be encountered during development at the proposed Project from surface down through the stratigraphic profile (including economic and uneconomic coal seams) to the base of the open pit.

The number of samples was selected to provide a good statistical representation of the amount and types of mining waste materials expected to be generated at the Project, whilst accounting for the risk profile indicated from the geology at the Project and a working knowledge of the Rangal Coal Measures.

A range of static and kinetic geochemical tests were completed on the samples. The geochemical tests were used to assess the presence and degree of risk from oxidation of reactive sulfides, potential for acid generation, and leaching of soluble metals/metalloids and salts. The assessment also included some characterisation of chemical parameters related to sodicity and material stability.

ES4 Conclusions

The main findings of the geochemical assessment are as follows:

- All of the mining waste samples tested are Non-Acid Forming (NAF), have excess Acid Neutralising Capacity (ANC) and typically have low sulfur content. The sulfur content of coal and carbonaceous siltstone can be elevated compared to typical background concentrations, but is mainly present in a non-sulfidic form, which does not contribute to acid generation. Overall, these materials have a low risk of acid generation and a high factor of safety with respect to potential for AMD.
- Initial and ongoing surface runoff and seepage from mining waste materials is expected to be moderately alkaline and have a moderate level of salinity.
- Kinetic leach column (KLC) test results indicate that mining waste materials are unlikely to generate acid conditions and are more likely to generate pH neutral to alkaline conditions.
- Metal/metalloid enrichment in mining wastes, compared to median crustal abundance in unmineralised soils, is limited to cobalt in a single carbonaceous siltstone sample. The nature of a coal deposit means some metals/metalloids are expected to be slightly elevated in some materials.
- Most metals/metalloids are sparingly soluble at the neutral to alkaline pH of leachate expected from bulk mining waste materials. Dissolved metal/metalloid concentrations in surface runoff and leachate from bulk mining waste materials are therefore expected to be low and unlikely to pose a significant risk to the quality of surface and groundwater resources at relevant storage facilities.
- Mining waste materials should be amenable to revegetation as part of rehabilitation activities, although, gypsum and fertiliser addition may need to be considered for sodic materials to limit dispersion and erosion and to provide a reasonable growth medium for revegetation and rehabilitation.
- As most mining materials appear to be susceptible to dispersion and erosion, additional testing including field trials, may be needed when the mine is operational and bulk materials are being generated. Such tests would help to determine the most appropriate management option for progressive rehabilitation of these materials during operations at mine closure.

ES5 Recommendations

As a result of the geochemical assessment work completed on mining waste materials at the Project, a number of recommendations are provided for these materials to minimise the risk of any significant environmental harm to the immediate and downstream environment.

- Placement of any carbonaceous mining waste material encountered during mining at the surface and outer batters of spoil emplacement areas should be avoided.
- Additional overburden/interburden testing and rehabilitation field trials should be completed during operations when bulk materials become available to confirm the most appropriate management option for progressive rehabilitation of these materials during operations and at mine closure.
- Surface water and seepage from the proposed mining and mining waste storage areas should be monitored to ensure that key water quality parameters remain within appropriate criteria. Water quality monitoring parameters should include pH, EC, total suspended solids (TSS) on a quarterly basis and the suite of water quality analyses described in **Table B4** (**Attachment B**) of this report opportunistically and at least on an annual basis.

TABLE OF CONTENTS

1.0 INTRODUCTION 1
1.1 Project Description 1
1.2 Scope of Work 2
2.0 REGIONAL AND LOCAL GEOLOGY 4
2.1 Resource Description 4
3.0 METHODOLOGY 5
3.1 Material Sampling 5
3.2 Geochemical Characterisation 5
3.2.1 Static Tests 6
3.2.2 Kinetic Tests 7
4.0 GEOCHEMICAL TEST RESULTS 8
4.1 Acid Base Account 8
4.2 Multi-Element Concentration in Solids 11
4.3 Geochemical Abundance Index 12
4.4 Cation Exchange Capacity and Sodicity 13
4.5 Water Quality Static Tests 13
4.6 Water Quality Kinetic Tests 14
5.0 DISCUSSION 17
5.1 AMD Potential and Management 17
5.2 Multi-Element Composition and Water Quality 17
5.2.1 Multi-element Composition and Enrichment 17
5.2.2 Water Quality 17
5.3 Revegetation and Rehabilitation 18
6.0 CONCLUSIONS AND RECOMMENDATIONS 19
6.1 Conclusions 19
6.2 Recommendations 19
7.0 REFERENCES 20
8.0 LIMITATIONS 21

LIST OF FIGURES (Attachment A – end of text)

Figure A1: Project Location
Figure A2: Representative Stratigraphic Column
Figure A3: Conceptual Project Layout

LIST OF TABLES (In text)

Table 3-1: Drill hole maximum sample depth and number of samples
Table 4-1: Geochemical classification criteria for mining waste materials
Table 4-2: Geochemical Abundance Index (GAI) values and enrichment factors
Table 4-3: Ratings for effective Cation Exchange Capacity
Table 4-4: Sulfate generation and sulfide oxidation rates for KLC Tests on mining waste

LIST OF GRAPHS

Graph 4-1: pH values for mining waste from Gemini Project
Graph 4-2: EC values for mining waste from Gemini Project
Graph 4-3: Total sulfur for mining waste from Gemini Project
Graph 4-4: NAPP values for mining waste from Gemini Project
Graph 4-5: ANC v MPA for mining waste from Gemini Project

LIST OF ATTACHMENTS

Attachment A: Figures
Attachment B: Tables of Results
Attachment C: Geochemical Assessment of Mining Waste Materials
Attachment D: KLC Test Results and Trends
Attachment E: ALS Laboratory Results

GLOSSARY OF TERMS AND ACRONYMS

Acidity	A measure of hydrogen ion (H+) concentration; generally expressed as pH.
Acid Base Account	Evaluation of the balance between acid generation and acid neutralisation processes. Generally determines the maximum potential acidity (MPA) and the inherent acid neutralising capacity (ANC), as defined below.
AMD	Acid and metalliferous drainage caused by exposure of sulfide minerals in mining waste materials to oxygen and water. Typically characterised by low pH and elevated concentrations of salts, sulfate and metals.
ANC	Acid neutralising capacity of a sample as kg H_2SO_4 per tonne of sample.
ANC:MPA Ratio	Ratio of the acid neutralising capacity and maximum potential acidity of a sample. Used to assess the risk of a sample generating acid conditions.
pH	Measure of the hydrogen ion (H+) activity in a sample solution, expressed in pH units.
EC	Electrical Conductivity, expressed as µS/cm.
eCEC	Effective cation exchange capacity provides a measure of the amount of exchangeable cations (Ca, Mg, Na and K) in a sample.
ESP	Exchangeable sodium percentage provides a measure of the sodicity of a materials and propensity to erode.
KLC test	Kinetic leach column tests are procedures used to measure the geochemical/ weathering behaviour of a sample of mine material over time.
MPA	Maximum Potential Acidity calculated by multiplying the total sulfur content of a sample by 30.6 (stoichiometric factor) and expressed as kg H_2SO_4 per tonne.
NAF	Non-acid forming. Geochemical classification criterion for a sample that will not generate acid conditions.
NAG test	Net acid generation test. Hydrogen peroxide solution is used to oxidise sulfides in a sample, then any acid generated through oxidation may be consumed by neutralising components in the sample. Any remaining acidity is expressed as kg H_2SO_4 per tonne.
NAPP	Net acid producing potential expressed as kg H_2SO_4 per tonne. Calculated by subtracting the ANC from the MPA.
Overburden	Material that overlays a coal resource and must be removed to mine the coal.
PAF	Potentially acid forming. Geochemical classification criterion for a sample that has the potential to generate acid conditions.
Static test	Procedure for characterising the geochemical nature of a sample at one point in time. Static tests may include measurements of mineral and chemical composition of a sample and the Acid Base Account.
Total Sulfur	Total sulfur content of a sample generally measured using a 'Leco' analyser expressed as % S.
Uncertain	Geochemical classification criterion for a sample where the potential to generate acid conditions remains uncertain and may require further analysis.

1.0 INTRODUCTION

1.1 Project Description

Magnetic South Pty Ltd (Magnetic South) is the project proponent and the applicant for Mining Lease (ML) and Environmental Authority (EA) to develop the Gemini Project (the Project), a greenfield open cut mine to produce pulverised coal injection (PCI) coal and Coking Coal products for export for steel production. The Project term is anticipated to be 25 years from grant of the ML with this term including initial construction, mine operation and rehabilitation activities.

The Project is located on EPC 881 in the Bowen Basin, Central Queensland. Located 20 km east of Bluff and 6 km west of Dingo, the tenement straddles the Capricorn Highway and the Blackwater-Gladstone rail network (**Figure 1**, **Attachment A**).

The main activities associated with the Project include:

- Exploration activities continuing in order to support mine planning.
- Development of a Mine Infrastructure Area (MIA) including mine offices, bathhouse, crib rooms, warehouse/stores, workshop, fuel storage, refuelling facilities, explosives magazine and sewage, effluent and liquid waste storage.
- Construction and operation of a Coal Handling Preparation Plant (CHPP) and coal handling facilities adjacent to the MIA (including Run-of-Mine (ROM) coal, product stockpiles and reject stockpiles [coarse and fine rejects]).
- Construction and operation of a surface conveyor from the product stockpiles to a Train Load Out (TLO) facility and rail loop connecting to the Blackwater-Gladstone Branch Rail to transport product coal to coal terminals at Gladstone for export.
- Construction of access roads from the Capricorn Highway to the MIA, and to the TLO facility.
- Installation of a raw water supply pipeline to connect to the Blackwater Pipeline network.
- Construction of a 66 kV transmission line and switching/substation to connect to the existing regional network.
- Other associated minor infrastructure, plant, equipment and activities.
- Development of mine areas (open cut pits) and out-of-pit waste rock emplacements.
- Drilling and blasting of competent waste material.
- Mine operations using conventional surface mining equipment (excavators, front end loaders, rear dump trucks, dozers).
- Mining up to 1.9 Mtpa ROM Coal – average 1.8 Mtpa for an operational mine life of approximately 20 years.
- Progressive placement of waste rock (overburden/interburden) in:
  - Emplacements, adjacent to and near the open cut voids.
  - Mine voids, behind the advancing open cut mining operations.
- Progressive rehabilitation of waste rock emplacement areas and mined voids.
- Progressive establishment of soil stockpiles, laydown area and borrow pits (for road base and civil works). Material will be sourced from local quarries where required.

- Disposal of CHPP rejects (coarse and fine rejects) in out of pit waste rock emplacements, and in-pit behind the mining void.
- Progressive development of internal roads and haul roads including a causeway over Charlevue Creek to enable coal haulage and pit access.
- Development of water storage dams and sediment dams, and the installation of pumps, pipelines, and other water management equipment and structures including temporary levees, diversions and drains.

Existing local and regional infrastructure, facilities and services will be used to support Project activities. These include the SunWater water distribution network, the Aurizon rail network, Ergon's electricity network, the Capricorn Highway, and Gladstone export coal terminals.

The proposed mine will target the Rangal coal measures. Up to seven seams/plies are targeted, ranging in thickness from 0.5 m to 3.0 m. The seams are impacted by faulting and seam splitting and are typically overlain by overburden ranging in depth from 45 m to 60 m.

As the mine is planned to be an open cut mine, there will be spoil generated from removal of the overburden and interburden to access to the target coal seams. This spoil will report to the overburden emplacement facility and therefore needs to be geochemically characterised. Similarly, coal and coal reject (coarse reject and tailings) likely to be generated from washing of the target coal seams at the CHPP may also report to surface storage facilities and needs to be geochemically characterised, although the geochemical characteristics of coal reject materials are the subject of a separate report (RGS, 2019).

1.2 Scope of Work

As part of the technical studies being completed for input into the environmental approvals process for the Project, RGS Environmental Pty Ltd (RGS) was commissioned by Magnetic South to complete a geochemical assessment of mining waste (overburden and interburden) materials at the Project.

The scope of work is based upon that described in RGS Proposal No. 2017002, dated 17th January, 2017 (RGS, 2017a). The objective of the scope of work was to complete a geochemical assessment of representative samples of mining waste materials in accordance with relevant legislation, guidelines and policies and with a level of rigour consistent with the Queensland EIS approvals process.

The scope of work included:

- Review of available geochemical and geological data and drill hole database (including plans, drill hole logs and drill core photographs) associated with the Project;
- Design of a geochemical assessment program, including sampling for and testing of representative overburden and potential coal reject materials within the Project boundary. The program utilised exploration drill core/drill chip samples from drilling programs;
- Coordination of the material sampling and geochemical characterisation programs;
- Geochemical characterisation of overburden from the proposed open pit area and potential coal reject material from strata in and around the target seams;
- Development of any necessary environmental management measures related to overburden and potential coal reject emplacement and rehabilitation; and
- Preparation of a Geochemical Assessment Report based on existing information, sample analyses and discussion regarding any acid and metalliferous drainage (AMD) potential or other salinity and sodicity issues related to the Project.

The outcome of completion of the scope of work is this stand-alone technical report (suitable for inclusion as an appendix to the regulatory approvals documentation), which provides an overview of the proposed

Project; a description of the sampling and geochemical testing methodology; presentation and discussion of the results and findings; and develops conclusions and recommendations.

The focus of this report is the acquisition and interpretation of the results of a static geochemical testing program of mining waste materials and the report also evaluates the results of a subsequent six-month kinetic geochemical testing program.

2.0 REGIONAL AND LOCAL GEOLOGY

2.1 Resource Description

The Project is located in one of the principal geological structural units of the Bowen Basin, the Dawson Fold Zone, which overlays part of the western extent of the Taroom Trough. The area comprises sediments from the Rewan, Rangal, Burngrove and Fairhill Formations, and is bound in the west by the Yarrabee Fault.

The Project contains the Aries, Castor, Pollux, Orion and Pisces Seams of the Rangal Coal Measures. A representation of the typical stratigraphic profile in the Project area is provided in **Figure A2** (**Attachment A**). The Rangal Coal Measures conformably overlie the Burngrove Formation and consist primarily of siltstones, sandstones and coal seams. The sediments are consistent with a deltaic depositional environment.

The Rangal coal seams form the dominant resource across several areas of the central Bowen Basin. The Aries, Castor and Pollux seams are minable entities at most of the local mines in the Blackwater area and commonly coalesce and split from each other. These relationships are controlled structurally by differential subsidence in different areas during deposition.

Recoverable coal will come from the Rangal coal seams but may also target the Upper Burngrove formation. The Burngrove Formation contains several coal seams and is generally considered of lesser importance due to moderate to high ash levels. It is possible that some seams may have potential to produce domestic or export thermal products, depending on wash plant density cut points and acceptable yields.

The relatively shallow depth of the targeted seams and the cumulative thickness of 3.5 to 4.5 m from the Pollux and overlying seams make the Gemini area suitable for open cut mining.

3.0 METHODOLOGY

3.1 Material Sampling

The sampling strategy and subsequent geochemical characterisation strategy for overburden and potential coal reject materials from the proposed Project was guided by Australian (DME, 1995, DEHP, 2013; and COA, 2016) and international (INAP, 2009) technical guidelines for the geochemical assessment of mining wastes. The more recent guidelines favour a risk-based approach to determine the sampling frequency at a proposed mining operation. The sampling strategy at the Gemini Project identified and collected representative (fresh drill core/drill chip) samples of overburden and potential coal reject materials from the exploration drilling program.

The results of the sampling and geochemical testing program provided important information to assist with the planning and management of operational and mine closure issues. In particular, characterisation of overburden materials potentially intended for use in mine rehabilitation activities was completed so that the geochemical characteristics of these materials were sufficiently well understood to ensure performance according to operational and mine closure planning expectations.

A total of 70 waste rock samples were collected from three drill holes at the proposed Project (DW7002, DW7003 and DW7012). The location of the drill holes used for drill core/drill chip sampling and geochemical testing with respect to the proposed open pit areas is provided in **Figure A3 (Attachment A).**

The samples represented the main overburden, interburden, potential coal reject materials likely to be encountered during development at the proposed Project from surface down through the stratigraphic profile (including economic and uneconomic coal seams) to the base of the open pit. The number of samples was selected to provide a good statistical representation of the amount and types of mining waste materials expected to be generated at the Project, whilst accounting for the risk profile indicated from the geology at the Project and a working knowledge of the Rangal Coal Measures. The samples were collected by JC Irvine Pty Ltd geological personnel (with some guidance from RGS), who also dispatched the samples to ALS Environmental Brisbane laboratory (ALS Brisbane) for geochemical characterisation.

The maximum drill hole depth and number of samples at each hole is provided at **Table 3-1**. The samples were selected for the geochemical assessment program to reflect the occurrence and distribution of the overburden and interburden materials that occur within the open pit.

Table 3-1: Drill Hole Maximum Sample Depth and Number of Samples

Drill Hole ID	Total Depth (m)	Number of Samples
DW7002	158.00	22
DW7003	120.00	22
DW7012	148.00	26
	TOTAL	**70**

3.2 Geochemical Characterisation

All geochemical test work completed in this project was based on industry recognised procedures for the geochemical characterisation and assessment of mine materials (Parker and Robertson, 1999; AMIRA, 2002; INAP, 2009 and COA, 2016). A summary of those parameters involved in completing a static and kinetic geochemical characterisation and assessment of mine materials is provided in **Attachment C**.

3.2.1 Static Tests

Static geochemical tests provide a ‘snapshot’ of the characteristics of a sample material at a single point in time. These tests were completed to screen all samples before selecting individual samples for more detailed static test and kinetic geochemical tests.

All 70 samples received by ALS were crushed, sub-sampled and pulverised before being subjected to a series of static geochemical tests on the pulverised (<75 µm) sample fractions. The geochemical test program was coordinated by RGS personnel and designed to assess the degree of risk from potential oxidation of sulfides, acid generation, and the presence of (and leaching of) soluble metals/metalloids and salts. Each solid sample underwent static geochemical testing for:

- pH (1:5 w:v);
- Electrical conductivity (EC) (1:5 w:v);
- Total sulfur [Leco method]; and
- Acid neutralising capacity (ANC) [AMIRA, 2002];

Selected samples (19 samples) were also tested for:

- Sulfide (chromium reducible sulfur – Scr) [AS 4969.7-2008 method].

From the total sulfur (or Scr where available) and ANC results, maximum potential acidity (MPA) and net acid producing potential (NAPP) values were calculated. Where available, the MPA and NAPP of these samples were calculated using the Scr data instead of total sulfur data. The use of Scr data (for fresh samples) provides a more accurate representation of the MPA that could theoretically be generated, as acid generation primarily occurs from reactive sulfide, whereas total sulfur can include other sulfur forms such as elemental sulfur, sulfate and organic sulfur.

After the results of the initial static geochemical tests were received and reviewed, 10 samples of mining waste materials were selected, prepared and subjected to whole rock multi-element tests. The samples were tested for:

- Total metals/metalloids (Al, As, B, Cd, Cr, Co, Cu, Fe, P, Pb, Mn, Ni, Sb, Se and Zn) in solids [HCl and HNO_3 acid digest followed by ICP-AES/MS];
- Total cations (Ca, Mg, Na and K) [HCl and HNO_3 acid digest followed by ICP-AES];
- Soluble metals/metalloids (Al, As, B, Cd, Cr, Co, Cu, Fe, P, Pb, Mn, Mo, Ni, Sb, Se, Si, V and Zn) [ICP-AES/MS (1:5 w:v water extracts)];
- Major cations (Ca, Mg, Na and K) [ICP-AES/MS (1:5 w:v water extracts)];
- Major anions (Cl, F, and SO_4) [ICP-AES/MS and PC Titrator (1:5 w:v water extracts)];

Ten (10) individual mining waste samples were also tested for:

- Exchangeable cations [ICP-AES].

The results were then used to calculate:

- Cation Exchange Capacity (eCEC); and
- Exchangeable Sodium Percentage (ESP).

A copy of the static geochemical results received from ALS is provided in **Attachment E**.

3.2.2 Kinetic Tests

Following receipt and interpretation of the static geochemical test results, six Kinetic Leach Column (KLC) tests were set up at the RGS in-house laboratory using crushed samples (passing a 10mm sieve size). The KLC tests comprised composite mining samples representing the main lithological rock types likely to be generated at the proposed open pit as well as some carbonaceous material and uneconomic coal. The KLC tests were completed over a period of six months from July 2017 to January 2018, under a monthly watering and leaching cycle.

1.5 kg of each selected sample was accurately weighed and used in the KLC tests. Heat lamps were used on a daily basis to simulate sunshine and ensure that the KLC test materials were unsaturated and subject to oxidising conditions, between leaching events (essentially an assumed 'worst case' scenario for sulfide oxidation and potential acid/salt generation). Further details and a schematic of the KLC test arrangement are provided in **Attachment D**.

All leachate samples collected from the KLC tests were tested at ALS Brisbane for:

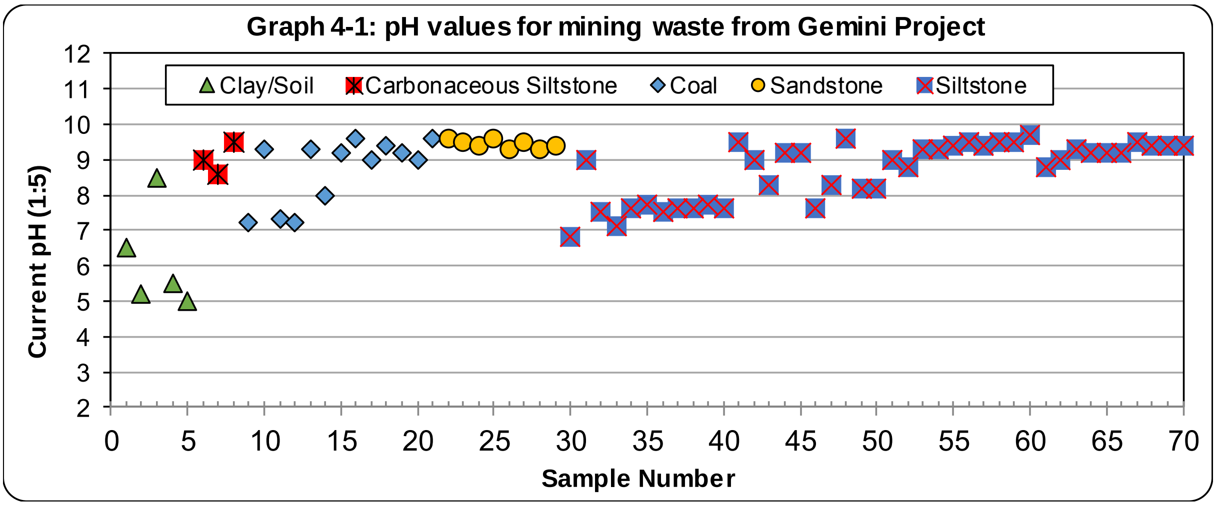
- pH and EC;
- Acidity and alkalinity [Automatic titrator];
- Dissolved metals/metalloids (Al, As, B, Cd, Cr, Co, Cu, F, Fe, Pb, Mn, Mo, Ni, Sb, Se, Si, V and Zn) [ICP-AES];
- Dissolved major cations (Ca, Mg, Na and K) [ICP-AES]; and
- Dissolved major anions (Cl, SO_4) [ICP-AES].

4.0 GEOCHEMICAL TEST RESULTS

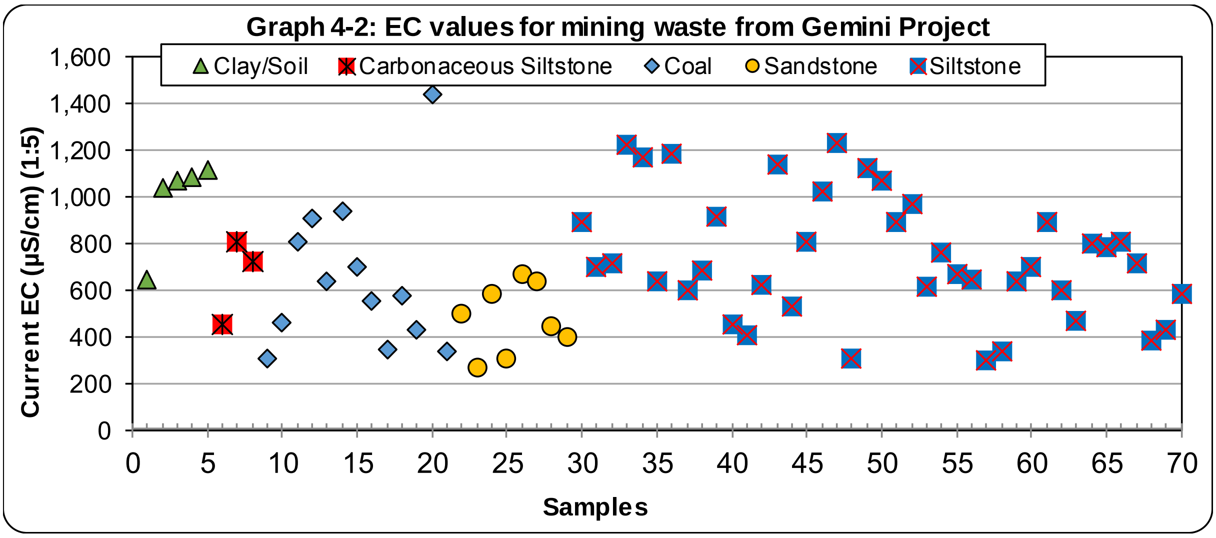
4.1 Acid Base Account

Acid Base Account results for the 70 mining waste samples from the Project are presented in **Table B1** (**Attachment B**) and summarised below. Results are shown by lithology to facilitate interpretation.

- **pH**: The $pH_{(1:5)}$ of the 70 samples across all sample types ranges from 5.0 to 9.7 and has a median value of 9.2 (**Graph 4-1**). The typical range of the deionised water used in these tests ranges from pH 5 to 6.5. The samples with the lowest pH values (pH 5.0 to 5.5) represent clay and soil material.

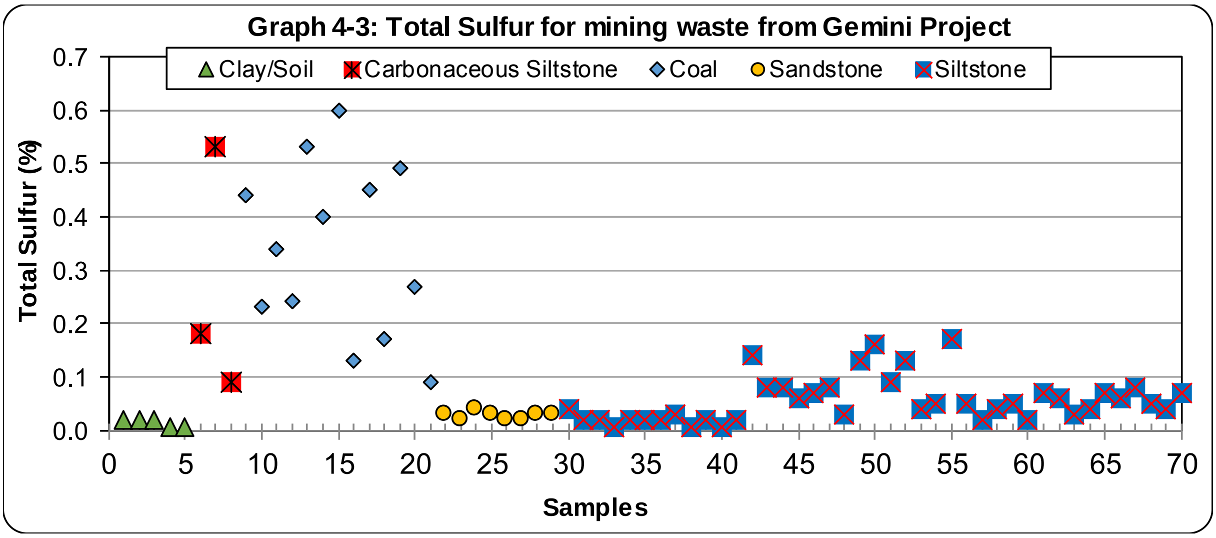


- **EC**: The current $EC_{(1:5)}$ for the 70 samples ranges from 270 to 1,440 µS/cm (**Graph 4-2**) and is typically moderate (median 646 µS/cm). The weathered material tends to have a higher EC value than the fresh material.



The pH and EC tests were completed on pulverised samples (≤ 75 µm) with a large surface area in contact with the leaching solution, thereby providing greater potential for dissolution and reaction, and represent an assumed 'worst case' scenario. It is also expected that the salinity of leachate from these low sulfur mining waste materials will diminish with time as salts are flushed from the rock matrix and a state of equilibrium develops. At that point, the salinity of seepage/runoff should stabilise at a lower asymptotic concentration relative to the weathering/erosion of the materials.

- **Sulfur**: The total sulfur content of the samples ranges from <0.01% to 0.60% (median 0.06 %S) (**Graph 4-3**). Compared to the median crustal abundance of sulfur (0.07%) (INAP, 2009) the median values of the mining waste materials is relatively low. Materials with a total sulfur content less than or equal to 0.1 % are essentially barren of sulfur, generally represent background concentrations, and have negligible capacity to generate acidity[1]. The sulfur content of carbonaceous siltstone and coal are both higher than natural background values and both lithologies show greater variation in sulfur content than the weathered material, sandstone and siltstone.

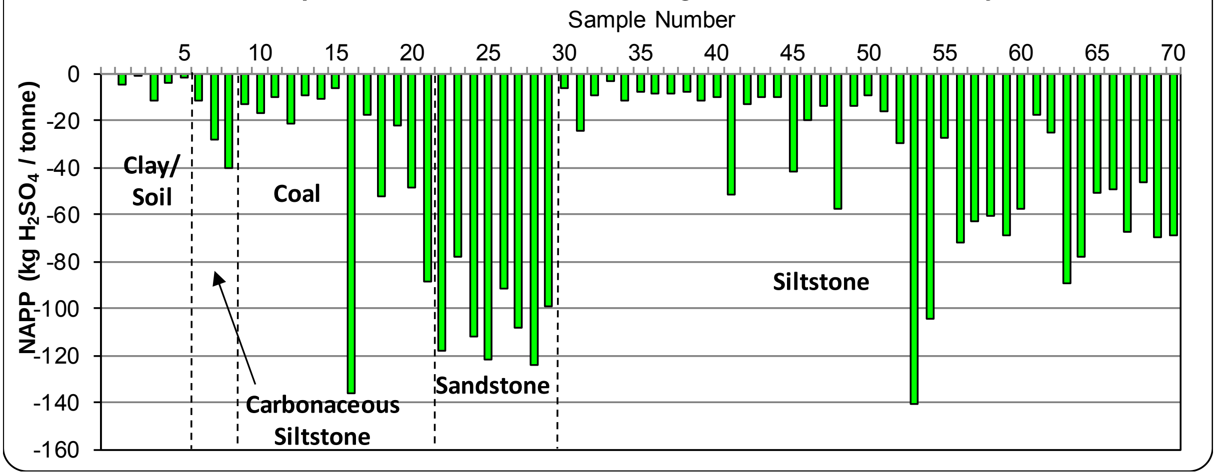


- **Sulfide Sulfur:** The sulfide sulfur content of 19 selected samples with total sulfur content greater than 0.1 %S was also tested (as measured in the Scr test). The results indicate that in the selected samples, an average of two-thirds of the sulfur content is present as non-sulfide sulfur, which is typically associated with non-acid generating forms of sulfur, such as organic sulfur, sulfate or secondary mineral sulfates such as gypsum. On average, one-third of the total sulfur content is present in the selected samples as sulfide sulfur (probably pyrite or marcasite) and has the potential to generate a small amount of acidity.
- **MPA**: Based on the total sulfur content (and sulfide sulfur content where available), the maximum potential acidity (MPA) that could be generated by the mining waste samples ranges from < 0.3 (below laboratory limit of reporting - LoR) to 6.0 kg H_2SO_4/t and has a low median value of 1.2 kg H_2SO_4/t.
- **ANC**: The ANC for the mining waste samples ranges from 1.6 to 142.0 kg H_2SO_4/t and has a moderate median value of 25.9 kg H_2SO_4/t. The fresh samples typically have higher ANC values compared to the weathered material.
- **ANC:MPA ratio**: The ANC:MPA ratio for the samples ranges from 2.1 to 178.0 and has a high median value of 23.6. Simplistically, this means that the samples have excess ANC over MPA.

[1] The median crustal abundance of sulfur (0.07 %S) has been rounded up to 0.1 % (INAP, 2009).

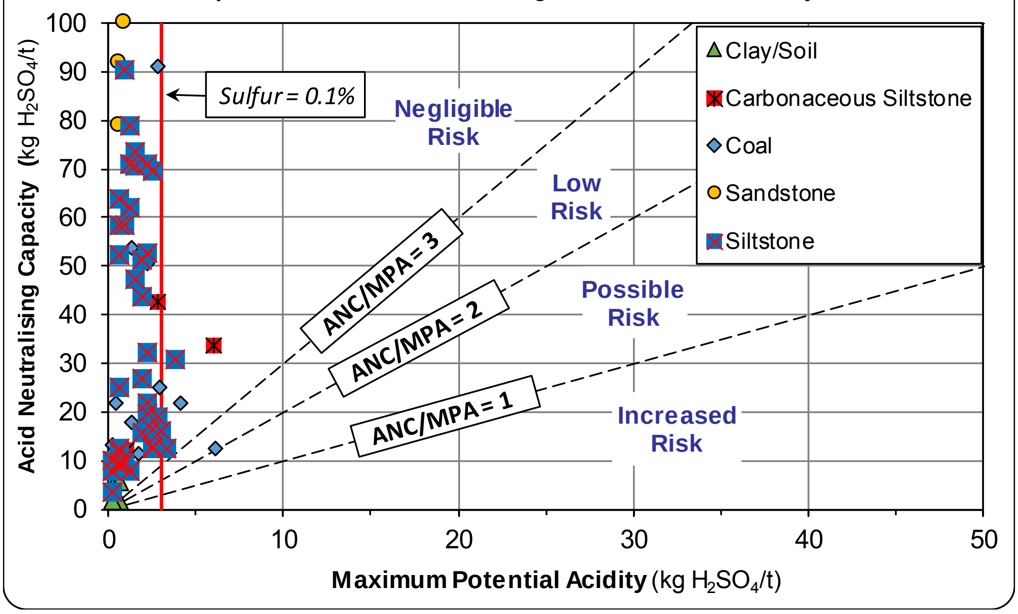
- **NAPP**: The calculated NAPP value for the mining waste samples is calculated by subtracting the ANC from the MPA and ranges from -140.8 to -1.0 kg H_2SO_4/t and has a median value of -24.6 kg H_2SO_4/t. **Graph 4-4** illustrates that all samples have a negative NAPP value, which is typically more negative for fresh materials compared to weathered materials.

Graph 4-4: NAPP values for mining waste from Gemini Project



Graph 4-5 shows a plot of ANC versus MPA for the 70 mining waste samples tested (by lithology). ANC/MPA ratio lines have been plotted on the graph to illustrate the factor of safety associated with the samples. Generally, those samples with an ANC:MPA ratio greater than 2 (or with a total or sulfide sulfur content ≤ 0.1 %) are considered to have a low to negligible risk of acid generation and a high factor of safety in terms of potential for AMD (INAP, 2009[2]; COA, 2016).

Graph 4-5: ANC v MPA for mining waste from Gemini Project



[2] INAP considers that mine materials with an ANC/MPA ratio greater than 2 are likely to be NAF unless significant preferential exposure of sulfides along fracture planes occurs in combination with insufficiently reactive ANC.

The results indicate that all of the mining waste samples tested plot in the low to negligible risk domains shown in the graph and represent materials with a very low risk of acid generation and a high factor of safety with respect to potential AMD.

Table 4-1 provides a summary of the geochemical classification criteria used by RGS to classify the acid forming nature of the 70 mining waste samples at the Project, and a breakdown of the number of samples in each classification category by lithology.

Table 4-1: Geochemical Classification Criteria for Mining Waste Materials

Geochemical Classification	Total Sulfur[1] (%)	ANC: MPA Ratio	NAPP (kg H_2SO_4/t)	Soil/Clay (n=5)	Carb. Siltstone (n=3)	Coal (n=13)	Sandstone (n=8)	Siltstone (n=41)
Non-Acid Forming (Barren)	≤ 0.1	-	-	5	2	9	8	39
Non-Acid Forming	> 0.1	> 2	≤ 0	0	1	4	0	2
Uncertain[2]	> 0.1	< 2	> -5 and ≤ +5	0	0	0	0	0
Potentially Acid Forming (Low Capacity)	> 0.1	< 2	≤ 5	0	0	0	0	0
Potentially Acid Forming	> 0.1	< 2	> 5	0	0	0	0	0

Notes:
1. Sulfide sulfur (using the Scr test) has been measured for selected waste rock samples and where available, sulfide sulfur has been used in place of total sulfur for sample classification and to calculate MPA.
2. Samples that fall outside the stated NAF/PAF classifications based on the criteria provided are classified as Uncertain.

The ABA test data presented in **Table B1 (Attachment B)** and discussed in this section have been used to classify the acid forming nature of the 70 mining waste samples from the Project. The results indicate that of the 70 samples tested, 90 % are classified as Non-Acid Forming (Barren) and 10 % are classified as Non-Acid Forming (NAF). No samples are classified as Uncertain or Potentially Acid Forming (PAF).

Overall, the ABA results confirm that the overwhelming majority of the mining waste materials have low sulfur content, excess ANC, a high factor of safety and a low risk of generating acidic drainage. Some of the carbonaceous siltstone and uneconomic coal samples have slightly elevated sulfide sulfur content compared to typical median crustal abundance, however these materials also have excess ANC and a low risk of generating acidic drainage.

4.2 Multi-Element Concentration in Solids

Multi-element scans were carried out on 10 selected samples to identify any elements (particularly metals/metalloids) present in the Project mining waste materials at concentrations that may be of environmental concern with respect to revegetation and surface water/groundwater quality. The total metals/metalloids concentration for individual elements in mine materials can be relevant for revegetation activities and/or where the potential exists for human contact (*eg*. if the material was to be used off-site).

The results from multi-element testing (total metals/metalloids) of the selected mining waste samples are presented in **Table B2 (Attachment B)**.

4.3 Geochemical Abundance Index

Total metal/metalloid concentrations in mining waste materials can be compared to the median crustal abundance for unmineralised soils (Bowen, 1979, INAP, 2009). The extent of enrichment is reported as the Geochemical Abundance Index (GAI), which relates the actual concentration in a sample with the median (or average) crustal abundance on a $\log_{10}$ scale. The GAI is expressed in integer increments from 0 to 6, where a GAI value of 0 indicates that the element is present at a concentration less than, or similar to, the median crustal abundance; and a GAI value of 6 indicates approximately a 100-fold enrichment above median crustal abundance **(Table 4-2)**.

Table 4-2: Geochemical Abundance Index (GAI) values and Enrichment Factors

GAI	Enrichment Factor	GAI	Enrichment Factor
-	Less than 3-fold enrichment	**4**	24 – 48 fold enrichment
1	3 – 6 fold enrichment	**5**	48 – 96 fold enrichment
2	6 – 12 fold enrichment	**6**	Greater than 96 fold enrichment
3	12 – 24 fold enrichment		

As a general rule, a GAI of 3 or greater signifies enrichment that may warrant further examination. This is particularly the case with some environmentally important 'trace' elements, such as As, Cr, Cd, Cu, Pb, Se and Zn, more so than with major rock-forming elements, such as Al, Ca, Fe, Mg and Na.

Elements identified as enriched may not necessarily be a concern for revegetation, drainage water quality or public health, but their significance should still be evaluated. The GAI provides an indication of metals/metalloids that may be enriched relative to the global median crustal abundance, however the following points should also be considered:

- The median crustal abundance varies between different literature sources, therefore affecting the calculated GAI values.
- If a sample is shown to be enriched relative to the median crustal abundance, there is no direct correlation that that particular sample will also leach metals/metalloids at elevated concentrations. The mobility of metals/metalloids is dependent on mineralogy, adsorption/desorption and the environment in which it occurs.
- Whilst some element concentrations can be elevated relative to the median crustal abundance, the nature of an ore deposit means the background levels are generally expected to be elevated.

Similarly, because an element is not enriched does not mean it will never be a concern, because under some conditions (eg. low pH) the solubility of common environmentally important elements such as Al, Cu, Cd, Fe and Zn increases significantly.

Table B2 (Attachment B) provides total metal/metalloid concentrations for the 10 selected mining waste samples described in **Section 4.2.** The relative enrichment of metals/metalloids in these samples compared to median crustal abundance (the Geochemical Abundance Index - GAI) is presented in **Table B3 (Attachment B)**.

The GAI results indicate that of the metals/metalloids measured, only one of the 10 selected samples was enriched compared to median crustal abundance with cobalt. While the concentration of cobalt is elevated relative to median crustal abundance, the nature of a coal deposit means some metals/metalloids are expected to be slightly elevated in mining waste materials.

The potential solubility of cobalt and other metals/metalloids was investigated further using water extract and KLC tests as presented in **Section 4.5** and **Section 4.6**, respectively.

4.4 Cation Exchange Capacity and Sodicity

The effective cation exchange capacity (eCEC) and exchangeable sodium percentage (ESP) results for 10 selected mining waste samples are presented in **Table B2 (Attachment B).** These samples were selected for testing as they will report to the spoil emplacement areas and could also be used in other site infrastructure and rehabilitation works.

The effective eCEC results show that the eCEC of the selected mining waste samples ranges from 4.2 to 18.0 meq/100g, and is typically low (mean = 10.0 meq/100g) (**Table 4-3**). For mining waste materials with low eCEC value, some fertiliser addition may be required to provide a reasonable growth medium for vegetation roots.

Table 4-3: Ratings for Effective Cation Exchange Capacity

eCEC Rating	CEC meq/100g
Very Low	<6
Low	6-12
Moderate	12-25
High	25-40
Very High	>40

The ESP results for the mining waste samples range from low (4.5%) to very high (31.5%) and are typically elevated (median = 19.3%), indicating that some of the sample materials are likely to be sodic. Generally, samples with ESP values less than 6 are considered non-sodic, whereas greater than 6 are considered moderately sodic, and greater than 14 are considered strongly sodic and may be susceptible to dispersion and erosion (Isbell, 2002; and Northcote and Skene, 1972).

Overall, the results of the eCEC and ESP tests on the selected mining waste samples indicate that most of the materials represented by these samples are likely to have elevated sodicity levels and may be susceptible to dispersion and erosion, although these characteristics may be improved to some extent by the addition of gypsum. In addition, fertiliser addition will need to be considered for some mining waste materials to provide a reasonable growth medium for revegetation and rehabilitation.

4.5 Water Quality Static Tests

There are no specific regulatory criteria for metal/metalloid concentrations in leachate from mining waste materials on mine sites in Queensland. As such, RGS has compared the multi-element results in water extracts from the 10 mining waste samples described in **Sections 4.2** and **4.3**, with Australian guidelines for livestock drinking water and aquatic freshwater ecosystems (ANZECC & ARMCANZ, 2000) guideline values. These guidelines are provided for context only and are not intended to be interpreted as “maximum permissible levels” for site water storage or discharge.

It should also be recognised that direct comparison of geochemical data with guideline values can be misleading. For the purpose of this study, guideline values are only provided for broad context and should not be interpreted as arbitrary ‘maximum’ values or ‘trigger’ values. Using sample pulps (ground to passing 75 µm) provides a very high surface area to solution ratio, which encourages mineral reaction and dissolution of the solid phase. Therefore, the results of screening tests on water extract solutions are assumed to represent an assumed ‘worst case’ scenario for initial surface runoff and seepage from mining waste materials.

The results from multi-element testing of water extracts (1:5 sample:water) from the 10 selected mining waste samples are presented in **Table B4 (Attachment B)**.

The pH of the water extracts ranges from 7.1 to 9.6 (median 9.2) and six samples have a pH value that is slightly greater than the upper limit of the pH range (pH 6 to 9) for 95 % species protection in freshwater aquatic ecosystems (ANZECC & ARMCANZ, 2000).

The water extracts have low to moderate EC values ranging from 270 to 1,220 µS/cm (median 710 µS/cm) indicating low to moderate salinity (and low to moderate concentrations of dissolved solids).

The current total alkalinity in the water extracts ranges from 244 to 3,620 mg $CaCO_3$/L) and has a median value of 720 mg $CaCO_3$/L. The alkalinity is mainly present as bicarbonate (HCO_3) in the samples. Most water extracts have a relatively low acidity value ranging from <1 to 101 mg $CaCO_3$/L, and excess alkalinity, leading to a positive net alkalinity value.

The total concentration of major ions in the water extracts is variable, with the dominant major ion typically being bicarbonate, accompanied by lower concentrations of sodium and chloride. Calcium magnesium, potassium and sulfate are also present in the water extracts in comparatively minor amounts. The concentration of dissolved sulfate in the water extracts ranges from 8 to 64 mg/L (median 24 mg/L) and therefore all the samples have a sulfate concentration more than an order of magnitude below the applied (ANZECC & ARMCANZ, 2000) water quality guideline criterion (1,000 mg/L) for livestock drinking water for this anion.

The concentration of trace metals/metalloids tested in the water extracts is typically low and predominantly below the laboratory LoR. Most metal/metalloid concentrations tested in the water extracts are below the applied water quality guideline criteria. The concentrations of arsenic (2 samples) and selenium (4 samples) are above the applied aquatic freshwater ecosystem water quality guideline concentrations for 95 % species protection (ANZECC & ARMCANZ, 2000). One of the water extracts samples has a selenium concentration (0.04 mg/L) higher than the applied livestock drinking watyer guideline value (0.02 mg/L). All other water extract samples have trace metal/metalloid concentrations at or below the applied livestock drinking water guidelines.

On the basis of these results, it is expected that the risk of potential impact on the quality of surface and groundwater water from water in contact with mining waste materials at the Project should be low.

The dynamic quality of mining waste contact water and any potential risk of to water resources at the site is investigated further using KLC tests in **Section 4.6.**

4.6 Water Quality Kinetic Tests

KLC testing has been completed on six composite samples of mining waste materials (using the methodology described in **Section 3.2.2** and **Attachment C**. The samples used in the KLC tests are listed in **Table B5** (**Attachment B**). The KLC tests were completed for a period of six months from July 2017 to January 2018 under a monthly watering and leaching cycle. The KLC tests were operated following mining industry guidelines for such tests (AMIRA, 2002; COA, 2016).

The leachate results from the KLC test program are presented alongside Australian water quality guideline values for livestock drinking water quality (ANZECC & ARCANZ, 2000). These guidelines are provided for context only and are not intended to be interpreted as "maximum permissible levels" for site water storage or discharge. It should be noted that the KLC samples were crushed to pass a 10 mm sieve size and therefore have a high surface area for potential geochemical reaction. The ratio of sample to water in the KLC tests was approximately 2:1 (w/v) (ie. concentrated), whereas the ratio of sample to water generally used in tests where results can (arbitrarily) be compared against guideline concentrations to provide relevant context is an order of magnitude more dilute at 1:5 (w/v). Whilst arbitrary comparisons against guideline concentrations can be helpful in some situations to provide relevant context, such comparisons cannot be directly extrapolated to the field situation at the Project.

The monthly KLC leach test results for the six composite mining waste samples are presented in **Attachment D**. Tables **KLC1** to **KLC6** provide the KLC test data for seven leach events (over six months), selected components of which are also shown graphically. The KLC test results obtained to date indicate that:

- Leachate from the six KLC tests typically remains in the pH range 6 to 9 throughout the test period. The leachate pH from the sandstone sample (KLC3) was marginally above this pH range on one occasion.
- The acidity concentration in leachate from the six KLC tests is typically very low and ≤ 3 mg/L (as $CaCO_3$). In contrast, the alkalinity concentration in leachate for the six KLC tests is elevated and varies between 4 and 77 mg/L (as $CaCO_3$). These sample characteristics lead to positive net alkalinity values for all leachate samples.
- Apart from the carbonaceous siltstone and coal sample (KLC6), leachate from all KLC tests has an EC value less than 800 µs/cm. The EC value generally shows a steady or decreasing EC trend throughout the test period and at the end of six months the EC value is less than 203 µs/cm in leachate from all samples. The elevated EC value in the initial 'first flush' from KLC6 is probably at least partly due to the increased solubility of minerals through crushing the sample material before loading into the KLC test column.
- The major ion concentrations in leachate from the KLC tests are dominated by sodium and chloride (and bicarbonate) with lesser concentrations of sulfate in the siltstone samples KLC1 and KLC 2.
- The sulfate concentration in KLC leachate from all mining waste samples remains well below the applied ANZECC & ARMCANZ stock water quality guideline criterion (1,000 mg/L) over the test period.
- The KLC test samples retain at least ~95 % of their inherent total sulfur content after six months of exposure to idealised oxidising conditions, which reflects the slow rate of sulfide oxidation for these materials.
- The KLC test samples retain at least 99 % of their inherent ANC value after six months of exposure to idealised oxidising conditions.
- The sulfate generation rate results obtained for the six KLC tests on the mining waste samples have been used to determine the rate of sulfide oxidation in these materials. Most sulfate salts generated from sulfide reaction involving materials with a relatively low sulfide sulfur concentration are highly soluble, and therefore will be collected in column leachate. The dissolved sulfate (and calcium) concentrations in the KLC leachate are typically less than the solubility limit of gypsum ($CaSO_4$), for example, which indicates that sulfate generation is not controlled by gypsum dissolution in the KLC test materials. Therefore, the sulfate concentrations and oxidation rate calculations provide reasonable estimates of these parameters and the results align well with existing static and dynamic geochemical data derived from a wide range of mining waste materials (AMIRA, 1995). The sulfate generation rate and associated sulfide oxidation rate for the six KLC tests are shown in **Table 4-4**.
- The sulfate generation rate from the KLC samples ranges from 0.34 to 4.47 mg/kg/week indicating that the rate of sulfide oxidation is low in these materials (equivalent to an oxidation rate ranging from 1.40×10^{-10} to 1.91×10^{-9} kg $O_2/m^3/s$). Mining waste materials with an oxidation rate in the low range (ie. less than 1×10^{-8} kg $O_2/m^3/s$) and a moderate ANC level have an increased factor of safety, and are likely to generate leachate that is pH neutral and/or has low levels of acidity (AMIRA, 1995; Bennett *et al*., 2000). Hence, all of the KLC samples tested fall into this category. Overall, the KLC results reflect the range of material characteristics predicted from the static geochemical test results presented in **Section 4.1**.

Table 4-4: Sulfate Generation and Sulfide Oxidation Rates for KLC Tests on Mining Waste

KLC Sample Number	Sample Description	Sulfate Generation Rate (mg/kg/week)	Oxidation Rate (kg $O_2/m^3/s$)
KLC1	Siltstone	0.65	2.69×10^{-10}
KLC2	Siltstone	0.34	1.40×10^{-10}
KLC3	Sandstone	2.00	8.20×10^{-10}
KLC4	Coal	2.45	1.00×10^{-9}
KLC5	Weathered Coal	1.41	5.77×10^{-10}
KLC6	Carbonaceous Siltstone & Coal	4.47	1.91×10^{-9}

- The concentration of trace metals/metalloids in leachate from the KLC samples is low and typically below the laboratory limit of reporting (LoR). This suggests that most trace metals/metalloids are sparingly soluble at the current pH of the KLC leachate. All measured leached metals/metalloids have concentrations below the applied water quality guideline values (ANZECC & ARMCANZ, 2000). The only exception is the concentration of selenium in initial leachate from KLC 6 (carbonaceous siltstone and coal), although the selenium concentration reduces to below the laboratory LoR for all subsequent leaching events.

Potential implications of these results with respect to the management of mining waste materials at the Project are discussed further in **Section 5.0.**

5.0 DISCUSSION

5.1 AMD Potential and Management

The results of the ABA tests presented in **Section 4** indicate that the AMD potential of the mining waste samples low. The overwhelming majority of the mining waste samples are classified as NAF, have excess ANC, and have very low sulfur content. Whilst the sulfur content of coal and carbonaceous siltstone can be elevated compared to typical background concentrations, it is mainly present in the non-sulfidic form, which does not contribute to acid generation. Overall, these samples represent materials with a very low risk of acid generation and a high factor of safety with respect to potential AMD.

Operational sampling and geochemical testing of mining waste materials should be used strategically throughout the mine life to verify these findings. The focus of the testing should be on potential coal reject (coal seam roof and floor samples from drill core) and actual coal rejects (coarse rejects and tailings from the coal quality laboratory or CHPP when the mine is operational).

Whilst no actual coal reject samples were available to be included in this geochemical assessment, representative sample of these materials are the subject of a separate geochemical assessment program (RGS, 2019). In the test program described herein, geochemical results for carbonaceous siltstone and coal materials suggest that inherent sulfur is mainly present in a NAF (non-sulfide) form. Coal materials will only remain stockpiled at the Run-of-Mine (ROM) area for a relatively short period of time, and management of these materials should for this reason, involve regular collection and monitoring of surface runoff and seepage from the ROM area.

Representative samples of coal reject materials likely to be generated from the Project have already been subjected to a program of both static and kinetic geochemical tests to verify the static and dynamic geochemical nature of these materials (RGS, 2019). It is expected that a relatively small amount of PAF coal reject materials will be encountered at the Project, and this material will be encapsulated within a much larger volume of NAF overburden materials with excess neutralising capacity at spoil dumps, with little risk of any adverse environmental outcome. This strategy is successfully employed at several coal mines in the Bowen Basin (eg. Middlemount Coal Mine).

5.2 Multi-Element Composition and Water Quality

5.2.1 Multi-element Composition and Enrichment

The multi-element concentrations of metal/metalloids in mining waste materials are presented in **Section 4.2**, along with a comparison with median crustal abundance in soils. The results indicate that most of the mining waste materials are not significantly enriched with metals/metalloids compared to median crustal abundance for non-mineralised areas. Whilst one of the siltstone samples was enriched with cobalt compared to median crustal abundance, the nature of a coal deposit means some metals/metalloids are expected to be slightly elevated in some mining waste materials.

5.2.2 Water Quality

Static and kinetic geochemical test results indicate that initial surface run-off and seepage from the NAF mining waste materials is likely to be pH neutral to alkaline and have a moderate salinity value. Weathered mining waste materials tends to have a higher salinity value than fresh materials. Surface runoff and seepage from bulk mining waste materials is likely to be in the range (pH 6 to 9) required for 95 % species protection in freshwater aquatic ecosystems (ANZECC & ARMCANZ, 2000).

The major ion concentrations in leachate from NAF mining waste materials are relatively low and dominated by bicarbonate, sodium, chloride and to a lesser extent sulfate. The sulfate concentration in leachate from all mining waste samples tested is well below the applied ANZECC & ARMCANZ livestock water quality guideline criterion (1,000 mg/L).

The initial concentration of most trace metals/metalloids tested for water in contact with most mining waste materials is typically low and predominantly below the laboratory LoR and applied water quality guideline criteria. The static water extract results suggest that whilst the concentrations of arsenic and selenium can be above applied aquatic freshwater ecosystem water quality guideline concentrations for 95 % species protection (ANZECC & ARMCANZ, 2000) in a few individual samples. However, the concentration of these metals/metalloids in surface runoff and seepage from bulk mining waste materials is likely to be much lower and within the applied guideline concentrations described above. Whilst one carbonaceous siltstone water extract sample had a selenium concentration marginally above the applied livestock drinking water guideline value, all other water extract samples have trace metal/metalloid concentrations at or below the applied livestock drinking water guideline values.

Direct comparison of dynamic KLC test leachate concentration values against the applied livestock water quality guideline criteria is not strictly valid due to a number of factors including scale-up effects, the high sample:water ratio (2:1), the high sample surface area used in the KLC tests, and the highly oxidising (cyclical wet and dry) assumed “worst case” conditions. However, it does highlight those elements, which may have the potential to be mobile under fully oxidising conditions.

The KLC leachate results from the NAF mining waste materials indicate that most metals/ metalloids are sparingly soluble under the current water extract and KLC leachate pH conditions, when compared against applied Australian water quality guideline values (ANZECC & ARMCANZ, 2000). The only minor exception is selenium in the initial leachate from one carbonaceous siltstone/coal sample. It should be noted that this metalloid is commonly indicated as elevated in KLC test programs for mining waste materials from coal mines in the Bowen Basin, but is not commonly detected in surface and groundwater monitoring programs in the field.

On the basis of the water extract and KLC test results described above, it is expected that the risk of potential impact on the quality of surface and groundwater water from water in contact with mining waste materials at the Project should be low.

5.3 Revegetation and Rehabilitation

From a soil chemistry viewpoint, bulk mining waste materials are likely to be pH neutral to alkaline. Most of these materials may also have some risk of being susceptible to dispersion and erosion, although these material characteristics could be improved to some extent by the addition of gypsum. In addition, fertiliser addition may also need to be considered for these materials to provide a reasonable growth medium for revegetation and rehabilitation.

Additional testing, including field trials, may be needed when the mine is operational and bulk mining waste materials become available, to determine the best management option for progressive rehabilitation of these materials during operations and at mine closure.

6.0 CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

RGS has completed a geochemical assessment of mining waste materials at the Gemini Coal Project. The scope of work completed by RGS is described in **Section 1.2**. The main findings of the geochemical assessment are as follows:

- All of the mining waste samples are classified as NAF, have excess ANC and typically have low sulfur. Whilst the sulfur content of coal and carbonaceous siltstone can be elevated compared to typical background concentrations, it is mainly present in the non-sulfidic form, which does not contribute to acid generation. Overall, these samples represent materials with a very low risk of acid generation and a high factor of safety with respect to potential for AMD.
- Initial and ongoing surface runoff and seepage from mining waste materials is expected to be moderately alkaline and have a moderate level of salinity.
- Kinetic leach column (KLC) test results indicate that mining waste materials are unlikely to generate acid conditions and are more likely to generate pH neutral to alkaline conditions.
- Metal/metalloid enrichment in mining waste materials, compared to median crustal abundance in non-mineralised soils, is limited to cobalt in a single carbonaceous siltstone sample. However, the nature of a coal deposit means some metals/metalloids are expected to be slightly elevated in some materials.
- Most metals/metalloids are sparingly soluble at the neutral to alkaline pH of leachate expected from bulk mining waste materials. Dissolved metal/metalloid concentrations in surface runoff and leachate from bulk mining waste materials are therefore expected to be low and unlikely to pose a significant risk to the quality of surface and groundwater resources at relevant storage facilities.
- Mining waste materials should be amenable to revegetation as part of rehabilitation activities, although, gypsum and fertiliser addition may need to be considered for sodic materials to limit dispersion and erosion and to provide a reasonable growth medium for revegetation and rehabilitation.
- As most mining materials appear to be susceptible to dispersion and erosion, additional testing including field trials, may be needed when the mine is operational and bulk materials are being generated. Such tests would help to determine the most appropriate management option for progressive rehabilitation of these materials during operations at mine closure.

6.2 Recommendations

As a result of the geochemical assessment work completed on mining waste materials at the Project, a number of recommendations are provided for these materials to minimise the risk of any significant environmental harm to the immediate and downstream environment.

- Placement of any carbonaceous mining waste material encountered during mining at the surface and outer batters of spoil emplacement areas should be avoided.
- Additional overburden/interburden testing and rehabilitation field trials should be completed during operations when bulk materials become available to confirm the most appropriate management option for progressive rehabilitation of these materials during operations and at mine closure.
- Surface water and seepage from the proposed mining and mining waste storage areas should be monitored to ensure that key water quality parameters remain within appropriate criteria. Water quality monitoring parameters should include pH, EC, total suspended solids (TSS) on a quarterly basis and the suite of water quality analyses described in **Table B4** (**Attachment B**) of this report opportunistically and at least on an annual basis.

7.0 REFERENCES

AMIRA (1995). Mine Waste Management: *Project P387 Prediction and Identification of Acid Forming Mine Waste*. Australian Minerals Industry Research Association, Report prepared by EGi Pty Ltd, August 1995.

AMIRA (2002). *ARD Test Handbook: Project 387A Prediction and Kinetic Control of Acid Mine Drainage*. Australian Minerals Industry Research Association, Ian Wark Research Institute and Environmental Geochemistry International Pty Ltd, May 2002.

ANZECC & ARMCANZ (2000). *Australian and New Zealand Guidelines for Fresh and Marine Water Quality*. Australian and New Zealand Environment Conservation Council and Agriculture and Resource Management Council of Australia and New Zealand, Canberra, ACT (2000). Livestock drinking water (low risk trigger levels).

AS 4969.7-2008. *Analysis of acid sulfate soil – Dried samples – Methods of test. Method 7: Determination of chromium reducible sulfur (Scr)*. Standards Australia, June 2008.

Bandanna Energy (2011). Initial Advice Statement. Dingo West Coal Mine Project. Document prepared by Bandanna Energy Pty Ltd, 31 October.

Bowen, H.J.M. (1979). *Environmental Chemistry of the Elements,* Academic Press, New York, p36-37.

Commonwealth of Australia (2016). *Leading Practice Sustainable Development Program for the Mining Industry. Prevention of Acid and Metalliferous Drainage*. September, Canberra ACT.

DME (1995). *Draft Technical Guidelines for the Environmental Management of Exploration and Mining in Queensland, Technical Guideline – Assessment and Management of Acid Drainage*. Queensland Department of Minerals and Energy (DME), January.

DEHP (2013). *Application Requirements for Activities with Impacts to Land Guideline.* Queensland Department of Environment and Heritage Protection.

INAP (2009). *Global Acid Rock Drainage Guide (GARD Guide)*. Document prepared by Golder Associates on behalf of the International Network on Acid Prevention (INAP). June 2009 (http://www.inap.com.au/).

Isbell, R.F. (2002). *The Australian Soil Classification (revised edition).* CSIRO Publishing. Victoria.

Northcote, K.H., and Skene, J.K.M. (1972). *Australian Soils with Saline and Sodic properties.* CSIRO Australia, Soil Publication No. 27, Canberra.

Parker G and Robertson A M. (1999) *Acid Drainage.* Occasional paper on acid drainage published by the Australian Minerals and Energy Environment Foundation (AMEEF), November, Melbourne, Victoria, Australia.

RGS (2017a). *Geochemical Assessment of Mining Waste Materials from the Dingo West Coal Project.* Proposal number 2017002 prepared by RGS Environmental Pty Ltd for Magnetic South Pty Ltd. 17 January.

RGS (2017b). *Geochemical Assessment of Mining Waste Materials. Sampling Plan.* Letter report prepared by RGS Environmental Pty Ltd for Magnetic South Pty Ltd and JC Irvine Pty Ltd. 29 May.

RGS (2019). Geochemical Assessment of Coal Reject Material. Report prepared by RGS Environmental Pty Ltd for Magnetic South Pty Ltd. 20 September.

8.0 LIMITATIONS

RGS has prepared this report in accordance with the generally accepted practices and standards of the consulting profession for the use of Magnetic South, and only those third parties who have been authorised in writing by RGS to rely on the report. No other warranty is made as to the professional advice in this report. The report has been prepared in accordance with the scope of work described in **Section 1.2**.

The methodology adopted and information sources used by RGS are outlined in this report. RGS has made no independent verification of this information beyond the agreed scope of works and assumes no responsibility for any inaccuracies or omissions. No indications were found during our investigations that information contained in this report as provided to RGS was false.

This report was prepared from July 2017 to September 2019 and is based on the information provided by Magnetic South and AARC at the time of preparation. RGS disclaims responsibility for any changes that may have occurred after this time.

This report should be read 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. This report does not provide legal advice which, can only be given by qualified legal practitioners.

If you have any questions regarding the information presented in this report, please contact the undersigned on (+617) 3344 1222 or (+61) 431 620 623.

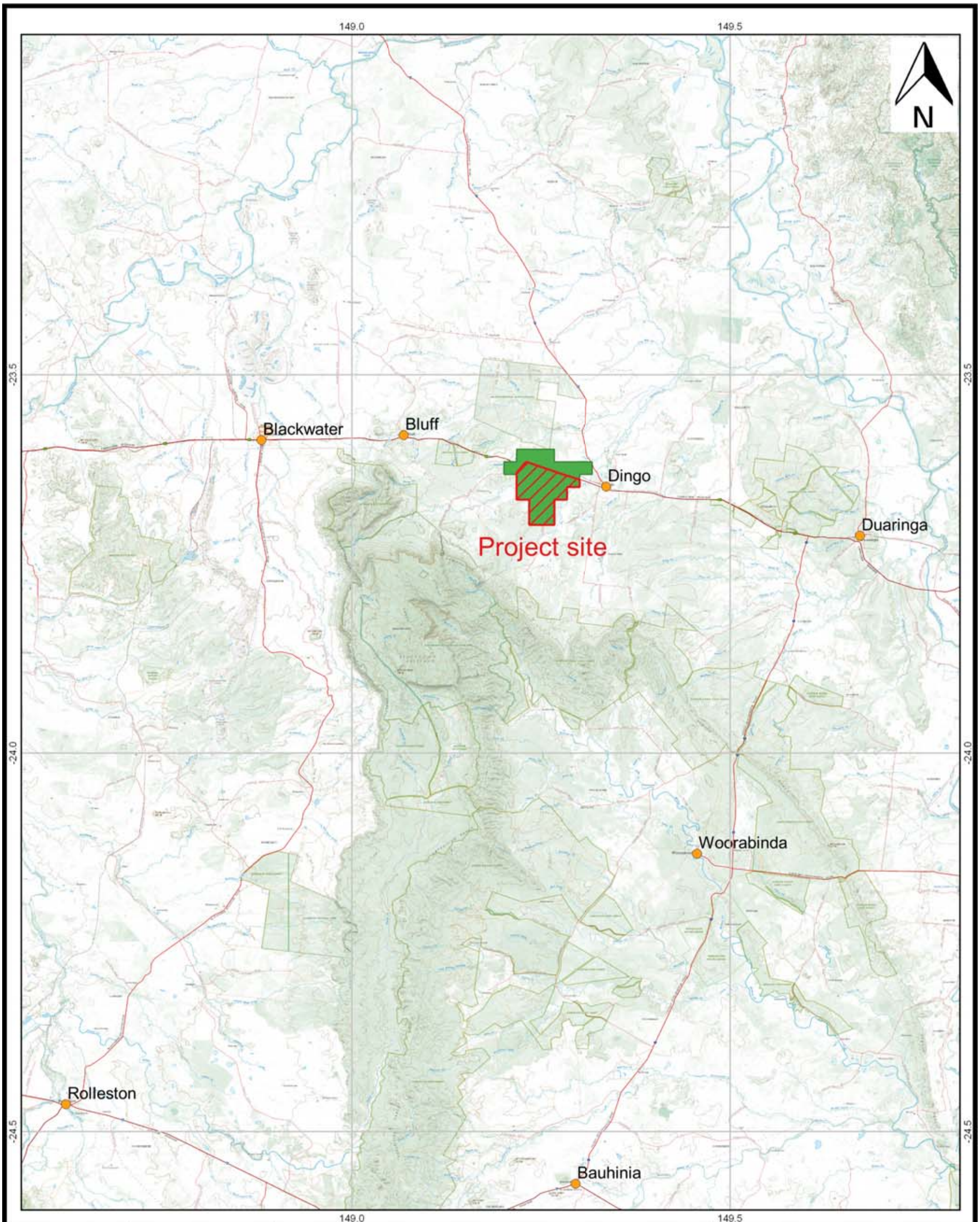
Yours sincerely,

RGS ENVIRONMENTAL PTY LTD

Dr. Alan M. Robertson
Principal Geochemist/Director

ATTACHMENT A

Figures



Scale:
1:500000
0 6 12 km

RGS
LEADERS IN MINING GEOCHEMISTRY

RGS Environmental Pty Ltd
123 Wynne Street,
Sunnybank Hills QLD
Tel +61 7 3344 1222

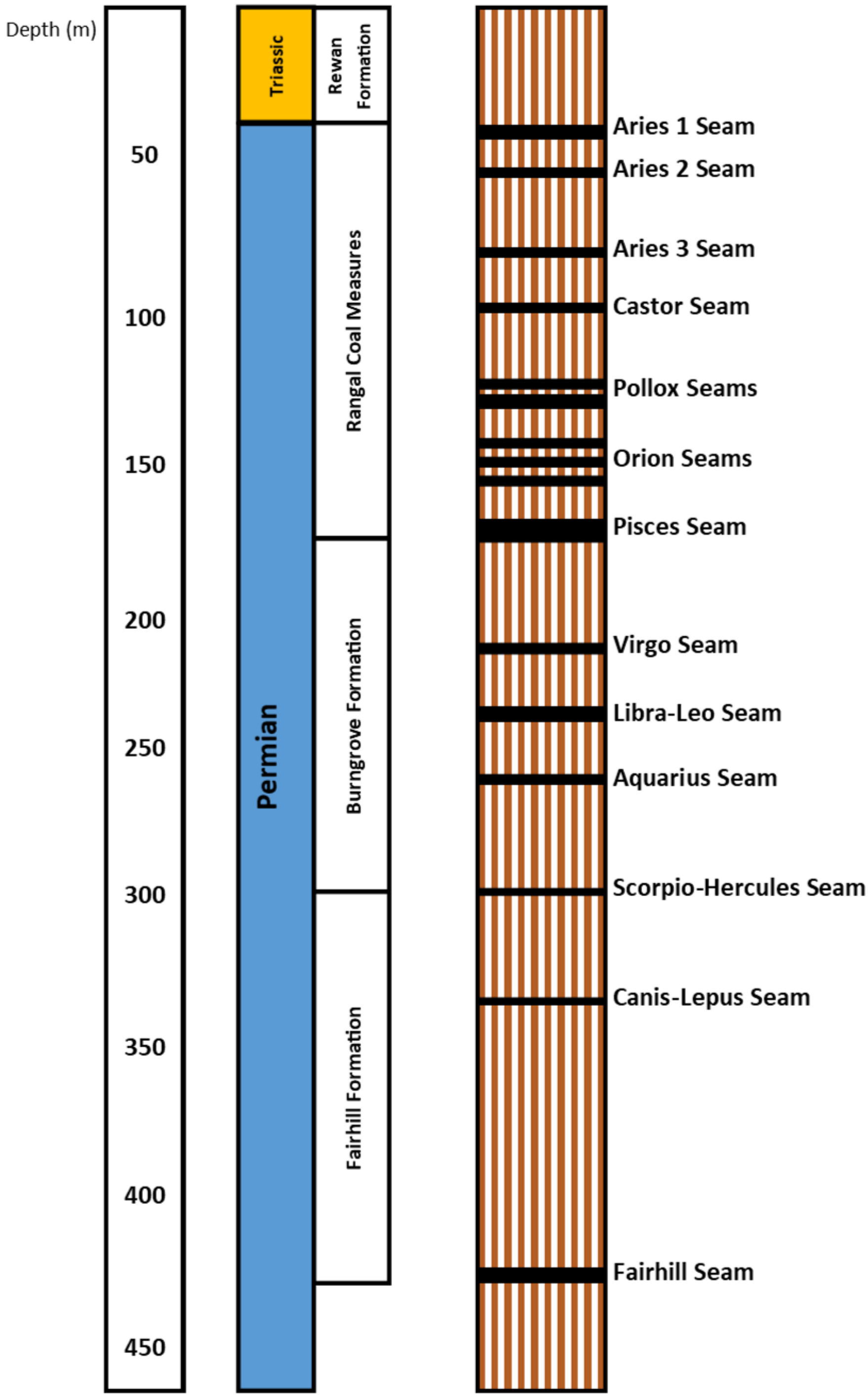
Figure A1
Project Location

Gemini Coal Project

Job Number: 2017002
02/09/2019

Legend

MLA Boundary
EPC 881 Boundary



RGS
LEADERS IN MINING GEOCHEMISTRY

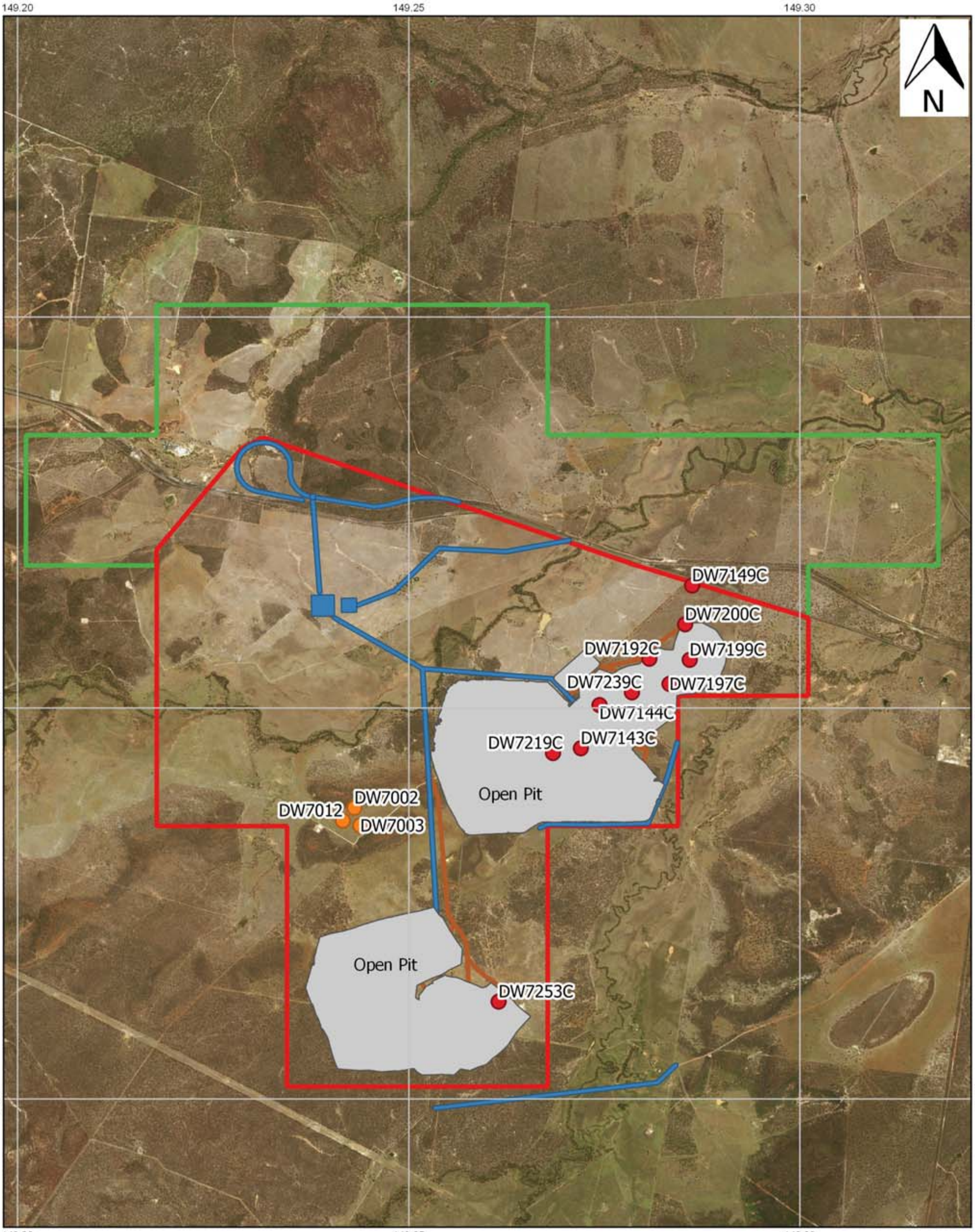
Figure A2

Representative Stratigraphic Column

RGS Environmental Pty Ltd
123 Wynne Street,
Sunnybank Hills QLD
Tel +61 7 3344 1222

Gemini Coal Project

Job Number: 2017002
02/09/2019



RGS
LEADERS IN MINING GEOCHEMISTRY

Scale:
1:50000
0 0.5 1 km

RGS Environmental Pty Ltd
123 Wynne Street,
Sunnybank Hills QLD
Tel +61 7 3344 1222

Figure A3
Conceptual Project Layout

Gemini Coal Project

Job Number: 2017002
02/09/2019

Legend
- Open pit extent
- Regional infrastructure
- Haulroads
- MLA Boundary
- EPC 881 Boundary

Geochemical sampled drillholes
- 2017 program
- 2019 program

ATTACHMENT B

Tables of Results

Table B1: Acid Base Account results for mining waste from the Gemini Project

RGS Sample No.	Drill Hole ID	Client Sample ID	Sample Lithology	From (m)	To (m)	Depth Interval (m)	pH[1]	EC[1]	Total S	Scr	MPA[2]	ANC[2]	NAPP[2]	ANC: MPA Ratio	Sample Classification[3]
1	DW7002	7002G01	Soil 100%	0.00	2.00	2.00	6.5	646	0.02		0.6	5.5	-4.9	9.0	Non Acid Forming (Barren)
23	DW7003	7003G01	Soil 100%	0.00	2.00	2.00	5.2	1,040	0.02		0.6	1.6	-1.0	2.6	Non Acid Forming (Barren)
45	DW7012	7012G01	Soil 100%	0.00	2.50	2.50	8.5	1,070	0.02		0.6	12.1	-11.5	19.8	Non Acid Forming (Barren)
24	DW7003	7003G02	Clay 100%	2.00	4.00	2.00	5.5	1,080	0.005		0.2	4.4	-4.2	28.7	Non Acid Forming (Barren)
2	DW7002	7002G02	Clay 100%	5.00	6.00	1.00	5.0	1,110	0.005		0.2	1.6	-1.4	10.4	Non Acid Forming (Barren)
53	DW7012	7012G09	COAL 17%, Carb Siltstone 83%	27.00	30.00	3.00	9.0	454	0.18	0.033	1.0	12.2	-11.2	12.1	Non Acid Forming (Barren)
38	DW7003	7003G16	Carb Siltstone 100%	46.40	49.00	2.60	8.6	807	0.53	0.194	5.9	33.7	-27.8	5.7	Non Acid Forming
70	DW7012	7012G26	Carb Siltstone 100%	146.28	148.00	1.72	9.5	722	0.09		2.8	42.6	-39.8	15.5	Non Acid Forming (Barren)
48	DW7012	7012G04	COAL 100%	14.29	15.32	1.03	7.2	306	0.44	0.006	0.2	13.2	-13.0	71.8	Non Acid Forming (Barren)
51	DW7012	7012G07	COAL 100%	24.60	25.60	1.00	9.3	460	0.23	0.041	1.3	17.8	-16.5	14.2	Non Acid Forming
31	DW7003	7003G09	COAL 100% (Weathered)	31.60	33.00	1.40	7.3	807	0.34	0.056	1.7	11.5	-9.8	6.7	Non Acid Forming (Barren)
32	DW7003	7003G10	COAL 100% (Weathered)	33.00	35.20	2.20	7.2	906	0.24	0.014	0.4	21.7	-21.3	50.6	Non Acid Forming (Barren)
55	DW7012	7012G11	COAL 100%	33.08	33.75	0.67	9.3	640	0.53	0.090	2.8	12.0	-9.2	4.4	Non Acid Forming (Barren)
35	DW7003	7003G13	COAL 100%	40.00	41.10	1.10	8.0	937	0.40	0.102	3.1	13.6	-10.5	4.4	Non Acid Forming
58	DW7012	7012G14	COAL 100%	53.57	53.89	0.32	9.2	697	0.60	0.197	6.0	12.6	-6.6	2.1	Non Acid Forming
64	DW7012	7012G20	COAL 93%, Siltstone 7%	96.40	98.61	2.21	9.6	554	0.13	0.037	1.1	137.0	-135.9	120.9	Non Acid Forming (Barren)
12	DW7002	7002G12	COAL 100%	97.20	98.95	1.75	9.0	345	0.45	0.134	4.1	21.7	-17.6	5.3	Non Acid Forming
43	DW7003	7003G21	COAL 100%	114.10	115.90	1.80	9.4	573	0.17	0.041	1.3	53.6	-52.3	42.7	Non Acid Forming (Barren)
18	DW7002	7002G18	COAL 100%	137.13	140.82	3.69	9.2	429	0.49	0.094	2.9	25.1	-22.2	8.7	Non Acid Forming (Barren)
69	DW7012	7012G25	COAL 46%, Carb Claystone 15%, Carb Siltstone 39%	140.52	146.28	5.76	9.0	1,440	0.27	0.070	2.1	50.6	-48.5	23.6	Non Acid Forming (Barren)
21	DW7002	7002G21	COAL 100%	156.45	157.26	0.81	9.6	333	0.09		2.8	91.2	-88.4	33.1	Non Acid Forming (Barren)
50	DW7012	7012G06	Sandstone 100%	23.00	24.60	1.60	9.6	495	0.03		0.9	119.0	-118.1	129.5	Non Acid Forming (Barren)
8	DW7002	7002G08	Sandstone 100%	68.00	71.00	3.00	9.5	270	0.02		0.6	78.9	-78.3	128.8	Non Acid Forming (Barren)
62	DW7012	7012G18	Sandstone 100%	85.00	89.00	4.00	9.4	585	0.04		1.2	113.0	-111.8	92.2	Non Acid Forming (Barren)
10	DW7002	7002G10	Sandstone 100%	92.00	94.00	2.00	9.6	304	0.03		0.9	123.0	-122.1	133.9	Non Acid Forming (Barren)
41	DW7003	7003G19	Sandstone 100%	95.00	96.00	1.00	9.3	665	0.02		0.6	91.8	-91.2	149.9	Non Acid Forming (Barren)
66	DW7012	7012G22	Sandstone 100%	106.00	109.00	3.00	9.5	640	0.02		0.6	109.0	-108.4	178.0	Non Acid Forming (Barren)
16	DW7002	7002G16	Sandstone 100%	116.00	120.00	4.00	9.3	442	0.03		0.9	125.0	-124.1	136.1	Non Acid Forming (Barren)
17	DW7002	7002G17	COAL 11%, Sandstone 89%	135.00	137.13	2.13	9.4	398	0.03		0.9	100.0	-99.1	108.8	Non Acid Forming (Barren)
25	DW7003	7003G03	Siltstone 100%	4.00	5.00	1.00	6.8	893	0.04		1.2	7.8	-6.6	6.4	Non Acid Forming (Barren)
46	DW7012	7012G02	Siltstone 100%	5.00	8.00	3.00	9.0	700	0.02		0.6	25.0	-24.4	40.8	Non Acid Forming (Barren)
26	DW7003	7003G04	Siltstone 100%	6.00	7.00	1.00	7.5	710	0.02		0.6	9.7	-9.1	15.8	Non Acid Forming (Barren)
3	DW7002	7002G03	Siltstone 100%	7.00	8.00	1.00	7.1	1,220	0.005		0.2	3.5	-3.3	22.9	Non Acid Forming (Barren)
27	DW7003	7003G05	Siltstone 100%	8.00	11.00	3.00	7.6	1,170	0.02		0.6	12.4	-11.8	20.2	Non Acid Forming (Barren)
47	DW7012	7012G03	Siltstone 100%	13.00	14.29	1.29	7.7	640	0.02		0.6	8.7	-8.1	14.2	Non Acid Forming (Barren)
28	DW7003	7003G06	Siltstone 100%	14.00	20.00	6.00	7.5	1,180	0.02		0.6	9.0	-8.4	14.7	Non Acid Forming (Barren)
49	DW7012	7012G05	Siltstone 100%	15.32	15.56	0.24	7.6	598	0.03		0.9	9.6	-8.7	10.4	Non Acid Forming (Barren)
4	DW7002	7002G04	Siltstone 100%	17.00	18.00	1.00	7.6	684	0.005		0.2	7.7	-7.5	50.3	Non Acid Forming (Barren)
29	DW7003	7003G07	Siltstone 100%	20.00	23.00	3.00	7.7	911	0.02		0.6	11.8	-11.2	19.3	Non Acid Forming (Barren)
5	DW7002	7002G05	Siltstone 100%	22.00	24.00	2.00	7.6	450	0.005		0.2	9.8	-9.6	64.0	Non Acid Forming (Barren)
6	DW7002	7002G06	Siltstone 100%	25.00	28.00	3.00	9.5	409	0.02		0.6	52.2	-51.6	85.2	Non Acid Forming (Barren)

Table B1: Acid Base Account results for mining waste from the Gemini Project

RGS Sample No.	Drill Hole ID	Client Sample ID	Sample Lithology	From (m)	To (m)	Depth Interval (m)	pH[1]	EC[1]	Total S	Scr	MPA[2]	ANC[2]	NAPP[2]	ANC: MPA Ratio	Sample Classification[3]
52	DW7012	7012G08	Siltstone 100%	25.60	27.00	1.40	9.0	620	0.14	0.096	2.9	16.0	-13.1	5.4	Non Acid Forming (Barren)
30	DW7003	7003G08	Siltstone 100%	30.00	31.60	1.60	8.3	1,140	0.08		2.5	12.7	-10.3	5.2	Non Acid Forming (Barren)
54	DW7012	7012G10	Siltstone 100%	30.00	33.08	3.08	9.2	529	0.08		2.5	12.4	-10.0	5.1	Non Acid Forming (Barren)
56	DW7012	7012G12	COAL 6%, Siltstone 94%	33.75	38.00	4.25	9.2	802	0.06		1.8	43.5	-41.7	23.7	Non Acid Forming (Barren)
33	DW7003	7003G11	Siltstone 100%	35.20	36.50	1.30	7.6	1,020	0.07		2.1	21.8	-19.7	10.2	Non Acid Forming (Barren)
34	DW7003	7003G12	Siltstone 100%	37.85	40.00	2.15	8.3	1,230	0.08		2.5	16.3	-13.9	6.7	Non Acid Forming (Barren)
7	DW7002	7002G07	Siltstone 100%	40.00	42.00	2.00	9.6	305	0.03		0.9	58.5	-57.6	63.7	Non Acid Forming (Barren)
36	DW7003	7003G14	Siltstone 100%	41.10	43.30	2.20	8.2	1,120	0.13	0.060	1.8	15.5	-13.7	8.4	Non Acid Forming (Barren)
37	DW7003	7003G15	Siltstone 100%	45.40	46.40	1.00	8.2	1,070	0.16	0.106	3.2	12.3	-9.1	3.8	Non Acid Forming
39	DW7003	7003G17	Siltstone 100%	49.00	50.00	1.00	9.0	890	0.09		2.8	18.9	-16.1	6.9	Non Acid Forming (Barren)
40	DW7003	7003G18	Siltstone 100%	51.00	53.00	2.00	8.8	964	0.13	0.072	2.2	32.2	-30.0	14.6	Non Acid Forming (Barren)
57	DW7012	7012G13	Siltstone 100%	52.55	53.57	1.02	9.3	616	0.04		1.2	142.0	-140.8	115.9	Non Acid Forming (Barren)
59	DW7012	7012G15	Siltstone 100%	53.89	56.00	2.11	9.3	758	0.05		1.5	106.0	-104.5	69.2	Non Acid Forming (Barren)
60	DW7012	7012G16	Siltstone 100%	67.00	72.00	5.00	9.4	666	0.17	0.125	3.8	30.9	-27.1	8.1	Non Acid Forming
61	DW7012	7012G17	Siltstone 100%	76.16	78.00	1.84	9.5	646	0.05		1.5	73.4	-71.9	47.9	Non Acid Forming (Barren)
9	DW7002	7002G09	Siltstone 100%	78.00	82.00	4.00	9.4	296	0.02		0.6	63.6	-63.0	103.8	Non Acid Forming (Barren)
11	DW7002	7002G11	Siltstone 100%	94.00	97.20	3.20	9.5	335	0.04		1.2	61.8	-60.6	50.4	Non Acid Forming (Barren)
63	DW7012	7012G19	Siltstone 100%	94.00	96.40	2.40	9.5	634	0.05		1.5	70.7	-69.2	46.2	Non Acid Forming (Barren)
65	DW7012	7012G21	Siltstone 100%	98.61	100.00	1.39	9.7	697	0.02		0.6	58.5	-57.9	95.5	Non Acid Forming (Barren)
13	DW7002	7002G13	Siltstone 100%	98.95	101.00	2.05	8.8	890	0.07		2.1	19.6	-17.5	9.1	Non Acid Forming (Barren)
14	DW7002	7002G14	Siltstone 100%	102.00	104.00	2.00	9.0	595	0.06		1.8	26.7	-24.9	14.5	Non Acid Forming (Barren)
15	DW7002	7002G15	Siltstone 100%	110.00	112.00	2.00	9.3	468	0.03		0.9	90.2	-89.3	98.2	Non Acid Forming (Barren)
42	DW7003	7003G20	Siltstone 100%	112.40	114.10	1.70	9.2	801	0.04		1.2	78.9	-77.7	64.4	Non Acid Forming (Barren)
44	DW7003	7003G22	Siltstone 100%	115.90	120.00	4.10	9.2	779	0.07		2.1	52.8	-50.7	24.6	Non Acid Forming (Barren)
67	DW7012	7012G23	Siltstone 100%	121.00	123.00	2.00	9.2	802	0.06		1.8	51.3	-49.5	27.9	Non Acid Forming (Barren)
68	DW7012	7012G24	Siltstone 100%	138.00	140.52	2.52	9.5	714	0.08		2.5	69.5	-67.1	28.4	Non Acid Forming (Barren)
19	DW7002	7002G19	Siltstone 100%	140.82	154.00	13.18	9.4	386	0.05		1.5	47.4	-45.9	31.0	Non Acid Forming (Barren)
20	DW7002	7002G20	Siltstone 100%	154.00	156.45	2.45	9.4	432	0.04		1.2	71.1	-69.9	58.0	Non Acid Forming (Barren)
22	DW7002	7002G22	Siltstone 100%	157.26	158.00	0.74	9.4	579	0.07		2.1	71.1	-69.0	33.2	Non Acid Forming (Barren)

Notes

1. Current pH, EC, Alkalinity and Acidity provided for 1:5 sample:water extracts
2. Scr = Chromium Reducible Sulfur; MPA = Maximum Potential Acidity; ANC = Acid Neutralising Capacity; and NAPP = Net Acid Producing Potential.
3. Sample classification criteria detail provided in report text.

* Where total sulfur or ANC results are less than the laboratory Limit of Reporting (LoR) a value of half of the LoR is used .

Table B2: Multi-element test results for mining waste from the Gemini Project

	RGS Sample Number →	2	3	8	20	28	38	24
	ALS Laboratory ID →	EB1713010001	EB1713010002	EB1713010007	EB1713010010	EB1713010016	EB1713010024	EB1713010012
	Client Sample ID →	7002G02	7002G03	7002G08	7002G20	7003G06	7003G16	7003G02
Parameters	Limit of Reporting	Clay	Siltstone	Sandstone	Siltstone	Siltstone	Carb. Siltstone	Clay
Major Cations		All units mg/kg						
Calcium (Ca)	50	----	610	26,600	----	3,480	8,890	----
Magnesium (Mg)	50	----	2,200	11,200	----	4,720	7,510	----
Potassium (K)	50	----	1,040	1,140	----	2,070	1,340	----
Sodium (Na)	50	----	2,130	530	----	3,020	1,320	----
Chloride	50	----	2,000	300	----	1,970	1,190	----
Major, Minor and Trace Elements		All units mg/kg						
Aluminium (Al)	50	----	5,570	12,000	----	11100	12100	----
Antimony (Sb)	5	----	<5	<5	----	<5	<5	----
Arsenic (As)	5	----	10	5	----	43	48	----
Barium (Ba)	10	----	240	120	----	130	760	----
Cadmium (Cd)	1	----	<1	<1	----	<1	<1	----
Chromium (Cr) - hexavalent	2	----	14	29	----	12	10	----
Cobalt (Co)	2	----	114	13	----	9	14	----
Copper (Cu)	5	----	63	20	----	58	25	----
Iron (Fe)	50	----	14,000	36,200	----	19,800	69,700	----
Lead (Pb)	5	----	16	11	----	16	10	----
Manganese (Mn)	5	----	748	1,030	----	79	1580	----
Nickel (Ni)	2	----	75	24	----	33	25	----
Selenium (Se)	5	----	<5	<5	----	<5	<5	----
Vanadium (V)	0.1	----	31.0	49.0	----	40	55	----
Zinc (Zn)	5	----	76	60	----	69	50	----
Exchangable Cations		All units meq/100g (except Exchangable Sodium & Aluminium Percentage (%))						
Exch. Calcium	0.1	1.8	2.3	3.0	3.4	2.6	1.3	2.0
Exch. Magnesium	0.1	10.8	11.9	2	2.2	6.8	1.9	8.5
Exch. Potassium	0.1	0.4	0.4	0.05	0.05	0.05	0.05	0.3
Exch. Sodium	0.1	2.9	3.3	0.2	0.8	4.4	1.0	4.2
Cation Exchange Capacity	0.1	16.1	18.0	5.3	6.4	13.9	4.2	15.1
Calcium:Magnesium Ratio	-	0.2	0.2	1.5	1.5	0.4	0.7	0.2
Magnesium:Potassium Ratio	-	27.0	29.8	40.0	44.0	136.0	38.0	28.3
Exchangable Sodium Percentage	0.1%	18.2	18.4	4.5	12.8	31.5	24.0	28.0

Notes: < indicates less than the laboratory limit of reporting (LoR).

Table B2: Multi-element test results for mining waste from the Gemini Project

	RGS Sample Number →	18	31	50	62	70	58
	ALS Laboratory ID →	EB1713010009	EB1713010019	EB1713010028	EB1713010035	EB1713010039	EB1713010033
	Client Sample ID →	7002G18	7003G09	7012G06	7012G18	7012G26	7012G14
Parameters	Limit of Reporting	Coal	Coal	Sandstone	Sandstone	Carb. Siltstone	Coal
Major Cations		All units mg/kg					
Calcium (Ca)	50	9,050	4,030	29,900	31,500	14,900	9,210
Magnesium (Mg)	50	5,130	3,220	12,000	13,500	5,660	3,730
Potassium (K)	50	1,280	1,450	1,450	1,130	1,620	1,390
Sodium (Na)	50	680	2,240	1,470	1,060	1,270	1,380
Chloride	50	470	1,380	480	600	1,030	980
Major, Minor and Trace Elements		All units mg/kg					
Aluminium (Al)	50	6680	6,280	7,210	11300	8660	6,660
Antimony (Sb)	5	<5	<5	<5	<5	<5	<5
Arsenic (As)	5	9	10	18	8	5	27
Barium (Ba)	10	500	620	20	40	20	950
Cadmium (Cd)	1	<1	<1	<1	<1	<1	<1
Chromium (Cr) - hexavalent	2	8	6	19	17	6	7
Cobalt (Co)	2	5	8	11	23	5	7
Copper (Cu)	5	27	34	25	28	42	30
Iron (Fe)	50	30,400	16,900	38,900	47,600	17,800	25,700
Lead (Pb)	5	10	7	11	7	20	10
Manganese (Mn)	5	448	59	1,000	991	278	604
Nickel (Ni)	2	20	15	20	32	10	11
Selenium (Se)	5	<5	<5	<5	<5	<5	<5
Vanadium (V)	0.1	18	29.0	28.0	59	20	26.0
Zinc (Zn)	5	49	55	74	74	58	43
Exchangable Cations		All units meq/100g (except Exchangable Sodium & Aluminium Percentage (%))					
Exch. Calcium	0.1	----	----	2.0	3.1	3.7	----
Exch. Magnesium	0.1	----	----	3.4	2.4	1.7	----
Exch. Potassium	0.1	----	----	0.05	0.05	0.05	----
Exch. Sodium	0.1	----	----	2.1	1	1.4	----
Cation Exchange Capacity	0.1	----	----	7.7	6.5	6.8	----
Calcium:Magnesium Ratio	-	----	----	0.6	1.3	2.2	----
Magnesium:Potassium Ratio	-	----	----	68.0	48.0	34.0	----
Exchangable Sodium Percentage	0.1%	----	----	27.3	15.4	20.2	----

Notes: < indicates less than the laboratory limit of reporting (LoR).

Table B3: Geochemical Abundance Index (GAI) results for mining waste from the Gemini Project

	RGS Sample Number →		3	8	28	38	18	31	50	62	70	58
	ALS Laboratory ID →		EB1713010002	EB1713010007	EB1713010016	EB1713010024	EB1713010009	EB1713010019	EB1713010028	EB1713010035	EB1713010039	EB1713010033
	Client Sample ID →		7002G03	7002G08	7003G06	7003G16	7002G17	7003G08	7012G06	7012G18	7012G26	7012G14
Parameters	Limit of Reporting	Average Crustal Abundance[1]	Siltstone	Sandstone	Siltstone	Carb. Siltstone	Coal	Coal	Sandstone	Sandstone	Carb. Siltstone	Coal
Major Elements	all units in mg/kg		Geochemical Abundance Index									
Calcium (Ca)	50	15,000	0	0	0	0	0	0	0	0	0	0
Magnesium (Mg)	50	5,000	0	1	0	0	0	0	1	1	0	0
Potassium (K)	50	14,000	0	0	0	0	0	0	0	0	0	0
Sodium (Na)	50	5,000	0	0	0	0	0	0	0	0	0	0
Chloride	50	500	1	0	1	1	0	1	0	0	0	0
Major, Minor and Trace Elements	all units in mg/kg		Geochemical Abundance Index									
Aluminium (Al)	50	71,000	0	0	0	0	0	0	0	0	0	0
Antimony (Sb)	5	5	0	0	0	0	0	0	0	0	0	0
Arsenic (As)	5	6	0	0	2	2	0	0	1	0	0	2
Barium (Ba)	10	500	0	0	0	0	0	0	0	0	0	0
Cadmium (Cd)	1	0.35	0	0	0	0	0	0	0	0	0	0
Chromium (Cr) - hexavalent	2	70	0	0	0	0	0	0	0	0	0	0
Cobalt (Co)	2	8	3	0	0	0	0	0	0	1	0	0
Copper (Cu)	5	30	0	0	0	0	0	0	0	0	0	0
Iron (Fe)	50	40,000	0	0	0	0	0	0	0	0	0	0
Lead (Pb)	5	35	0	0	0	0	0	0	0	0	0	0
Manganese (Mn)	5	1,000	0	0	0	0	0	0	0	0	0	0
Nickel (Ni)	2	50	0	0	0	0	0	0	0	0	0	0
Selenium (Se)	5	0.4	2	2	2	2	2	2	2	2	2	2
Zinc (Zn)	5	90	0	0	0	0	0	0	0	0	0	0

Notes: GAI's greater than or equal to 3 are highlighted.
1. Average Crustal Abundance values sourced from the "GARD Guide", Chapter 5 (INAP, 2009).
1. When no GARD Guide value is available for particular element, then values are taken from Bowen H.J.M.(1979) Environmental Chemistry of the Elements, pages 60-61.

Table B4: Multi-Element Test results for water extracts from mining waste from the Gemini Project

			RGS Sample Number →	3	8	28	38	18	31	50	62	70	58
			ALS Laboratory ID →	EB1713010002	EB1713010007	EB1713010016	EB1713010024	EB1713010009	EB1713010019	EB1713010028	EB1713010035	EB1713010039	EB1713010033
			Client Sample ID →	7002G03	7002G08	7003G06	7003G16	7002G18	7003G09	7012G06	7012G18	7012G26	7012G14
		Water Quality Guidelines:											
Parameters	Limit of Reporting	Aquatic Ecosystems (freshwater)[1]	Livestock Drinking Water[2]	Siltstone	Sandstone	Siltstone	Carb. Siltstone	Coal	Coal	Sandstone	Sandstone	Carb. Siltstone	Coal
pH	0.01 pH unit	6 to 9	-	7.1	9.5	7.5	8.6	9.2	7.3	9.6	9.4	9.5	9.2
Electrical Conductivity	1 µS/cm	<1,000[#]	3,580[^]	1,220	270	1,180	807	429	807	495	585	722	697
Carbonate Alkalinity (mg$CaCO_3$/L)	1 mg/L	-	-	<1	54	<1	<1	18	<1	72	54	36	18
Bicarbonate Alkalinity (mg$CaCO_3$/L)	1 mg/L	-	-	244	3,300	612	378	540	828	3,540	2,740	2,020	396
Total Alkalinity (mg$CaCO_3$/L)	1 mg/L	-	-	244	3,360	612	378	558	828	3,620	2,800	2,060	414
Acidity (mg$CaCO_3$/L)	1 mg/L	-	-	41	1	39	3	1	101	1	1	1	1
Net Alkalinity (mg$CaCO_3$/L)	1 mg/L	-	-	203	3,360	573	375	558	727	3,620	2,800	2,060	414
Major Ions		All units mg/L						All units mg/L					
Calcium (Ca)	2	-	1,000	<2	6	<2	4	8	<2	<2	2	4	<2
Magnesium (Mg)	2	-	-	6	4	1	4	4	2	<2	<2	2	<2
Potassium (K)	2	-	-	4	10	4	10	8	8	8	6	6	6
Sodium (Na)	2	-	-	248	46	252	170	70	188	124	108	144	124
Chloride (Cl)	2	-	-	400	60	394	238	94	276	96	120	206	196
Fluoride (F)	0.2	-	2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2
Sulfate (SO_4)	2	-	1,000	<2	8	8	64	30	44	16	24	14	26
Trace Metals/Metalloids		All units mg/L						All units mg/L					
Aluminium (Al)	1.0	0.055	5	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Antimony (Sb)	0.1	-	-	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Arsenic (As) - triavalent	0.1	0.024 **	0.5	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0.08	<0.1	0.02	0.04
Barium (Ba)	1.0	-	-	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Cadmium (Cd)	0.1	0.0002	0.01	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Chromium (Cr) - total	0.1	0.001 (hex)*	1 (total)	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Copper (Cu)	0.1	0.0014	1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Iron (Fe)	1.0	-	-	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Lead (Pb)	0.1	0.0034	0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Manganese (Mn)	0.1	1.90	-	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Molybdenum (Mo)	0.1	-	0.15	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0.02	0.08	0.04	0.04
Nickel (Ni)	0.1	0.011	1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Selenium (Se)	0.1	0.011	0.02	0.02	<0.1	<0.1	0.04	<0.1	0.02	<0.1	0.02	<0.1	<0.1
Vanadium (V)	0.1	-	-	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Zinc (Zn)	0.1	0.008	20	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1

* Cr (VI) = hexavalent. ** 0.013 mg/Lfor pentavalent Arsenic (V).

\# for still water bodies only, moving rivers at low flow rates should not exceed 2,200µS/cm

^ calculated based on total dissolved solids (TDS) conversion rate of 0.67% of EC. TDS is an approximate measure of inorganic dissolved salts and should not exceed 2,400mg/L for livestock drinking water.

Notes: < indicates concentration less than the detection limit. Shaded cells exceed applied guideline values.

1. ANZECC & ARMCANZ (2000). Trigger values for aquatic ecosystems (95% species protection level)

2. ANZECC & ARMCANZ (2000). Recommended guideline limits for Livestock Drinking Water.

1 + 2. both taken from the "Australian and New Zealand Guidelines for Fresh and Marine Water Quality", National Water Quality Management Strategy, 2000, compilation by ANZECC and ARMCANZ.

ATTACHMENT C

Geochemical Assessment of Mining Waste Materials

ATTACHMENT C

GEOCHEMICAL ASSESSMENT OF MINING WASTE MATERIALS

ACID GENERATION AND PREDICTION

Acid generation is caused by the exposure of sulfide minerals, most commonly pyrite (FeS_2), to atmospheric oxygen and water. Sulfur assay results are used to calculate the maximum acid that could be generated by the sample by either directly determining the pyritic S content or assuming that all sulfur not present as sulfate occurs as pyrite. Pyrite reacts under oxidising conditions to generate acid according to the following overall reaction:

$$FeS_2 + 15/4\ O_2 + 7/2\ H_2O \dashrightarrow Fe(OH)_3 + 2\ H_2SO_4$$

According to this reaction, the maximum potential acidity (MPA) of a sample containing 1%S as pyrite would be 30.6 kg H_2SO_4/t. The chemical components of the acid generation process consist of the above sulfide oxidation reaction and acid neutralization, which is mainly provided by inherent carbonates and to a lesser extent silicate materials. The amount and rate of acid generation is determined by the interaction and overall balance of the acid generation and neutralisation components.

Net Acid Producing Potential

The net acid producing potential (NAPP) is used as an indicator of materials that may be of concern with respect to acid generation. The NAPP calculation represents the balance between the maximum potential acidity (MPA) of a sample, which is derived from the sulfide sulfur content, and the acid neutralising capacity (ANC) of the material, which is determined experimentally. By convention, the NAPP result is expressed in units of kg H_2SO_4/t sample. If the capacity of the solids to neutralise acid (ANC) exceeds their capacity to generate acid (MPA), then the NAPP of the material is negative. Conversely, if the MPA exceeds the ANC, the NAPP of the material is positive. A NAPP assessment involves a series of analytical tests that include:

Determination of pH and EC

pH and EC measured on 1:5 w/w water extract. This gives an indication of the inherent acidity and salinity of the waste material when initially exposed in a waste emplacement area.

Total sulfur content and Maximum Potential Acidity (MPA)

Total sulfur content is determined by the Leco high temperature combustion method. The total sulfur content is then used to calculate the MPA, which is based on the assumption that the entire sulfur content is present as reactive pyrite. Direct determination of the pyritic sulfur content can provide a more accurate estimate of the MPA.

Acid neutralising capacity (ANC)

By addition of acid to a known weight of sample, then titration with NaOH to determine the amount of residual acid. The ANC measures the capacity of a sample to react with and neutralise acid. The ANC can be further evaluated by slow acid titration to a set end-point in the Acid Buffering Characteristic Curve (ABCC) test through calculation of the amount of acid consumed and evaluation of the resultant titration curve.

Net acid producing potential (NAPP)

Calculated from the MPA and ANC results. The NAPP represents the balance between a sample's inherent capacities to generate and neutralise acid. If the MPA is greater than the ANC then the NAPP is positive. If the MPA is less than the ANC then the NAPP is negative.

Net Acid Generation (NAG)

The net acid generation (NAG) test involves the addition of hydrogen peroxide to a sample of mine rock or process residue to oxidise reactive sulfide, then measurement of pH and titration of any net acidity produced by the acid generation and neutralisation reactions occurring in the sample. A significant NAG result (*i.e.* final NAG_{pH} < 4.5) indicates that the sample is potentially acid forming (PAF) and the test provides a direct measure of the net amount of acid remaining in the sample after all acid generating and acid neutralising reactions have taken place. A NAG_{pH} > 4.5 indicates that the sample is non-acid forming (NAF). The NAG test provides a direct assessment of the potential for a material to produce acid after a period of exposure and weathering and is used to refine the results of the theoretical NAPP predictions. The NAG test can be used as a stand-alone test, but is recommended that this only be considered after site specific calibration work is carried out. RGS generally avoids use the NAG test at coal mining projects as the high organic content of some materials can cause erroneous results.

ASSESSMENT OF ELEMENT ENRICHMENT AND SOLUBILITY

In mineralised areas it is common to find a suite of enriched elements that have resulted from natural geological processes. Multi-element scans are carried out to identify any elements that are present in a material (or readily leachable from a material) at concentrations that may be of environmental concern with respect to surface water quality, revegetation and public health. The samples are generally analysed for the following elements:

Major elements	Al, Ca, Fe, K, Mg, Na and S.
Minor elements	As, B, Cd, Co, Cr, Cu, F, Hg, Mn, Mo, Ni, Pb, Sb, Se and Zn.

The concentration of these elements in samples can be directly compared with relevant state or national environmental and health based concentration guideline criteria to determine the level of significance. Water extracts are used to determine the immediate element solubilities under the existing sample pH conditions of the sample. The following tests are normally carried out:

Multi-element composition of solids.

Multi-element composition of solid samples determined using a combination of ICP-mass spectroscopy (ICP-MS), ICP-optical emission spectroscopy (OES), and atomic absorption spectrometry (AAS).

Multi-element composition of water extracts (1:5 sample:deionised water).

Multi-element composition of water extracts from solid samples determined using a combination of ICP-mass spectroscopy (ICP-MS), ICP-optical emission spectroscopy (OES), and atomic absorption spectrometry (AAS).

Under some conditions (*e.g*. low pH) the solubility and mobility of common environmentally important elements can increase significantly. If element mobility under initial pH conditions is deemed likely and/or subsequent low pH conditions may occur, kinetic leach column test work may be completed on representative samples.

KINETIC LEACH COLUMN TESTS

Kinetic leach column (KLC) tests can be used to provide information on the reaction kinetics of mining waste materials. The major objectives of kinetics tests are to:

- Provide time-dependent data on the kinetics and rate of acid generation and acid neutralising reactions under laboratory controlled (or onsite conditions);
- Investigate metal release and drainage/seepage quality; and
- Assess treatment options such as addition of alkaline materials.

The KLC tests simulate the weathering process that leads to acid and base generation and reaction under laboratory controlled or site conditions. The kinetic tests allow an assessment of the acid forming characteristics and indicate the rate of acid generation, over what period it will occur, and what management controls may be required.

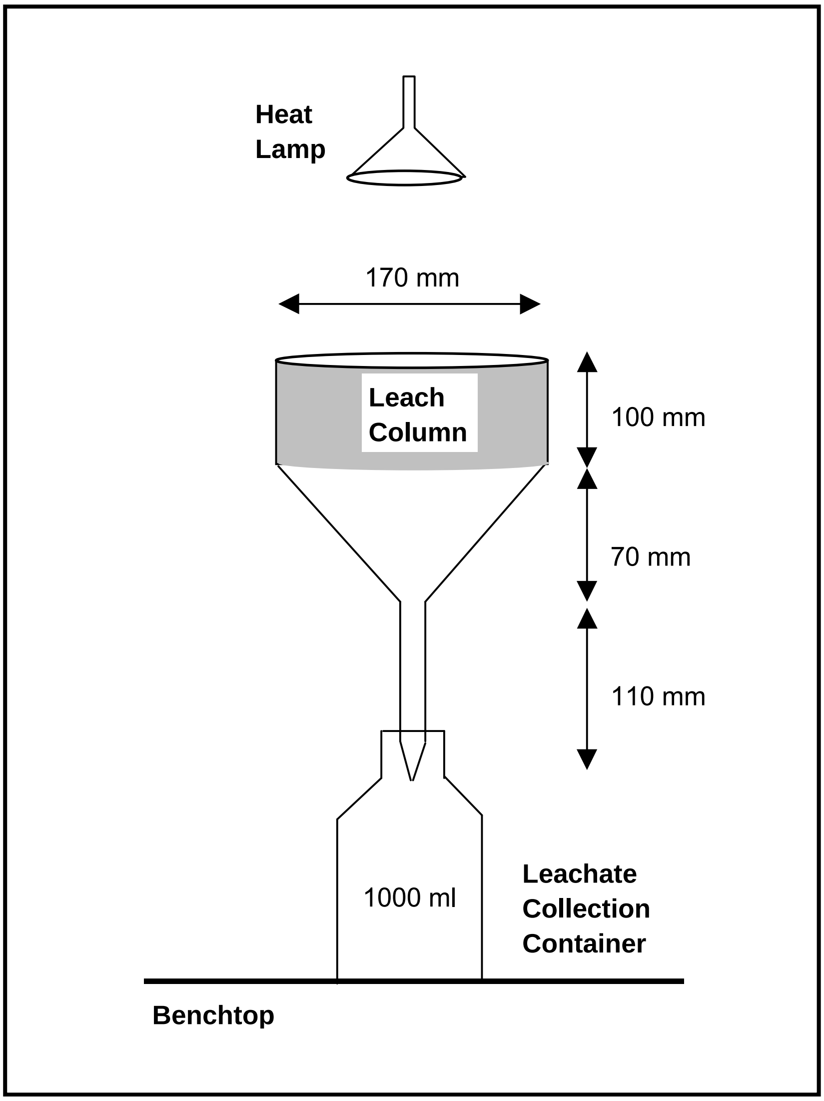
In KLC tests, water is added to a sample and the mixture allowed to leach products and by-products of acid producing and consuming reactions. Samples of leachate are then collected and analysed. Intermittent water application is applied to simulate rainfall and heat lamps are used to simulate sunshine. These tests provide real-time information and may have to continue for months or years. Monitoring includes trends in pH, sulfate, acidity or alkalinity, and metals, for example. The pH of the collected leachate simulates the acid drainage process, acidity or alkalinity levels indicate the rate of acid production and acid neutralisation, and sulfate production can be related to the rate of sulfide oxidation. Metal concentration data provides an assessment of metal solubility and leaching behaviour.

Figure C1 shows the kinetic leach column set up used by RGS adapted from *AMIRA, 2002*. The columns are placed under heat lamps to allow the sample to dry between water additions to ensure adequate oxygen ingress into the sample material.

Approximately 2 kg of sample is accurately weighed and used in the leach columns and depending on the physical nature of the material and particle size can be used on an as-received basis (*i.e.* no crushing as with process residues) or crushed to nominal 5-10 mm particle size (as with waste rock). The sample in the column is initially leached with deionised water at a rate of about 400 ml/kg of sample and the initial leachate from the columns collected and analysed. Subsequent column leaching is carried out at a rate of about 400 ml/kg per month and again collected and analysed. The leaching rate can be varied to better simulate expected site conditions or satisfy test program data requirements. The column must be exposed to drying conditions in between watering events. The residual water content and air void content in the column can be determined by comparing the wet and dry column weights. A heat lamp is generally used above the sample during daylight hours to maintain the leach column surface temperature at about 30^{o}C.

Figure C1

Kinetic Leach Column Setup



ATTACHMENT D

KLC Test Results and Trends

KLC 1 (Siltstone 100%)

Weight (kg)	1.50	Total S (%)	0.01	ANC	26.3
pH (1:5)	8.30	Scr (%)	0.01	NAPP	-25.9
EC (µS/cm)	613	MPA	0.4	ANC:MPA	66.1

Date			09-May-17	09-Aug-17	05-Sep-17	03-Oct-17	07-Nov-17	15-Dec-17	16-Jan-18
Number of Weeks			0	4	9	13	17	22	26
Leach Number			1	2	3	4	5	6	7
ALS Laboratory Number			EB1713594	EB1716503	EB1718214	EB1720293	EB1723258	EB1725752	EB1801935
Volume On (L)			1.5	1.0	1.0	1.0	1.0	1.0	1.0
Volume Off (L)			0.723	0.725	0.754	0.840	0.659	0.850	0.828
Cum. Volume (L)			0.72	1.45	2.20	3.04	3.70	4.55	5.38
Pore Volumes			0.5	1.1	1.6	2.3	2.7	3.4	4.0
pH (RGS Measurement)			7.45	7.50	7.40	7.50	7.43	8.56	7.61
pH (ALS Measurement)			7.55	7.48	6.98	7.47	7.64	7.52	7.74
pH (deionised water used in test)			5.27	5.78	5.60	5.78	5.11	4.90	5.64
EC (RGS Measurement) (µS/cm)			700	403	228	272	182	136	98
EC (ALS Measurement) (µS/cm)			769	508	195	281	190	131	95
Acidity (mg/L)*			2	2	<1	<1	<1	1	<1
Alkalinity (mg/L)*			36	23	8	11	12	17	11
Net Alkalinity (mg/L)*			34	21	8	11	12	16	11
Major Ions (mg/L)	**LoR**	**WQ Guidelines[#]**							
Calcium (Ca)	1	1,000	5	3	1	0.5	0.5	0.5	0.5
Potassium (K)	1	-	3	1	<1	<1	<1	<1	<1
Magnesium (Mg)	1	-	8	5	2	0.5	0.5	0.5	0.5
Sodium (Na)	1	-	126	65	32	50	33	22	18
Chloride (Cl)	1	-	214	119	43	75	44	27	22
Fluoride (F)	0.1	2	0.4	0.2	0.1	0.2	0.1	<0.1	<0.1
Sulfate (SO_4)	1	1,000	6	8	7	7	3	4	3
Trace metals/ metalloids	**LoR**	**WQ Guidelines[#]**	All units mg/L						
Aluminium (Al)	0.01	5	0.12	0.02	0.24	0.9	0.27	0.51	1.07
Arsenic (As)	0.001	0.5	0.004	<0.001	<0.001	<0.001	0.001	<0.001	0.002
Boron (B)	0.05	5	0.06	0.16	<0.05	<0.05	<0.05	<0.05	0.06
Cadmium (Cd)	0.0001	0.01	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Cobalt (Co)	0.001	1	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Chromium (Cr)	0.001	1	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Copper (Cu)	0.001	1	0.001	<0.001	<0.001	0.001	0.001	<0.001	0.002
Iron (Fe)	0.05	1	0.07	<0.05	0.08	0.13	0.09	0.17	0.21
Manganese (Mn)	0.001	2	0.010	0.002	0.006	0.007	0.014	0.005	0.003
Molybdenum (Mo)	0.001	0.15	0.003	0.001	0.001	0.001	<0.001	<0.001	<0.001
Nickel (Ni)	0.001	1	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Lead (Pb)	0.001	0.1	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Antimony (Sb)	0.001	-	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Selenium (Se)	0.01	0.02	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Vanadium	0.01	-	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Zinc (Zn)	0.005	20	0.006	<0.005	<0.005	<0.005	<0.005	<0.005	0.007
Calculations**									
SO_4 Release Rate			3	4	4	4	1	2	2
Cumulative SO_4 Release			3	7	4	7	1	4	5
Ca Release Rate			2.4	1.5	0.5	0.3	0.2	0.3	0.3
Cumulative Ca Release			2.4	3.9	0.5	0.8	0.2	0.5	0.8
Mg Release Rate			3.9	2.4	1.0	0.3	0.2	0.3	0.3
Cumulative Mg Release			3.9	6.3	1.0	1.3	0.2	0.5	0.8
Residual ANC (%)			99.9	99.9	99.8	99.8	99.8	99.8	99.8
Residual Sulfur (%)			99.3	98.3	97.4	96.4	96.0	95.4	95.0
SO_4/(Ca+Mg) molar ratio			0.1	0.3	0.7	2.2	0.9	1.3	0.9

< indicates less than the analytical detection limit. * Acidity and alkalinity data calculated in mg $CaCO_3$/L.
** SO_4, Ca and Mg release rates calculated in mg/kg/flush.
Total S = Total Sulfur; Scr = Chromium Reducible Sulfur; and ANC = Acid Neutralising Capacity.
MPA = Maximum Potential Acidity, and NAPP = Net Acid Producing Potential.

ANZECC & ARMCANZ (2000). Australian and New Zealand Guidelines for Fresh and Marine Water Quality, National Water Quality Management Strategy, 2000, ANZECC (Australian and New Zealand Environment Conservation Council) and ARMCANZ (Agriculture and Resource Management Council of Australia and New Zealand). Livestock Drinking Water Levels (Irrigation Levels used for Fe and Mn).

KLC 2 (Siltstone 100%)

Weight (kg)	1.50	Total S (%)	0.03	ANC	10.6
pH (1:5)	7.60	Scr (%)	0.03	NAPP	-9.6
EC (µS/cm)	1,001	MPA	1.0	ANC:MPA	10.5

Date			09-May-17	09-Aug-17	05-Sep-17	03-Oct-17	07-Nov-17	15-Dec-18	16-Jan-18
Number of Weeks			0	4	9	13	17	22	26
Leach Number			1	2	3	4	5	6	7
ALS Laboratory Number			EB1713594	EB1716503	EB1718214	EB1720293	EB1723258	EB1725752	EB1801935
Volume On (L)			1.0	1.0	1.0	1.0	1.0	1.0	1.0
Volume Off (L)			0.662	0.815	0.963	0.850	0.875	0.870	0.874
Cum. Volume (L)			0.66	1.48	2.44	3.29	4.17	5.04	5.91
Pore Volumes			0.5	1.1	1.8	2.4	3.1	3.7	4.4
pH (RGS Measurement)			8.58	7.79	8.15	7.14	7.32	8.21	6.65
pH (ALS Measurement)			7.74	6.56	6.59	7.06	6.97	7.12	7.06
pH (deionised water used in test)			5.27	5.78	5.60	5.78	5.11	4.90	5.64
EC (RGS Measurement) (µS/cm)			169	140	173	200	130	108	134
EC (ALS Measurement) (µS/cm)			162	181	175	207	116	106	139
Acidity (mg/L)*			<1	2	<1	<1	<1	<1	<1
Alkalinity (mg/L)*			11	9	6	4	5	9	4
Net Alkalinity (mg/L)*			11	7	6	4	5	9	4
Major Ions (mg/L)	**LoR**	**WQ Guidelines#**							
Calcium (Ca)	1	1,000	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Potassium (K)	1	-	1	<1	<1	<1	<1	<1	<1
Magnesium (Mg)	1	-	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Sodium (Na)	1	-	30	28	34	37	20	20	26
Chloride (Cl)	1	-	33	35	42	58	27	25	36
Fluoride (F)	0.1	2	0.2	0.3	0.1	0.2	0.2	0.1	0.2
Sulfate (SO_4)	1	1,000	2	3	2	3	2	3	3
Trace metals/ metalloids	**LoR**	**WQ Guidelines#**	All units mg/L						
Aluminium (Al)	0.01	5	3.72	2.42	0.23	0.51	0.36	0.42	0.77
Arsenic (As)	0.001	0.5	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Boron (B)	0.05	5	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	0.06
Cadmium (Cd)	0.0001	0.01	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Cobalt (Co)	0.001	1	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Chromium (Cr)	0.001	1	0.002	0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Copper (Cu)	0.001	1	0.003	0.002	<0.001	0.002	0.001	<0.001	0.001
Iron (Fe)	0.05	1	0.61	0.38	<0.05	0.08	0.10	0.07	0.13
Manganese (Mn)	0.001	2	0.044	0.018	0.001	0.009	0.021	0.009	0.010
Molybdenum (Mo)	0.001	0.15	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Nickel (Ni)	0.001	1	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Lead (Pb)	0.001	0.1	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Antimony (Sb)	0.001	-	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Selenium (Se)	0.01	0.02	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Vanadium	0.01	-	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Zinc (Zn)	0.005	20	0.007	<0.005	<0.005	<0.005	<0.005	<0.005	0.012
Calculations**									
SO_4 Release Rate			1	2	1	2	1	2	2
Cumulative SO_4 Release			1	3	4	5	7	8	10
Ca Release Rate			0.2	0.3	0.3	0.3	0.3	0.3	0.3
Cumulative Ca Release			0.2	0.5	0.8	1.1	1.4	1.7	2.0
Mg Release Rate			0.2	0.3	0.3	0.3	0.3	0.3	0.3
Cumulative Mg Release			0.2	0.5	0.8	1.1	1.4	1.7	2.0
Residual ANC (%)			100.0	100.0	100.0	99.9	99.9	99.9	99.9
Residual Sulfur (%)			99.9	99.7	99.6	99.4	99.3	99.2	99.0
SO_4/(Ca+Mg) molar ratio			0.6	0.9	0.6	0.9	0.6	0.9	0.9

< indicates less than the analytical detection limit. * Acidity and alkalinity data calculated in mg $CaCO_3$/L.
** SO_4, Ca and Mg release rates calculated in mg/kg/flush.
Total S = Total Sulfur; Scr = Chromium Reducible Sulfur; and ANC = Acid Neutralising Capacity.
MPA = Maximum Potential Acidity, and NAPP = Net Acid Producing Potential.

ANZECC & ARMCANZ (2000). Australian and New Zealand Guidelines for Fresh and Marine Water Quality, National Water Quality Management Strategy, 2000, ANZECC (Australian and New Zealand Environment Conservation Council) and ARMCANZ (Agriculture and Resource Management Council of Australia and New Zealand). Livestock Drinking Water Levels (Irrigation Levels used for Fe and Mn).

KLC 3 (Sandstone 100%)

Weight (kg)	1.50	Total S (%)	0.03	ANC	113.7
pH (1:5)	9.50	Scr (%)	0.03	NAPP	-112.8
EC (µS/cm)	573	MPA	0.9	ANC:MPA	123.8

Date			09-May-17	09-Aug-17	05-Sep-17	03-Oct-17	07-Nov-17	15-Dec-18	16-Jan-18
Number of Weeks			0	4	9	13	17	22	26
Leach Number			1	2	3	4	5	6	7
ALS Laboratory Number			EB1713594	EB1716503	EB1718214	EB1720293	EB1723258	EB1725752	EB1801935
Volume On (L)			1.0	1.0	1.0	1.0	1.0	1.0	1.0
Volume Off (L)			0.738	0.775	0.803	0.655	0.851	0.755	0.833
Cum. Volume (L)			0.74	1.51	2.32	2.97	3.82	4.58	5.41
Pore Volumes			0.5	1.1	1.7	2.2	2.8	3.4	4.0
pH (RGS Measurement)			8.18	7.35	8.22	7.29	7.26	9.15	7.68
pH (ALS Measurement)			7.47	7.13	7.07	7.29	7.43	8.69	8.42
pH (deionised water used in test)			5.27	5.78	5.60	5.78	5.11	4.90	5.64
EC (RGS Measurement) (µS/cm)			360	499	395	268	232	268	202
EC (ALS Measurement) (µS/cm)			317	582	424	282	254	267	229
Acidity (mg/L)*			2	2	<1	2	2	<1	<1
Alkalinity (mg/L)*			14	30	12	12	14	31	30
Net Alkalinity (mg/L)*			12	28	12	10	12	31	30
Major Ions (mg/L)	**LoR**	**WQ Guidelines#**							
Calcium (Ca)	1	1,000	2	7	6	3	4	4	4
Potassium (K)	1	-	1	2	2	2	2	2	2
Magnesium (Mg)	1	-	1	7	5	3	3	3	2
Sodium (Na)	1	-	33	75	64	42	37	42	37
Chloride (Cl)	1	-	75	147	105	67	55	56	40
Fluoride (F)	0.1	2	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Sulfate (SO_4)	1	1,000	13	16	20	15	13	18	21
Trace metals/ metalloids	**LoR**	**WQ Guidelines#**	All units mg/L						
Aluminium (Al)	0.01	5	0.14	0.02	0.04	0.13	0.1	0.21	0.22
Arsenic (As)	0.001	0.5	0.005	0.002	0.003	0.002	0.003	0.003	0.003
Boron (B)	0.05	5	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Cadmium (Cd)	0.0001	0.01	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Cobalt (Co)	0.001	1	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Chromium (Cr)	0.001	1	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Copper (Cu)	0.001	1	0.001	<0.001	<0.001	0.001	<0.001	<0.001	0.002
Iron (Fe)	0.05	1	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Manganese (Mn)	0.001	2	0.002	0.012	0.009	0.010	0.006	0.005	0.003
Molybdenum (Mo)	0.001	0.15	0.006	0.042	0.029	0.024	0.015	0.015	0.014
Nickel (Ni)	0.001	1	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Lead (Pb)	0.001	0.1	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Antimony (Sb)	0.001	-	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Selenium (Se)	0.01	0.02	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Vanadium	0.01	-	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Zinc (Zn)	0.005	20	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	0.006
Calculations**									
SO_4 Release Rate			6	8	11	7	7	9	12
Cumulative SO_4 Release			6	15	25	32	39	48	60
Ca Release Rate			1.0	3.6	3.2	1.3	2.3	2.0	2.2
Cumulative Ca Release			1.0	4.6	7.8	9.1	11.4	13.4	15.6
Mg Release Rate			0.5	3.6	2.7	1.3	1.7	1.5	1.1
Cumulative Mg Release			0.5	4.1	6.8	8.1	9.8	11.3	12.4
Residual ANC (%)			100.0	99.8	99.7	99.7	99.6	99.5	99.5
Residual Sulfur (%)			99.9	99.8	99.7	99.6	99.5	99.4	99.3
SO_4/(Ca+Mg) molar ratio			1.5	0.4	0.6	0.8	0.6	0.8	1.2

< indicates less than the analytical detection limit. * Acidity and alkalinity data calculated in mg $CaCO_3$/L.
** SO_4, Ca and Mg release rates calculated in mg/kg/flush.
Total S = Total Sulfur; Scr = Chromium Reducible Sulfur; and ANC = Acid Neutralising Capacity.
MPA = Maximum Potential Acidity, and NAPP = Net Acid Producing Potential.

ANZECC & ARMCANZ (2000). Australian and New Zealand Guidelines for Fresh and Marine Water Quality, National Water Quality Management Strategy, 2000, ANZECC (Australian and New Zealand Environment Conservation Council) and ARMCANZ (Agriculture and Resource Management Council of Australia and New Zealand). Livestock Drinking Water Levels (Irrigation Levels used for Fe and Mn).

KLC 4 (Coal 100%)

Weight (kg)	1.50	**Total S (%)**	0.38	**ANC**	41.8
pH (1:5)	9.30	**Scr (%)**	0.140	**NAPP**	-37.5
EC (µS/cm)	458	**MPA**	4.3	**ANC:MPA**	9.7

Date			**09-May-17**	**09-Aug-17**	**05-Sep-17**	**03-Oct-17**	**07-Nov-17**	**15-Dec-18**	**16-Jan-18**
Number of Weeks			**0**	**4**	**9**	**13**	**17**	**22**	**26**
Leach Number			**1**	**2**	**3**	**4**	**5**	**6**	**7**
ALS Laboratory Number			EB1713594	EB1716503	EB1718214	EB1720293	EB1723258	EB1725752	EB1801935
Volume On (L)			1.0	1.0	1.0	1.0	1.0	1.0	1.0
Volume Off (L)			0.677	0.790	0.803	0.813	0.791	0.832	0.781
Cum. Volume (L)			0.68	1.47	2.27	3.08	3.87	4.71	5.49
Pore Volumes			0.5	1.1	1.7	2.3	2.9	3.5	4.1
pH (RGS Measurement)			8.67	7.32	8.27	7.33	7.26	8.48	7.47
pH (ALS Measurement)			7.14	7.04	7.14	7.22	7.45	7.77	7.68
pH (deionised water used in test)			5.27	5.78	5.60	5.78	5.11	4.90	5.64
EC (RGS Measurement) (µS/cm)			147	193	333	131	289	253	200
EC (ALS Measurement) (µS/cm)			185	231	352	135	303	230	220
Acidity (mg/L)*			1	1	<1	<1	1	1	<1
Alkalinity (mg/L)*			11	21	14	10	16	24	45
Net Alkalinity (mg/L)*			10	20	14	10	15	23	45
Major Ions (mg/L)	**LoR**	**WQ Guidelines#**							
Calcium (Ca)	1	1,000	2	4	6	2	7	4	4
Potassium (K)	1	-	<1	1	2	1	2	2	2
Magnesium (Mg)	1	-	0.5	3	5	2	4	4	3
Sodium (Na)	1	-	22	29	52	19	42	33	33
Chloride (Cl)	1	-	27	48	84	26	52	39	30
Fluoride (F)	0.1	2	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Sulfate (SO_4)	1	1,000	6	7	16	10	36	30	34
Trace metals/ metalloids	**LoR**	**WQ Guidelines#**	All units mg/L						
Aluminium (Al)	0.01	5	0.05	0.05	0.03	0.11	0.04	0.08	0.11
Arsenic (As)	0.001	0.5	0.002	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Boron (B)	0.05	5	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Cadmium (Cd)	0.0001	0.01	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Cobalt (Co)	0.001	1	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Chromium (Cr)	0.001	1	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Copper (Cu)	0.001	1	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Iron (Fe)	0.05	1	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Manganese (Mn)	0.001	2	<0.001	0.005	0.001	0.002	0.006	0.006	0.006
Molybdenum (Mo)	0.001	0.15	0.003	0.007	0.014	0.006	0.011	0.007	0.008
Nickel (Ni)	0.001	1	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Lead (Pb)	0.001	0.1	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Antimony (Sb)	0.001	-	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Selenium (Se)	0.01	0.02	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Vanadium	0.01	-	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Zinc (Zn)	0.005	20	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Calculations**									
SO_4 Release Rate			2.7	3.7	8.6	5.4	19	17	18
Cumulative SO_4 Release			2.7	6.4	15.0	20.4	39	56	74
Ca Release Rate			0.9	2.1	3.2	1.1	3.7	2.2	2.1
Cumulative Ca Release			0.9	3.0	6.2	7.3	11.0	13.2	15.3
Mg Release Rate			0.2	1.6	2.7	1.1	2.1	2.2	1.6
Cumulative Mg Release			0.2	1.8	4.5	5.6	7.7	9.9	11.5
Residual ANC (%)			100.0	99.9	99.9	99.8	99.7	99.7	99.6
Residual Sulfur (%)			100.0	99.9	99.9	99.8	99.6	99.5	99.3
SO_4/(Ca+Mg) molar ratio			0.9	0.3	0.5	0.8	1.1	1.2	1.6

< indicates less than the analytical detection limit. * Acidity and alkalinity data calculated in mg $CaCO_3$/L.
** SO_4, Ca and Mg release rates calculated in mg/kg/flush.
Total S = Total Sulfur; Scr = Chromium Reducible Sulfur; and ANC = Acid Neutralising Capacity.
MPA = Maximum Potential Acidity, and NAPP = Net Acid Producing Potential.

ANZECC & ARMCANZ (2000). Australian and New Zealand Guidelines for Fresh and Marine Water Quality, National Water Quality Management Strategy, 2000, ANZECC (Australian and New Zealand Environment Conservation Council) and ARMCANZ (Agriculture and Resource Management Council of Australia and New Zealand). Livestock Drinking Water Levels (Irrigation Levels used for Fe and Mn).

KLC 5 (Weathered Coal)

Weight (kg)	1.50	Total S (%)	0.29	ANC	16.6
pH (1:5)	7.30	Scr (%)	0.035	NAPP	-15.5
EC (µS/cm)	857	MPA	1.1	ANC:MPA	15.5

Date			09-May-17	09-Aug-17	05-Sep-17	03-Oct-17	07-Nov-17	15-Dec-18	16-Jan-18
Number of Weeks			0	4	9	13	17	22	26
Leach Number			1	2	3	4	5	6	7
ALS Laboratory Number			EB1713594	EB1716503	EB1718214	EB1720293	EB1723258	EB1725752	EB1801935
Volume On (L)			1.0	1.0	1.0	1.0	1.0	1.0	1.0
Volume Off (L)			0.641	0.795	0.846	0.752	0.845	0.851	0.870
Cum. Volume (L)			0.64	1.44	2.28	3.03	3.88	4.73	5.60
Pore Volumes			0.5	1.1	1.7	2.2	2.9	3.5	4.1
pH (RGS Measurement)			7.89	6.50	6.78	6.49	7.36	7.91	7.14
pH (ALS Measurement)			7.09	6.73	6.32	6.65	7.04	7.06	6.82
pH (deionised water used in test)			5.27	5.78	5.60	5.78	5.11	4.90	5.64
EC (RGS Measurement) (µS/cm)			171	385	403	795	305	245	169
EC (ALS Measurement) (µS/cm)			180	433	425	859	320	237	176
Acidity (mg/L)*			2	1	1	2	3	2	1
Alkalinity (mg/L)*			7	12	5	5	12	9	5
Net Alkalinity (mg/L)*			5	11	4	3	9	7	4
Major Ions (mg/L)	LoR	WQ Guidelines#							
Calcium (Ca)	1	1,000	0.5	3	47	5	0.5	0.5	0.5
Potassium (K)	1	-	1	1	2	3	1	1	1
Magnesium (Mg)	1	-	0.5	5	6	9	1	1	0.5
Sodium (Na)	1	-	31	60	65	140	49	41	31
Chloride (Cl)	1	-	27	117	114	275	82	62	44
Fluoride (F)	0.1	2	0.2	<0.1	<0.1	0.1	0.2	<0.1	<0.1
Sulfate (SO_4)	1	1,000	4	9	17	21	12	9	7
Trace metals/ metalloids	LoR	WQ Guidelines#	All units mg/L						
Aluminium (Al)	0.01	5	2.3	0.06	0.04	0.01	0.26	0.46	0.88
Arsenic (As)	0.001	0.5	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Boron (B)	0.05	5	<0.05	<0.05	0.06	0.09	<0.05	<0.05	0.06
Cadmium (Cd)	0.0001	0.01	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Cobalt (Co)	0.001	1	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Chromium (Cr)	0.001	1	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Copper (Cu)	0.001	1	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Iron (Fe)	0.05	1	0.82	<0.05	<0.05	<0.05	0.17	0.19	0.32
Manganese (Mn)	0.001	2	0.002	0.004	0.005	0.006	0.001	0.002	<0.001
Molybdenum (Mo)	0.001	0.15	0.002	0.001	<0.001	0.001	0.001	<0.001	<0.001
Nickel (Ni)	0.001	1	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Lead (Pb)	0.001	0.1	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Antimony (Sb)	0.001	-	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Selenium (Se)	0.01	0.02	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Vanadium	0.01	-	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Zinc (Zn)	0.005	20	0.007	<0.005	<0.005	<0.005	<0.005	<0.005	0.179
Calculations**									
SO_4 Release Rate			2	5	10	11	7	5	4
Cumulative SO_4 Release			2	6	16	27	33	38	43
Ca Release Rate			0.2	1.6	26.5	2.5	0.3	0.3	0.3
Cumulative Ca Release			0.2	1.8	28.3	30.8	31.1	31.4	31.7
Mg Release Rate			0.2	2.7	3.4	4.5	0.6	0.6	0.3
Cumulative Mg Release			0.2	2.9	6.2	10.8	11.3	11.9	12.2
Residual ANC (%)			100.0	99.9	99.4	99.3	99.3	99.2	99.2
Residual Sulfur (%)			100.0	99.9	99.8	99.7	99.6	99.6	99.5
SO_4/(Ca+Mg) molar ratio			1.3	0.3	0.1	0.4	2.3	1.7	2.2

< indicates less than the analytical detection limit. * Acidity and alkalinity data calculated in mg $CaCO_3$/L.
** SO_4, Ca and Mg release rates calculated in mg/kg/flush.
Total S = Total Sulfur; Scr = Chromium Reducible Sulfur; and ANC = Acid Neutralising Capacity.
MPA = Maximum Potential Acidity, and NAPP = Net Acid Producing Potential.

ANZECC & ARMCANZ (2000). Australian and New Zealand Guidelines for Fresh and Marine Water Quality, National Water Quality Management Strategy, 2000, ANZECC (Australian and New Zealand Environment Conservation Council) and ARMCANZ (Agriculture and Resource Management Council of Australia and New Zealand). Livestock Drinking Water Levels (Irrigation Levels used for Fe and Mn).

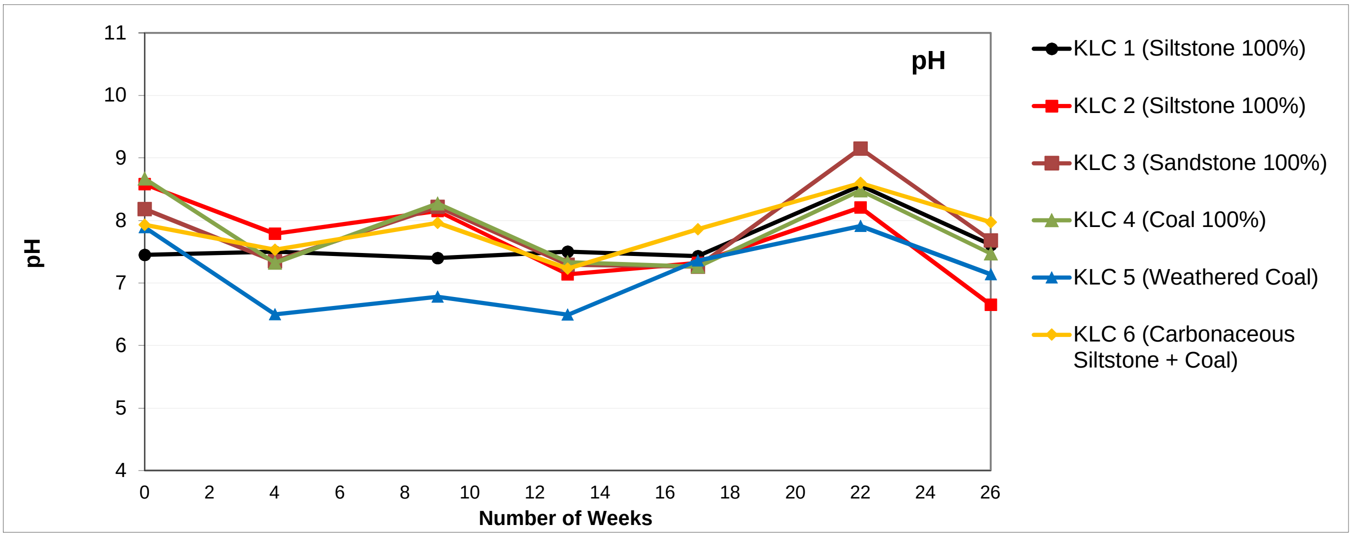
KLC 6 (Carbonaceous Siltstone + Coal)

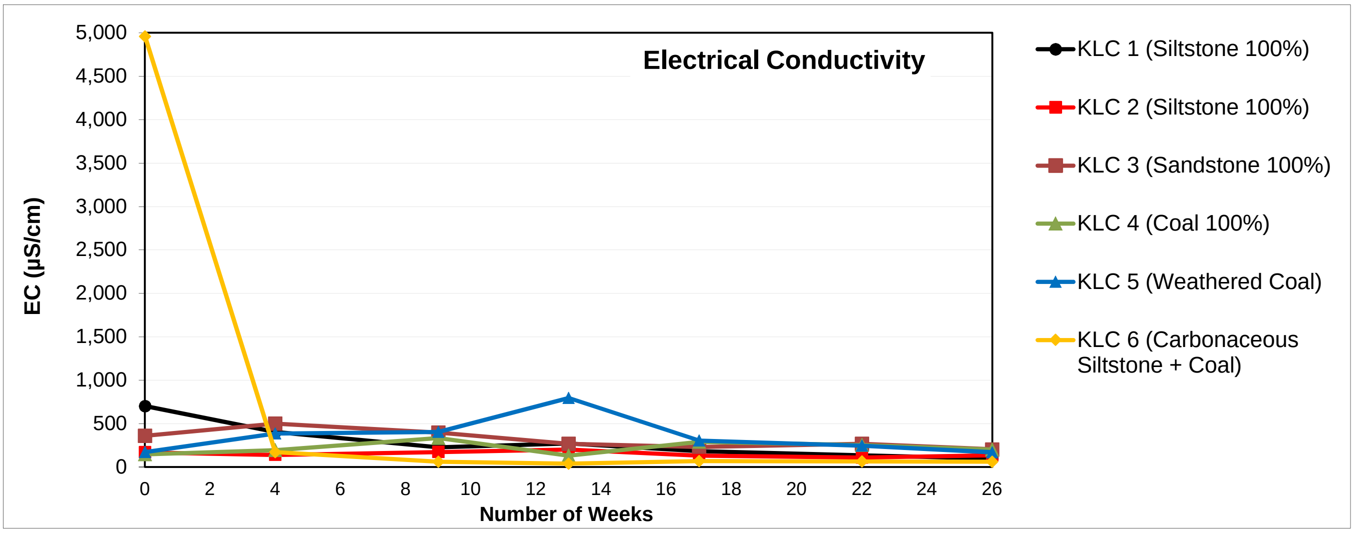
Weight (kg)	1.50	Total S (%)	0.36	ANC	23
pH (1:5)	8.80	Scr (%)	0.114	NAPP	-19.5
EC (µS/cm)	630	MPA	3.5	ANC:MPA	6.6

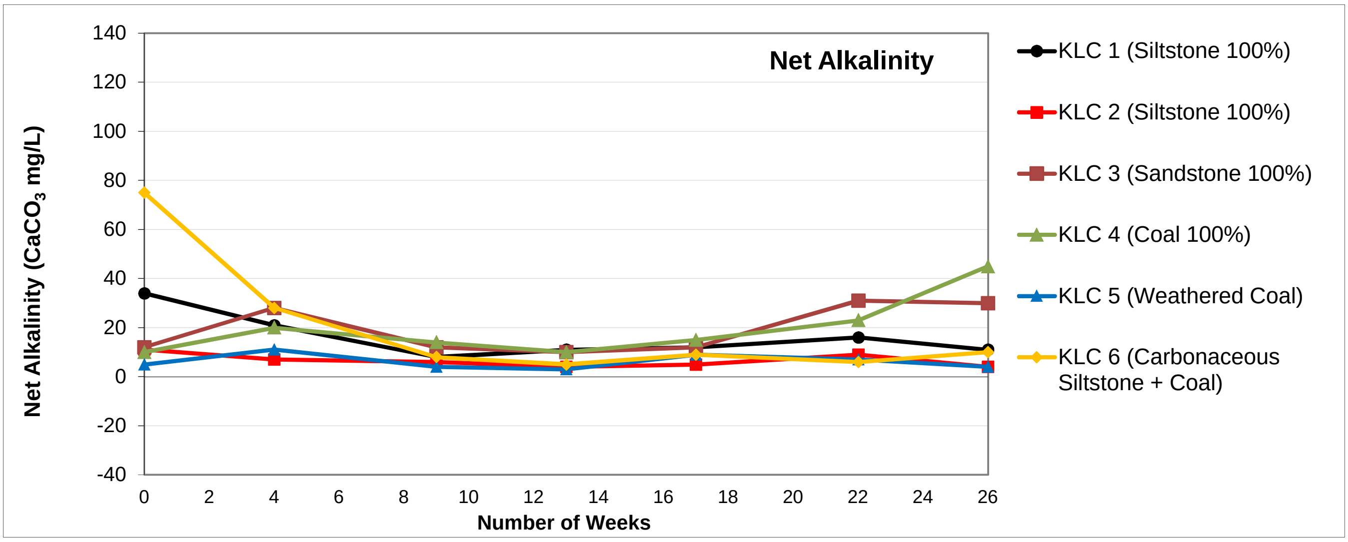
Date			09-May-17	09-Aug-17	05-Sep-17	03-Oct-17	07-Nov-17	15-Dec-18	16-Jan-18
Number of Weeks			0	4	9	13	17	22	26
Leach Number			1	2	3	4	5	6	7
ALS Laboratory Number			EB1713594	EB1716503	EB1718214	EB1720293	EB1723258	EB1725752	EB1801935
Volume On (L)			1.0	1.0	1.0	1.0	1.0	1.0	1.0
Volume Off (L)			0.591	0.754	0.837	0.811	0.887	0.893	0.876
Cum. Volume (L)			0.59	1.35	2.18	2.99	3.88	4.77	5.65
Pore Volumes			0.4	1.0	1.6	2.2	2.9	3.5	4.2
pH (RGS Measurement)			7.93	7.53	7.96	7.23	7.86	8.60	7.97
pH (ALS Measurement)			7.76	7.39	7.07	7.07	7.39	7.52	7.51
pH (deionised water used in test)			5.27	5.78	5.60	5.78	5.11	4.90	5.64
EC (RGS Measurement) (µS/cm)			4,960	171	60	39	69	63	61
EC (ALS Measurement) (µS/cm)			4,420	218	63	32	67	56	67
Acidity (mg/L)*			2	1	<1	<1	1	2	2
Alkalinity (mg/L)*			77	29	8	5	10	8	12
Net Alkalinity (mg/L)*			75	28	8	5	9	6	10
Major Ions (mg/L)	**LoR**	**WQ Guidelines#**							
Calcium (Ca)	1	1,000	21	0.5	0.5	0.5	0.5	0.5	0.5
Potassium (K)	1	-	13	1	<1	<1	<1	<1	1
Magnesium (Mg)	1	-	21	0.5	0.5	0.5	0.5	0.5	0.5
Sodium (Na)	1	-	496	31	11	5	10	10	13
Chloride (Cl)	1	-	1,140	33	10	4	8	9	7
Fluoride (F)	0.1	2	1.3	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Sulfate (SO_4)	1	1,000	242	16	8	4	10	9	10
Trace metals/ metalloids	**LoR**	**WQ Guidelines#**	All units mg/L						
Aluminium (Al)	0.01	5	<0.01	0.58	0.54	0.25	0.21	0.41	1.29
Arsenic (As)	0.001	0.5	0.214	0.008	0.006	0.004	0.007	0.005	0.008
Boron (B)	0.05	5	0.1	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Cadmium (Cd)	0.0001	0.01	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Cobalt (Co)	0.001	1	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Chromium (Cr)	0.001	1	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Copper (Cu)	0.001	1	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Iron (Fe)	0.05	1	<0.05	0.07	0.07	<0.05	0.05	0.07	0.16
Manganese (Mn)	0.001	2	0.023	0.002	0.001	0.002	0.002	0.003	0.002
Molybdenum (Mo)	0.001	0.15	0.067	0.009	0.005	0.002	0.003	0.002	0.002
Nickel (Ni)	0.001	1	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Lead (Pb)	0.001	0.1	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Antimony (Sb)	0.001	-	0.003	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Selenium (Se)	0.01	0.02	0.05	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Vanadium	0.01	-	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Zinc (Zn)	0.005	20	0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Calculations**									
SO_4 Release Rate			95.3	8.0	4.5	2.2	6	5	6
Cumulative SO_4 Release			95.3	103.4	107.9	110.0	116	121	127
Ca Release Rate			8.3	0.3	0.3	0.3	0.3	0.3	0.3
Cumulative Ca Release			8.3	8.5	8.8	9.1	9.4	9.7	10.0
Mg Release Rate			8.3	0.3	0.3	0.3	0.3	0.3	0.3
Cumulative Mg Release			8.3	8.5	8.8	9.1	9.4	9.7	10.0
Residual ANC (%)			99.8	99.8	99.8	99.7	99.7	99.7	99.7
Residual Sulfur (%)			99.1	99.0	99.0	99.0	98.9	98.9	98.8
SO_4/(Ca+Mg) molar ratio			1.8	5.0	2.5	1.3	3.2	2.8	3.2

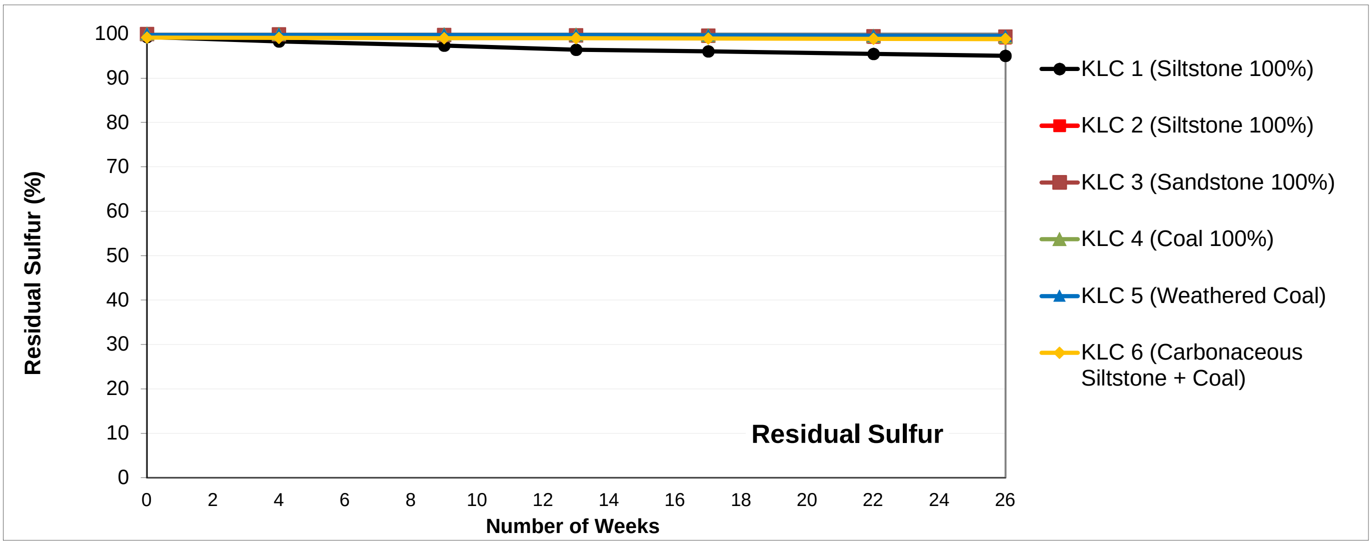
< indicates less than the analytical detection limit. * Acidity and alkalinity data calculated in mg $CaCO_3$/L.
** SO_4, Ca and Mg release rates calculated in mg/kg/flush.
Total S = Total Sulfur; Scr = Chromium Reducible Sulfur; and ANC = Acid Neutralising Capacity.
MPA = Maximum Potential Acidity, and NAPP = Net Acid Producing Potential.

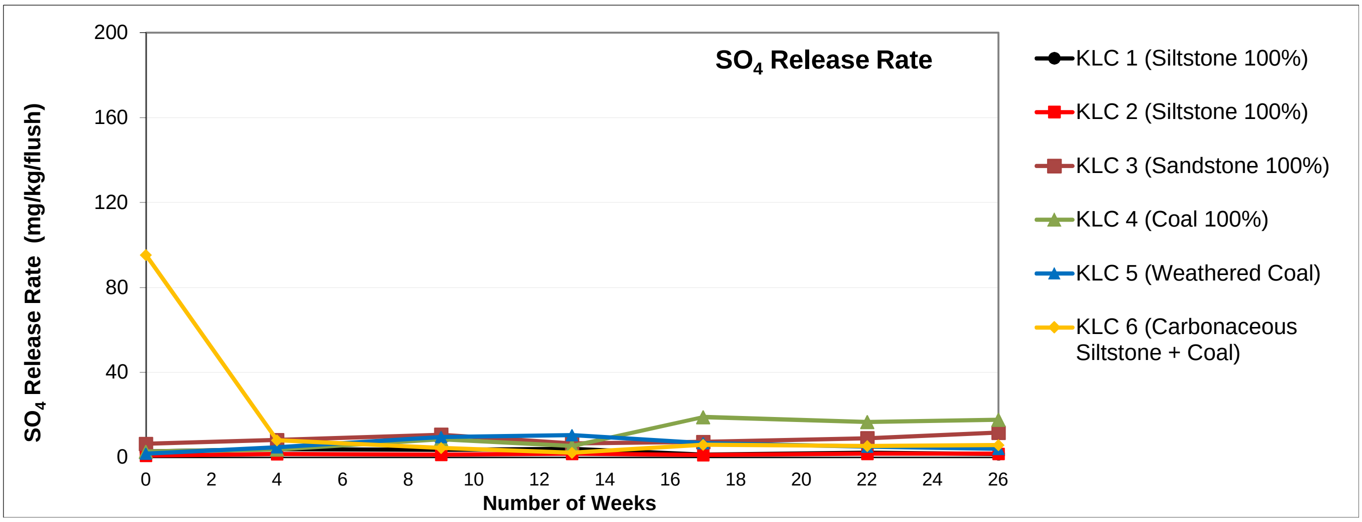
ANZECC & ARMCANZ (2000). Australian and New Zealand Guidelines for Fresh and Marine Water Quality, National Water Quality Management Strategy, 2000, ANZECC (Australian and New Zealand Environment Conservation Council) and ARMCANZ (Agriculture and Resource Management Council of Australia and New Zealand). Livestock Drinking Water Levels (Irrigation Levels used for Fe and Mn).

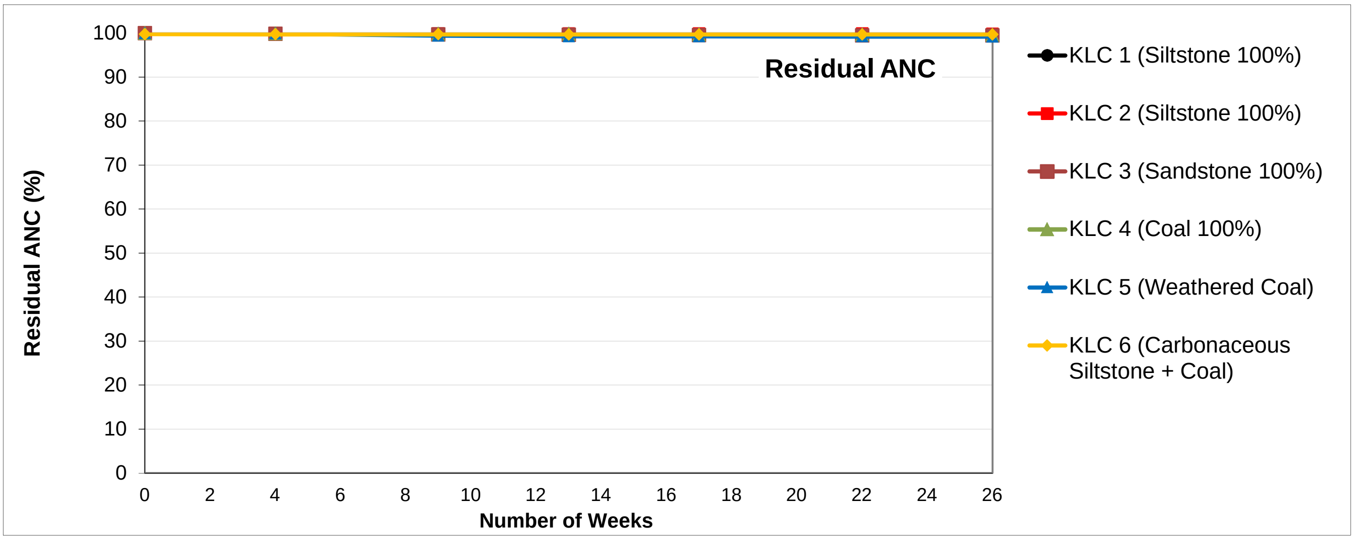

pH
pH
Number of Weeks
KLC 1 (Siltstone 100%)
KLC 2 (Siltstone 100%)
KLC 3 (Sandstone 100%)
KLC 4 (Coal 100%)
KLC 5 (Weathered Coal)
KLC 6 (Carbonaceous Siltstone + Coal)

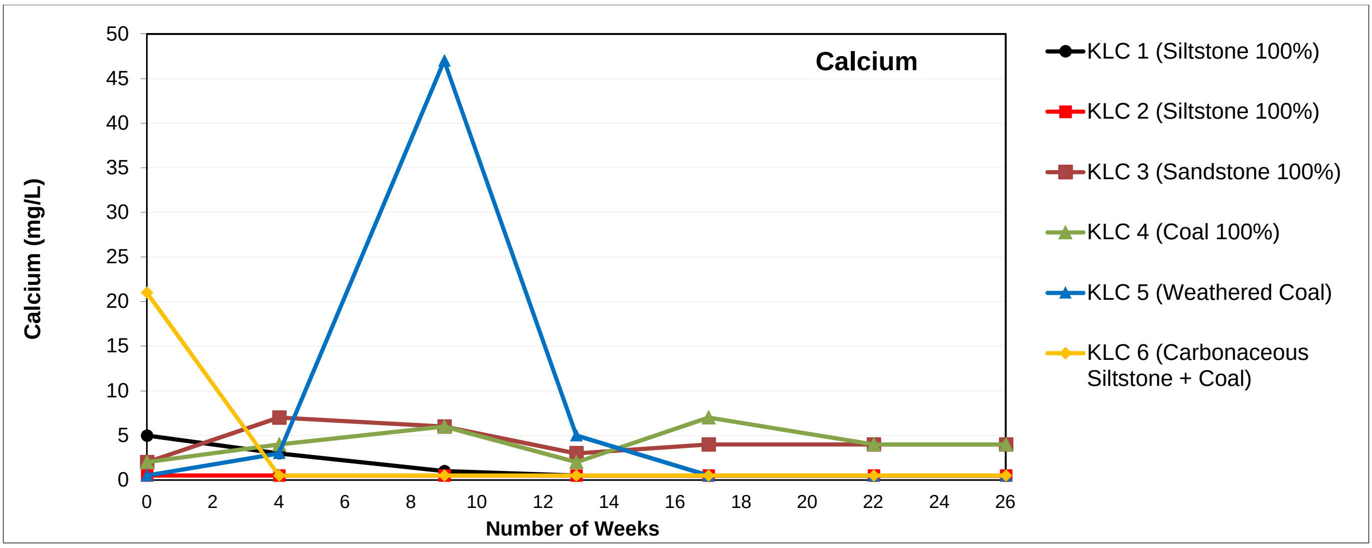

Electrical Conductivity
EC (µS/cm)
Number of Weeks
KLC 1 (Siltstone 100%)
KLC 2 (Siltstone 100%)
KLC 3 (Sandstone 100%)
KLC 4 (Coal 100%)
KLC 5 (Weathered Coal)
KLC 6 (Carbonaceous Siltstone + Coal)

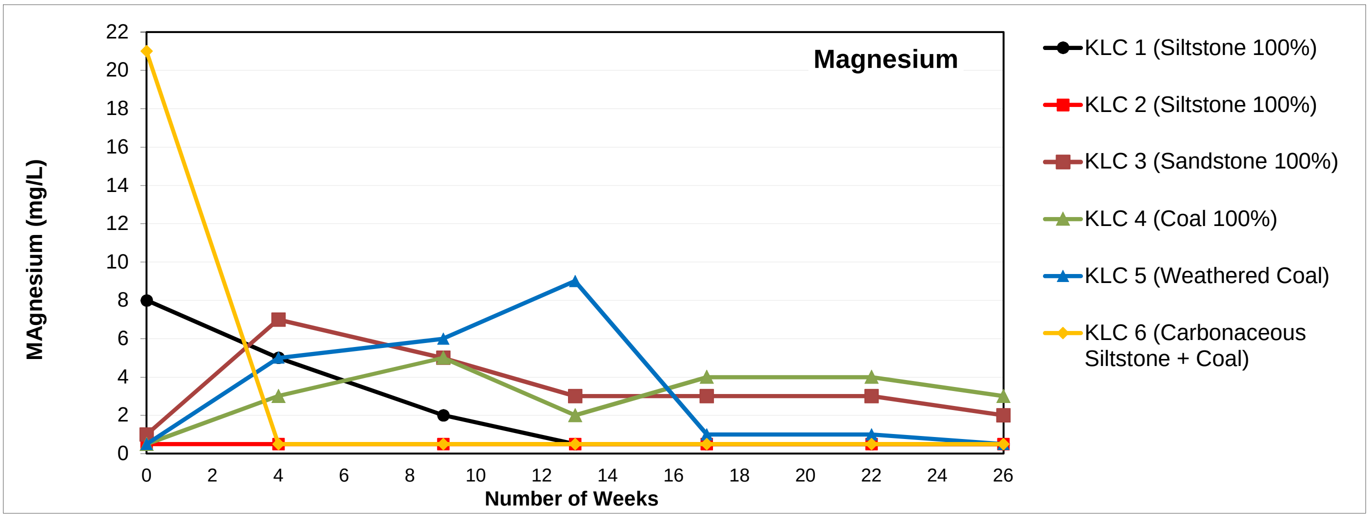

Net Alkalinity
Net Alkalinity ($CaCO_3$ mg/L)
Number of Weeks
KLC 1 (Siltstone 100%)
KLC 2 (Siltstone 100%)
KLC 3 (Sandstone 100%)
KLC 4 (Coal 100%)
KLC 5 (Weathered Coal)
KLC 6 (Carbonaceous Siltstone + Coal)

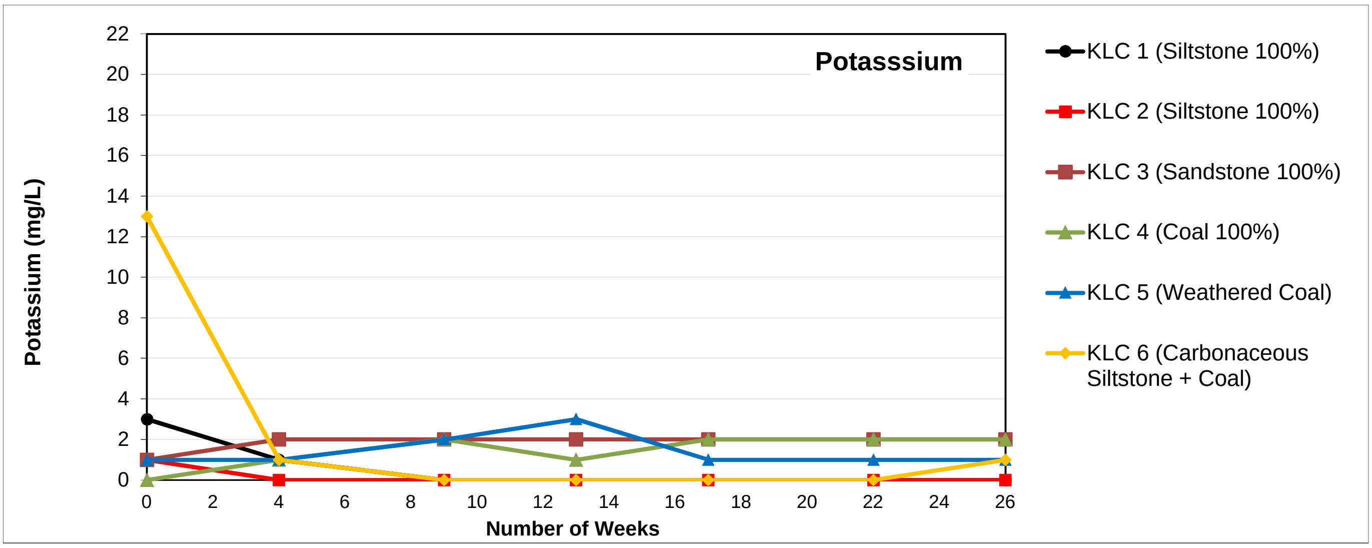

Residual Sulfur
Residual Sulfur (%)
Number of Weeks
100
90
80
70
60
50
40
30
20
10
0
0
2
4
6
8
10
12
14
16
18
20
22
24
26
KLC 1 (Siltstone 100%)
KLC 2 (Siltstone 100%)
KLC 3 (Sandstone 100%)
KLC 4 (Coal 100%)
KLC 5 (Weathered Coal)
KLC 6 (Carbonaceous Siltstone + Coal)

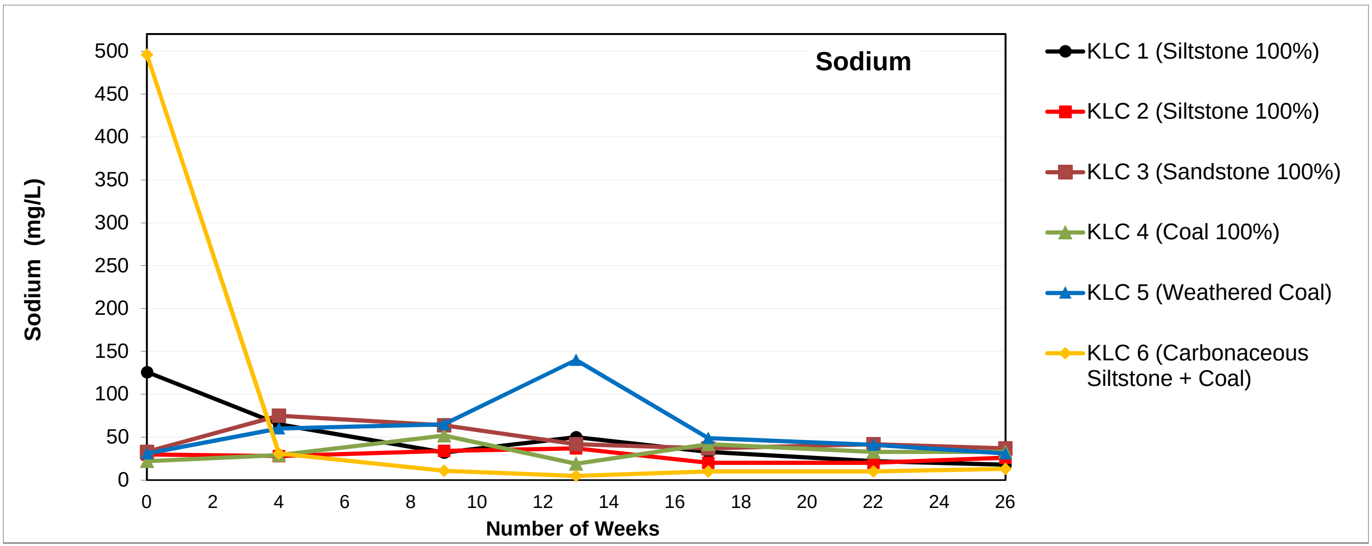

SO_4 Release Rate
SO_4 Release Rate (mg/kg/flush)
Number of Weeks
200
160
120
80
40
0
0
2
4
6
8
10
12
14
16
18
20
22
24
26
KLC 1 (Siltstone 100%)
KLC 2 (Siltstone 100%)
KLC 3 (Sandstone 100%)
KLC 4 (Coal 100%)
KLC 5 (Weathered Coal)
KLC 6 (Carbonaceous Siltstone + Coal)

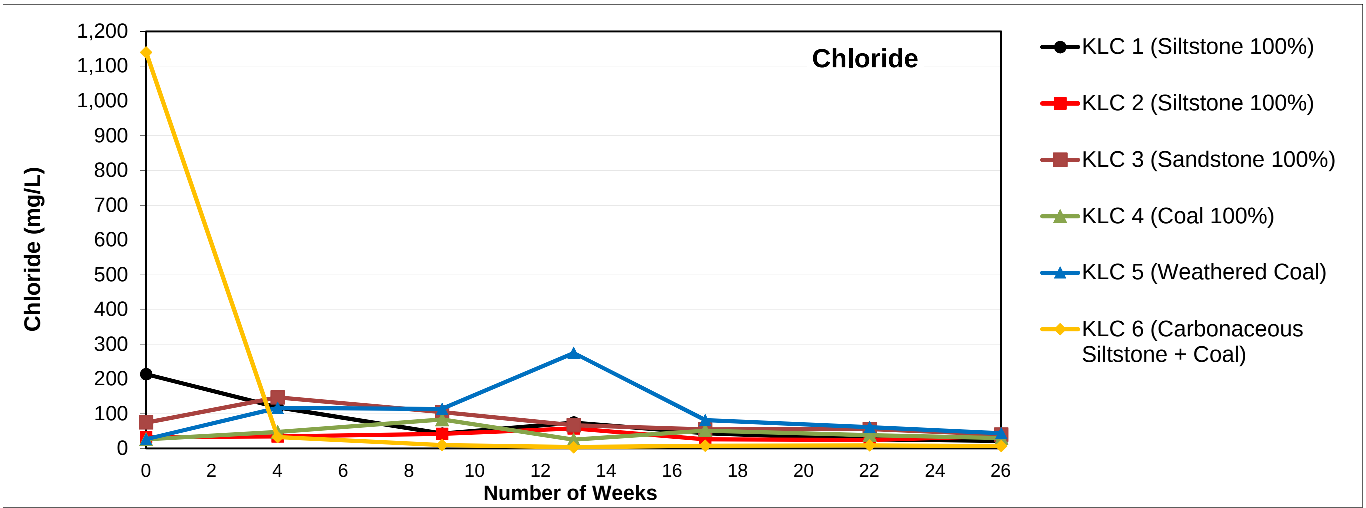

Residual ANC
Residual ANC (%)
Number of Weeks
100
90
80
70
60
50
40
30
20
10
0
0
2
4
6
8
10
12
14
16
18
20
22
24
26
KLC 1 (Siltstone 100%)
KLC 2 (Siltstone 100%)
KLC 3 (Sandstone 100%)
KLC 4 (Coal 100%)
KLC 5 (Weathered Coal)
KLC 6 (Carbonaceous Siltstone + Coal)

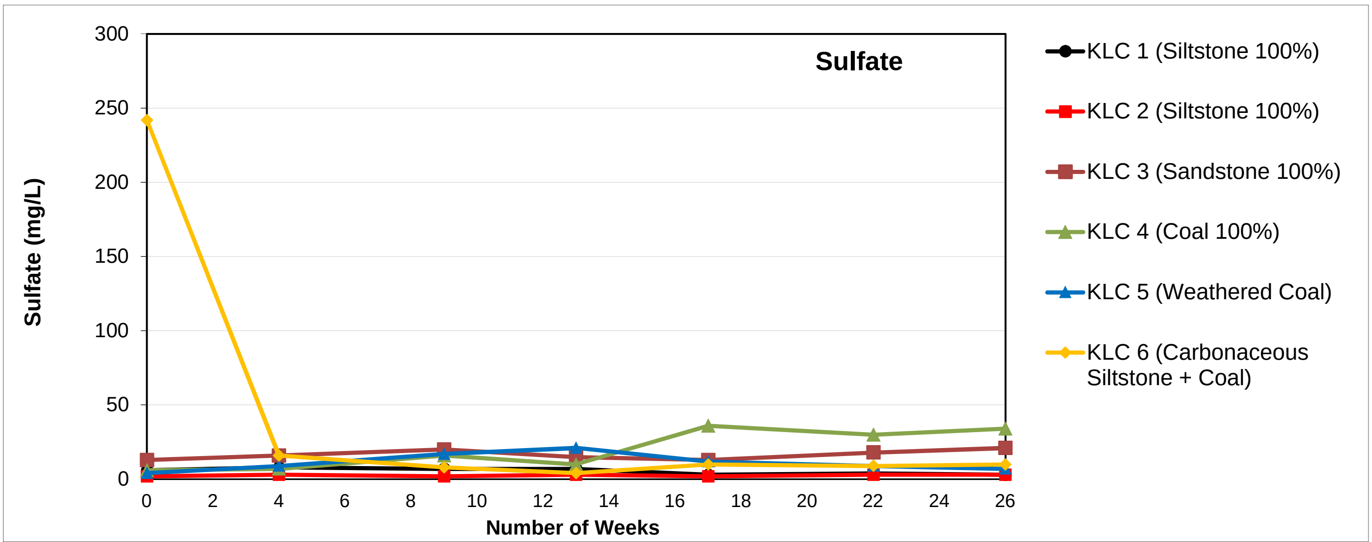

Calcium
Calcium (mg/L)
Number of Weeks
0
5
10
15
20
25
30
35
40
45
50
0
2
4
6
8
10
12
14
16
18
20
22
24
26
KLC 1 (Siltstone 100%)
KLC 2 (Siltstone 100%)
KLC 3 (Sandstone 100%)
KLC 4 (Coal 100%)
KLC 5 (Weathered Coal)
KLC 6 (Carbonaceous Siltstone + Coal)

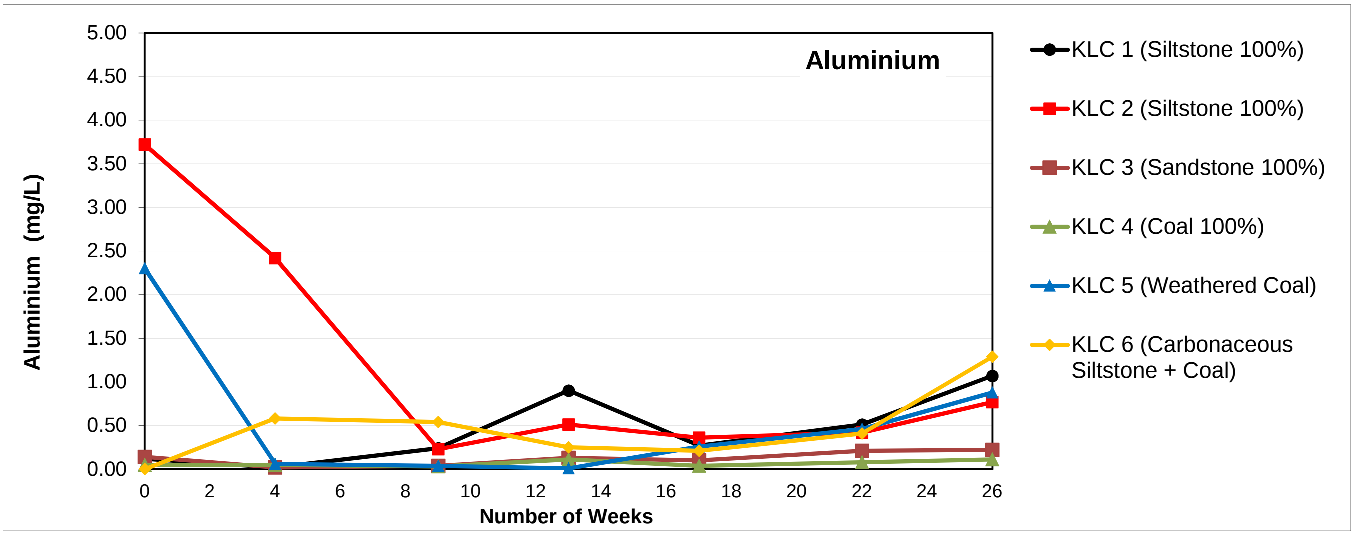

Magnesium
MAgnesium (mg/L)
Number of Weeks
0
2
4
6
8
10
12
14
16
18
20
22
0
2
4
6
8
10
12
14
16
18
20
22
24
26
KLC 1 (Siltstone 100%)
KLC 2 (Siltstone 100%)
KLC 3 (Sandstone 100%)
KLC 4 (Coal 100%)
KLC 5 (Weathered Coal)
KLC 6 (Carbonaceous Siltstone + Coal)

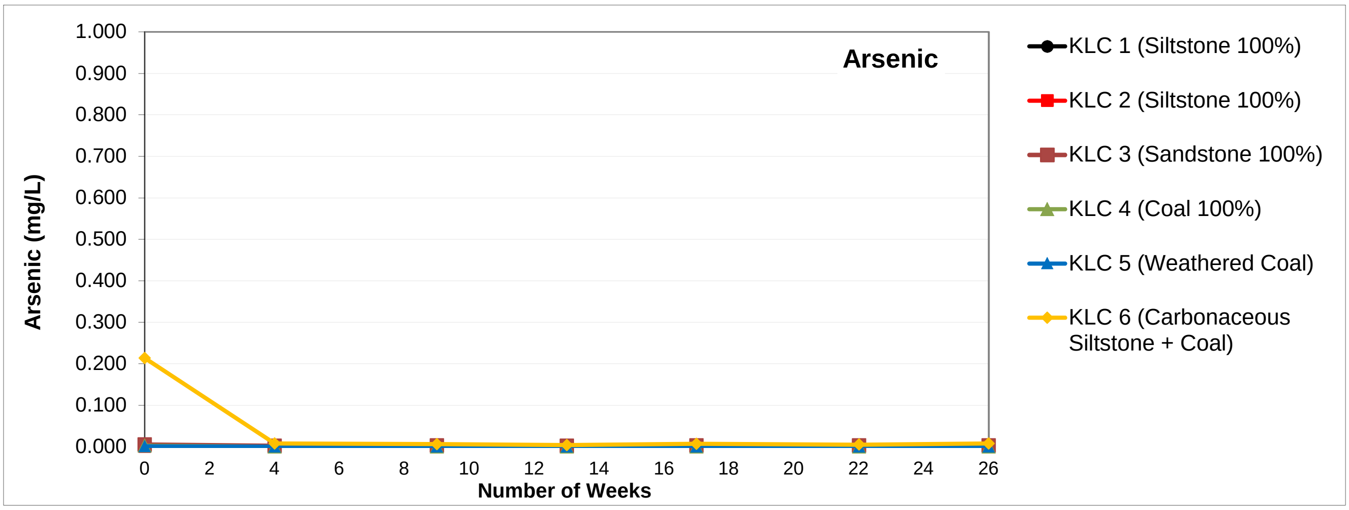

Potasssium
Potassium (mg/L)
Number of Weeks
0
2
4
6
8
10
12
14
16
18
20
22
0
2
4
6
8
10
12
14
16
18
20
22
24
26
KLC 1 (Siltstone 100%)
KLC 2 (Siltstone 100%)
KLC 3 (Sandstone 100%)
KLC 4 (Coal 100%)
KLC 5 (Weathered Coal)
KLC 6 (Carbonaceous Siltstone + Coal)

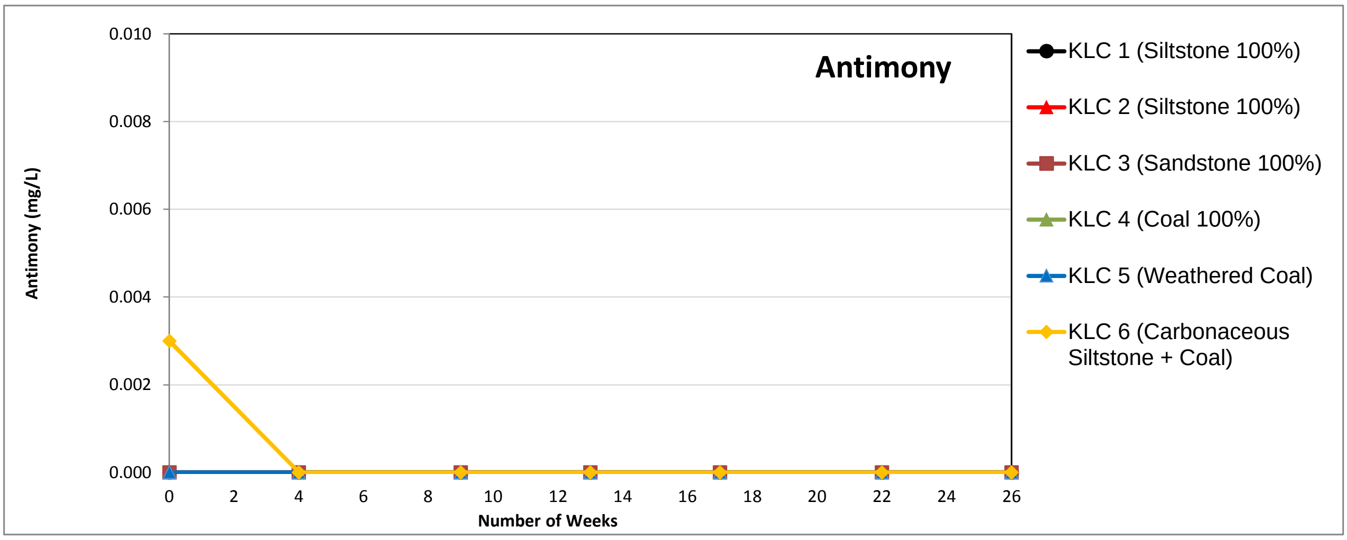

Sodium
Sodium (mg/L)
Number of Weeks
KLC 1 (Siltstone 100%)
KLC 2 (Siltstone 100%)
KLC 3 (Sandstone 100%)
KLC 4 (Coal 100%)
KLC 5 (Weathered Coal)
KLC 6 (Carbonaceous Siltstone + Coal)

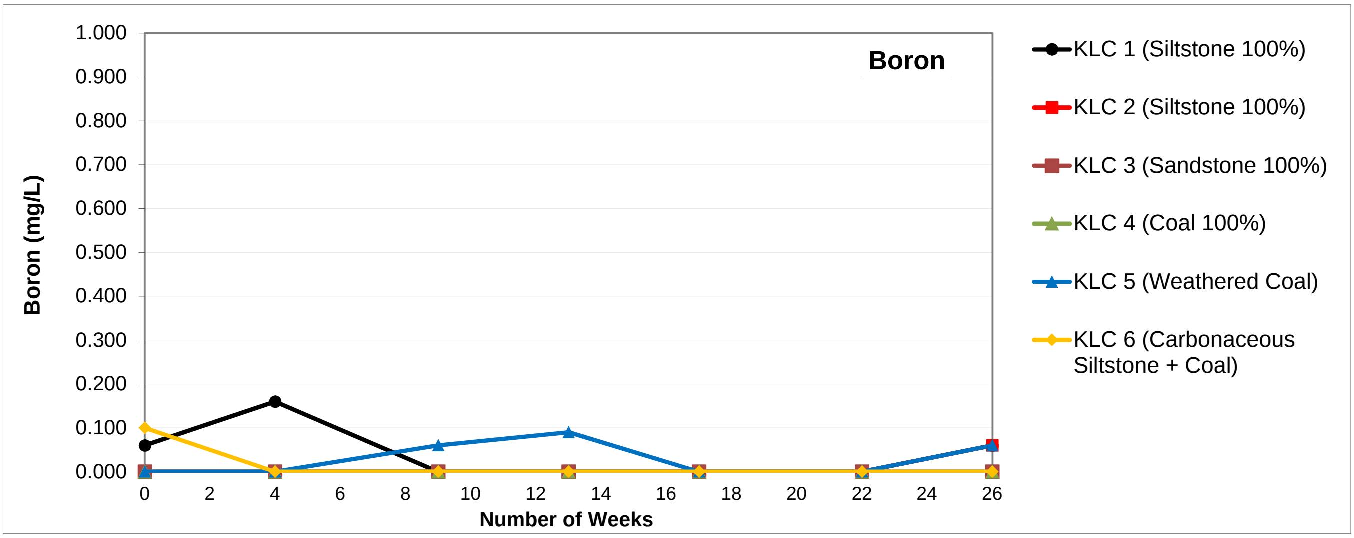

Chloride
Chloride (mg/L)
Number of Weeks
KLC 1 (Siltstone 100%)
KLC 2 (Siltstone 100%)
KLC 3 (Sandstone 100%)
KLC 4 (Coal 100%)
KLC 5 (Weathered Coal)
KLC 6 (Carbonaceous Siltstone + Coal)

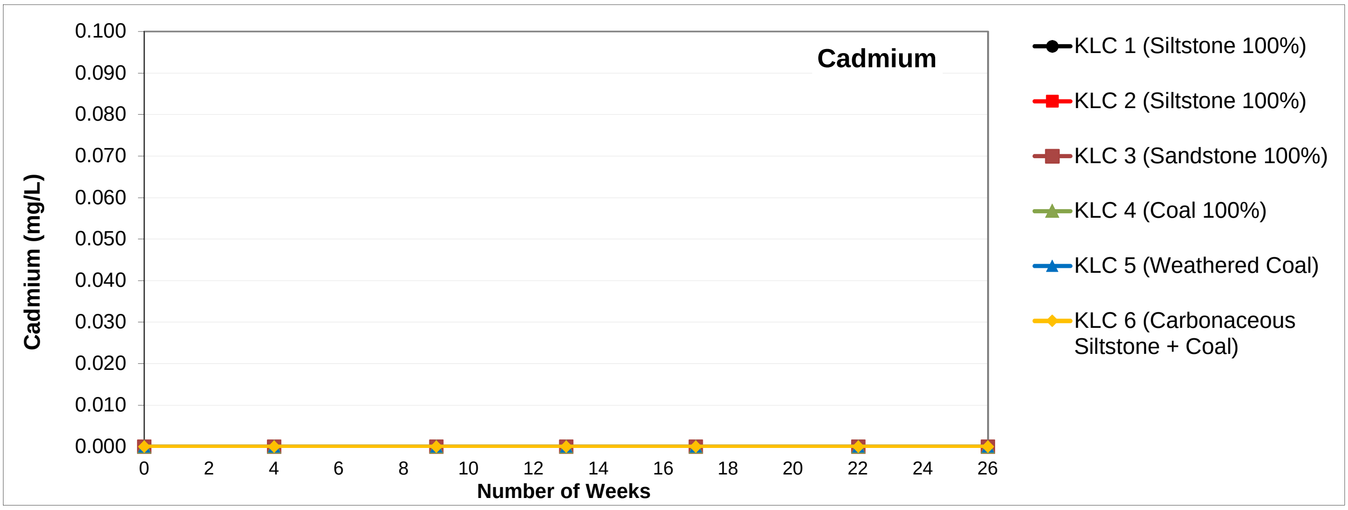

Sulfate
Sulfate (mg/L)
Number of Weeks
KLC 1 (Siltstone 100%)
KLC 2 (Siltstone 100%)
KLC 3 (Sandstone 100%)
KLC 4 (Coal 100%)
KLC 5 (Weathered Coal)
KLC 6 (Carbonaceous Siltstone + Coal)

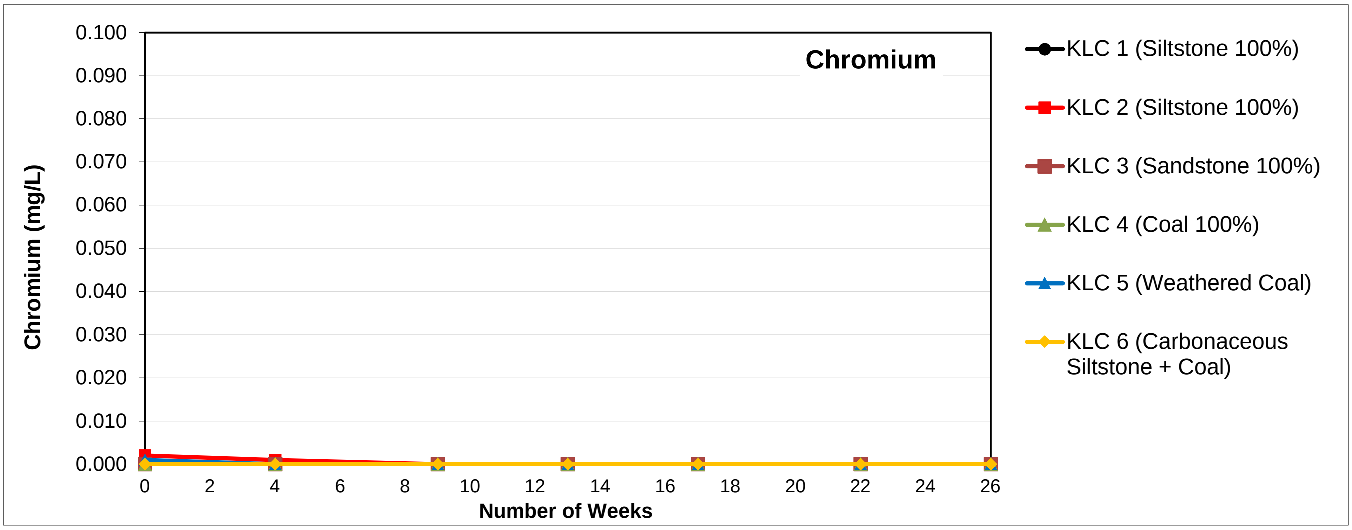

Aluminium
Aluminium (mg/L)
Number of Weeks
KLC 1 (Siltstone 100%)
KLC 2 (Siltstone 100%)
KLC 3 (Sandstone 100%)
KLC 4 (Coal 100%)
KLC 5 (Weathered Coal)
KLC 6 (Carbonaceous Siltstone + Coal)

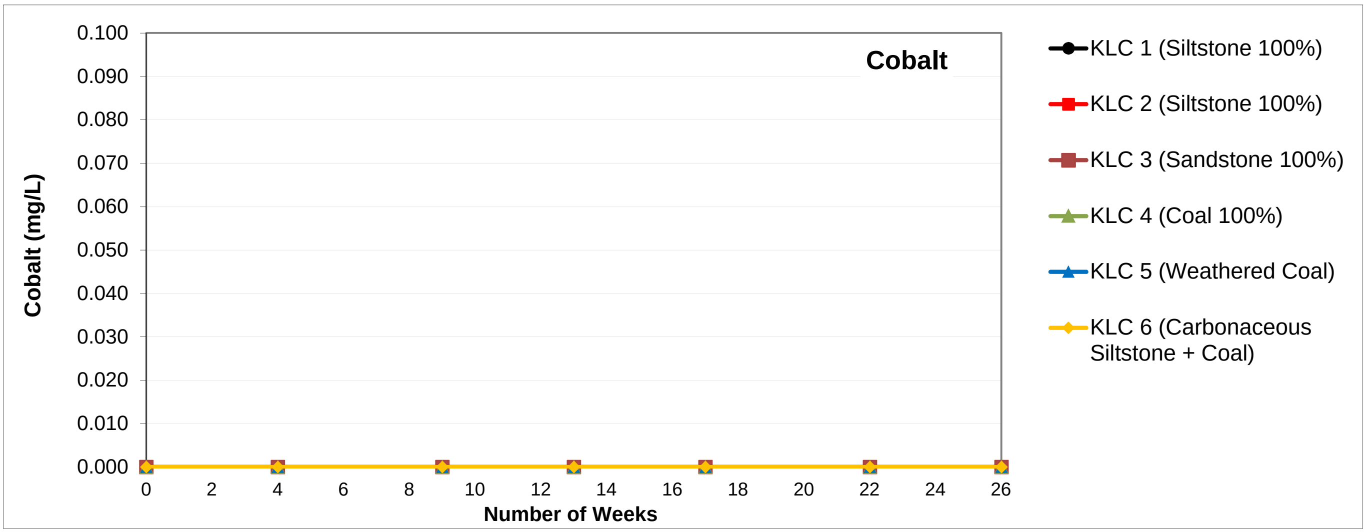

Arsenic
Arsenic (mg/L)
Number of Weeks
KLC 1 (Siltstone 100%)
KLC 2 (Siltstone 100%)
KLC 3 (Sandstone 100%)
KLC 4 (Coal 100%)
KLC 5 (Weathered Coal)
KLC 6 (Carbonaceous Siltstone + Coal)

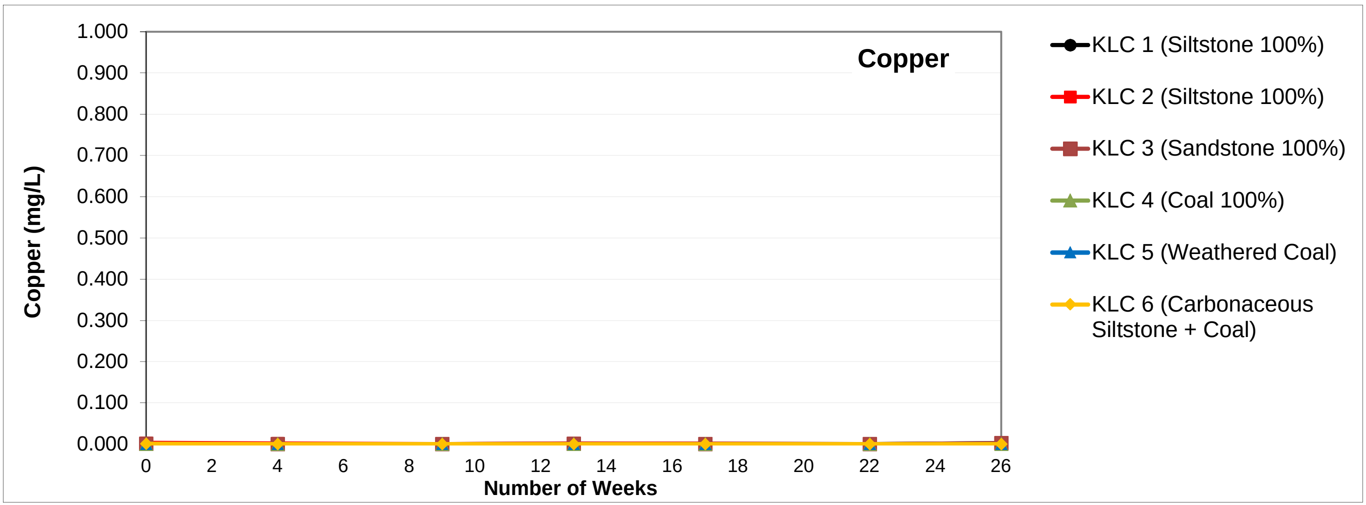

Antimony
Antimony (mg/L)
Number of Weeks
KLC 1 (Siltstone 100%)
KLC 2 (Siltstone 100%)
KLC 3 (Sandstone 100%)
KLC 4 (Coal 100%)
KLC 5 (Weathered Coal)
KLC 6 (Carbonaceous Siltstone + Coal)

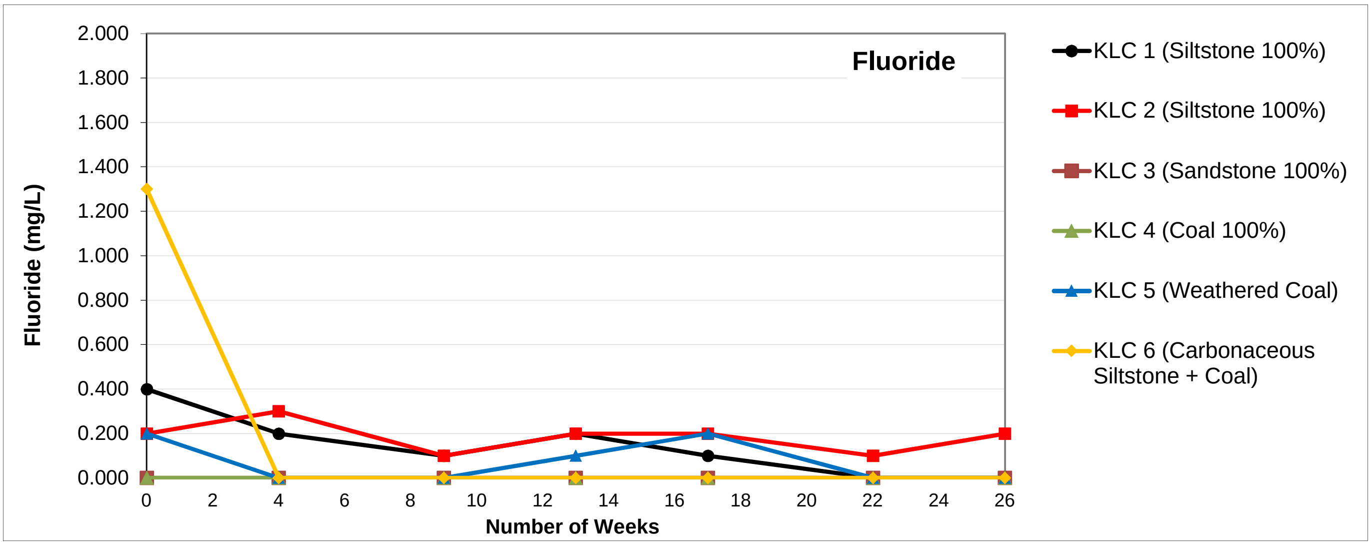

Boron
Boron (mg/L)
1.000
0.900
0.800
0.700
0.600
0.500
0.400
0.300
0.200
0.100
0.000
0
2
4
6
8
10
12
14
16
18
20
22
24
26
Number of Weeks
KLC 1 (Siltstone 100%)
KLC 2 (Siltstone 100%)
KLC 3 (Sandstone 100%)
KLC 4 (Coal 100%)
KLC 5 (Weathered Coal)
KLC 6 (Carbonaceous Siltstone + Coal)

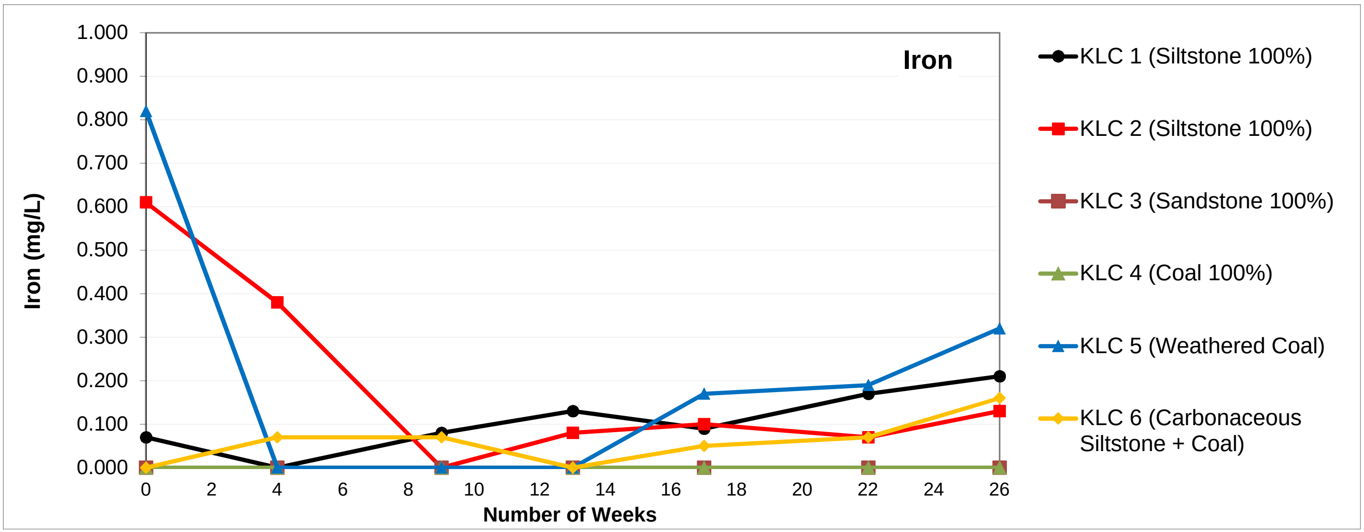

Cadmium
Cadmium (mg/L)
0.100
0.090
0.080
0.070
0.060
0.050
0.040
0.030
0.020
0.010
0.000
0
2
4
6
8
10
12
14
16
18
20
22
24
26
Number of Weeks
KLC 1 (Siltstone 100%)
KLC 2 (Siltstone 100%)
KLC 3 (Sandstone 100%)
KLC 4 (Coal 100%)
KLC 5 (Weathered Coal)
KLC 6 (Carbonaceous Siltstone + Coal)

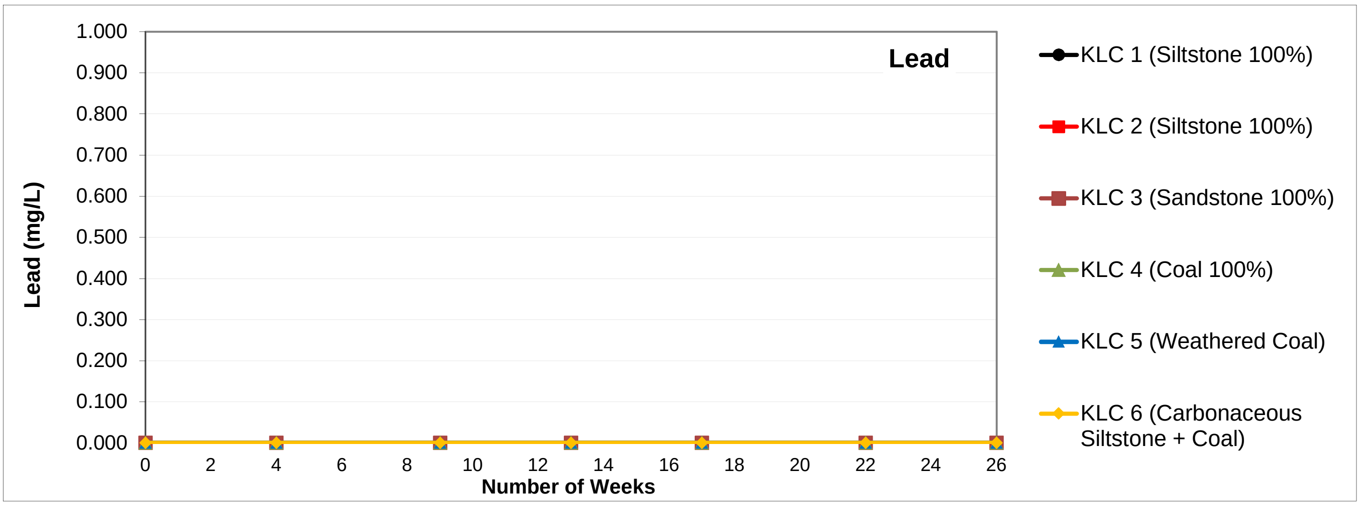

Chromium
Chromium (mg/L)
0.100
0.090
0.080
0.070
0.060
0.050
0.040
0.030
0.020
0.010
0.000
0
2
4
6
8
10
12
14
16
18
20
22
24
26
Number of Weeks
KLC 1 (Siltstone 100%)
KLC 2 (Siltstone 100%)
KLC 3 (Sandstone 100%)
KLC 4 (Coal 100%)
KLC 5 (Weathered Coal)
KLC 6 (Carbonaceous Siltstone + Coal)

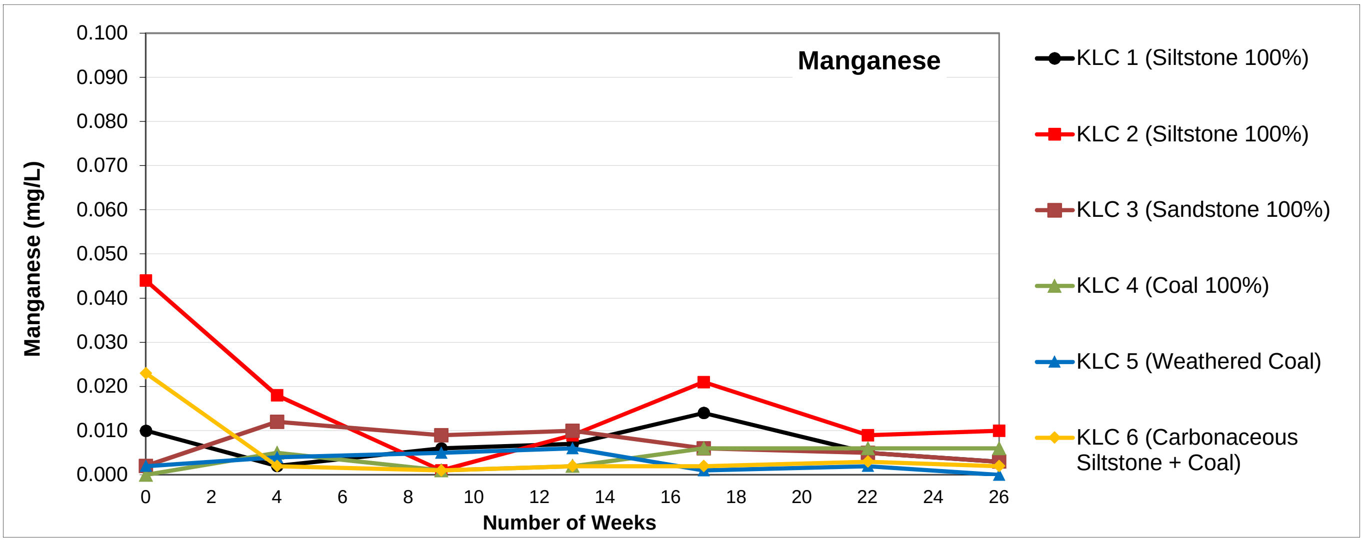

Cobalt
Cobalt (mg/L)
0.100
0.090
0.080
0.070
0.060
0.050
0.040
0.030
0.020
0.010
0.000
0
2
4
6
8
10
12
14
16
18
20
22
24
26
Number of Weeks
KLC 1 (Siltstone 100%)
KLC 2 (Siltstone 100%)
KLC 3 (Sandstone 100%)
KLC 4 (Coal 100%)
KLC 5 (Weathered Coal)
KLC 6 (Carbonaceous Siltstone + Coal)

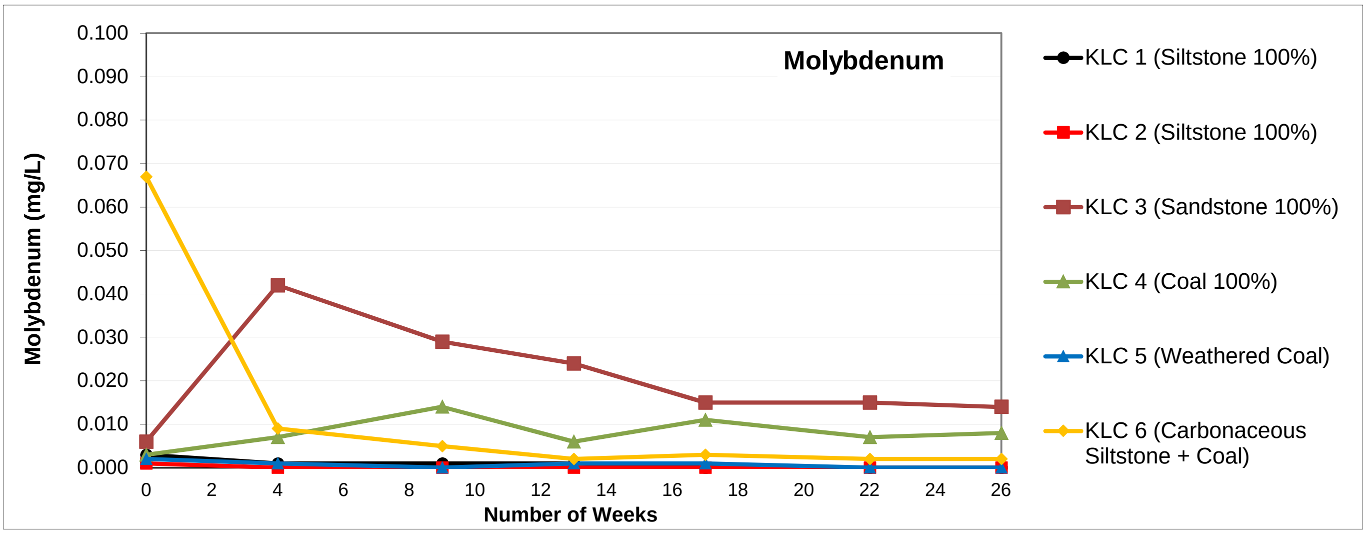

Copper
Copper (mg/L)
1.000
0.900
0.800
0.700
0.600
0.500
0.400
0.300
0.200
0.100
0.000
0
2
4
6
8
10
12
14
16
18
20
22
24
26
Number of Weeks
KLC 1 (Siltstone 100%)
KLC 2 (Siltstone 100%)
KLC 3 (Sandstone 100%)
KLC 4 (Coal 100%)
KLC 5 (Weathered Coal)
KLC 6 (Carbonaceous Siltstone + Coal)

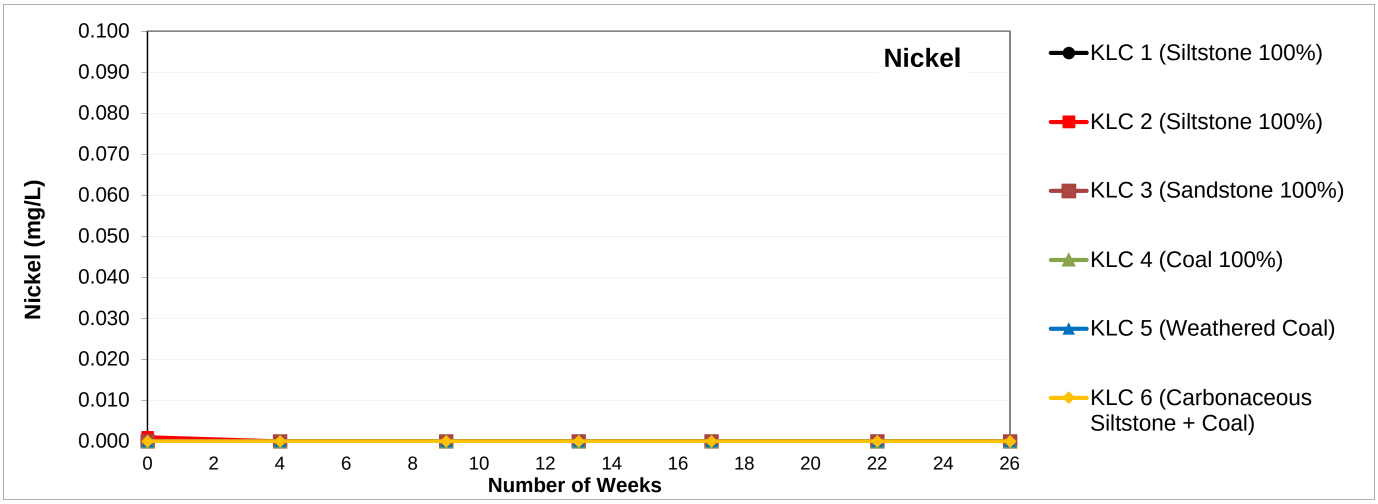

Fluoride
Fluoride (mg/L)
2.000
1.800
1.600
1.400
1.200
1.000
0.800
0.600
0.400
0.200
0.000
0
2
4
6
8
10
12
14
16
18
20
22
24
26
Number of Weeks
KLC 1 (Siltstone 100%)
KLC 2 (Siltstone 100%)
KLC 3 (Sandstone 100%)
KLC 4 (Coal 100%)
KLC 5 (Weathered Coal)
KLC 6 (Carbonaceous Siltstone + Coal)

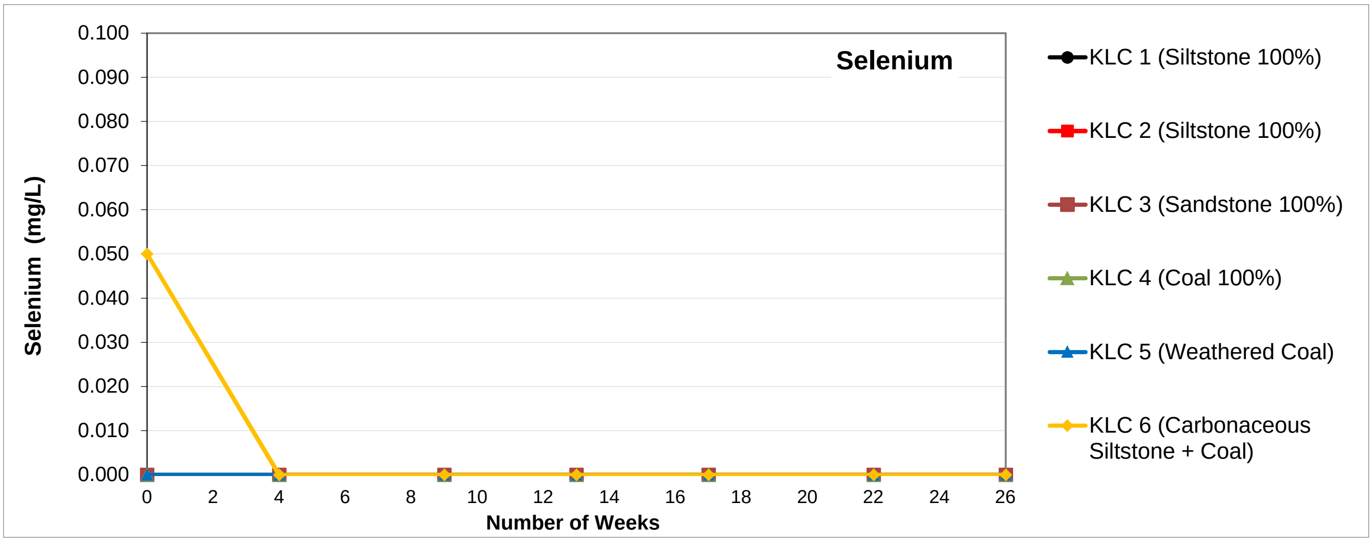

Iron
Iron (mg/L)
1.000
0.900
0.800
0.700
0.600
0.500
0.400
0.300
0.200
0.100
0.000
0
2
4
6
8
10
12
14
16
18
20
22
24
26
Number of Weeks
KLC 1 (Siltstone 100%)
KLC 2 (Siltstone 100%)
KLC 3 (Sandstone 100%)
KLC 4 (Coal 100%)
KLC 5 (Weathered Coal)
KLC 6 (Carbonaceous Siltstone + Coal)

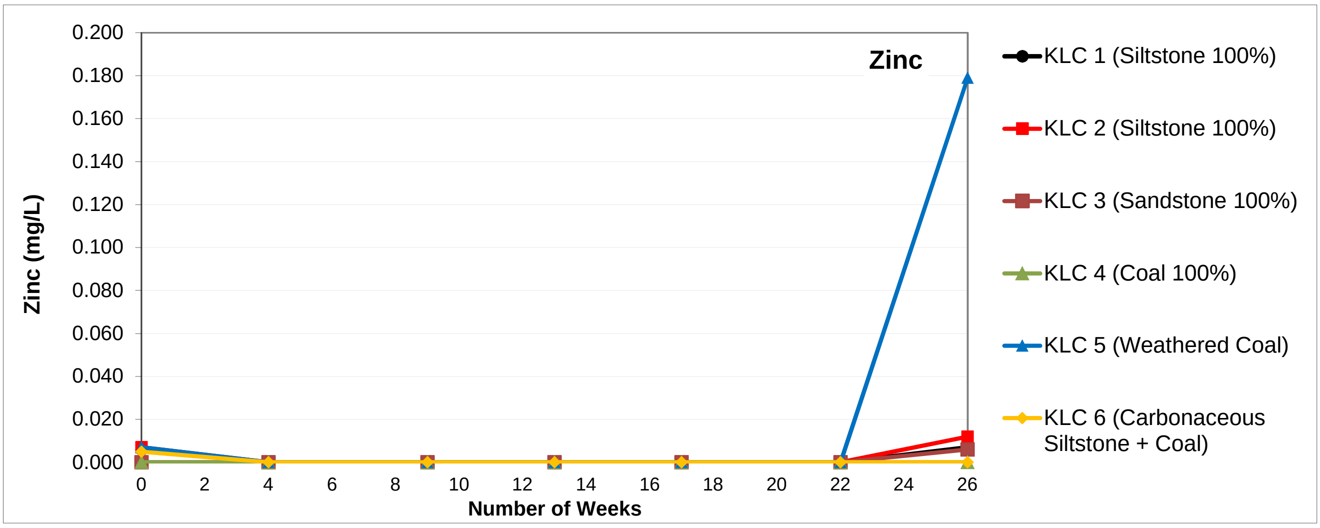

Lead
Lead (mg/L)
1.000
0.900
0.800
0.700
0.600
0.500
0.400
0.300
0.200
0.100
0.000
0
2
4
6
8
10
12
14
16
18
20
22
24
26
Number of Weeks
KLC 1 (Siltstone 100%)
KLC 2 (Siltstone 100%)
KLC 3 (Sandstone 100%)
KLC 4 (Coal 100%)
KLC 5 (Weathered Coal)
KLC 6 (Carbonaceous Siltstone + Coal)


Manganese
Manganese (mg/L)
0.100
0.090
0.080
0.070
0.060
0.050
0.040
0.030
0.020
0.010
0.000
0
2
4
6
8
10
12
14
16
18
20
22
24
26
Number of Weeks
KLC 1 (Siltstone 100%)
KLC 2 (Siltstone 100%)
KLC 3 (Sandstone 100%)
KLC 4 (Coal 100%)
KLC 5 (Weathered Coal)
KLC 6 (Carbonaceous Siltstone + Coal)


Molybdenum
Molybdenum (mg/L)
0.100
0.090
0.080
0.070
0.060
0.050
0.040
0.030
0.020
0.010
0.000
0
2
4
6
8
10
12
14
16
18
20
22
24
26
Number of Weeks
KLC 1 (Siltstone 100%)
KLC 2 (Siltstone 100%)
KLC 3 (Sandstone 100%)
KLC 4 (Coal 100%)
KLC 5 (Weathered Coal)
KLC 6 (Carbonaceous Siltstone + Coal)


Nickel
Nickel (mg/L)
0.100
0.090
0.080
0.070
0.060
0.050
0.040
0.030
0.020
0.010
0.000
0
2
4
6
8
10
12
14
16
18
20
22
24
26
Number of Weeks
KLC 1 (Siltstone 100%)
KLC 2 (Siltstone 100%)
KLC 3 (Sandstone 100%)
KLC 4 (Coal 100%)
KLC 5 (Weathered Coal)
KLC 6 (Carbonaceous Siltstone + Coal)


Selenium
Selenium (mg/L)
0.100
0.090
0.080
0.070
0.060
0.050
0.040
0.030
0.020
0.010
0.000
0
2
4
6
8
10
12
14
16
18
20
22
24
26
Number of Weeks
KLC 1 (Siltstone 100%)
KLC 2 (Siltstone 100%)
KLC 3 (Sandstone 100%)
KLC 4 (Coal 100%)
KLC 5 (Weathered Coal)
KLC 6 (Carbonaceous Siltstone + Coal)


Zinc
Zinc (mg/L)
0.200
0.180
0.160
0.140
0.120
0.100
0.080
0.060
0.040
0.020
0.000
0
2
4
6
8
10
12
14
16
18
20
22
24
26
Number of Weeks
KLC 1 (Siltstone 100%)
KLC 2 (Siltstone 100%)
KLC 3 (Sandstone 100%)
KLC 4 (Coal 100%)
KLC 5 (Weathered Coal)
KLC 6 (Carbonaceous Siltstone + Coal)

ATTACHMENT E

ALS Laboratory Results

CERTIFICATE OF ANALYSIS

Work Order	: **EB1711745**	Page	: 1 of 17
Client	: **RGS ENVIRONMENTAL PTY LTD**	Laboratory	: Environmental Division Brisbane
Contact	: MR ALAN ROBERTSON	Contact	: Customer Services EB
Address	: PO Box 3091 SUNNYBANK SOUTH QLD, AUSTRALIA 4109	Address	: 2 Byth Street Stafford QLD Australia 4053
Telephone	: +61 07 3344 1222	Telephone	: +61-7-3243 7222
Project	: Dingo West Coal Project	Date Samples Received	: 07-Jun-2017 15:30
Order number	: ----	Date Analysis Commenced	: 10-Jun-2017
C-O-C number	: ----	Issue Date	: 23-Jun-2017 07:35
Sampler	: ----		
Site	: ----		
Quote number	: BNBQ/218/16		
No. of samples received	: 71		
No. of samples analysed	: 71		

Accreditation No. 825
Accredited for compliance with
ISO/IEC 17025 - Testing

This report supersedes any previous report(s) with this reference. Results apply to the sample(s) as submitted. This document shall not be reproduced, except in full.

This Certificate of Analysis contains the following information:

- General Comments
- Analytical Results

Additional information pertinent to this report will be found in the following separate attachments: Quality Control Report, QA/QC Compliance Assessment to assist with Quality Review and Sample Receipt Notification.

Signatories

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

Signatories	*Position*	*Accreditation Category*
Ben Felgendrejeris		Brisbane Acid Sulphate Soils, Stafford, QLD
Kim McCabe	Senior Inorganic Chemist	Brisbane Inorganics, Stafford, QLD
Satishkumar Trivedi	Acid Sulfate Soils Supervisor	Brisbane Acid Sulphate Soils, Stafford, QLD

General Comments

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

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

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

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

When no sampling time is provided, the sampling time will default 00:00 on the date of sampling. If no sampling date is provided, the sampling date will be assumed by the laboratory and displayed in brackets without a time component.

Where a result is required to meet compliance limits the associated uncertainty must be considered. Refer to the ALS Contact for details.

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

- ASS: EA013 (ANC) Fizz Rating: 0- None; 1- Slight; 2- Moderate; 3- Strong; 4- Very Strong; 5- Lime.

Analytical Results

Sub-Matrix: **ROCK**
(Matrix: **SOIL**)

Compound	CAS Number	LOR	Unit	7002G01	7002G02	7002G03	7002G04	7002G05
Client sampling date / time				26-May-2017 00:00	26-May-2017 00:00	26-May-2017 00:00	26-May-2017 00:00	26-May-2017 00:00
				EB1711745-001	EB1711745-002	EB1711745-003	EB1711745-004	EB1711745-005
				Result	Result	Result	Result	Result
EA002 : pH (Soils)								
pH Value	----	0.1	pH Unit	6.5	5.0	7.1	7.6	7.6
EA009: Nett Acid Production Potential								
Net Acid Production Potential	----	0.5	kg H2SO4/t	-4.9	-1.6	-3.5	-7.7	-9.8
EA010: Conductivity								
Electrical Conductivity @ 25°C	----	1	µS/cm	646	1110	1220	684	450
EA013: Acid Neutralising Capacity								
ANC as H2SO4	----	0.5	kg H2SO4 equiv./t	5.5	1.6	3.5	7.7	9.8
ANC as CaCO3	----	0.1	% CaCO3	0.6	0.2	0.4	0.8	1.0
Fizz Rating	----	0	Fizz Unit	0	0	0	0	0
ED042T: Total Sulfur by LECO								
Sulfur - Total as S (LECO)	----	0.01	%	0.02	<0.01	<0.01	<0.01	<0.01

Analytical Results

Sub-Matrix: ROCK
(Matrix: SOIL)

			Client sample ID	7002G06	7002G07	7002G08	7002G09	7002G10
			Client sampling date / time	26-May-2017 00:00	26-May-2017 00:00	26-May-2017 00:00	26-May-2017 00:00	26-May-2017 00:00
Compound	CAS Number	LOR	Unit	EB1711745-006	EB1711745-007	EB1711745-008	EB1711745-009	EB1711745-010
				Result	Result	Result	Result	Result
EA002 : pH (Soils)								
pH Value	----	0.1	pH Unit	9.5	9.6	9.5	9.4	9.6
EA009: Nett Acid Production Potential								
Net Acid Production Potential	----	0.5	kg H2SO4/t	-51.6	-57.6	-78.3	-63.0	-122
EA010: Conductivity								
Electrical Conductivity @ 25°C	----	1	µS/cm	409	305	270	296	304
EA013: Acid Neutralising Capacity								
ANC as H2SO4	----	0.5	kg H2SO4 equiv./t	52.2	58.5	78.9	63.6	123
ANC as CaCO3	----	0.1	% CaCO3	5.3	6.0	8.0	6.5	12.6
Fizz Rating	----	0	Fizz Unit	2	2	2	2	3
ED042T: Total Sulfur by LECO								
Sulfur - Total as S (LECO)	----	0.01	%	0.02	0.03	0.02	0.02	0.03

Analytical Results

Sub-Matrix: ROCK (Matrix: SOIL)			Client sample ID	7002G11	7002G12	7002G13	7002G14	7002G15
			Client sampling date / time	26-May-2017 00:00	26-May-2017 00:00	26-May-2017 00:00	26-May-2017 00:00	26-May-2017 00:00
Compound	CAS Number	LOR	Unit	EB1711745-011	EB1711745-012	EB1711745-013	EB1711745-014	EB1711745-015
				Result	Result	Result	Result	Result
EA002 : pH (Soils)								
pH Value	----	0.1	pH Unit	9.5	9.0	8.8	9.0	9.3
EA009: Nett Acid Production Potential								
Net Acid Production Potential	----	0.5	kg H2SO4/t	-60.6	-7.9	-17.4	-24.9	-89.3
EA010: Conductivity								
Electrical Conductivity @ 25°C	----	1	µS/cm	335	345	890	595	468
EA013: Acid Neutralising Capacity								
ANC as H2SO4	----	0.5	kg H2SO4 equiv./t	61.8	21.7	19.6	26.7	90.2
ANC as CaCO3	----	0.1	% CaCO3	6.3	2.2	2.0	2.7	9.2
Fizz Rating	----	0	Fizz Unit	2	1	1	1	2
ED042T: Total Sulfur by LECO								
Sulfur - Total as S (LECO)	----	0.01	%	0.04	0.45	0.07	0.06	0.03

Analytical Results

Sub-Matrix: ROCK (Matrix: SOIL)			Client sample ID	7002G16	7002G17	7002G18	7002G19	7002G20
			Client sampling date / time	26-May-2017 00:00	26-May-2017 00:00	26-May-2017 00:00	26-May-2017 00:00	26-May-2017 00:00
Compound	CAS Number	LOR	Unit	EB1711745-016	EB1711745-017	EB1711745-018	EB1711745-019	EB1711745-020
				Result	Result	Result	Result	Result
EA002 : pH (Soils)								
pH Value	----	0.1	pH Unit	9.3	9.4	9.2	9.4	9.4
EA009: Nett Acid Production Potential								
Net Acid Production Potential	----	0.5	kg H2SO4/t	-124	-99.1	-10.1	-45.9	-69.9
EA010: Conductivity								
Electrical Conductivity @ 25°C	----	1	µS/cm	442	398	429	386	432
EA013: Acid Neutralising Capacity								
ANC as H2SO4	----	0.5	kg H2SO4 equiv./t	125	100	25.1	47.4	71.1
ANC as CaCO3	----	0.1	% CaCO3	12.7	10.2	2.6	4.8	7.2
Fizz Rating	----	0	Fizz Unit	3	2	1	2	2
ED042T: Total Sulfur by LECO								
Sulfur - Total as S (LECO)	----	0.01	%	0.03	0.03	0.49	0.05	0.04

Analytical Results

Sub-Matrix: ROCK (Matrix: SOIL)			Client sample ID	7002G21	7002G22	7003G01	7003G02	7003G03
			Client sampling date / time	26-May-2017 00:00	26-May-2017 00:00	26-May-2017 00:00	26-May-2017 00:00	26-May-2017 00:00
Compound	CAS Number	LOR	Unit	EB1711745-021	EB1711745-022	EB1711745-023	EB1711745-024	EB1711745-025
				Result	Result	Result	Result	Result
EA002 : pH (Soils)								
pH Value	----	0.1	pH Unit	9.6	9.4	5.2	5.5	6.8
EA009: Nett Acid Production Potential								
Net Acid Production Potential	----	0.5	kg H2SO4/t	-88.4	-69.0	-1.0	-4.4	-6.6
EA010: Conductivity								
Electrical Conductivity @ 25°C	----	1	µS/cm	333	579	1040	1080	893
EA013: Acid Neutralising Capacity								
ANC as H2SO4	----	0.5	kg H2SO4 equiv./t	91.2	71.1	1.6	4.4	7.8
ANC as CaCO3	----	0.1	% CaCO3	9.3	7.2	0.2	0.4	0.8
Fizz Rating	----	0	Fizz Unit	2	2	0	0	0
ED042T: Total Sulfur by LECO								
Sulfur - Total as S (LECO)	----	0.01	%	0.09	0.07	0.02	<0.01	0.04

Analytical Results

Sub-Matrix: ROCK
(Matrix: SOIL)

Compound	CAS Number	LOR	Unit	7003G04	7003G05	7003G06	7003G07	7003G08
Client sampling date / time				26-May-2017 00:00	26-May-2017 00:00	26-May-2017 00:00	26-May-2017 00:00	26-May-2017 00:00
				EB1711745-026	EB1711745-027	EB1711745-028	EB1711745-029	EB1711745-030
				Result	Result	Result	Result	Result
EA002 : pH (Soils)								
pH Value	----	0.1	pH Unit	7.5	7.6	7.5	7.7	8.3
EA009: Nett Acid Production Potential								
Net Acid Production Potential	----	0.5	kg H2SO4/t	-9.1	-11.8	-8.4	-11.2	-10.2
EA010: Conductivity								
Electrical Conductivity @ 25°C	----	1	µS/cm	710	1170	1180	911	1140
EA013: Acid Neutralising Capacity								
ANC as H2SO4	----	0.5	kg H2SO4 equiv./t	9.7	12.4	9.0	11.8	12.7
ANC as CaCO3	----	0.1	% CaCO3	1.0	1.3	0.9	1.2	1.3
Fizz Rating	----	0	Fizz Unit	0	1	0	1	1
ED042T: Total Sulfur by LECO								
Sulfur - Total as S (LECO)	----	0.01	%	0.02	0.02	0.02	0.02	0.08

Analytical Results

Sub-Matrix: ROCK
(Matrix: SOIL)

Compound	CAS Number	LOR	Unit	7003G09	7003G10	7003G11	7003G12	7003G13
Client sampling date / time				26-May-2017 00:00	26-May-2017 00:00	26-May-2017 00:00	26-May-2017 00:00	26-May-2017 00:00
				EB1711745-031	EB1711745-032	EB1711745-033	EB1711745-034	EB1711745-035
				Result	Result	Result	Result	Result
EA002 : pH (Soils)								
pH Value	----	0.1	pH Unit	7.3	7.2	7.6	8.3	8.0
EA009: Nett Acid Production Potential								
Net Acid Production Potential	----	0.5	kg H2SO4/t	-1.1	-14.4	-19.6	-13.8	-1.4
EA010: Conductivity								
Electrical Conductivity @ 25°C	----	1	µS/cm	807	906	1020	1230	937
EA013: Acid Neutralising Capacity								
ANC as H2SO4	----	0.5	kg H2SO4 equiv./t	11.5	21.7	21.8	16.3	13.6
ANC as CaCO3	----	0.1	% CaCO3	1.2	2.2	2.2	1.7	1.4
Fizz Rating	----	0	Fizz Unit	1	1	1	1	1
ED042T: Total Sulfur by LECO								
Sulfur - Total as S (LECO)	----	0.01	%	0.34	0.24	0.07	0.08	0.40

Analytical Results

Sub-Matrix: ROCK (Matrix: SOIL)			Client sample ID	7003G14	7003G15	7003G16	7003G17	7003G18
			Client sampling date / time	26-May-2017 00:00	26-May-2017 00:00	26-May-2017 00:00	26-May-2017 00:00	26-May-2017 00:00
Compound	CAS Number	LOR	Unit	EB1711745-036	EB1711745-037	EB1711745-038	EB1711745-039	EB1711745-040
				Result	Result	Result	Result	Result
EA002 : pH (Soils)								
pH Value	----	0.1	pH Unit	8.2	8.2	8.6	9.0	8.8
EA009: Nett Acid Production Potential								
Net Acid Production Potential	----	0.5	kg H2SO4/t	-11.5	-7.4	-17.5	-16.1	-28.2
EA010: Conductivity								
Electrical Conductivity @ 25°C	----	1	µS/cm	1120	1070	807	890	964
EA013: Acid Neutralising Capacity								
ANC as H2SO4	----	0.5	kg H2SO4 equiv./t	15.5	12.3	33.7	18.9	32.2
ANC as CaCO3	----	0.1	% CaCO3	1.6	1.2	3.4	1.9	3.3
Fizz Rating	----	0	Fizz Unit	1	1	2	1	2
ED042T: Total Sulfur by LECO								
Sulfur - Total as S (LECO)	----	0.01	%	0.13	0.16	0.53	0.09	0.13

Analytical Results

Sub-Matrix: ROCK (Matrix: SOIL)			Client sample ID	7003G19	7003G20	7003G21	7003G22	7012G01
			Client sampling date / time	26-May-2017 00:00	26-May-2017 00:00	26-May-2017 00:00	26-May-2017 00:00	01-Jun-2017 00:00
Compound	CAS Number	LOR	Unit	EB1711745-041	EB1711745-042	EB1711745-043	EB1711745-044	EB1711745-045
				Result	Result	Result	Result	Result
EA002 : pH (Soils)								
pH Value	----	0.1	pH Unit	9.3	9.2	9.4	9.2	8.5
EA009: Nett Acid Production Potential								
Net Acid Production Potential	----	0.5	kg H_2SO_4/t	-91.2	-77.7	-48.4	-50.6	-11.5
EA010: Conductivity								
Electrical Conductivity @ 25°C	----	1	µS/cm	665	801	573	779	1070
EA013: Acid Neutralising Capacity								
ANC as H_2SO_4	----	0.5	kg H_2SO_4 equiv./t	91.8	78.9	53.6	52.8	12.1
ANC as $CaCO_3$	----	0.1	% $CaCO_3$	9.4	8.0	5.5	5.4	1.2
Fizz Rating	----	0	Fizz Unit	2	2	2	2	1
ED042T: Total Sulfur by LECO								
Sulfur - Total as S (LECO)	----	0.01	%	0.02	0.04	0.17	0.07	0.02

Analytical Results

Sub-Matrix: ROCK (Matrix: SOIL)			Client sample ID	7012G02	7012G03	7012G04	7012G05	7012G06
			Client sampling date / time	01-Jun-2017 00:00	01-Jun-2017 00:00	01-Jun-2017 00:00	01-Jun-2017 00:00	01-Jun-2017 00:00
Compound	CAS Number	LOR	Unit	EB1711745-046	EB1711745-047	EB1711745-048	EB1711745-049	EB1711745-050
				Result	Result	Result	Result	Result
EA002 : pH (Soils)								
pH Value	----	0.1	pH Unit	9.0	7.7	7.2	7.6	9.6
EA009: Nett Acid Production Potential								
Net Acid Production Potential	----	0.5	kg H2SO4/t	-24.4	-8.1	<0.5	-8.7	-118
EA010: Conductivity								
Electrical Conductivity @ 25°C	----	1	µS/cm	700	640	306	598	495
EA013: Acid Neutralising Capacity								
ANC as H2SO4	----	0.5	kg H2SO4 equiv./t	25.0	8.7	13.2	9.6	119
ANC as CaCO3	----	0.1	% CaCO3	2.6	0.9	1.4	1.0	12.2
Fizz Rating	----	0	Fizz Unit	1	1	1	0	3
ED042T: Total Sulfur by LECO								
Sulfur - Total as S (LECO)	----	0.01	%	0.02	0.02	0.44	0.03	0.03

Analytical Results

Sub-Matrix: ROCK (Matrix: SOIL)			Client sample ID	7012G07	7012G08	7012G09	7012G10	7012G11
			Client sampling date / time	01-Jun-2017 00:00	01-Jun-2017 00:00	01-Jun-2017 00:00	01-Jun-2017 00:00	01-Jun-2017 00:00
Compound	CAS Number	LOR	Unit	EB1711745-051	EB1711745-052	EB1711745-053	EB1711745-054	EB1711745-055
				Result	Result	Result	Result	Result
EA002 : pH (Soils)								
pH Value	----	0.1	pH Unit	9.3	9.0	9.0	9.2	9.3
EA009: Nett Acid Production Potential								
Net Acid Production Potential	----	0.5	kg H2SO4/t	-10.8	-11.7	-6.7	-10.0	4.2
EA010: Conductivity								
Electrical Conductivity @ 25°C	----	1	µS/cm	460	620	454	529	640
EA013: Acid Neutralising Capacity								
ANC as H2SO4	----	0.5	kg H2SO4 equiv./t	17.8	16.0	12.2	12.4	12.0
ANC as CaCO3	----	0.1	% CaCO3	1.8	1.6	1.2	1.3	1.2
Fizz Rating	----	0	Fizz Unit	1	1	1	1	1
ED042T: Total Sulfur by LECO								
Sulfur - Total as S (LECO)	----	0.01	%	0.23	0.14	0.18	0.08	0.53

Analytical Results

Sub-Matrix: ROCK
(Matrix: SOIL)

Compound	CAS Number	LOR	Unit	7012G12	7012G13	7012G14	7012G15	7012G16
Client sampling date / time				01-Jun-2017 00:00	01-Jun-2017 00:00	01-Jun-2017 00:00	01-Jun-2017 00:00	01-Jun-2017 00:00
				EB1711745-056	EB1711745-057	EB1711745-058	EB1711745-059	EB1711745-060
				Result	Result	Result	Result	Result
EA002 : pH (Soils)								
pH Value	----	0.1	pH Unit	9.2	9.3	9.2	9.3	9.4
EA009: Nett Acid Production Potential								
Net Acid Production Potential	----	0.5	kg H2SO4/t	-41.7	-141	5.8	-104	-25.7
EA010: Conductivity								
Electrical Conductivity @ 25°C	----	1	µS/cm	802	616	697	758	666
EA013: Acid Neutralising Capacity								
ANC as H2SO4	----	0.5	kg H2SO4 equiv./t	43.5	142	12.6	106	30.9
ANC as CaCO3	----	0.1	% CaCO3	4.4	14.5	1.3	10.8	3.2
Fizz Rating	----	0	Fizz Unit	2	3	1	2	2
ED042T: Total Sulfur by LECO								
Sulfur - Total as S (LECO)	----	0.01	%	0.06	0.04	0.60	0.05	0.17

Analytical Results

Sub-Matrix: ROCK (Matrix: SOIL)			Client sample ID	7012G17	7012G18	7012G19	7012G20	7012G21
			Client sampling date / time	01-Jun-2017 00:00	01-Jun-2017 00:00	01-Jun-2017 00:00	01-Jun-2017 00:00	01-Jun-2017 00:00
Compound	CAS Number	LOR	Unit	EB1711745-061	EB1711745-062	EB1711745-063	EB1711745-064	EB1711745-065
				Result	Result	Result	Result	Result
EA002 : pH (Soils)								
pH Value	----	0.1	pH Unit	9.5	9.4	9.5	9.6	9.7
EA009: Nett Acid Production Potential								
Net Acid Production Potential	----	0.5	kg H2SO4/t	-71.9	-112	-69.2	-133	-57.9
EA010: Conductivity								
Electrical Conductivity @ 25°C	----	1	µS/cm	646	585	634	554	697
EA013: Acid Neutralising Capacity								
ANC as H2SO4	----	0.5	kg H2SO4 equiv./t	73.4	113	70.7	137	58.5
ANC as CaCO3	----	0.1	% CaCO3	7.5	11.6	7.2	13.9	6.0
Fizz Rating	----	0	Fizz Unit	2	2	2	3	2
ED042T: Total Sulfur by LECO								
Sulfur - Total as S (LECO)	----	0.01	%	0.05	0.04	0.05	0.13	0.02

Analytical Results

Sub-Matrix: **ROCK** (Matrix: **SOIL**)			Client sample ID	**7012G22**	**7012G23**	**7012G24**	**7012G25**	**7012G26**
			Client sampling date / time	01-Jun-2017 00:00	01-Jun-2017 00:00	01-Jun-2017 00:00	01-Jun-2017 00:00	01-Jun-2017 00:00
Compound	*CAS Number*	*LOR*	*Unit*	**EB1711745-066**	**EB1711745-067**	**EB1711745-068**	**EB1711745-069**	**EB1711745-070**
				Result	Result	Result	Result	Result
EA002 : pH (Soils)								
pH Value	----	0.1	pH Unit	**9.5**	**9.2**	**9.5**	**9.0**	**9.5**
EA009: Nett Acid Production Potential								
Net Acid Production Potential	----	0.5	kg H2SO4/t	**-108**	**-49.5**	**-67.0**	**-42.3**	**-39.8**
EA010: Conductivity								
Electrical Conductivity @ 25°C	----	1	µS/cm	**640**	**802**	**714**	**1440**	**722**
EA013: Acid Neutralising Capacity								
ANC as H2SO4	----	0.5	kg H2SO4 equiv./t	**109**	**51.3**	**69.5**	**50.6**	**42.6**
ANC as CaCO3	----	0.1	% CaCO3	**11.1**	**5.2**	**7.1**	**5.2**	**4.3**
Fizz Rating	----	0	Fizz Unit	**3**	**2**	**2**	**2**	**2**
ED042T: Total Sulfur by LECO								
Sulfur - Total as S (LECO)	----	0.01	%	**0.02**	**0.06**	**0.08**	**0.27**	**0.09**

Analytical Results

Sub-Matrix: **WATER** (Matrix: **WATER**)			Client sample ID	**DI water used in 1:5 leach**	----	----	----	----
			Client sampling date / time	07-Jun-2017 00:00	----	----	----	----
Compound	*CAS Number*	*LOR*	*Unit*	**EB1711745-071**	--------	--------	--------	--------
				Result	----	----	----	----
EA005P: pH by PC Titrator								
pH Value	----	0.01	pH Unit	**6.61**	----	----	----	----
EA010P: Conductivity by PC Titrator								
Electrical Conductivity @ 25°C	----	1	µS/cm	<1	----	----	----	----

CERTIFICATE OF ANALYSIS

Work Order	: **EB1713010**	Page	: 1 of 16
Client	: **RGS ENVIRONMENTAL PTY LTD**	Laboratory	: Environmental Division Brisbane
Contact	: MR ALAN ROBERTSON	Contact	: Customer Services EB
Address	: PO Box 3091 SUNNYBANK SOUTH QLD, AUSTRALIA 4109	Address	: 2 Byth Street Stafford QLD Australia 4053
Telephone	: +61 07 3344 1222	Telephone	: +61-7-3243 7222
Project	: 2017002 Dingo west	Date Samples Received	: 26-Jun-2017 09:32
Order number	: ----	Date Analysis Commenced	: 29-Jun-2017
C-O-C number	: ----	Issue Date	: 04-Jul-2017 14:39
Sampler	: ----		
Site	: ----		
Quote number	: BNBQ/218/16		
No. of samples received	: 39		
No. of samples analysed	: 28		

ilac-MRA NATA

Accreditation No. 825
Accredited for compliance with
ISO/IEC 17025 - Testing

This report supersedes any previous report(s) with this reference. Results apply to the sample(s) as submitted. This document shall not be reproduced, except in full.

This Certificate of Analysis contains the following information:

- General Comments
- Analytical Results

Additional information pertinent to this report will be found in the following separate attachments: Quality Control Report, QA/QC Compliance Assessment to assist with Quality Review and Sample Receipt Notification.

Signatories

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

Signatories	*Position*	*Accreditation Category*
Andrew Epps	Senior Inorganic Chemist	Brisbane Acid Sulphate Soils, Stafford, QLD
Andrew Epps	Senior Inorganic Chemist	Brisbane Inorganics, Stafford, QLD
Ben Felgendrejeris		Brisbane Acid Sulphate Soils, Stafford, QLD

General Comments

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

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

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

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

When no sampling time is provided, the sampling time will default 00:00 on the date of sampling. If no sampling date is provided, the sampling date will be assumed by the laboratory and displayed in brackets without a time component.

Where a result is required to meet compliance limits the associated uncertainty must be considered. Refer to the ALS Contact for details.

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

- **The samples in this work order have been re-batched from EB1711745.**
- ED037 (Alkalinity): NATA accreditation does not cover the performance of this service.
- ED038 (Acidity): NATA accreditation does not cover the performance of this service.

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Client sample ID	7002G02	7002G03	7002G08	7002G12	7002G18
			Client sampling date / time	26-Jun-2017 00:00	26-Jun-2017 00:00	26-Jun-2017 00:00	26-May-2017 00:00	26-May-2017 00:00
Compound	CAS Number	LOR	Unit	EB1713010-001	EB1713010-002	EB1713010-007	EB1713010-008	EB1713010-009
				Result	Result	Result	Result	Result
EA026 : Chromium Reducible Sulfur								
Chromium Reducible Sulphur	----	0.005	%	----	----	----	0.134	0.094
ED005: Exchange Acidity								
Exchange Acidity	----	0.1	meq/100g	0.2	----	----	----	----
Exchangeable Aluminium	----	0.1	meq/100g	0.1	----	----	----	----
ED006: Exchangeable Cations on Alkaline Soils								
Exchangeable Calcium	----	0.2	meq/100g	----	----	3.0	----	----
Exchangeable Magnesium	----	0.2	meq/100g	----	----	2.0	----	----
Exchangeable Potassium	----	0.2	meq/100g	----	----	<0.2	----	----
Exchangeable Sodium	----	0.2	meq/100g	----	----	0.2	----	----
Cation Exchange Capacity	----	0.2	meq/100g	----	----	5.3	----	----
Exchangeable Sodium Percent	----	0.2	%	----	----	4.5	----	----
ED008: Exchangeable Cations								
Exchangeable Calcium	----	0.1	meq/100g	1.8	2.3	----	----	----
Exchangeable Magnesium	----	0.1	meq/100g	10.8	11.9	----	----	----
Exchangeable Potassium	----	0.1	meq/100g	0.4	0.4	----	----	----
Exchangeable Sodium	----	0.1	meq/100g	2.9	3.3	----	----	----
Cation Exchange Capacity	----	0.1	meq/100g	16.1	----	----	----	----
Cation Exchange Capacity	----	0.1	meq/100g	----	18.0	----	----	----
Exchangeable Sodium Percent	----	0.1	%	18.2	18.4	----	----	----
ED037: Alkalinity								
ø Total Alkalinity as CaCO3	----	1	mg/kg	----	1220	16800	----	2790
ø Bicarbonate Alkalinity as CaCO3	71-52-3	1	mg/kg	----	1220	16500	----	2700
ø Carbonate Alkalinity as CaCO3	3812-32-6	1	mg/kg	----	<5	270	----	90
ED038A: Acidity								
ø Acidity	----	1	mg/kg	----	204	<5	----	<5
ED040S : Soluble Sulfate by ICPAES								
Sulfate as SO4 2-	14808-79-8	10	mg/kg	----	<10	40	----	150
ED045G: Chloride by Discrete Analyser								
Chloride	16887-00-6	10	mg/kg	----	2000	300	----	470
ED093S: Soluble Major Cations								
Calcium	7440-70-2	10	mg/kg	----	<10	30	----	40
Magnesium	7439-95-4	10	mg/kg	----	30	20	----	20
Sodium	7440-23-5	10	mg/kg	----	1240	230	----	350
Potassium	7440-09-7	10	mg/kg	----	20	50	----	40

Analytical Results

Sub-Matrix: SOIL
(Matrix: SOIL)

Compound	CAS Number	LOR	Unit	7002G02	7002G03	7002G08	7002G12	7002G18
Client sampling date / time				26-Jun-2017 00:00	26-Jun-2017 00:00	26-Jun-2017 00:00	26-May-2017 00:00	26-May-2017 00:00
				EB1713010-001	EB1713010-002	EB1713010-007	EB1713010-008	EB1713010-009
				Result	Result	Result	Result	Result
ED093T: Total Major Cations								
Calcium	7440-70-2	50	mg/kg	----	**610**	**26600**	----	**9050**
Magnesium	7439-95-4	50	mg/kg	----	**2200**	**11200**	----	**5130**
Sodium	7440-23-5	50	mg/kg	----	**2130**	**530**	----	**680**
Potassium	7440-09-7	50	mg/kg	----	**1040**	**1140**	----	**1280**
EG005S : Soluble Metals by ICPAES								
Aluminium	7429-90-5	1	mg/kg	----	<1	<1	----	<1
Antimony	7440-36-0	0.1	mg/kg	----	<0.1	<0.1	----	<0.1
Arsenic	7440-38-2	0.1	mg/kg	----	<0.1	<0.1	----	<0.1
Barium	7440-39-3	1	mg/kg	----	<1	<1	----	<1
Cadmium	7440-43-9	0.1	mg/kg	----	<0.1	<0.1	----	<0.1
Chromium	7440-47-3	0.1	mg/kg	----	<0.1	<0.1	----	<0.1
Copper	7440-50-8	0.1	mg/kg	----	<0.1	<0.1	----	<0.1
Iron	7439-89-6	1	mg/kg	----	<1	<1	----	<1
Lead	7439-92-1	0.1	mg/kg	----	<0.1	<0.1	----	<0.1
Manganese	7439-96-5	0.1	mg/kg	----	<0.1	<0.1	----	<0.1
Molybdenum	7439-98-7	0.1	mg/kg	----	<0.1	<0.1	----	<0.1
Nickel	7440-02-0	0.1	mg/kg	----	<0.1	<0.1	----	<0.1
Selenium	7782-49-2	0.1	mg/kg	----	**0.1**	<0.1	----	<0.1
Vanadium	7440-62-2	0.1	mg/kg	----	<0.1	<0.1	----	<0.1
Zinc	7440-66-6	0.1	mg/kg	----	<0.1	<0.1	----	<0.1
EG005T: Total Metals by ICP-AES								
Aluminium	7429-90-5	50	mg/kg	----	**5570**	**12000**	----	**6680**
Antimony	7440-36-0	5	mg/kg	----	<5	<5	----	<5
Arsenic	7440-38-2	5	mg/kg	----	**10**	**5**	----	**9**
Barium	7440-39-3	10	mg/kg	----	**240**	**120**	----	**500**
Cadmium	7440-43-9	1	mg/kg	----	<1	<1	----	<1
Chromium	7440-47-3	2	mg/kg	----	**14**	**29**	----	**8**
Cobalt	7440-48-4	2	mg/kg	----	**114**	**13**	----	**5**
Copper	7440-50-8	5	mg/kg	----	**63**	**20**	----	**27**
Iron	7439-89-6	50	mg/kg	----	**14000**	**36200**	----	**30400**
Lead	7439-92-1	5	mg/kg	----	**16**	**11**	----	**10**
Manganese	7439-96-5	5	mg/kg	----	**748**	**1030**	----	**448**
Molybdenum	7439-98-7	2	mg/kg	----	<2	<2	----	<2
Nickel	7440-02-0	2	mg/kg	----	**75**	**24**	----	**20**

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Client sample ID	7002G02	7002G03	7002G08	7002G12	7002G18
			Client sampling date / time	26-Jun-2017 00:00	26-Jun-2017 00:00	26-Jun-2017 00:00	26-May-2017 00:00	26-May-2017 00:00
Compound	CAS Number	LOR	Unit	EB1713010-001	EB1713010-002	EB1713010-007	EB1713010-008	EB1713010-009
				Result	Result	Result	Result	Result
EG005T: Total Metals by ICP-AES - Continued								
Selenium	7782-49-2	5	mg/kg	----	<5	<5	----	<5
Vanadium	7440-62-2	5	mg/kg	----	**31**	**49**	----	**18**
Zinc	7440-66-6	5	mg/kg	----	**76**	**60**	----	**49**

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Client sample ID	7002G20	7003G02	7003G06	7003G09	7003G10
			Client sampling date / time	26-Jun-2017 00:00	26-Jun-2017 00:00	26-Jun-2017 00:00	26-May-2017 00:00	26-May-2017 00:00
Compound	CAS Number	LOR	Unit	EB1713010-010	EB1713010-012	EB1713010-016	EB1713010-019	EB1713010-020
				Result	Result	Result	Result	Result
EA026 : Chromium Reducible Sulfur								
Chromium Reducible Sulphur	----	0.005	%	----	----	----	0.056	0.014
ED005: Exchange Acidity								
Exchange Acidity	----	0.1	meq/100g	----	<0.1	----	----	----
Exchangeable Aluminium	----	0.1	meq/100g	----	<0.1	----	----	----
ED006: Exchangeable Cations on Alkaline Soils								
Exchangeable Calcium	----	0.2	meq/100g	3.4	----	2.6	----	----
Exchangeable Magnesium	----	0.2	meq/100g	2.2	----	6.8	----	----
Exchangeable Potassium	----	0.2	meq/100g	<0.2	----	<0.2	----	----
Exchangeable Sodium	----	0.2	meq/100g	0.8	----	4.4	----	----
Cation Exchange Capacity	----	0.2	meq/100g	6.4	----	13.9	----	----
Exchangeable Sodium Percent	----	0.2	%	12.8	----	31.5	----	----
ED008: Exchangeable Cations								
Exchangeable Calcium	----	0.1	meq/100g	----	2.0	----	----	----
Exchangeable Magnesium	----	0.1	meq/100g	----	8.5	----	----	----
Exchangeable Potassium	----	0.1	meq/100g	----	0.3	----	----	----
Exchangeable Sodium	----	0.1	meq/100g	----	4.2	----	----	----
Cation Exchange Capacity	----	0.1	meq/100g	----	15.1	----	----	----
Exchangeable Sodium Percent	----	0.1	%	----	28.0	----	----	----
ED037: Alkalinity								
ø Total Alkalinity as CaCO3	----	1	mg/kg	----	----	3060	4140	----
ø Bicarbonate Alkalinity as CaCO3	71-52-3	1	mg/kg	----	----	3060	4140	----
ø Carbonate Alkalinity as CaCO3	3812-32-6	1	mg/kg	----	----	<5	<5	----
ED038A: Acidity								
ø Acidity	----	1	mg/kg	----	----	196	506	----
ED040S : Soluble Sulfate by ICPAES								
Sulfate as SO4 2-	14808-79-8	10	mg/kg	----	----	40	220	----
ED045G: Chloride by Discrete Analyser								
Chloride	16887-00-6	10	mg/kg	----	----	1970	1380	----
ED093S: Soluble Major Cations								
Calcium	7440-70-2	10	mg/kg	----	----	<10	<10	----
Magnesium	7439-95-4	10	mg/kg	----	----	<10	10	----
Sodium	7440-23-5	10	mg/kg	----	----	1260	940	----
Potassium	7440-09-7	10	mg/kg	----	----	20	40	----
ED093T: Total Major Cations								

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Client sample ID	7002G20	7003G02	7003G06	7003G09	7003G10
			Client sampling date / time	26-Jun-2017 00:00	26-Jun-2017 00:00	26-Jun-2017 00:00	26-May-2017 00:00	26-May-2017 00:00
Compound	CAS Number	LOR	Unit	EB1713010-010	EB1713010-012	EB1713010-016	EB1713010-019	EB1713010-020
				Result	Result	Result	Result	Result
ED093T: Total Major Cations - Continued								
Calcium	7440-70-2	50	mg/kg	----	----	3480	4030	----
Magnesium	7439-95-4	50	mg/kg	----	----	4720	3220	----
Sodium	7440-23-5	50	mg/kg	----	----	3020	2240	----
Potassium	7440-09-7	50	mg/kg	----	----	2070	1450	----
EG005S : Soluble Metals by ICPAES								
Aluminium	7429-90-5	1	mg/kg	----	----	<1	<1	----
Antimony	7440-36-0	0.1	mg/kg	----	----	<0.1	<0.1	----
Arsenic	7440-38-2	0.1	mg/kg	----	----	<0.1	<0.1	----
Barium	7440-39-3	1	mg/kg	----	----	<1	<1	----
Cadmium	7440-43-9	0.1	mg/kg	----	----	<0.1	<0.1	----
Chromium	7440-47-3	0.1	mg/kg	----	----	<0.1	<0.1	----
Copper	7440-50-8	0.1	mg/kg	----	----	<0.1	<0.1	----
Iron	7439-89-6	1	mg/kg	----	----	<1	<1	----
Lead	7439-92-1	0.1	mg/kg	----	----	<0.1	<0.1	----
Manganese	7439-96-5	0.1	mg/kg	----	----	<0.1	<0.1	----
Molybdenum	7439-98-7	0.1	mg/kg	----	----	<0.1	<0.1	----
Nickel	7440-02-0	0.1	mg/kg	----	----	<0.1	<0.1	----
Selenium	7782-49-2	0.1	mg/kg	----	----	<0.1	0.1	----
Vanadium	7440-62-2	0.1	mg/kg	----	----	<0.1	<0.1	----
Zinc	7440-66-6	0.1	mg/kg	----	----	<0.1	<0.1	----
EG005T: Total Metals by ICP-AES								
Aluminium	7429-90-5	50	mg/kg	----	----	11100	6280	----
Antimony	7440-36-0	5	mg/kg	----	----	<5	<5	----
Arsenic	7440-38-2	5	mg/kg	----	----	43	10	----
Barium	7440-39-3	10	mg/kg	----	----	130	620	----
Cadmium	7440-43-9	1	mg/kg	----	----	<1	<1	----
Chromium	7440-47-3	2	mg/kg	----	----	12	6	----
Cobalt	7440-48-4	2	mg/kg	----	----	9	8	----
Copper	7440-50-8	5	mg/kg	----	----	58	34	----
Iron	7439-89-6	50	mg/kg	----	----	19800	16900	----
Lead	7439-92-1	5	mg/kg	----	----	16	7	----
Manganese	7439-96-5	5	mg/kg	----	----	79	59	----
Molybdenum	7439-98-7	2	mg/kg	----	----	<2	<2	----
Nickel	7440-02-0	2	mg/kg	----	----	33	15	----

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Client sample ID	7002G20	7003G02	7003G06	7003G09	7003G10
			Client sampling date / time	26-Jun-2017 00:00	26-Jun-2017 00:00	26-Jun-2017 00:00	26-May-2017 00:00	26-May-2017 00:00
Compound	CAS Number	LOR	Unit	EB1713010-010	EB1713010-012	EB1713010-016	EB1713010-019	EB1713010-020
				Result	Result	Result	Result	Result
EG005T: Total Metals by ICP-AES - Continued								
Selenium	7782-49-2	5	mg/kg	----	----	<5	<5	----
Vanadium	7440-62-2	5	mg/kg	----	----	**40**	**29**	----
Zinc	7440-66-6	5	mg/kg	----	----	**69**	**55**	----

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Client sample ID	7003G13	7003G14	7003G15	7003G16	7003G18
			Client sampling date / time	26-May-2017 00:00	26-May-2017 00:00	26-May-2017 00:00	26-May-2017 00:00	26-May-2017 00:00
Compound	CAS Number	LOR	Unit	EB1713010-021	EB1713010-022	EB1713010-023	EB1713010-024	EB1713010-025
				Result	Result	Result	Result	Result
EA026 : Chromium Reducible Sulfur								
Chromium Reducible Sulphur	----	0.005	%	0.102	0.060	0.106	0.194	0.072
ED006: Exchangeable Cations on Alkaline Soils								
Exchangeable Calcium	----	0.2	meq/100g	----	----	----	1.3	----
Exchangeable Magnesium	----	0.2	meq/100g	----	----	----	1.9	----
Exchangeable Potassium	----	0.2	meq/100g	----	----	----	<0.2	----
Exchangeable Sodium	----	0.2	meq/100g	----	----	----	1.0	----
Cation Exchange Capacity	----	0.2	meq/100g	----	----	----	4.2	----
Exchangeable Sodium Percent	----	0.2	%	----	----	----	24.0	----
ED037: Alkalinity								
ø Total Alkalinity as CaCO3	----	1	mg/kg	----	----	----	1890	----
ø Bicarbonate Alkalinity as CaCO3	71-52-3	1	mg/kg	----	----	----	1890	----
ø Carbonate Alkalinity as CaCO3	3812-32-6	1	mg/kg	----	----	----	<5	----
ED038A: Acidity								
ø Acidity	----	1	mg/kg	----	----	----	16	----
ED040S : Soluble Sulfate by ICPAES								
Sulfate as SO4 2-	14808-79-8	10	mg/kg	----	----	----	320	----
ED045G: Chloride by Discrete Analyser								
Chloride	16887-00-6	10	mg/kg	----	----	----	1190	----
ED093S: Soluble Major Cations								
Calcium	7440-70-2	10	mg/kg	----	----	----	20	----
Magnesium	7439-95-4	10	mg/kg	----	----	----	20	----
Sodium	7440-23-5	10	mg/kg	----	----	----	850	----
Potassium	7440-09-7	10	mg/kg	----	----	----	50	----
ED093T: Total Major Cations								
Calcium	7440-70-2	50	mg/kg	----	----	----	8890	----
Magnesium	7439-95-4	50	mg/kg	----	----	----	7510	----
Sodium	7440-23-5	50	mg/kg	----	----	----	1320	----
Potassium	7440-09-7	50	mg/kg	----	----	----	1340	----
EG005S : Soluble Metals by ICPAES								
Aluminium	7429-90-5	1	mg/kg	----	----	----	<1	----
Antimony	7440-36-0	0.1	mg/kg	----	----	----	<0.1	----
Arsenic	7440-38-2	0.1	mg/kg	----	----	----	<0.1	----
Barium	7440-39-3	1	mg/kg	----	----	----	<1	----
Cadmium	7440-43-9	0.1	mg/kg	----	----	----	<0.1	----

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Client sample ID	7003G13	7003G14	7003G15	7003G16	7003G18
			Client sampling date / time	26-May-2017 00:00	26-May-2017 00:00	26-May-2017 00:00	26-May-2017 00:00	26-May-2017 00:00
Compound	CAS Number	LOR	Unit	EB1713010-021	EB1713010-022	EB1713010-023	EB1713010-024	EB1713010-025
				Result	Result	Result	Result	Result
EG005S : Soluble Metals by ICPAES - Continued								
Chromium	7440-47-3	0.1	mg/kg	----	----	----	<0.1	----
Copper	7440-50-8	0.1	mg/kg	----	----	----	<0.1	----
Iron	7439-89-6	1	mg/kg	----	----	----	<1	----
Lead	7439-92-1	0.1	mg/kg	----	----	----	<0.1	----
Manganese	7439-96-5	0.1	mg/kg	----	----	----	<0.1	----
Molybdenum	7439-98-7	0.1	mg/kg	----	----	----	<0.1	----
Nickel	7440-02-0	0.1	mg/kg	----	----	----	<0.1	----
Selenium	7782-49-2	0.1	mg/kg	----	----	----	**0.2**	----
Vanadium	7440-62-2	0.1	mg/kg	----	----	----	<0.1	----
Zinc	7440-66-6	0.1	mg/kg	----	----	----	<0.1	----
EG005T: Total Metals by ICP-AES								
Aluminium	7429-90-5	50	mg/kg	----	----	----	**12100**	----
Antimony	7440-36-0	5	mg/kg	----	----	----	<5	----
Arsenic	7440-38-2	5	mg/kg	----	----	----	**48**	----
Barium	7440-39-3	10	mg/kg	----	----	----	**760**	----
Cadmium	7440-43-9	1	mg/kg	----	----	----	<1	----
Chromium	7440-47-3	2	mg/kg	----	----	----	**10**	----
Cobalt	7440-48-4	2	mg/kg	----	----	----	**14**	----
Copper	7440-50-8	5	mg/kg	----	----	----	**25**	----
Iron	7439-89-6	50	mg/kg	----	----	----	**69700**	----
Lead	7439-92-1	5	mg/kg	----	----	----	**10**	----
Manganese	7439-96-5	5	mg/kg	----	----	----	**1580**	----
Molybdenum	7439-98-7	2	mg/kg	----	----	----	<2	----
Nickel	7440-02-0	2	mg/kg	----	----	----	**25**	----
Selenium	7782-49-2	5	mg/kg	----	----	----	<5	----
Vanadium	7440-62-2	5	mg/kg	----	----	----	**55**	----
Zinc	7440-66-6	5	mg/kg	----	----	----	**50**	----

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Client sample ID	7003G21	7012G04	7012G06	7012G07	7012G08
			Client sampling date / time	26-May-2017 00:00	01-Jun-2017 00:00	26-Jun-2017 00:00	01-Jun-2017 00:00	01-Jun-2017 00:00
Compound	CAS Number	LOR	Unit	EB1713010-026	EB1713010-027	EB1713010-028	EB1713010-029	EB1713010-030
				Result	Result	Result	Result	Result
EA026 : Chromium Reducible Sulfur								
Chromium Reducible Sulphur	----	0.005	%	**0.041**	**0.006**	----	**0.041**	**0.096**
ED006: Exchangeable Cations on Alkaline Soils								
Exchangeable Calcium	----	0.2	meq/100g	----	----	**2.0**	----	----
Exchangeable Magnesium	----	0.2	meq/100g	----	----	**3.4**	----	----
Exchangeable Potassium	----	0.2	meq/100g	----	----	<0.2	----	----
Exchangeable Sodium	----	0.2	meq/100g	----	----	**2.1**	----	----
Cation Exchange Capacity	----	0.2	meq/100g	----	----	**7.7**	----	----
Exchangeable Sodium Percent	----	0.2	%	----	----	**27.3**	----	----
ED037: Alkalinity								
ø Total Alkalinity as CaCO3	----	1	mg/kg	----	----	**18100**	----	----
ø Bicarbonate Alkalinity as CaCO3	71-52-3	1	mg/kg	----	----	**17700**	----	----
ø Carbonate Alkalinity as CaCO3	3812-32-6	1	mg/kg	----	----	**360**	----	----
ED038A: Acidity								
ø Acidity	----	1	mg/kg	----	----	<5	----	----
ED040S : Soluble Sulfate by ICPAES								
Sulfate as SO4 2-	14808-79-8	10	mg/kg	----	----	**80**	----	----
ED045G: Chloride by Discrete Analyser								
Chloride	16887-00-6	10	mg/kg	----	----	**480**	----	----
ED093S: Soluble Major Cations								
Calcium	7440-70-2	10	mg/kg	----	----	<10	----	----
Magnesium	7439-95-4	10	mg/kg	----	----	<10	----	----
Sodium	7440-23-5	10	mg/kg	----	----	**620**	----	----
Potassium	7440-09-7	10	mg/kg	----	----	**40**	----	----
ED093T: Total Major Cations								
Calcium	7440-70-2	50	mg/kg	----	----	**29900**	----	----
Magnesium	7439-95-4	50	mg/kg	----	----	**12000**	----	----
Sodium	7440-23-5	50	mg/kg	----	----	**1470**	----	----
Potassium	7440-09-7	50	mg/kg	----	----	**1450**	----	----
EG005S : Soluble Metals by ICPAES								
Aluminium	7429-90-5	1	mg/kg	----	----	<1	----	----
Antimony	7440-36-0	0.1	mg/kg	----	----	<0.1	----	----
Arsenic	7440-38-2	0.1	mg/kg	----	----	**0.4**	----	----
Barium	7440-39-3	1	mg/kg	----	----	<1	----	----
Cadmium	7440-43-9	0.1	mg/kg	----	----	<0.1	----	----

Analytical Results

Sub-Matrix: SOIL
(Matrix: SOIL)

Compound	CAS Number	LOR	Unit	7003G21	7012G04	7012G06	7012G07	7012G08
Client sampling date / time				26-May-2017 00:00	01-Jun-2017 00:00	26-Jun-2017 00:00	01-Jun-2017 00:00	01-Jun-2017 00:00
				EB1713010-026	EB1713010-027	EB1713010-028	EB1713010-029	EB1713010-030
				Result	Result	Result	Result	Result
EG005S : Soluble Metals by ICPAES - Continued								
Chromium	7440-47-3	0.1	mg/kg	----	----	<0.1	----	----
Copper	7440-50-8	0.1	mg/kg	----	----	<0.1	----	----
Iron	7439-89-6	1	mg/kg	----	----	<1	----	----
Lead	7439-92-1	0.1	mg/kg	----	----	<0.1	----	----
Manganese	7439-96-5	0.1	mg/kg	----	----	<0.1	----	----
Molybdenum	7439-98-7	0.1	mg/kg	----	----	**0.1**	----	----
Nickel	7440-02-0	0.1	mg/kg	----	----	<0.1	----	----
Selenium	7782-49-2	0.1	mg/kg	----	----	<0.1	----	----
Vanadium	7440-62-2	0.1	mg/kg	----	----	<0.1	----	----
Zinc	7440-66-6	0.1	mg/kg	----	----	<0.1	----	----
EG005T: Total Metals by ICP-AES								
Aluminium	7429-90-5	50	mg/kg	----	----	**7210**	----	----
Antimony	7440-36-0	5	mg/kg	----	----	<5	----	----
Arsenic	7440-38-2	5	mg/kg	----	----	**18**	----	----
Barium	7440-39-3	10	mg/kg	----	----	**20**	----	----
Cadmium	7440-43-9	1	mg/kg	----	----	<1	----	----
Chromium	7440-47-3	2	mg/kg	----	----	**19**	----	----
Cobalt	7440-48-4	2	mg/kg	----	----	**11**	----	----
Copper	7440-50-8	5	mg/kg	----	----	**25**	----	----
Iron	7439-89-6	50	mg/kg	----	----	**38900**	----	----
Lead	7439-92-1	5	mg/kg	----	----	**11**	----	----
Manganese	7439-96-5	5	mg/kg	----	----	**1000**	----	----
Molybdenum	7439-98-7	2	mg/kg	----	----	<2	----	----
Nickel	7440-02-0	2	mg/kg	----	----	**20**	----	----
Selenium	7782-49-2	5	mg/kg	----	----	<5	----	----
Vanadium	7440-62-2	5	mg/kg	----	----	**28**	----	----
Zinc	7440-66-6	5	mg/kg	----	----	**74**	----	----

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Client sample ID	7012G09	7012G11	7012G14	7012G16	7012G18
			Client sampling date / time	01-Jun-2017 00:00	01-Jun-2017 00:00	01-Jun-2017 00:00	01-Jun-2017 00:00	26-Jun-2017 00:00
Compound	CAS Number	LOR	Unit	EB1713010-031	EB1713010-032	EB1713010-033	EB1713010-034	EB1713010-035
				Result	Result	Result	Result	Result
EA026 : Chromium Reducible Sulfur								
Chromium Reducible Sulphur	----	0.005	%	**0.033**	**0.090**	**0.197**	**0.125**	----
ED006: Exchangeable Cations on Alkaline Soils								
Exchangeable Calcium	----	0.2	meq/100g	----	----	----	----	**3.1**
Exchangeable Magnesium	----	0.2	meq/100g	----	----	----	----	**2.4**
Exchangeable Potassium	----	0.2	meq/100g	----	----	----	----	<0.2
Exchangeable Sodium	----	0.2	meq/100g	----	----	----	----	**1.0**
Cation Exchange Capacity	----	0.2	meq/100g	----	----	----	----	**6.5**
Exchangeable Sodium Percent	----	0.2	%	----	----	----	----	**15.4**
ED037: Alkalinity								
ø Total Alkalinity as CaCO3	----	1	mg/kg	----	----	**2070**	----	**14000**
ø Bicarbonate Alkalinity as CaCO3	71-52-3	1	mg/kg	----	----	**1980**	----	**13700**
ø Carbonate Alkalinity as CaCO3	3812-32-6	1	mg/kg	----	----	**90**	----	**270**
ED038A: Acidity								
ø Acidity	----	1	mg/kg	----	----	<5	----	<5
ED040S : Soluble Sulfate by ICPAES								
Sulfate as SO4 2-	14808-79-8	10	mg/kg	----	----	**130**	----	**120**
ED045G: Chloride by Discrete Analyser								
Chloride	16887-00-6	10	mg/kg	----	----	**980**	----	**600**
ED093S: Soluble Major Cations								
Calcium	7440-70-2	10	mg/kg	----	----	<10	----	**10**
Magnesium	7439-95-4	10	mg/kg	----	----	<10	----	<10
Sodium	7440-23-5	10	mg/kg	----	----	**620**	----	**540**
Potassium	7440-09-7	10	mg/kg	----	----	**30**	----	**30**
ED093T: Total Major Cations								
Calcium	7440-70-2	50	mg/kg	----	----	**9210**	----	**31500**
Magnesium	7439-95-4	50	mg/kg	----	----	**3730**	----	**13500**
Sodium	7440-23-5	50	mg/kg	----	----	**1380**	----	**1060**
Potassium	7440-09-7	50	mg/kg	----	----	**1390**	----	**1130**
EG005S : Soluble Metals by ICPAES								
Aluminium	7429-90-5	1	mg/kg	----	----	<1	----	<1
Antimony	7440-36-0	0.1	mg/kg	----	----	<0.1	----	<0.1
Arsenic	7440-38-2	0.1	mg/kg	----	----	**0.2**	----	<0.1
Barium	7440-39-3	1	mg/kg	----	----	<1	----	<1
Cadmium	7440-43-9	0.1	mg/kg	----	----	<0.1	----	<0.1

Analytical Results

Sub-Matrix: **SOIL**
(Matrix: **SOIL)**

Compound	CAS Number	LOR	Unit	7012G09	7012G11	7012G14	7012G16	7012G18
			Client sampling date / time	01-Jun-2017 00:00	01-Jun-2017 00:00	01-Jun-2017 00:00	01-Jun-2017 00:00	26-Jun-2017 00:00
				EB1713010-031	EB1713010-032	EB1713010-033	EB1713010-034	EB1713010-035
				Result	Result	Result	Result	Result
EG005S : Soluble Metals by ICPAES - Continued								
Chromium	7440-47-3	0.1	mg/kg	----	----	<0.1	----	<0.1
Copper	7440-50-8	0.1	mg/kg	----	----	<0.1	----	<0.1
Iron	7439-89-6	1	mg/kg	----	----	<1	----	<1
Lead	7439-92-1	0.1	mg/kg	----	----	<0.1	----	<0.1
Manganese	7439-96-5	0.1	mg/kg	----	----	<0.1	----	<0.1
Molybdenum	7439-98-7	0.1	mg/kg	----	----	**0.2**	----	**0.4**
Nickel	7440-02-0	0.1	mg/kg	----	----	<0.1	----	<0.1
Selenium	7782-49-2	0.1	mg/kg	----	----	<0.1	----	**0.1**
Vanadium	7440-62-2	0.1	mg/kg	----	----	<0.1	----	<0.1
Zinc	7440-66-6	0.1	mg/kg	----	----	<0.1	----	<0.1
EG005T: Total Metals by ICP-AES								
Aluminium	7429-90-5	50	mg/kg	----	----	**6660**	----	**11300**
Antimony	7440-36-0	5	mg/kg	----	----	<5	----	<5
Arsenic	7440-38-2	5	mg/kg	----	----	**27**	----	**8**
Barium	7440-39-3	10	mg/kg	----	----	**950**	----	**40**
Cadmium	7440-43-9	1	mg/kg	----	----	<1	----	<1
Chromium	7440-47-3	2	mg/kg	----	----	**7**	----	**17**
Cobalt	7440-48-4	2	mg/kg	----	----	**7**	----	**23**
Copper	7440-50-8	5	mg/kg	----	----	**30**	----	**28**
Iron	7439-89-6	50	mg/kg	----	----	**25700**	----	**47600**
Lead	7439-92-1	5	mg/kg	----	----	**10**	----	**7**
Manganese	7439-96-5	5	mg/kg	----	----	**604**	----	**991**
Molybdenum	7439-98-7	2	mg/kg	----	----	<2	----	<2
Nickel	7440-02-0	2	mg/kg	----	----	**11**	----	**32**
Selenium	7782-49-2	5	mg/kg	----	----	<5	----	<5
Vanadium	7440-62-2	5	mg/kg	----	----	**26**	----	**59**
Zinc	7440-66-6	5	mg/kg	----	----	**43**	----	**74**

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Client sample ID	7012G20	7012G25	7012G26	----	----
			Client sampling date / time	01-Jun-2017 00:00	01-Jun-2017 00:00	26-Jun-2017 00:00	----	----
Compound	CAS Number	LOR	Unit	EB1713010-036	EB1713010-038	EB1713010-039	--------	--------
				Result	Result	Result	----	----
EA026 : Chromium Reducible Sulfur								
Chromium Reducible Sulphur	----	0.005	%	**0.037**	**0.070**	----	----	----
ED006: Exchangeable Cations on Alkaline Soils								
Exchangeable Calcium	----	0.2	meq/100g	----	----	**3.7**	----	----
Exchangeable Magnesium	----	0.2	meq/100g	----	----	**1.7**	----	----
Exchangeable Potassium	----	0.2	meq/100g	----	----	<0.2	----	----
Exchangeable Sodium	----	0.2	meq/100g	----	----	**1.4**	----	----
Cation Exchange Capacity	----	0.2	meq/100g	----	----	**6.8**	----	----
Exchangeable Sodium Percent	----	0.2	%	----	----	**20.2**	----	----
ED037: Alkalinity								
ø Total Alkalinity as CaCO3	----	1	mg/kg	----	----	**10300**	----	----
ø Bicarbonate Alkalinity as CaCO3	71-52-3	1	mg/kg	----	----	**10100**	----	----
ø Carbonate Alkalinity as CaCO3	3812-32-6	1	mg/kg	----	----	**180**	----	----
ED038A: Acidity								
ø Acidity	----	1	mg/kg	----	----	<5	----	----
ED040S : Soluble Sulfate by ICPAES								
Sulfate as SO4 2-	14808-79-8	10	mg/kg	----	----	**70**	----	----
ED045G: Chloride by Discrete Analyser								
Chloride	16887-00-6	10	mg/kg	----	----	**1030**	----	----
ED093S: Soluble Major Cations								
Calcium	7440-70-2	10	mg/kg	----	----	**20**	----	----
Magnesium	7439-95-4	10	mg/kg	----	----	**10**	----	----
Sodium	7440-23-5	10	mg/kg	----	----	**720**	----	----
Potassium	7440-09-7	10	mg/kg	----	----	**30**	----	----
ED093T: Total Major Cations								
Calcium	7440-70-2	50	mg/kg	----	----	**14900**	----	----
Magnesium	7439-95-4	50	mg/kg	----	----	**5660**	----	----
Sodium	7440-23-5	50	mg/kg	----	----	**1270**	----	----
Potassium	7440-09-7	50	mg/kg	----	----	**1620**	----	----
EG005S : Soluble Metals by ICPAES								
Aluminium	7429-90-5	1	mg/kg	----	----	<1	----	----
Antimony	7440-36-0	0.1	mg/kg	----	----	<0.1	----	----
Arsenic	7440-38-2	0.1	mg/kg	----	----	**0.1**	----	----
Barium	7440-39-3	1	mg/kg	----	----	<1	----	----
Cadmium	7440-43-9	0.1	mg/kg	----	----	<0.1	----	----

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Client sample ID	7012G20	7012G25	7012G26	----	----
			Client sampling date / time	01-Jun-2017 00:00	01-Jun-2017 00:00	26-Jun-2017 00:00	----	----
Compound	CAS Number	LOR	Unit	EB1713010-036	EB1713010-038	EB1713010-039	--------	--------
				Result	Result	Result	----	----
EG005S : Soluble Metals by ICPAES - Continued								
Chromium	7440-47-3	0.1	mg/kg	----	----	<0.1	----	----
Copper	7440-50-8	0.1	mg/kg	----	----	<0.1	----	----
Iron	7439-89-6	1	mg/kg	----	----	<1	----	----
Lead	7439-92-1	0.1	mg/kg	----	----	<0.1	----	----
Manganese	7439-96-5	0.1	mg/kg	----	----	<0.1	----	----
Molybdenum	7439-98-7	0.1	mg/kg	----	----	**0.2**	----	----
Nickel	7440-02-0	0.1	mg/kg	----	----	<0.1	----	----
Selenium	7782-49-2	0.1	mg/kg	----	----	<0.1	----	----
Vanadium	7440-62-2	0.1	mg/kg	----	----	<0.1	----	----
Zinc	7440-66-6	0.1	mg/kg	----	----	<0.1	----	----
EG005T: Total Metals by ICP-AES								
Aluminium	7429-90-5	50	mg/kg	----	----	**8660**	----	----
Antimony	7440-36-0	5	mg/kg	----	----	<5	----	----
Arsenic	7440-38-2	5	mg/kg	----	----	**5**	----	----
Barium	7440-39-3	10	mg/kg	----	----	**20**	----	----
Cadmium	7440-43-9	1	mg/kg	----	----	<1	----	----
Chromium	7440-47-3	2	mg/kg	----	----	**6**	----	----
Cobalt	7440-48-4	2	mg/kg	----	----	**5**	----	----
Copper	7440-50-8	5	mg/kg	----	----	**42**	----	----
Iron	7439-89-6	50	mg/kg	----	----	**17800**	----	----
Lead	7439-92-1	5	mg/kg	----	----	**20**	----	----
Manganese	7439-96-5	5	mg/kg	----	----	**278**	----	----
Molybdenum	7439-98-7	2	mg/kg	----	----	**2**	----	----
Nickel	7440-02-0	2	mg/kg	----	----	**10**	----	----
Selenium	7782-49-2	5	mg/kg	----	----	<5	----	----
Vanadium	7440-62-2	5	mg/kg	----	----	**20**	----	----
Zinc	7440-66-6	5	mg/kg	----	----	**58**	----	----

ALS Environmental

CERTIFICATE OF ANALYSIS

Work Order	: **EB1713594**	Page	: 1 of 6
Client	: **RGS ENVIRONMENTAL PTY LTD**	Laboratory	: Environmental Division Brisbane
Contact	: MR ALAN ROBERTSON	Contact	: Customer Services EB
Address	: PO Box 3091 SUNNYBANK SOUTH QLD, AUSTRALIA 4109	Address	: 2 Byth Street Stafford QLD Australia 4053
Telephone	: +61 07 3344 1222	Telephone	: +61-7-3243 7222
Project	: 2017002 Dingo west	Date Samples Received	: 04-Jul-2017 13:35
Order number	: ----	Date Analysis Commenced	: 05-Jul-2017
C-O-C number	: ----	Issue Date	: 10-Jul-2017 16:43
Sampler	: VERONICA CANALES		
Site	: ----		
Quote number	: BNBQ/218/16		
No. of samples received	: 6		
No. of samples analysed	: 6		

Accreditation No. 825
Accredited for compliance with
ISO/IEC 17025 - Testing

This report supersedes any previous report(s) with this reference. Results apply to the sample(s) as submitted. This document shall not be reproduced, except in full.

This Certificate of Analysis contains the following information:

- General Comments
- Analytical Results

Additional information pertinent to this report will be found in the following separate attachments: Quality Control Report, QA/QC Compliance Assessment to assist with Quality Review and Sample Receipt Notification.

Signatories

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

Signatories	*Position*	*Accreditation Category*
Andrew Epps	Senior Inorganic Chemist	Brisbane Inorganics, Stafford, QLD
Kim McCabe	Senior Inorganic Chemist	Brisbane Inorganics, Stafford, QLD

General Comments

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

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

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

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

When no sampling time is provided, the sampling time will default 00:00 on the date of sampling. If no sampling date is provided, the sampling date will be assumed by the laboratory and displayed in brackets without a time component.

Where a result is required to meet compliance limits the associated uncertainty must be considered. Refer to the ALS Contact for details.

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

Analytical Results

Sub-Matrix: **LEACHATE** (Matrix: **WATER**)			Client sample ID	**KLC 1**	**KLC 2**	**KLC 3**	**KLC 4**	**KLC 5**
			Client sampling date / time	30-Jun-2017 00:00	30-Jun-2017 00:00	30-Jun-2017 00:00	30-Jun-2017 00:00	30-Jun-2017 00:00
Compound	*CAS Number*	*LOR*	*Unit*	**EB1713594-001**	**EB1713594-002**	**EB1713594-003**	**EB1713594-004**	**EB1713594-005**
				Result	Result	Result	Result	Result
EA005P: pH by PC Titrator								
pH Value	----	0.01	pH Unit	**7.55**	**7.74**	**7.47**	**7.14**	**7.09**
EA010P: Conductivity by PC Titrator								
Electrical Conductivity @ 25°C	----	1	µS/cm	**769**	**162**	**317**	**185**	**180**
ED037P: Alkalinity by PC Titrator								
Hydroxide Alkalinity as CaCO3	DMO-210-001	1	mg/L	<1	<1	<1	<1	<1
Carbonate Alkalinity as CaCO3	3812-32-6	1	mg/L	<1	<1	<1	<1	<1
Bicarbonate Alkalinity as CaCO3	71-52-3	1	mg/L	**36**	**11**	**14**	**11**	**7**
Total Alkalinity as CaCO3	----	1	mg/L	**36**	**11**	**14**	**11**	**7**
ED038A: Acidity								
Acidity as CaCO3	----	1	mg/L	**2**	<1	**2**	**1**	**2**
ED041G: Sulfate (Turbidimetric) as SO4 2- by DA								
Sulfate as SO4 - Turbidimetric	14808-79-8	1	mg/L	**6**	**2**	**13**	**6**	**4**
ED045G: Chloride by Discrete Analyser								
Chloride	16887-00-6	1	mg/L	**214**	**33**	**75**	**27**	**27**
ED093F: Dissolved Major Cations								
Calcium	7440-70-2	1	mg/L	**5**	<1	**2**	**2**	<1
Magnesium	7439-95-4	1	mg/L	**8**	<1	**1**	<1	<1
Sodium	7440-23-5	1	mg/L	**126**	**30**	**33**	**22**	**31**
Potassium	7440-09-7	1	mg/L	**3**	**1**	**1**	<1	**1**
EG020F: Dissolved Metals by ICP-MS								
Aluminium	7429-90-5	0.01	mg/L	**0.12**	**3.72**	**0.14**	**0.05**	**2.30**
Antimony	7440-36-0	0.001	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001
Arsenic	7440-38-2	0.001	mg/L	**0.004**	<0.001	**0.005**	**0.002**	**0.001**
Cadmium	7440-43-9	0.0001	mg/L	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Chromium	7440-47-3	0.001	mg/L	<0.001	**0.002**	<0.001	<0.001	**0.001**
Copper	7440-50-8	0.001	mg/L	**0.001**	**0.003**	**0.001**	<0.001	<0.001
Cobalt	7440-48-4	0.001	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001
Nickel	7440-02-0	0.001	mg/L	<0.001	**0.001**	<0.001	<0.001	<0.001
Lead	7439-92-1	0.001	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001
Zinc	7440-66-6	0.005	mg/L	**0.006**	**0.007**	<0.005	<0.005	**0.007**
Manganese	7439-96-5	0.001	mg/L	**0.010**	**0.044**	**0.002**	<0.001	**0.002**
Molybdenum	7439-98-7	0.001	mg/L	**0.003**	**0.001**	**0.006**	**0.003**	**0.002**
Selenium	7782-49-2	0.01	mg/L	<0.01	<0.01	<0.01	<0.01	<0.01
Vanadium	7440-62-2	0.01	mg/L	<0.01	<0.01	<0.01	<0.01	<0.01

Analytical Results

Sub-Matrix: LEACHATE (Matrix: WATER)			Client sample ID	KLC 1	KLC 2	KLC 3	KLC 4	KLC 5
			Client sampling date / time	30-Jun-2017 00:00	30-Jun-2017 00:00	30-Jun-2017 00:00	30-Jun-2017 00:00	30-Jun-2017 00:00
Compound	CAS Number	LOR	Unit	EB1713594-001	EB1713594-002	EB1713594-003	EB1713594-004	EB1713594-005
				Result	Result	Result	Result	Result
EG020F: Dissolved Metals by ICP-MS - Continued								
Boron	7440-42-8	0.05	mg/L	**0.06**	<0.05	<0.05	<0.05	<0.05
Iron	7439-89-6	0.05	mg/L	**0.07**	**0.61**	<0.05	<0.05	**0.82**
EK040P: Fluoride by PC Titrator								
Fluoride	16984-48-8	0.1	mg/L	**0.4**	**0.2**	<0.1	<0.1	**0.2**

Analytical Results

Sub-Matrix: LEACHATE (Matrix: WATER)			Client sample ID	KLC 6	----	----	----	----
			Client sampling date / time	30-Jun-2017 00:00	----	----	----	----
Compound	CAS Number	LOR	Unit	EB1713594-006	--------	--------	--------	--------
				Result	----	----	----	----
EA005P: pH by PC Titrator								
pH Value	----	0.01	pH Unit	**7.76**	----	----	----	----
EA010P: Conductivity by PC Titrator								
Electrical Conductivity @ 25°C	----	1	µS/cm	**4420**	----	----	----	----
ED037P: Alkalinity by PC Titrator								
Hydroxide Alkalinity as CaCO3	DMO-210-001	1	mg/L	<1	----	----	----	----
Carbonate Alkalinity as CaCO3	3812-32-6	1	mg/L	<1	----	----	----	----
Bicarbonate Alkalinity as CaCO3	71-52-3	1	mg/L	**77**	----	----	----	----
Total Alkalinity as CaCO3	----	1	mg/L	**77**	----	----	----	----
ED038A: Acidity								
Acidity as CaCO3	----	1	mg/L	**2**	----	----	----	----
ED041G: Sulfate (Turbidimetric) as SO4 2- by DA								
Sulfate as SO4 - Turbidimetric	14808-79-8	1	mg/L	**242**	----	----	----	----
ED045G: Chloride by Discrete Analyser								
Chloride	16887-00-6	1	mg/L	**1140**	----	----	----	----
ED093F: Dissolved Major Cations								
Calcium	7440-70-2	1	mg/L	**21**	----	----	----	----
Magnesium	7439-95-4	1	mg/L	**21**	----	----	----	----
Sodium	7440-23-5	1	mg/L	**496**	----	----	----	----
Potassium	7440-09-7	1	mg/L	**13**	----	----	----	----
EG020F: Dissolved Metals by ICP-MS								
Aluminium	7429-90-5	0.01	mg/L	<0.01	----	----	----	----
Antimony	7440-36-0	0.001	mg/L	**0.003**	----	----	----	----
Arsenic	7440-38-2	0.001	mg/L	**0.214**	----	----	----	----
Cadmium	7440-43-9	0.0001	mg/L	<0.0001	----	----	----	----
Chromium	7440-47-3	0.001	mg/L	<0.001	----	----	----	----
Copper	7440-50-8	0.001	mg/L	**0.001**	----	----	----	----
Cobalt	7440-48-4	0.001	mg/L	<0.001	----	----	----	----
Nickel	7440-02-0	0.001	mg/L	<0.001	----	----	----	----
Lead	7439-92-1	0.001	mg/L	<0.001	----	----	----	----
Zinc	7440-66-6	0.005	mg/L	**0.005**	----	----	----	----
Manganese	7439-96-5	0.001	mg/L	**0.023**	----	----	----	----
Molybdenum	7439-98-7	0.001	mg/L	**0.067**	----	----	----	----
Selenium	7782-49-2	0.01	mg/L	**0.05**	----	----	----	----
Vanadium	7440-62-2	0.01	mg/L	<0.01	----	----	----	----

Analytical Results

Sub-Matrix: **LEACHATE**
(Matrix: **WATER**)

			Client sample ID	KLC 6	----	----	----	----
			Client sampling date / time	30-Jun-2017 00:00	----	----	----	----
Compound	CAS Number	LOR	Unit	EB1713594-006	--------	--------	--------	--------
				Result	----	----	----	----
EG020F: Dissolved Metals by ICP-MS - Continued								
Boron	7440-42-8	0.05	mg/L	**0.10**	----	----	----	----
Iron	7439-89-6	0.05	mg/L	<0.05	----	----	----	----
EK040P: Fluoride by PC Titrator								
Fluoride	16984-48-8	0.1	mg/L	**1.3**	----	----	----	----

ALS Environmental

CERTIFICATE OF ANALYSIS

Work Order	: **EB1716503**	Page	: 1 of 6
Client	: **RGS ENVIRONMENTAL PTY LTD**	Laboratory	: Environmental Division Brisbane
Contact	: MR ALAN ROBERTSON	Contact	: Customer Services EB
Address	: PO Box 3091 SUNNYBANK SOUTH QLD, AUSTRALIA 4109	Address	: 2 Byth Street Stafford QLD Australia 4053
Telephone	: +61 07 3344 1222	Telephone	: +61-7-3243 7222
Project	: 2017002 Dingo West	Date Samples Received	: 11-Aug-2017 17:00
Order number	: ----	Date Analysis Commenced	: 14-Aug-2017
C-O-C number	: ----	Issue Date	: 22-Aug-2017 13:25
Sampler	: MARY MACELROY		
Site	: ----		
Quote number	: BNBQ/218/16		
No. of samples received	: 6		
No. of samples analysed	: 6		

NATA Accreditation No. 825
Accredited for compliance with
ISO/IEC 17025 - Testing

This report supersedes any previous report(s) with this reference. Results apply to the sample(s) as submitted. This document shall not be reproduced, except in full.

This Certificate of Analysis contains the following information:

- General Comments
- Analytical Results

Additional information pertinent to this report will be found in the following separate attachments: Quality Control Report, QA/QC Compliance Assessment to assist with Quality Review and Sample Receipt Notification.

Signatories

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

Signatories	*Position*	*Accreditation Category*
Andrew Epps	Senior Inorganic Chemist	Brisbane Inorganics, Stafford, QLD
Greg Vogel	Laboratory Manager	Brisbane Inorganics, Stafford, QLD
Kim McCabe	Senior Inorganic Chemist	Brisbane Inorganics, Stafford, QLD

General Comments

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

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

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

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

When no sampling time is provided, the sampling time will default 00:00 on the date of sampling. If no sampling date is provided, the sampling date will be assumed by the laboratory and displayed in brackets without a time component.

Where a result is required to meet compliance limits the associated uncertainty must be considered. Refer to the ALS Contact for details.

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

- EG020-F (Dissolved Metals): Sample EB1716488-002 shows poor matrix spike recovery due to matrix interference. Confirmed by re-extraction re-analysis.

Analytical Results

Sub-Matrix: WATER (Matrix: WATER)			Client sample ID	KLC1	KLC2	KLC3	KLC4	KLC5
			Client sampling date / time	11-Aug-2017 00:00	11-Aug-2017 00:00	11-Aug-2017 00:00	11-Aug-2017 00:00	11-Aug-2017 00:00
Compound	CAS Number	LOR	Unit	EB1716503-001	EB1716503-002	EB1716503-003	EB1716503-004	EB1716503-005
				Result	Result	Result	Result	Result
EA005P: pH by PC Titrator								
pH Value	----	0.01	pH Unit	7.48	6.56	7.13	7.04	6.73
EA010P: Conductivity by PC Titrator								
Electrical Conductivity @ 25°C	----	1	µS/cm	508	181	582	231	433
ED037P: Alkalinity by PC Titrator								
Hydroxide Alkalinity as CaCO3	DMO-210-001	1	mg/L	<1	<1	<1	<1	<1
Carbonate Alkalinity as CaCO3	3812-32-6	1	mg/L	<1	<1	<1	<1	<1
Bicarbonate Alkalinity as CaCO3	71-52-3	1	mg/L	23	9	30	21	12
Total Alkalinity as CaCO3	----	1	mg/L	23	9	30	21	12
ED038A: Acidity								
Acidity as CaCO3	----	1	mg/L	2	2	2	1	1
ED041G: Sulfate (Turbidimetric) as SO4 2- by DA								
Sulfate as SO4 - Turbidimetric	14808-79-8	1	mg/L	8	3	16	7	9
ED045G: Chloride by Discrete Analyser								
Chloride	16887-00-6	1	mg/L	119	35	147	48	117
ED093F: Dissolved Major Cations								
Calcium	7440-70-2	1	mg/L	3	<1	7	4	3
Magnesium	7439-95-4	1	mg/L	5	<1	7	3	5
Sodium	7440-23-5	1	mg/L	65	28	75	29	60
Potassium	7440-09-7	1	mg/L	1	<1	2	1	1
EG020F: Dissolved Metals by ICP-MS								
Aluminium	7429-90-5	0.01	mg/L	0.02	2.42	0.02	0.05	0.06
Antimony	7440-36-0	0.001	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001
Arsenic	7440-38-2	0.001	mg/L	<0.001	<0.001	0.002	<0.001	<0.001
Cadmium	7440-43-9	0.0001	mg/L	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Chromium	7440-47-3	0.001	mg/L	<0.001	0.001	<0.001	<0.001	<0.001
Copper	7440-50-8	0.001	mg/L	<0.001	0.002	<0.001	<0.001	<0.001
Cobalt	7440-48-4	0.001	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001
Nickel	7440-02-0	0.001	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001
Lead	7439-92-1	0.001	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001
Zinc	7440-66-6	0.005	mg/L	<0.005	<0.005	<0.005	<0.005	<0.005
Manganese	7439-96-5	0.001	mg/L	0.002	0.018	0.012	0.005	0.004
Molybdenum	7439-98-7	0.001	mg/L	0.001	<0.001	0.042	0.007	0.001
Selenium	7782-49-2	0.01	mg/L	<0.01	<0.01	<0.01	<0.01	<0.01
Vanadium	7440-62-2	0.01	mg/L	<0.01	<0.01	<0.01	<0.01	<0.01

Analytical Results

Sub-Matrix: WATER (Matrix: WATER)			Client sample ID	KLC1	KLC2	KLC3	KLC4	KLC5
			Client sampling date / time	11-Aug-2017 00:00	11-Aug-2017 00:00	11-Aug-2017 00:00	11-Aug-2017 00:00	11-Aug-2017 00:00
Compound	CAS Number	LOR	Unit	EB1716503-001	EB1716503-002	EB1716503-003	EB1716503-004	EB1716503-005
				Result	Result	Result	Result	Result
EG020F: Dissolved Metals by ICP-MS - Continued								
Boron	7440-42-8	0.05	mg/L	**0.16**	<0.05	<0.05	<0.05	<0.05
Iron	7439-89-6	0.05	mg/L	<0.05	**0.38**	<0.05	<0.05	<0.05
EK040P: Fluoride by PC Titrator								
Fluoride	16984-48-8	0.1	mg/L	**0.2**	**0.3**	<0.1	<0.1	<0.1
EN055: Ionic Balance								
Total Anions	----	0.01	meq/L	**3.98**	**1.23**	**5.08**	**1.92**	**3.73**
Total Cations	----	0.01	meq/L	**3.41**	**1.22**	**4.24**	**1.73**	**3.20**
Ionic Balance	----	0.01	%	**7.69**	**----**	**9.02**	**----**	**7.67**

Analytical Results

Sub-Matrix: WATER (Matrix: WATER)			Client sample ID	KLC6	----	----	----	----
			Client sampling date / time	11-Aug-2017 00:00	----	----	----	----
Compound	CAS Number	LOR	Unit	EB1716503-006	--------	--------	--------	--------
				Result	----	----	----	----
EA005P: pH by PC Titrator								
pH Value	----	0.01	pH Unit	**7.39**	----	----	----	----
EA010P: Conductivity by PC Titrator								
Electrical Conductivity @ 25°C	----	1	µS/cm	**218**	----	----	----	----
ED037P: Alkalinity by PC Titrator								
Hydroxide Alkalinity as CaCO3	DMO-210-001	1	mg/L	<1	----	----	----	----
Carbonate Alkalinity as CaCO3	3812-32-6	1	mg/L	<1	----	----	----	----
Bicarbonate Alkalinity as CaCO3	71-52-3	1	mg/L	**29**	----	----	----	----
Total Alkalinity as CaCO3	----	1	mg/L	**29**	----	----	----	----
ED038A: Acidity								
Acidity as CaCO3	----	1	mg/L	**1**	----	----	----	----
ED041G: Sulfate (Turbidimetric) as SO4 2- by DA								
Sulfate as SO4 - Turbidimetric	14808-79-8	1	mg/L	**16**	----	----	----	----
ED045G: Chloride by Discrete Analyser								
Chloride	16887-00-6	1	mg/L	**33**	----	----	----	----
ED093F: Dissolved Major Cations								
Calcium	7440-70-2	1	mg/L	<1	----	----	----	----
Magnesium	7439-95-4	1	mg/L	<1	----	----	----	----
Sodium	7440-23-5	1	mg/L	**31**	----	----	----	----
Potassium	7440-09-7	1	mg/L	**1**	----	----	----	----
EG020F: Dissolved Metals by ICP-MS								
Aluminium	7429-90-5	0.01	mg/L	**0.58**	----	----	----	----
Antimony	7440-36-0	0.001	mg/L	<0.001	----	----	----	----
Arsenic	7440-38-2	0.001	mg/L	**0.008**	----	----	----	----
Cadmium	7440-43-9	0.0001	mg/L	<0.0001	----	----	----	----
Chromium	7440-47-3	0.001	mg/L	<0.001	----	----	----	----
Copper	7440-50-8	0.001	mg/L	<0.001	----	----	----	----
Cobalt	7440-48-4	0.001	mg/L	<0.001	----	----	----	----
Nickel	7440-02-0	0.001	mg/L	<0.001	----	----	----	----
Lead	7439-92-1	0.001	mg/L	<0.001	----	----	----	----
Zinc	7440-66-6	0.005	mg/L	<0.005	----	----	----	----
Manganese	7439-96-5	0.001	mg/L	**0.002**	----	----	----	----
Molybdenum	7439-98-7	0.001	mg/L	**0.009**	----	----	----	----
Selenium	7782-49-2	0.01	mg/L	<0.01	----	----	----	----
Vanadium	7440-62-2	0.01	mg/L	<0.01	----	----	----	----

Analytical Results

Sub-Matrix: WATER (Matrix: WATER)			Client sample ID	KLC6	----	----	----	----
			Client sampling date / time	11-Aug-2017 00:00	----	----	----	----
Compound	CAS Number	LOR	Unit	EB1716503-006	--------	--------	--------	--------
				Result	----	----	----	----
EG020F: Dissolved Metals by ICP-MS - Continued								
Boron	7440-42-8	0.05	mg/L	<0.05	----	----	----	----
Iron	7439-89-6	0.05	mg/L	**0.07**	----	----	----	----
EK040P: Fluoride by PC Titrator								
Fluoride	16984-48-8	0.1	mg/L	<0.1	----	----	----	----
EN055: Ionic Balance								
Total Anions	----	0.01	meq/L	**1.84**	----	----	----	----
Total Cations	----	0.01	meq/L	**1.37**	----	----	----	----

ALS Environmental

CERTIFICATE OF ANALYSIS

Work Order	: **EB1718214**	Page	: 1 of 6
Client	: **RGS ENVIRONMENTAL PTY LTD**	Laboratory	: Environmental Division Brisbane
Contact	: MR ALAN ROBERTSON	Contact	: Customer Services EB
Address	: PO Box 3091 SUNNYBANK SOUTH QLD, AUSTRALIA 4109	Address	: 2 Byth Street Stafford QLD Australia 4053
Telephone	: +61 07 3344 1222	Telephone	: +61-7-3243 7222
Project	: 2017002 Dingo West	Date Samples Received	: 05-Sep-2017 17:05
Order number	: ----	Date Analysis Commenced	: 06-Sep-2017
C-O-C number	: ----	Issue Date	: 12-Sep-2017 18:37
Sampler	: MARY MACELROY		
Site	: ----		
Quote number	: BNBQ/218/16		
No. of samples received	: 6		
No. of samples analysed	: 6		

Accreditation No. 825
Accredited for compliance with
ISO/IEC 17025 - Testing

This report supersedes any previous report(s) with this reference. Results apply to the sample(s) as submitted. This document shall not be reproduced, except in full.

This Certificate of Analysis contains the following information:

- General Comments
- Analytical Results

Additional information pertinent to this report will be found in the following separate attachments: Quality Control Report, QA/QC Compliance Assessment to assist with Quality Review and Sample Receipt Notification.

Signatories

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

Signatories	*Position*	*Accreditation Category*
Kim McCabe	Senior Inorganic Chemist	Brisbane Inorganics, Stafford, QLD

General Comments

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

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

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

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

When no sampling time is provided, the sampling time will default 00:00 on the date of sampling. If no sampling date is provided, the sampling date will be assumed by the laboratory and displayed in brackets without a time component.

Where a result is required to meet compliance limits the associated uncertainty must be considered. Refer to the ALS Contact for details.

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

- EG020-F (Dissolved Metals): Sample EB1718212-002 (KLC 2) has poor spike recovery due to matrix interference. Confirmed by re-analysis.

Analytical Results

Sub-Matrix: WATER (Matrix: WATER)			Client sample ID	KLC 1	KLC 2	KLC 3	KLC 4	KLC 5
			Client sampling date / time	05-Sep-2017 00:00	05-Sep-2017 00:00	05-Sep-2017 00:00	05-Sep-2017 00:00	05-Sep-2017 00:00
Compound	CAS Number	LOR	Unit	EB1718214-001	EB1718214-002	EB1718214-003	EB1718214-004	EB1718214-005
				Result	Result	Result	Result	Result
EA005P: pH by PC Titrator								
pH Value	----	0.01	pH Unit	**6.98**	**6.59**	**7.07**	**7.14**	**6.32**
EA010P: Conductivity by PC Titrator								
Electrical Conductivity @ 25°C	----	1	µS/cm	**195**	**175**	**424**	**352**	**425**
ED037P: Alkalinity by PC Titrator								
Hydroxide Alkalinity as CaCO3	DMO-210-001	1	mg/L	<1	<1	<1	<1	<1
Carbonate Alkalinity as CaCO3	3812-32-6	1	mg/L	<1	<1	<1	<1	<1
Bicarbonate Alkalinity as CaCO3	71-52-3	1	mg/L	**8**	**6**	**12**	**14**	**5**
Total Alkalinity as CaCO3	----	1	mg/L	**8**	**6**	**12**	**14**	**5**
ED038A: Acidity								
Acidity as CaCO3	----	1	mg/L	<1	<1	<1	<1	**1**
ED041G: Sulfate (Turbidimetric) as SO4 2- by DA								
Sulfate as SO4 - Turbidimetric	14808-79-8	1	mg/L	**7**	**2**	**20**	**16**	**17**
ED045G: Chloride by Discrete Analyser								
Chloride	16887-00-6	1	mg/L	**43**	**42**	**105**	**84**	**114**
ED093F: Dissolved Major Cations								
Calcium	7440-70-2	1	mg/L	**1**	<1	**6**	**6**	**4**
Magnesium	7439-95-4	1	mg/L	**2**	<1	**5**	**5**	**6**
Sodium	7440-23-5	1	mg/L	**32**	**34**	**64**	**52**	**65**
Potassium	7440-09-7	1	mg/L	<1	<1	**2**	**2**	**2**
EG020F: Dissolved Metals by ICP-MS								
Aluminium	7429-90-5	0.01	mg/L	**0.24**	**0.23**	**0.04**	**0.03**	**0.04**
Antimony	7440-36-0	0.001	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001
Arsenic	7440-38-2	0.001	mg/L	<0.001	<0.001	**0.003**	<0.001	<0.001
Cadmium	7440-43-9	0.0001	mg/L	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Chromium	7440-47-3	0.001	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001
Copper	7440-50-8	0.001	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001
Cobalt	7440-48-4	0.001	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001
Nickel	7440-02-0	0.001	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001
Lead	7439-92-1	0.001	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001
Zinc	7440-66-6	0.005	mg/L	<0.005	<0.005	<0.005	<0.005	<0.005
Manganese	7439-96-5	0.001	mg/L	**0.006**	**0.001**	**0.009**	**0.001**	**0.005**
Molybdenum	7439-98-7	0.001	mg/L	**0.001**	<0.001	**0.029**	**0.014**	<0.001
Selenium	7782-49-2	0.01	mg/L	<0.01	<0.01	<0.01	<0.01	<0.01
Vanadium	7440-62-2	0.01	mg/L	<0.01	<0.01	<0.01	<0.01	<0.01

Analytical Results

Sub-Matrix: WATER (Matrix: WATER)			Client sample ID	KLC 1	KLC 2	KLC 3	KLC 4	KLC 5
			Client sampling date / time	05-Sep-2017 00:00	05-Sep-2017 00:00	05-Sep-2017 00:00	05-Sep-2017 00:00	05-Sep-2017 00:00
Compound	*CAS Number*	*LOR*	*Unit*	**EB1718214-001**	**EB1718214-002**	**EB1718214-003**	**EB1718214-004**	**EB1718214-005**
				Result	Result	Result	Result	Result
EG020F: Dissolved Metals by ICP-MS - Continued								
Boron	7440-42-8	0.05	mg/L	<0.05	<0.05	<0.05	<0.05	**0.06**
Iron	7439-89-6	0.05	mg/L	**0.08**	<0.05	<0.05	<0.05	<0.05
EK040P: Fluoride by PC Titrator								
Fluoride	16984-48-8	0.1	mg/L	**0.1**	**0.1**	<0.1	<0.1	<0.1
EN055: Ionic Balance								
Total Anions	----	0.01	meq/L	**1.52**	**1.35**	**3.62**	**2.98**	**3.67**
Total Cations	----	0.01	meq/L	**1.61**	**1.48**	**3.54**	**3.02**	**3.57**
Ionic Balance	----	0.01	%	**----**	**----**	**1.01**	**----**	**1.35**

Analytical Results

Sub-Matrix: WATER (Matrix: WATER)			Client sample ID	KLC 6	----	----	----	----
			Client sampling date / time	05-Sep-2017 00:00	----	----	----	----
Compound	CAS Number	LOR	Unit	EB1718214-006	--------	--------	--------	--------
				Result	----	----	----	----
EA005P: pH by PC Titrator								
pH Value	----	0.01	pH Unit	**7.07**	----	----	----	----
EA010P: Conductivity by PC Titrator								
Electrical Conductivity @ 25°C	----	1	µS/cm	**63**	----	----	----	----
ED037P: Alkalinity by PC Titrator								
Hydroxide Alkalinity as CaCO3	DMO-210-001	1	mg/L	<1	----	----	----	----
Carbonate Alkalinity as CaCO3	3812-32-6	1	mg/L	<1	----	----	----	----
Bicarbonate Alkalinity as CaCO3	71-52-3	1	mg/L	**8**	----	----	----	----
Total Alkalinity as CaCO3	----	1	mg/L	**8**	----	----	----	----
ED038A: Acidity								
Acidity as CaCO3	----	1	mg/L	<1	----	----	----	----
ED041G: Sulfate (Turbidimetric) as SO4 2- by DA								
Sulfate as SO4 - Turbidimetric	14808-79-8	1	mg/L	**8**	----	----	----	----
ED045G: Chloride by Discrete Analyser								
Chloride	16887-00-6	1	mg/L	**10**	----	----	----	----
ED093F: Dissolved Major Cations								
Calcium	7440-70-2	1	mg/L	<1	----	----	----	----
Magnesium	7439-95-4	1	mg/L	<1	----	----	----	----
Sodium	7440-23-5	1	mg/L	**11**	----	----	----	----
Potassium	7440-09-7	1	mg/L	<1	----	----	----	----
EG020F: Dissolved Metals by ICP-MS								
Aluminium	7429-90-5	0.01	mg/L	**0.54**	----	----	----	----
Antimony	7440-36-0	0.001	mg/L	<0.001	----	----	----	----
Arsenic	7440-38-2	0.001	mg/L	**0.006**	----	----	----	----
Cadmium	7440-43-9	0.0001	mg/L	<0.0001	----	----	----	----
Chromium	7440-47-3	0.001	mg/L	<0.001	----	----	----	----
Copper	7440-50-8	0.001	mg/L	<0.001	----	----	----	----
Cobalt	7440-48-4	0.001	mg/L	<0.001	----	----	----	----
Nickel	7440-02-0	0.001	mg/L	<0.001	----	----	----	----
Lead	7439-92-1	0.001	mg/L	<0.001	----	----	----	----
Zinc	7440-66-6	0.005	mg/L	<0.005	----	----	----	----
Manganese	7439-96-5	0.001	mg/L	**0.001**	----	----	----	----
Molybdenum	7439-98-7	0.001	mg/L	**0.005**	----	----	----	----
Selenium	7782-49-2	0.01	mg/L	<0.01	----	----	----	----
Vanadium	7440-62-2	0.01	mg/L	<0.01	----	----	----	----

Analytical Results

Sub-Matrix: WATER (Matrix: WATER)			Client sample ID	KLC 6	----	----	----	----
			Client sampling date / time	05-Sep-2017 00:00	----	----	----	----
Compound	CAS Number	LOR	Unit	EB1718214-006	--------	--------	--------	--------
				Result	----	----	----	----
EG020F: Dissolved Metals by ICP-MS - Continued								
Boron	7440-42-8	0.05	mg/L	<0.05	----	----	----	----
Iron	7439-89-6	0.05	mg/L	**0.07**	----	----	----	----
EK040P: Fluoride by PC Titrator								
Fluoride	16984-48-8	0.1	mg/L	<0.1	----	----	----	----
EN055: Ionic Balance								
Total Anions	----	0.01	meq/L	**0.61**	----	----	----	----
Total Cations	----	0.01	meq/L	**0.48**	----	----	----	----

ALS Environmental

CERTIFICATE OF ANALYSIS

Work Order	: **EB1720293**	Page	: 1 of 6
Client	: **RGS ENVIRONMENTAL PTY LTD**	Laboratory	: Environmental Division Brisbane
Contact	: MR ALAN ROBERTSON	Contact	: Customer Services EB
Address	: PO Box 3091 SUNNYBANK SOUTH QLD, AUSTRALIA 4109	Address	: 2 Byth Street Stafford QLD Australia 4053
Telephone	: +61 07 3344 1222	Telephone	: +61-7-3243 7222
Project	: 2017002 Dingo west	Date Samples Received	: 03-Oct-2017 14:05
Order number	: ----	Date Analysis Commenced	: 04-Oct-2017
C-O-C number	: ----	Issue Date	: 09-Oct-2017 14:15
Sampler	: MARY MACELROY		
Site	: ----		
Quote number	: BNBQ/218/16		
No. of samples received	: 6		
No. of samples analysed	: 6		

NATA

Accreditation No. 825
Accredited for compliance with
ISO/IEC 17025 - Testing

This report supersedes any previous report(s) with this reference. Results apply to the sample(s) as submitted. This document shall not be reproduced, except in full.

This Certificate of Analysis contains the following information:

- General Comments
- Analytical Results

Additional information pertinent to this report will be found in the following separate attachments: Quality Control Report, QA/QC Compliance Assessment to assist with Quality Review and Sample Receipt Notification.

Signatories

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

Signatories	*Position*	*Accreditation Category*
Andrew Epps	Senior Inorganic Chemist	Brisbane Inorganics, Stafford, QLD
Kim McCabe	Senior Inorganic Chemist	Brisbane Inorganics, Stafford, QLD

General Comments

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

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

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

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

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

Where a result is required to meet compliance limits the associated uncertainty must be considered. Refer to the ALS Contact for details.

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

Analytical Results

Sub-Matrix: LEACHATE (Matrix: WATER)			Client sample ID	KLC 1	KLC 2	KLC 3	KLC 4	KLC 5
			Client sampling date / time	03-Oct-2017 00:00	03-Oct-2017 00:00	03-Oct-2017 00:00	03-Oct-2017 00:00	03-Oct-2017 00:00
Compound	CAS Number	LOR	Unit	EB1720293-001	EB1720293-002	EB1720293-003	EB1720293-004	EB1720293-005
				Result	Result	Result	Result	Result
EA005P: pH by PC Titrator								
pH Value	----	0.01	pH Unit	7.47	7.06	7.29	7.22	6.65
EA010P: Conductivity by PC Titrator								
Electrical Conductivity @ 25°C	----	1	µS/cm	281	207	282	135	859
ED037P: Alkalinity by PC Titrator								
Hydroxide Alkalinity as CaCO3	DMO-210-001	1	mg/L	<1	<1	<1	<1	<1
Carbonate Alkalinity as CaCO3	3812-32-6	1	mg/L	<1	<1	<1	<1	<1
Bicarbonate Alkalinity as CaCO3	71-52-3	1	mg/L	11	4	12	10	5
Total Alkalinity as CaCO3	----	1	mg/L	11	4	12	10	5
ED038A: Acidity								
Acidity as CaCO3	----	1	mg/L	<1	<1	2	<1	2
ED041G: Sulfate (Turbidimetric) as SO4 2- by DA								
Sulfate as SO4 - Turbidimetric	14808-79-8	1	mg/L	7	3	15	10	21
ED045G: Chloride by Discrete Analyser								
Chloride	16887-00-6	1	mg/L	75	58	67	26	275
ED093F: Dissolved Major Cations								
Calcium	7440-70-2	1	mg/L	<1	<1	3	2	5
Magnesium	7439-95-4	1	mg/L	<1	<1	3	2	9
Sodium	7440-23-5	1	mg/L	50	37	42	19	140
Potassium	7440-09-7	1	mg/L	<1	<1	2	1	3
EG020F: Dissolved Metals by ICP-MS								
Aluminium	7429-90-5	0.01	mg/L	0.90	0.51	0.13	0.11	0.01
Antimony	7440-36-0	0.001	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001
Arsenic	7440-38-2	0.001	mg/L	<0.001	<0.001	0.002	<0.001	<0.001
Cadmium	7440-43-9	0.0001	mg/L	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Chromium	7440-47-3	0.001	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001
Copper	7440-50-8	0.001	mg/L	0.001	0.002	0.001	<0.001	<0.001
Cobalt	7440-48-4	0.001	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001
Nickel	7440-02-0	0.001	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001
Lead	7439-92-1	0.001	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001
Zinc	7440-66-6	0.005	mg/L	<0.005	<0.005	<0.005	<0.005	<0.005
Manganese	7439-96-5	0.001	mg/L	0.007	0.009	0.010	0.002	0.006
Molybdenum	7439-98-7	0.001	mg/L	0.001	<0.001	0.024	0.006	0.001
Selenium	7782-49-2	0.01	mg/L	<0.01	<0.01	<0.01	<0.01	<0.01
Vanadium	7440-62-2	0.01	mg/L	<0.01	<0.01	<0.01	<0.01	<0.01

Analytical Results

Sub-Matrix: **LEACHATE** (Matrix: **WATER**)			Client sample ID	**KLC 1**	**KLC 2**	**KLC 3**	**KLC 4**	**KLC 5**
			Client sampling date / time	03-Oct-2017 00:00	03-Oct-2017 00:00	03-Oct-2017 00:00	03-Oct-2017 00:00	03-Oct-2017 00:00
Compound	*CAS Number*	*LOR*	*Unit*	**EB1720293-001**	**EB1720293-002**	**EB1720293-003**	**EB1720293-004**	**EB1720293-005**
				Result	Result	Result	Result	Result
EG020F: Dissolved Metals by ICP-MS - Continued								
Boron	7440-42-8	0.05	mg/L	<0.05	<0.05	<0.05	<0.05	**0.09**
Iron	7439-89-6	0.05	mg/L	**0.13**	**0.08**	<0.05	<0.05	<0.05
EK040P: Fluoride by PC Titrator								
Fluoride	16984-48-8	0.1	mg/L	**0.2**	**0.2**	<0.1	<0.1	**0.1**

Analytical Results

Sub-Matrix: LEACHATE (Matrix: WATER)			Client sample ID	KLC 6	----	----	----	----
			Client sampling date / time	03-Oct-2017 00:00	----	----	----	----
Compound	CAS Number	LOR	Unit	EB1720293-006	--------	--------	--------	--------
				Result	----	----	----	----
EA005P: pH by PC Titrator								
pH Value	----	0.01	pH Unit	**7.07**	----	----	----	----
EA010P: Conductivity by PC Titrator								
Electrical Conductivity @ 25°C	----	1	µS/cm	**32**	----	----	----	----
ED037P: Alkalinity by PC Titrator								
Hydroxide Alkalinity as CaCO3	DMO-210-001	1	mg/L	<1	----	----	----	----
Carbonate Alkalinity as CaCO3	3812-32-6	1	mg/L	<1	----	----	----	----
Bicarbonate Alkalinity as CaCO3	71-52-3	1	mg/L	**5**	----	----	----	----
Total Alkalinity as CaCO3	----	1	mg/L	**5**	----	----	----	----
ED038A: Acidity								
Acidity as CaCO3	----	1	mg/L	<1	----	----	----	----
ED041G: Sulfate (Turbidimetric) as SO4 2- by DA								
Sulfate as SO4 - Turbidimetric	14808-79-8	1	mg/L	**4**	----	----	----	----
ED045G: Chloride by Discrete Analyser								
Chloride	16887-00-6	1	mg/L	**4**	----	----	----	----
ED093F: Dissolved Major Cations								
Calcium	7440-70-2	1	mg/L	<1	----	----	----	----
Magnesium	7439-95-4	1	mg/L	<1	----	----	----	----
Sodium	7440-23-5	1	mg/L	**5**	----	----	----	----
Potassium	7440-09-7	1	mg/L	<1	----	----	----	----
EG020F: Dissolved Metals by ICP-MS								
Aluminium	7429-90-5	0.01	mg/L	**0.25**	----	----	----	----
Antimony	7440-36-0	0.001	mg/L	<0.001	----	----	----	----
Arsenic	7440-38-2	0.001	mg/L	**0.004**	----	----	----	----
Cadmium	7440-43-9	0.0001	mg/L	<0.0001	----	----	----	----
Chromium	7440-47-3	0.001	mg/L	<0.001	----	----	----	----
Copper	7440-50-8	0.001	mg/L	<0.001	----	----	----	----
Cobalt	7440-48-4	0.001	mg/L	<0.001	----	----	----	----
Nickel	7440-02-0	0.001	mg/L	<0.001	----	----	----	----
Lead	7439-92-1	0.001	mg/L	<0.001	----	----	----	----
Zinc	7440-66-6	0.005	mg/L	<0.005	----	----	----	----
Manganese	7439-96-5	0.001	mg/L	**0.002**	----	----	----	----
Molybdenum	7439-98-7	0.001	mg/L	**0.002**	----	----	----	----
Selenium	7782-49-2	0.01	mg/L	<0.01	----	----	----	----
Vanadium	7440-62-2	0.01	mg/L	<0.01	----	----	----	----

Analytical Results

Sub-Matrix: **LEACHATE**
(Matrix: **WATER**)

			Client sample ID	KLC 6	----	----	----	----
			Client sampling date / time	03-Oct-2017 00:00	----	----	----	----
Compound	CAS Number	LOR	Unit	EB1720293-006	--------	--------	--------	--------
				Result	----	----	----	----
EG020F: Dissolved Metals by ICP-MS - Continued								
Boron	7440-42-8	0.05	mg/L	<0.05	----	----	----	----
Iron	7439-89-6	0.05	mg/L	<0.05	----	----	----	----
EK040P: Fluoride by PC Titrator								
Fluoride	16984-48-8	0.1	mg/L	<0.1	----	----	----	----

CERTIFICATE OF ANALYSIS

Work Order	: **EB1723258**	Page	: 1 of 6
Client	: **RGS ENVIRONMENTAL PTY LTD**	Laboratory	: Environmental Division Brisbane
Contact	: MR ALAN ROBERTSON	Contact	: Customer Services EB
Address	: PO Box 3091 SUNNYBANK SOUTH QLD, AUSTRALIA 4109	Address	: 2 Byth Street Stafford QLD Australia 4053
Telephone	: +61 07 3344 1222	Telephone	: +61-7-3243 7222
Project	: 2017002 Dingo west	Date Samples Received	: 07-Nov-2017 15:00
Order number	: ----	Date Analysis Commenced	: 08-Nov-2017
C-O-C number	: ----	Issue Date	: 15-Nov-2017 16:48
Sampler	: MARY MACELROY		
Site	: ----		
Quote number	: BNBQ/218/16		
No. of samples received	: 6		
No. of samples analysed	: 6		

NATA
Accreditation No. 825
Accredited for compliance with
ISO/IEC 17025 - Testing

This report supersedes any previous report(s) with this reference. Results apply to the sample(s) as submitted. This document shall not be reproduced, except in full.

This Certificate of Analysis contains the following information:

- General Comments
- Analytical Results

Additional information pertinent to this report will be found in the following separate attachments: Quality Control Report, QA/QC Compliance Assessment to assist with Quality Review and Sample Receipt Notification.

Signatories

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

Signatories	*Position*	*Accreditation Category*
Andrew Epps	Senior Inorganic Chemist	Brisbane Inorganics, Stafford, QLD
Kim McCabe	Senior Inorganic Chemist	Brisbane Inorganics, Stafford, QLD

General Comments

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

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

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

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

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

Where a result is required to meet compliance limits the associated uncertainty must be considered. Refer to the ALS Contact for details.

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

- EG020-F (Dissolved Metals): Sample EB1723252-002 has poor spike recovery due to matrix interference. Confirmed by re-analysis.

Analytical Results

Sub-Matrix: WATER (Matrix: WATER)			Client sample ID	KLC 1	KLC 2	KLC 3	KLC 4	KLC 5
			Client sampling date / time	07-Nov-2017 00:00	07-Nov-2017 00:00	07-Nov-2017 00:00	07-Nov-2017 00:00	07-Nov-2017 00:00
Compound	CAS Number	LOR	Unit	EB1723258-001	EB1723258-002	EB1723258-003	EB1723258-004	EB1723258-005
				Result	Result	Result	Result	Result
EA005P: pH by PC Titrator								
pH Value	----	0.01	pH Unit	7.64	6.97	7.43	7.45	7.04
EA010P: Conductivity by PC Titrator								
Electrical Conductivity @ 25°C	----	1	µS/cm	190	116	254	303	320
ED037P: Alkalinity by PC Titrator								
Hydroxide Alkalinity as $CaCO_3$	DMO-210-001	1	mg/L	<1	<1	<1	<1	<1
Carbonate Alkalinity as $CaCO_3$	3812-32-6	1	mg/L	<1	<1	<1	<1	<1
Bicarbonate Alkalinity as $CaCO_3$	71-52-3	1	mg/L	12	5	14	16	12
Total Alkalinity as $CaCO_3$	----	1	mg/L	12	5	14	16	12
ED038A: Acidity								
Acidity as $CaCO_3$	----	1	mg/L	<1	<1	2	1	3
ED041G: Sulfate (Turbidimetric) as SO_4 2- by DA								
Sulfate as SO_4 - Turbidimetric	14808-79-8	1	mg/L	3	2	13	36	12
ED045G: Chloride by Discrete Analyser								
Chloride	16887-00-6	1	mg/L	44	27	55	52	82
ED093F: Dissolved Major Cations								
Calcium	7440-70-2	1	mg/L	<1	<1	4	7	<1
Magnesium	7439-95-4	1	mg/L	<1	<1	3	4	1
Sodium	7440-23-5	1	mg/L	33	20	37	42	49
Potassium	7440-09-7	1	mg/L	<1	<1	2	2	1
EG020F: Dissolved Metals by ICP-MS								
Aluminium	7429-90-5	0.01	mg/L	0.27	0.36	0.10	0.04	0.26
Antimony	7440-36-0	0.001	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001
Arsenic	7440-38-2	0.001	mg/L	0.001	<0.001	0.003	<0.001	<0.001
Cadmium	7440-43-9	0.0001	mg/L	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Chromium	7440-47-3	0.001	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001
Copper	7440-50-8	0.001	mg/L	0.001	0.001	<0.001	<0.001	<0.001
Cobalt	7440-48-4	0.001	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001
Nickel	7440-02-0	0.001	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001
Lead	7439-92-1	0.001	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001
Zinc	7440-66-6	0.005	mg/L	<0.005	<0.005	<0.005	<0.005	<0.005
Manganese	7439-96-5	0.001	mg/L	0.014	0.021	0.006	0.006	0.001
Molybdenum	7439-98-7	0.001	mg/L	<0.001	<0.001	0.015	0.011	0.001
Selenium	7782-49-2	0.01	mg/L	<0.01	<0.01	<0.01	<0.01	<0.01
Vanadium	7440-62-2	0.01	mg/L	<0.01	<0.01	<0.01	<0.01	<0.01

Analytical Results

Sub-Matrix: WATER
(Matrix: WATER)

			Client sample ID	KLC 1	KLC 2	KLC 3	KLC 4	KLC 5
			Client sampling date / time	07-Nov-2017 00:00	07-Nov-2017 00:00	07-Nov-2017 00:00	07-Nov-2017 00:00	07-Nov-2017 00:00
Compound	CAS Number	LOR	Unit	EB1723258-001	EB1723258-002	EB1723258-003	EB1723258-004	EB1723258-005
				Result	Result	Result	Result	Result
EG020F: Dissolved Metals by ICP-MS - Continued								
Boron	7440-42-8	0.05	mg/L	<0.05	<0.05	<0.05	<0.05	<0.05
Iron	7439-89-6	0.05	mg/L	**0.09**	**0.10**	<0.05	<0.05	**0.17**
EK040P: Fluoride by PC Titrator								
Fluoride	16984-48-8	0.1	mg/L	**0.1**	**0.2**	<0.1	<0.1	**0.2**

Analytical Results

Sub-Matrix: WATER (Matrix: WATER)			Client sample ID	KLC 6	----	----	----	----
			Client sampling date / time	07-Nov-2017 00:00	----	----	----	----
Compound	CAS Number	LOR	Unit	EB1723258-006	--------	--------	--------	--------
				Result	----	----	----	----
EA005P: pH by PC Titrator								
pH Value	----	0.01	pH Unit	**7.39**	----	----	----	----
EA010P: Conductivity by PC Titrator								
Electrical Conductivity @ 25°C	----	1	µS/cm	**67**	----	----	----	----
ED037P: Alkalinity by PC Titrator								
Hydroxide Alkalinity as CaCO3	DMO-210-001	1	mg/L	<1	----	----	----	----
Carbonate Alkalinity as CaCO3	3812-32-6	1	mg/L	<1	----	----	----	----
Bicarbonate Alkalinity as CaCO3	71-52-3	1	mg/L	**10**	----	----	----	----
Total Alkalinity as CaCO3	----	1	mg/L	**10**	----	----	----	----
ED038A: Acidity								
Acidity as CaCO3	----	1	mg/L	**1**	----	----	----	----
ED041G: Sulfate (Turbidimetric) as SO4 2- by DA								
Sulfate as SO4 - Turbidimetric	14808-79-8	1	mg/L	**10**	----	----	----	----
ED045G: Chloride by Discrete Analyser								
Chloride	16887-00-6	1	mg/L	**8**	----	----	----	----
ED093F: Dissolved Major Cations								
Calcium	7440-70-2	1	mg/L	<1	----	----	----	----
Magnesium	7439-95-4	1	mg/L	<1	----	----	----	----
Sodium	7440-23-5	1	mg/L	**10**	----	----	----	----
Potassium	7440-09-7	1	mg/L	<1	----	----	----	----
EG020F: Dissolved Metals by ICP-MS								
Aluminium	7429-90-5	0.01	mg/L	**0.21**	----	----	----	----
Antimony	7440-36-0	0.001	mg/L	<0.001	----	----	----	----
Arsenic	7440-38-2	0.001	mg/L	**0.007**	----	----	----	----
Cadmium	7440-43-9	0.0001	mg/L	<0.0001	----	----	----	----
Chromium	7440-47-3	0.001	mg/L	<0.001	----	----	----	----
Copper	7440-50-8	0.001	mg/L	<0.001	----	----	----	----
Cobalt	7440-48-4	0.001	mg/L	<0.001	----	----	----	----
Nickel	7440-02-0	0.001	mg/L	<0.001	----	----	----	----
Lead	7439-92-1	0.001	mg/L	<0.001	----	----	----	----
Zinc	7440-66-6	0.005	mg/L	<0.005	----	----	----	----
Manganese	7439-96-5	0.001	mg/L	**0.002**	----	----	----	----
Molybdenum	7439-98-7	0.001	mg/L	**0.003**	----	----	----	----
Selenium	7782-49-2	0.01	mg/L	<0.01	----	----	----	----
Vanadium	7440-62-2	0.01	mg/L	<0.01	----	----	----	----

Analytical Results

Sub-Matrix: WATER (Matrix: WATER)			Client sample ID	KLC 6	----	----	----	----
			Client sampling date / time	07-Nov-2017 00:00	----	----	----	----
Compound	CAS Number	LOR	Unit	EB1723258-006	--------	--------	--------	--------
				Result	----	----	----	----
EG020F: Dissolved Metals by ICP-MS - Continued								
Boron	7440-42-8	0.05	mg/L	<0.05	----	----	----	----
Iron	7439-89-6	0.05	mg/L	**0.05**	----	----	----	----
EK040P: Fluoride by PC Titrator								
Fluoride	16984-48-8	0.1	mg/L	<0.1	----	----	----	----

CERTIFICATE OF ANALYSIS

Work Order	: **EB1725752**	Page	: 1 of 6
Client	: **RGS ENVIRONMENTAL PTY LTD**	Laboratory	: Environmental Division Brisbane
Contact	: MR ALAN ROBERTSON	Contact	: Customer Services EB
Address	: PO Box 3091 SUNNYBANK SOUTH QLD, AUSTRALIA 4109	Address	: 2 Byth Street Stafford QLD Australia 4053
Telephone	: +61 07 3344 1222	Telephone	: +61-7-3243 7222
Project	: 2017002 Dingo west	Date Samples Received	: 05-Dec-2017 16:00
Order number	: ----	Date Analysis Commenced	: 05-Dec-2017
C-O-C number	: ----	Issue Date	: 11-Dec-2017 21:51
Sampler	: MARY MACELROY		
Site	: ----		
Quote number	: EN/222/17		
No. of samples received	: 6		
No. of samples analysed	: 6		

Accreditation No. 825
Accredited for compliance with
ISO/IEC 17025 - Testing

This report supersedes any previous report(s) with this reference. Results apply to the sample(s) as submitted. This document shall not be reproduced, except in full.

This Certificate of Analysis contains the following information:

- General Comments
- Analytical Results

Additional information pertinent to this report will be found in the following separate attachments: Quality Control Report, QA/QC Compliance Assessment to assist with Quality Review and Sample Receipt Notification.

Signatories

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

Signatories	*Position*	*Accreditation Category*
Greg Vogel	Laboratory Manager	Brisbane Inorganics, Stafford, QLD
Kim McCabe	Senior Inorganic Chemist	Brisbane Inorganics, Stafford, QLD

General Comments

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

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

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

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

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

Where a result is required to meet compliance limits the associated uncertainty must be considered. Refer to the ALS Contact for details.

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

- Ionic Balance out of acceptable limits due to analytes not quantified in this report.

Analytical Results

Sub-Matrix: WATER
(Matrix: WATER)

Compound	CAS Number	LOR	Unit	KLC 1	KLC 2	KLC 3	KLC 4	KLC 5
Client sampling date / time				05-Dec-2017 00:00	05-Dec-2017 00:00	05-Dec-2017 00:00	05-Dec-2017 00:00	05-Dec-2017 00:00
				EB1725752-001	EB1725752-002	EB1725752-003	EB1725752-004	EB1725752-005
				Result	Result	Result	Result	Result
EA005P: pH by PC Titrator								
pH Value	----	0.01	pH Unit	7.52	7.12	8.69	7.77	7.06
EA010P: Conductivity by PC Titrator								
Electrical Conductivity @ 25°C	----	1	µS/cm	131	106	267	230	237
ED037P: Alkalinity by PC Titrator								
Hydroxide Alkalinity as CaCO3	DMO-210-001	1	mg/L	<1	<1	<1	<1	<1
Carbonate Alkalinity as CaCO3	3812-32-6	1	mg/L	<1	<1	8	<1	<1
Bicarbonate Alkalinity as CaCO3	71-52-3	1	mg/L	17	9	23	24	9
Total Alkalinity as CaCO3	----	1	mg/L	17	9	31	24	9
ED038A: Acidity								
Acidity as CaCO3	----	1	mg/L	1	<1	<1	1	2
ED041G: Sulfate (Turbidimetric) as SO4 2- by DA								
Sulfate as SO4 - Turbidimetric	14808-79-8	1	mg/L	4	3	18	30	9
ED045G: Chloride by Discrete Analyser								
Chloride	16887-00-6	1	mg/L	27	25	56	39	62
ED093F: Dissolved Major Cations								
Calcium	7440-70-2	1	mg/L	<1	<1	4	4	<1
Magnesium	7439-95-4	1	mg/L	<1	<1	3	4	1
Sodium	7440-23-5	1	mg/L	22	20	42	33	41
Potassium	7440-09-7	1	mg/L	<1	<1	2	2	1
EG020F: Dissolved Metals by ICP-MS								
Aluminium	7429-90-5	0.01	mg/L	0.51	0.42	0.21	0.08	0.46
Antimony	7440-36-0	0.001	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001
Arsenic	7440-38-2	0.001	mg/L	<0.001	<0.001	0.003	<0.001	<0.001
Cadmium	7440-43-9	0.0001	mg/L	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Chromium	7440-47-3	0.001	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001
Copper	7440-50-8	0.001	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001
Cobalt	7440-48-4	0.001	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001
Nickel	7440-02-0	0.001	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001
Lead	7439-92-1	0.001	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001
Zinc	7440-66-6	0.005	mg/L	<0.005	<0.005	<0.005	<0.005	<0.005
Manganese	7439-96-5	0.001	mg/L	0.005	0.009	0.005	0.006	0.002
Molybdenum	7439-98-7	0.001	mg/L	<0.001	<0.001	0.015	0.007	<0.001
Selenium	7782-49-2	0.01	mg/L	<0.01	<0.01	<0.01	<0.01	<0.01
Vanadium	7440-62-2	0.01	mg/L	<0.01	<0.01	<0.01	<0.01	<0.01

Analytical Results

Sub-Matrix: WATER (Matrix: WATER)			Client sample ID	KLC 1	KLC 2	KLC 3	KLC 4	KLC 5
			Client sampling date / time	05-Dec-2017 00:00	05-Dec-2017 00:00	05-Dec-2017 00:00	05-Dec-2017 00:00	05-Dec-2017 00:00
Compound	CAS Number	LOR	Unit	EB1725752-001	EB1725752-002	EB1725752-003	EB1725752-004	EB1725752-005
				Result	Result	Result	Result	Result
EG020F: Dissolved Metals by ICP-MS - Continued								
Boron	7440-42-8	0.05	mg/L	<0.05	<0.05	<0.05	<0.05	<0.05
Iron	7439-89-6	0.05	mg/L	**0.17**	**0.07**	<0.05	<0.05	**0.19**
EK040P: Fluoride by PC Titrator								
Fluoride	16984-48-8	0.1	mg/L	<0.1	**0.1**	<0.1	<0.1	<0.1
EN055: Ionic Balance								
Total Anions	----	0.01	meq/L	**1.18**	**0.95**	**2.57**	**2.20**	**2.12**
Total Cations	----	0.01	meq/L	**0.96**	**0.87**	**2.32**	**2.02**	**1.89**

Analytical Results

Sub-Matrix: WATER (Matrix: WATER)			Client sample ID	KLC 6	----	----	----	----
			Client sampling date / time	05-Dec-2017 00:00	----	----	----	----
Compound	CAS Number	LOR	Unit	EB1725752-006	--------	--------	--------	--------
				Result	----	----	----	----
EA005P: pH by PC Titrator								
pH Value	----	0.01	pH Unit	**7.52**	----	----	----	----
EA010P: Conductivity by PC Titrator								
Electrical Conductivity @ 25°C	----	1	µS/cm	**56**	----	----	----	----
ED037P: Alkalinity by PC Titrator								
Hydroxide Alkalinity as CaCO3	DMO-210-001	1	mg/L	<1	----	----	----	----
Carbonate Alkalinity as CaCO3	3812-32-6	1	mg/L	<1	----	----	----	----
Bicarbonate Alkalinity as CaCO3	71-52-3	1	mg/L	**8**	----	----	----	----
Total Alkalinity as CaCO3	----	1	mg/L	**8**	----	----	----	----
ED038A: Acidity								
Acidity as CaCO3	----	1	mg/L	**2**	----	----	----	----
ED041G: Sulfate (Turbidimetric) as SO4 2- by DA								
Sulfate as SO4 - Turbidimetric	14808-79-8	1	mg/L	**9**	----	----	----	----
ED045G: Chloride by Discrete Analyser								
Chloride	16887-00-6	1	mg/L	**9**	----	----	----	----
ED093F: Dissolved Major Cations								
Calcium	7440-70-2	1	mg/L	<1	----	----	----	----
Magnesium	7439-95-4	1	mg/L	<1	----	----	----	----
Sodium	7440-23-5	1	mg/L	**10**	----	----	----	----
Potassium	7440-09-7	1	mg/L	<1	----	----	----	----
EG020F: Dissolved Metals by ICP-MS								
Aluminium	7429-90-5	0.01	mg/L	**0.41**	----	----	----	----
Antimony	7440-36-0	0.001	mg/L	<0.001	----	----	----	----
Arsenic	7440-38-2	0.001	mg/L	**0.005**	----	----	----	----
Cadmium	7440-43-9	0.0001	mg/L	<0.0001	----	----	----	----
Chromium	7440-47-3	0.001	mg/L	<0.001	----	----	----	----
Copper	7440-50-8	0.001	mg/L	<0.001	----	----	----	----
Cobalt	7440-48-4	0.001	mg/L	<0.001	----	----	----	----
Nickel	7440-02-0	0.001	mg/L	<0.001	----	----	----	----
Lead	7439-92-1	0.001	mg/L	<0.001	----	----	----	----
Zinc	7440-66-6	0.005	mg/L	<0.005	----	----	----	----
Manganese	7439-96-5	0.001	mg/L	**0.003**	----	----	----	----
Molybdenum	7439-98-7	0.001	mg/L	**0.002**	----	----	----	----
Selenium	7782-49-2	0.01	mg/L	<0.01	----	----	----	----
Vanadium	7440-62-2	0.01	mg/L	<0.01	----	----	----	----

Analytical Results

Sub-Matrix: WATER (Matrix: WATER)			Client sample ID	KLC 6	----	----	----	----
			Client sampling date / time	05-Dec-2017 00:00	----	----	----	----
Compound	CAS Number	LOR	Unit	EB1725752-006	--------	--------	--------	--------
				Result	----	----	----	----
EG020F: Dissolved Metals by ICP-MS - Continued								
Boron	7440-42-8	0.05	mg/L	<0.05	----	----	----	----
Iron	7439-89-6	0.05	mg/L	**0.07**	----	----	----	----
EK040P: Fluoride by PC Titrator								
Fluoride	16984-48-8	0.1	mg/L	<0.1	----	----	----	----
EN055: Ionic Balance								
Total Anions	----	0.01	meq/L	**0.60**	----	----	----	----
Total Cations	----	0.01	meq/L	**0.43**	----	----	----	----

ALS Environmental

CERTIFICATE OF ANALYSIS

Work Order	: **EB1801935**	Page	: 1 of 6
Client	: **RGS ENVIRONMENTAL PTY LTD**	Laboratory	: Environmental Division Brisbane
Contact	: MR ALAN ROBERTSON	Contact	: Customer Services EB
Address	: PO Box 3091 SUNNYBANK SOUTH QLD, AUSTRALIA 4109	Address	: 2 Byth Street Stafford QLD Australia 4053
Telephone	: +61 07 3344 1222	Telephone	: +61-7-3243 7222
Project	: 2017002 Dingo west	Date Samples Received	: 16-Jan-2018 17:15
Order number	: 2017002	Date Analysis Commenced	: 18-Jan-2018
C-O-C number	: ----	Issue Date	: 22-Jan-2018 14:32
Sampler	: VERONICA CANALES		
Site	: ----		
Quote number	: EN/222/17		
No. of samples received	: 6		
No. of samples analysed	: 6		

NATA

Accreditation No. 825
Accredited for compliance with
ISO/IEC 17025 - Testing

This report supersedes any previous report(s) with this reference. Results apply to the sample(s) as submitted. This document shall not be reproduced, except in full.

This Certificate of Analysis contains the following information:

- General Comments
- Analytical Results

Additional information pertinent to this report will be found in the following separate attachments: Quality Control Report, QA/QC Compliance Assessment to assist with Quality Review and Sample Receipt Notification.

Signatories

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

Signatories	*Position*	*Accreditation Category*
Greg Vogel	Laboratory Manager	Brisbane Inorganics, Stafford, QLD
Kim McCabe	Senior Inorganic Chemist	Brisbane Inorganics, Stafford, QLD

General Comments

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

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

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

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

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

Where a result is required to meet compliance limits the associated uncertainty must be considered. Refer to the ALS Contact for details.

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

- Ionic Balance out of acceptable limits due to analytes not quantified in this report.

Analytical Results

Sub-Matrix: LEACHATE (Matrix: WATER)			Client sample ID	KLC 1	KLC 2	KLC 3	KLC 4	KLC 5
			Client sampling date / time	16-Jan-2018 00:00	16-Jan-2018 00:00	16-Jan-2018 00:00	16-Jan-2018 00:00	16-Jan-2018 00:00
Compound	CAS Number	LOR	Unit	EB1801935-001	EB1801935-002	EB1801935-003	EB1801935-004	EB1801935-005
				Result	Result	Result	Result	Result
EA005P: pH by PC Titrator								
pH Value	----	0.01	pH Unit	**7.74**	**7.06**	**8.42**	**7.68**	**6.82**
EA010P: Conductivity by PC Titrator								
Electrical Conductivity @ 25°C	----	1	µS/cm	**95**	**139**	**229**	**220**	**176**
ED037P: Alkalinity by PC Titrator								
Hydroxide Alkalinity as CaCO3	DMO-210-001	1	mg/L	<1	<1	<1	<1	<1
Carbonate Alkalinity as CaCO3	3812-32-6	1	mg/L	<1	<1	**3**	<1	<1
Bicarbonate Alkalinity as CaCO3	71-52-3	1	mg/L	**11**	**4**	**27**	**45**	**5**
Total Alkalinity as CaCO3	----	1	mg/L	**11**	**4**	**30**	**45**	**5**
ED038A: Acidity								
Acidity as CaCO3	----	1	mg/L	<1	<1	<1	<1	**1**
ED041G: Sulfate (Turbidimetric) as SO4 2- by DA								
Sulfate as SO4 - Turbidimetric	14808-79-8	1	mg/L	**3**	**3**	**21**	**34**	**7**
ED045G: Chloride by Discrete Analyser								
Chloride	16887-00-6	1	mg/L	**22**	**36**	**40**	**30**	**44**
ED093F: Dissolved Major Cations								
Calcium	7440-70-2	1	mg/L	<1	<1	**4**	**4**	<1
Magnesium	7439-95-4	1	mg/L	<1	<1	**2**	**3**	<1
Sodium	7440-23-5	1	mg/L	**18**	**26**	**37**	**33**	**31**
Potassium	7440-09-7	1	mg/L	<1	<1	**2**	**2**	**1**
EG020F: Dissolved Metals by ICP-MS								
Aluminium	7429-90-5	0.01	mg/L	**1.07**	**0.77**	**0.22**	**0.11**	**0.88**
Antimony	7440-36-0	0.001	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001
Arsenic	7440-38-2	0.001	mg/L	**0.002**	<0.001	**0.003**	<0.001	<0.001
Cadmium	7440-43-9	0.0001	mg/L	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Chromium	7440-47-3	0.001	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001
Copper	7440-50-8	0.001	mg/L	**0.002**	**0.001**	**0.002**	<0.001	<0.001
Cobalt	7440-48-4	0.001	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001
Nickel	7440-02-0	0.001	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001
Lead	7439-92-1	0.001	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001
Zinc	7440-66-6	0.005	mg/L	**0.007**	**0.012**	**0.006**	<0.005	**0.179**
Manganese	7439-96-5	0.001	mg/L	**0.003**	**0.010**	**0.003**	**0.006**	<0.001
Molybdenum	7439-98-7	0.001	mg/L	<0.001	<0.001	**0.014**	**0.008**	<0.001
Selenium	7782-49-2	0.01	mg/L	<0.01	<0.01	<0.01	<0.01	<0.01
Vanadium	7440-62-2	0.01	mg/L	<0.01	<0.01	<0.01	<0.01	<0.01

Analytical Results

Sub-Matrix: **LEACHATE** (Matrix: **WATER**)			Client sample ID	**KLC 1**	**KLC 2**	**KLC 3**	**KLC 4**	**KLC 5**
			Client sampling date / time	16-Jan-2018 00:00	16-Jan-2018 00:00	16-Jan-2018 00:00	16-Jan-2018 00:00	16-Jan-2018 00:00
Compound	*CAS Number*	*LOR*	*Unit*	**EB1801935-001**	**EB1801935-002**	**EB1801935-003**	**EB1801935-004**	**EB1801935-005**
				Result	Result	Result	Result	Result
EG020F: Dissolved Metals by ICP-MS - Continued								
Boron	7440-42-8	0.05	mg/L	**0.06**	**0.06**	<0.05	<0.05	**0.06**
Iron	7439-89-6	0.05	mg/L	**0.21**	**0.13**	<0.05	<0.05	**0.32**
EK040P: Fluoride by PC Titrator								
Fluoride	16984-48-8	0.1	mg/L	<0.1	**0.2**	<0.1	<0.1	<0.1

Analytical Results

Sub-Matrix: LEACHATE
(Matrix: WATER)

Compound	CAS Number	LOR	Unit	KLC 6	----	----	----	----
			Client sampling date / time	16-Jan-2018 00:00	----	----	----	----
				EB1801935-006	--------	--------	--------	--------
				Result	----	----	----	----
EA005P: pH by PC Titrator								
pH Value	----	0.01	pH Unit	**7.51**	----	----	----	----
EA010P: Conductivity by PC Titrator								
Electrical Conductivity @ 25°C	----	1	µS/cm	**67**	----	----	----	----
ED037P: Alkalinity by PC Titrator								
Hydroxide Alkalinity as $CaCO_3$	DMO-210-001	1	mg/L	<1	----	----	----	----
Carbonate Alkalinity as $CaCO_3$	3812-32-6	1	mg/L	<1	----	----	----	----
Bicarbonate Alkalinity as $CaCO_3$	71-52-3	1	mg/L	**12**	----	----	----	----
Total Alkalinity as $CaCO_3$	----	1	mg/L	**12**	----	----	----	----
ED038A: Acidity								
Acidity as $CaCO_3$	----	1	mg/L	**2**	----	----	----	----
ED041G: Sulfate (Turbidimetric) as SO_4 2- by DA								
Sulfate as SO_4 - Turbidimetric	14808-79-8	1	mg/L	**10**	----	----	----	----
ED045G: Chloride by Discrete Analyser								
Chloride	16887-00-6	1	mg/L	**7**	----	----	----	----
ED093F: Dissolved Major Cations								
Calcium	7440-70-2	1	mg/L	<1	----	----	----	----
Magnesium	7439-95-4	1	mg/L	<1	----	----	----	----
Sodium	7440-23-5	1	mg/L	**13**	----	----	----	----
Potassium	7440-09-7	1	mg/L	**1**	----	----	----	----
EG020F: Dissolved Metals by ICP-MS								
Aluminium	7429-90-5	0.01	mg/L	**1.29**	----	----	----	----
Antimony	7440-36-0	0.001	mg/L	<0.001	----	----	----	----
Arsenic	7440-38-2	0.001	mg/L	**0.008**	----	----	----	----
Cadmium	7440-43-9	0.0001	mg/L	<0.0001	----	----	----	----
Chromium	7440-47-3	0.001	mg/L	<0.001	----	----	----	----
Copper	7440-50-8	0.001	mg/L	<0.001	----	----	----	----
Cobalt	7440-48-4	0.001	mg/L	<0.001	----	----	----	----
Nickel	7440-02-0	0.001	mg/L	<0.001	----	----	----	----
Lead	7439-92-1	0.001	mg/L	<0.001	----	----	----	----
Zinc	7440-66-6	0.005	mg/L	<0.005	----	----	----	----
Manganese	7439-96-5	0.001	mg/L	**0.002**	----	----	----	----
Molybdenum	7439-98-7	0.001	mg/L	**0.002**	----	----	----	----
Selenium	7782-49-2	0.01	mg/L	<0.01	----	----	----	----
Vanadium	7440-62-2	0.01	mg/L	<0.01	----	----	----	----

Analytical Results

Sub-Matrix: LEACHATE (Matrix: WATER)			Client sample ID	KLC 6	----	----	----	----
			Client sampling date / time	16-Jan-2018 00:00	----	----	----	----
Compound	CAS Number	LOR	Unit	EB1801935-006	--------	--------	--------	--------
				Result	----	----	----	----
EG020F: Dissolved Metals by ICP-MS - Continued								
Boron	7440-42-8	0.05	mg/L	<0.05	----	----	----	----
Iron	7439-89-6	0.05	mg/L	**0.16**	----	----	----	----
EK040P: Fluoride by PC Titrator								
Fluoride	16984-48-8	0.1	mg/L	<0.1	----	----	----	----

RGS

LEADERS IN MINING
GEOCHEMISTRY

Appendix H Geochemical Assessment of Coal Reject Material

TECHNICAL REPORT

Geochemical assessment of coal reject material

Gemini Coal Project

***Prepared for*:** **Magnetic South Pty Ltd**

LEADERS IN MINING GEOCHEMISTRY

TECHNICAL REPORT

Geochemical assessment of coal reject material

Gemini Coal Project

Prepared for: **Magnetic South Pty Ltd**

DOCUMENT CONTROL			
Project Title	**Geochemical assessment of coal reject material**		
Client Name	**Magnetic South Pty Ltd**		
Project Number	**2017002**		

DOCUMENT DISTRIBUTION			
Document File Name	**Document Status**	**Distributed to**	**Date distributed**
2017002 Gemini Rejects Rev A	**Draft**	**Magnetic South Pty Ltd**	**4 September 2019**
2017002 Gemini Rejects Rev B	**Final**	**Magnetic South Pty Ltd**	**20 September 2019**
2017002 Gemini Rejects Rev C	**Final**	**Magnetic South Pty Ltd**	**15 March 2020**

Table of Contents

1 Introduction 1
1.1 Background 1
1.2 Previous Studies 2
1.3 Scope of work 2
1.4 Local geology 3
2 Methodology 4
2.1 Sample selection and preparation 4
2.2 Geochemical test program 5
2.2.1 Static tests 5
2.2.2 Kinetic tests 6
3 Results 7
3.1 ABA results 7
3.1.1 pH and EC 7
3.1.2 Total sulfur 8
3.1.3 Sulfide sulfur 9
3.1.4 Maximum potential acidity 9
3.1.5 Acid neutralising capacity 9
3.1.6 Net acid producing potential 9
3.1.7 ANC:MPA ratio 10
3.1.8 Geochemical classification 11
3.2 Multi-element concentration in solids 11
3.3 Geochemical abundance index 12
3.4 Water quality static tests 13
3.5 Water quality kinetic tests 14
3.5.1 Leachate chemistry 14
3.5.2 Sulfide oxidation and sulfate generation rates 15
4 Discussion 16
4.1 AMD potential and management 16
4.2 Multi-element composition and water quality 16
4.2.1 Multi-element composition and enrichment 16
4.2.2 Water quality 16
5 Conclusions and Recommendations 18
5.1 Conclusions 18
5.2 Recommendations 18
6 References 19

List of Figures

Figure 3.1: pH results 7
Figure 3.2: Electrical conductivity results 7
Figure 3.3: Total sulfur results 8
Figure 3.4: Sulfide sulfur results 9
Figure 3.5: Net acid producing potential results 10
Figure 3.6: ANC vs MPA 10

List of Tables

Table 2.1: Composite coal reject samples generated 4
Table 2.2: KLC material description 6
Table 3.1: Salinity and pH criteria for assessment of coal reject 8
Table 3.2: Geochemical classification criteria for coal reject 11
Table 3.3: Geochemical Abundance Index values and Enrichment Factors 12
Table 3.4: Major ion concentrations in solution 13
Table 3.5: Sulfate Generation and Sulfide Oxidation Rates for KLC tests on coal reject 15

List of Attachments

Attachment A Figures
Attachment B Geochemical assessment methods for mining waste materials
Attachment C Static geochemical results
Attachment D Kinetic geochemical results
Attachment E ALS laboratory results

1 Introduction

1.1 Background

Magnetic South Pty Ltd (Magnetic South) is the project proponent and the applicant for the Mining Lease (ML) and Environmental Authority (EA) to develop the Gemini Project (the Project), a greenfield open cut mine to produce pulverised coal injection (PCI) coal and Coking Coal products for export for steel production. The Project term is anticipated to be 25 years from grant of the ML with this term including initial construction, mine operation and rehabilitation activities.

The Project is located on EPC 881 in the Bowen Basin, Central Queensland. Located 20 km east of Bluff and 6 km west of Dingo, the tenement straddles the Capricorn Highway and the Blackwater-Gladstone rail network (**Figure A1**, **Attachment A**).

The main activities associated with the Project include:

- Exploration activities continuing in order to support mine planning.
- Development of a Mine Infrastructure Area (MIA) including mine offices, bathhouse, crib rooms, warehouse/stores, workshop, fuel storage, refuelling facilities, explosives magazine and sewage, effluent and liquid waste storage.
- Construction and operation of a Coal Handling Preparation Plant (CHPP) and coal handling facilities adjacent to the MIA (including Run-of-Mine (ROM) coal, product stockpiles and reject stockpiles [coarse and fine rejects]).
- Construction and operation of a surface conveyor from the product stockpiles to a Train Load Out (TLO) facility and rail loop connecting to the Blackwater-Gladstone Branch Rail to transport product coal to coal terminals at Gladstone for export.
- Construction of access roads from the Capricorn Highway to the MIA, and to the TLO facility.
- Installation of a raw water supply pipeline to connect to the Blackwater Pipeline network.
- Construction of a 66 kV transmission line and switching/substation to connect to the existing regional network.
- Other associated minor infrastructure, plant, equipment and activities.
- Development of mine areas (open cut pits) and out-of-pit waste rock emplacements.
- Drilling and blasting of competent waste material.
- Mine operations using conventional surface mining equipment (excavators, front end loaders, rear dump trucks, dozers).
- Mining up to 1.9 Mtpa ROM Coal – average 1.8 Mtpa for an operational mine life of approximately 20 years.
- Progressive placement of waste rock (overburden/interburden) in:
  - Emplacements, adjacent to and near the open cut voids.
  - Mine voids, behind the advancing open cut mining operations.
- Progressive rehabilitation of waste rock emplacement areas and mined voids.
- Progressive establishment of soil stockpiles, laydown area and borrow pits (for road base and civil works). Material will be sourced from local quarries where required.
- Disposal of CHPP rejects (coarse and fine rejects) in out of pit waste rock emplacements, and in-pit behind the mining void.

- Progressive development of internal roads and haul roads including a causeway over Charlevue Creek to enable coal haulage and pit access.
- Development of water storage dams and sediment dams, and the installation of pumps, pipelines, and other water management equipment and structures including temporary levees, diversions and drains.

Existing local and regional infrastructure, facilities and services will be used to support Project activities. These include the SunWater water distribution network, the Aurizon rail network, Ergon's electricity network, the Capricorn Highway, and Gladstone export coal terminals.

The proposed mine will target the Rangal coal measures. Up to seven seams/plies are targeted, ranging in thickness from 0.5 m to 3.0 m. The seams are impacted by faulting and seam splitting and are typically overlain by overburden ranging in depth from 45 m to 60 m.

As part of the technical studies being completed for input into the environmental approvals process, RGS Environmental Pty Ltd (RGS) was commissioned by Magnetic South to complete a geochemical assessment of potential coal reject material at the Project.

1.2 Previous Studies

RGS previously completed a geochemical assessment of representative samples of mining waste materials at the Project focussing on overburden and interburden materials (RGS, 2018). The assessment found that the mining waste materials were non-acid forming (NAF), with excess acid neutralising capacity (ANC), and typically low sulfur content. Where higher sulfur was present in coal and carbonaceous siltstones, it was mainly present as non-sulfidic sulfide, and unlikely to contribute to acid generation. Overall, the mining waste materials were found to have a high factor of safety and a very low risk of acid generation. Overall, initial and ongoing surface runoff and seepage from mining waste materials represented by the samples tested was expected to be moderately alkaline and have a moderate level of salinity.

The mining waste materials contained low concentration of total metals/metalloids compared to median crustal abundance in non-mineralised soils, and most metals/metalloids were expected to be sparingly soluble at the neutral to alkaline pH of leachate from bulk mining waste materials. Dissolved metal/metalloid concentrations in surface runoff and leachate from bulk mining waste materials were predicted to be low and unlikely to pose a significant risk to the quality of surface and groundwater resources at relevant storage facilities.

Mining waste materials were found to be amenable to revegetation as part of rehabilitation activities, although, it was suggested that sodic materials could require gypsum and fertiliser amendment to limit dispersion and erosion and to provide a reasonable growth medium for revegetation and rehabilitation. Rehabilitation field trials on bulk materials were recommended to be completed during the operational phase of the mine to determine the most appropriate management option for progressive rehabilitation and at mine closure.

1.3 Scope of work

The objective of the work program was to complete a geochemical assessment of representative samples of potential coal reject materials as part of the mine assessment and approvals process. The scope of work was developed by RGS based upon information provided to RGS by Magnetic South as well as previous site experience (RGS, 2018) and included:

- Selection of samples to best represent the coal reject materials;
- Coordination of the geochemical analysis program;
- Geochemical characterisation of the samples utilising both static and kinetic testing methods; and
- Preparation of a report to discuss the sample analysis results.

The work program was completed in accordance with relevant industry guidelines (DME, 1995, DEHP, 2013; COA, 2016a,b,c; and INAP, 2009).

1.4 Local geology

The project is located within the Dawson Fold Zone of the Bowen Basin. The project is focussed on the Rangal Coal Measures – Permian aged sediments consisting of siltstones, sandstone and coal seams. Up to seven seams/plies are planned to be targeted, ranging in thickness from 0.5 to 3.0 m. Typically, overburden in the project area ranges in depth from 45 m to 60 m, with varying interburden thicknesses between the seams. A representative stratigraphic column of the project area is shown in **Figure A2 (Attachment A)**.

Seams within the Rangal Coal Measures Seams (particularly the Aries, Castor and Pollux seams) commonly coalesce and split. The coal quality across the deposit is variable, but it generally described as low-volatile bituminous coal with moderate ash, sulfur and phosphorous. The geochemical assessment completed by RGS (RGS, 2018) on the overburden and interburden present at the proposed project indicated that the carbonaceous siltstone and coal material present at the site had elevated sulfur, mainly in the form of non-sulfide sulfur (ie., non-acid generating). The clay, sandstone and siltstone present showed sulfur concentrations below natural background concentration (ie., less than 0.1 %S).

2 Methodology

RGS personnel worked (Dr. Alan Robertson) worked closely with Magnetic South personnel and related coal quality consultants to facilitate the development of an appropriate sampling and geochemical testing plan for representative samples of coal reject materials from the Project.

2.1 Sample selection and preparation

The sampling methodology used to obtain representative samples of coal reject materials from the proposed Project area was undertaken in accordance with relevant guideline documents. Whilst there are no specific regulatory requirements regarding the number of samples required, existing risk-based technical guidelines for the geochemical assessment of mine rock in Australia (AMIRA, 2002; COA, 2016c) and worldwide (INAP, 2009) were used by RGS as a framework for the sampling program.

The sampling strategy was based on:

- Existing knowledge of the geology/stratigraphy and geochemistry of the site and expected low potential for any significant environmental or health impacts;
- Size of operation;
- Sample representation requirements;
- Material volumes;
- Level of confidence in predictive ability; and
- Cost.

A total of 80 coal reject samples from coal quality washability tests were provided to RGS from 14 different drill holes, which consisted of 52 coarse reject and 28 fine reject samples. The location of the drill holes in relation to the site is shown in **Figure A3** (**Attachment A**). The samples were combined into 22 composite samples by reject type and coal seam/ply (14 coarse reject samples and 8 fine reject samples). **Table 2.1** provides the number of combined samples generated for each coal seam.

Table 2.1: Composite coal reject samples generated

Coal Seam	Reject Type	Number of samples
AR2	Coarse	1
	Fine	1
AR3	Coarse	2
	Fine	1
CAS	Coarse	4
	Fine	2
PLU1	Coarse	5
	Fine	2
PLU2	Coarse	2
	Fine	2
Total		**22**

Samples were sent to Australian Laboratory Services (ALS) in Stafford Queensland. Once received, samples were prepared by crushing (where required) and pulverising to less than 75 µm size. This method of sample preparation results in a homogenous sample, but also generates a large sample surface area in contact with the resultant assay solution. This provides a greater potential for dissolution and reaction and represents an assumed initial 'worst case' scenario for these materials.

2.2 Geochemical test program

A series of geochemical tests were completed on the samples. The test program was designed to assess the degree of risk from the presence and potential oxidation of sulfides, and generation and the presence/leaching of soluble metals/metalloids and salts. A detailed summary of the parameters involved in completing a static and kinetic geochemical characterisation and assessment of mine materials is provided in **Attachment B**.

2.2.1 Static tests

Static geochemical tests provide a 'snapshot' of the characteristics of a sample material at a single point in time. These tests were staged to screen individual samples before selecting either individual and/or composite samples for more detailed static test work.

The Acid Base Account (ABA) was used as a screening procedure whereby the acid-neutralising and acid-generating characteristics of the samples were assessed. All 22 composite samples were screened using ABA. The ABA screening included static geochemical testing for the following parameters:

- pH (1:5 w:v, sample:deionised water);
- Electrical conductivity (EC) (1:5 w:v, sample:deionised water);
- Total sulfur [Leco method]; and
- Acid neutralising capacity (ANC) [AMIRA, 2002 method].

The results of the ABA tests are discussed in **Section 3.1**. After the results of the ABA screening test were received and interpreted, a total of 13 samples were also tested for sulfide sulfur as chromium reducible sulfur (Scr) using the Australian Standard (AS 4969.7, 2008) method. The remaining 9 samples did not have sufficient sample mass remaining for Scr analysis to be carried out.

From the total sulfur (or Scr where available) and ANC results, maximum potential acidity (MPA) and net acid producing potential (NAPP) values were calculated. Where available, the MPA and NAPP of these samples were calculated using the Scr data instead of total sulfur data. The use of Scr data (for fresh samples) provides a more accurate representation of the MPA that could theoretically be generated, as acid generation primarily occurs from reactive sulfide, whereas total sulfur can include other sulfur forms such as elemental sulfur, sulfate and organic sulfur.

After the results of the initial static geochemical tests were received and reviewed, all 22 samples were used to create three composite samples – one representing coarse reject material from the Castor (CAS) and Aries (AR) seams; one representing coarse reject material from the Pollox (PLU1 and PLU2) seams; and one representing fine reject material. All the composite samples were subjected to multi-element testing at ALS. The samples were tested for:

- pH and EC (1:5 w:v, sample:deionised water);
- Major Cations (Ca, Mg, K, Na) [HCl and HNO_3 acid digest followed by ICP-AES/MS];
- Major Anions (Cl, SO_4, F) [ICP-AES/MS and PC Titrator (1:5 w:v water extracts)].
- Acidity and Alkalinity as $CaCO_3$ mg/L [PC Titrator (1:5 w:v water extracts)];
- Total metals/metalloids in solids (Al, As, B, Ba, Be, Ca, Cd, Cr, Co, Cu, Fe, Hg, K, Mg, Mn, Mo, Na, Ni, Pb, Sb, Se, Si, Th, U, V, Zn) [HCl and HNO_3 acid digest followed by FIMS and/or ICP-AES/MS]; and
- Soluble metals/metalloids (Al, As, B, Ba, Be, Ca, Cd, Cr, Co, Cu, Fe, Hg, K, Mg, Mn, Mo, Na, Ni, Pb, Sb, Se, Si, Th, U, V, Zn) [ICP-AES/MS and FIMS (1:5 w:v water extracts)];

The ALS test results for the static geochemical test program are provided in **Attachment E**, and summary results tables provided in **Attachment C**. The static test results are discussed in **Sections 3.1** to **3.4**.

2.2.2 Kinetic tests

Following receipt and interpretation of the static geochemical test results, two kinetic leach column (KLC) tests were set up at the RGS 'in house' laboratory. One KLC was set up using material from the coarse reject samples, while the second KLC was set up using material from the fine coal reject samples. The KLC tests began in May 2019 on a monthly watering and leaching cycle and were operated for a period of six months until November 2019. A description of the material represented by each KLC is shown below in **Table 2.2**.

Table 2.2: KLC material description

KLC Sample #	Description
KLC1	Coarse reject
KLC2	Fine reject

Approximately 1.5 kg of each composite sample was accurately weighed and used in each of the KLC tests. Heat lamps were used daily to simulate sunshine and ensure that the KLC materials were unsaturated and subject to oxidising conditions between leaching events (this is essentially an assumed "worst case" scenario for sulfide oxidation and potential acid/salt generation). Further details and a schematic of the KLC test arrangement are provided in **Attachment B**.

All leachate samples collected from the KLC tests were assayed at ALS Brisbane for:

- pH and EC
- Acidity and alkalinity [PC Titrator]
- Dissolved metals/metalloids (Al, As, B, Cd, Co, Cr, Cu, Fe, Mn, Mo, Ni, Pb, Sb, Se, V and Zn) [ICP-AES/MS];
- Dissolved major cations (Ca, Mg, Na and K) [ICP-AES/MS]; and
- Dissolved major anions (Cl, SO_4) and F [ICP-AES/MS].

The ALS test results for the kinetic geochemical test program are provided in **Attachment E**, and summary results tables and trends provided in **Attachment D**. The kinetic test results are discussed in **Section 3.5**.

3 Results

3.1 ABA results

ABA test results for the 22 composite coal reject samples from the Project are presented in **Table C1** (**Attachment C**) and summarised below. The results are shown by reject type to facilitate interpretation.

3.1.1 pH and EC

The natural pH of the deionised water used in the pH tests is typically in the pH range of 5.0 to 6.5. The $pH_{(1:5)}$ of the 22 samples ranges from 5.1 to 8.3 (**Figure 3.1**) and has a median pH value of 7.4. The pH results indicate that the coal reject materials are typically in the pH neutral range. There does not appear to be any significant correlation between pH and reject type or coal seam/ply.

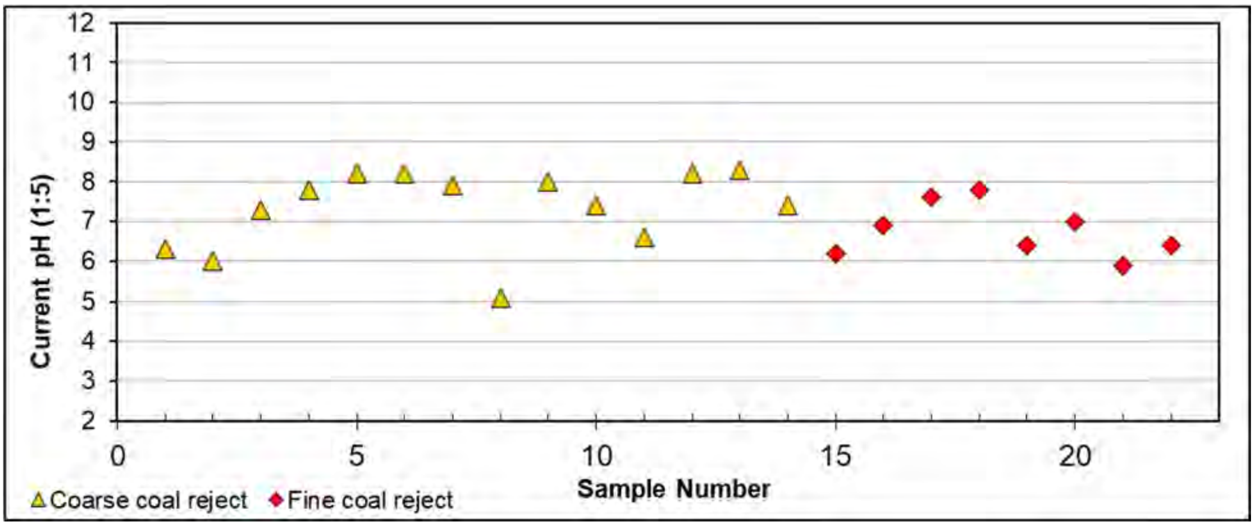


Figure 3.1: pH results for coal reject

The current $EC_{(1:5)}$ of the samples ranges from 398 to 1,620 µS/cm (median 774 µS/cm) (**Figure 3.2)**. There appears to be no significant correlation between EC and reject type or coal seam/ply.

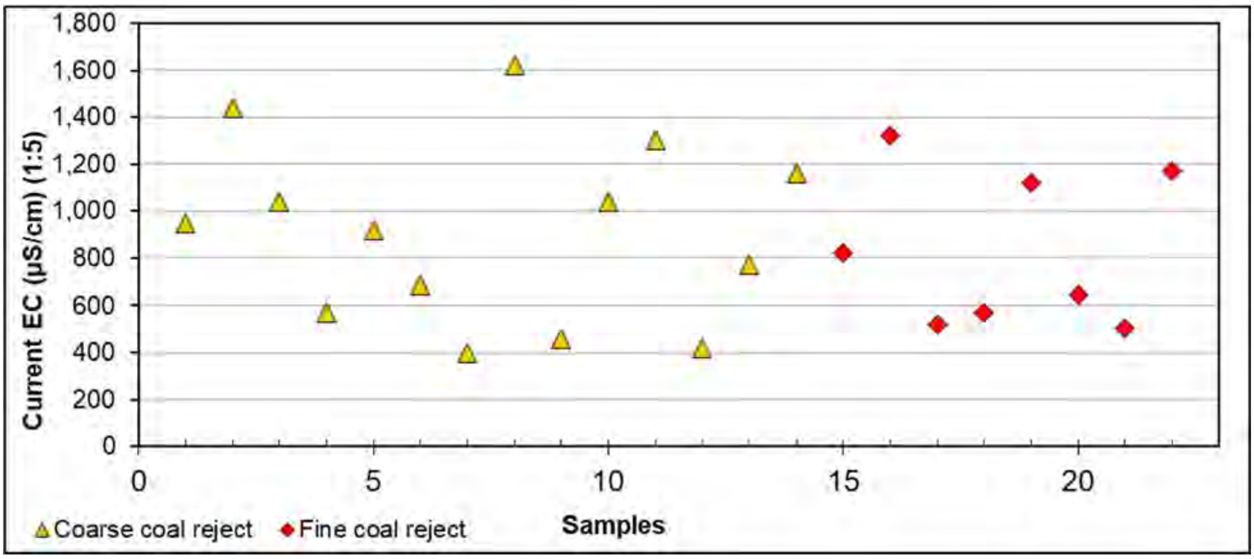


Figure 3.2: Electrical conductivity results for coal reject

To provide additional context, the $EC_{(1:5)}$ and $pH_{(1:5)}$ results are classified against pH and salinity criteria for mining waste materials, as defined by the Queensland DME (1995) technical guidelines for the environmental management of exploration and mining in Queensland (see **Table 3.1** below).

Table 3.1: Salinity and pH criteria for assessment of coal reject

	Very Low	Low	Medium	High	Very High
$pH_{1:5}$	**< 4.5**	**4.5 – 5.5**	**5.5 – 7.0**	**7.0 – 9.0** (Median – 7.4)	**> 9.0**
$EC_{1:5}$ (µS/cm)	**< 150**	**150 – 450**	**450 – 900** (Median – 774)	**900 – 2,000**	**> 2,000**

Note: Adapted from DME, 1995. Highlighted cells show the category corresponding to the median pH and EC values (orange shading) for the coal reject samples.

Based on the median pH and EC values, the coal reject samples tested are generally regarded as having 'high' soil pH and 'medium' salinity values.

The pH and EC tests were obtained from pulverised samples (≤ 75 µm) with a large surface area in contact with the leaching solution. This provides a greater potential for dissolution and reaction and represents an assumed initial 'worst case' scenario. It is also expected that the salinity of leachate from coal reject materials will diminish with time as salts are flushed from the sample matrix and a state of equilibrium develops. At that point, the salinity of seepage/runoff should stabilise at a lower asymptotic concentration relative to the oxidation/weathering/erosion of the materials.

3.1.2 Total sulfur

The total sulfur content of the samples ranges from 0.23 to 4.20 %S and has a median value of 1.03 %S, compared with the median crustal abundance value of 0.07 %S in unmineralised soils (Bowen, 1979; INAP, 2009). Materials containing greater than 0.1 %S are considered to potentially have some capacity to generate acidity. **Figure 3.3** provides the sulfur content of the sample materials and shows that most coal reject samples have a total sulfur concentration above median crustal abundance.

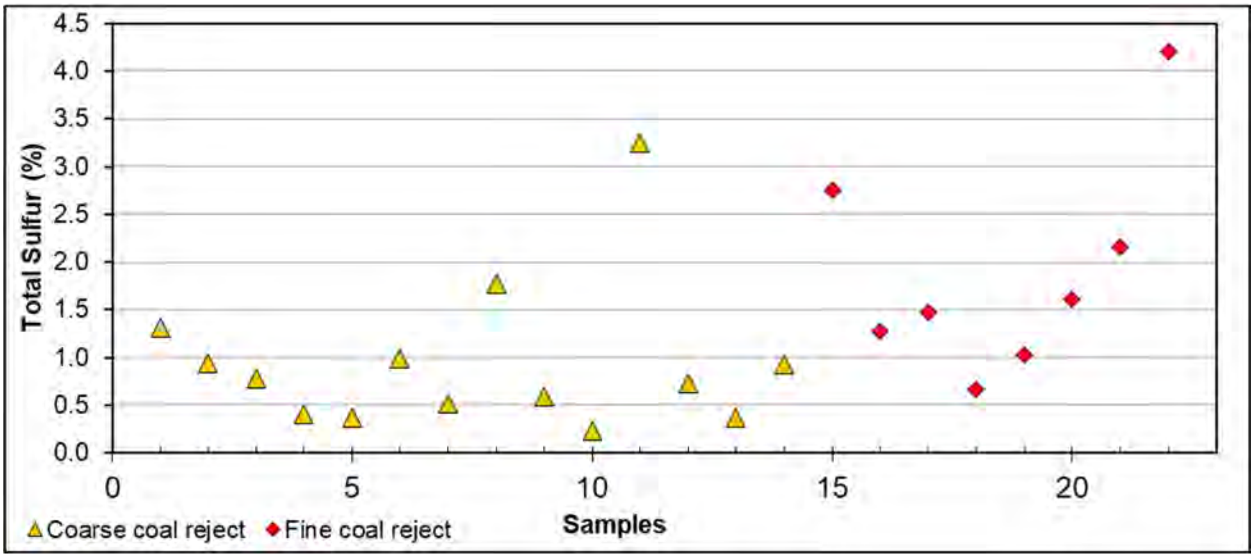


Figure 3.3: Total sulfur results for coal reject

3.1.3 Sulfide sulfur

The sulfide sulfur content for the 13 samples tested using the Scr method is illustrated in **Figure 3.4** . Sample 1 (coarse reject) and Samples 15 to 22 (fine reject) were not tested due to a lack of available sample material. The test results show a sulfide content ranging from 0.12 to 3.22 %S. The results indicate that, on average, more than half of the total sulfur content is present as sulfide sulfur (most likely pyrite/marcasite) and may have some potential to generate acidity.

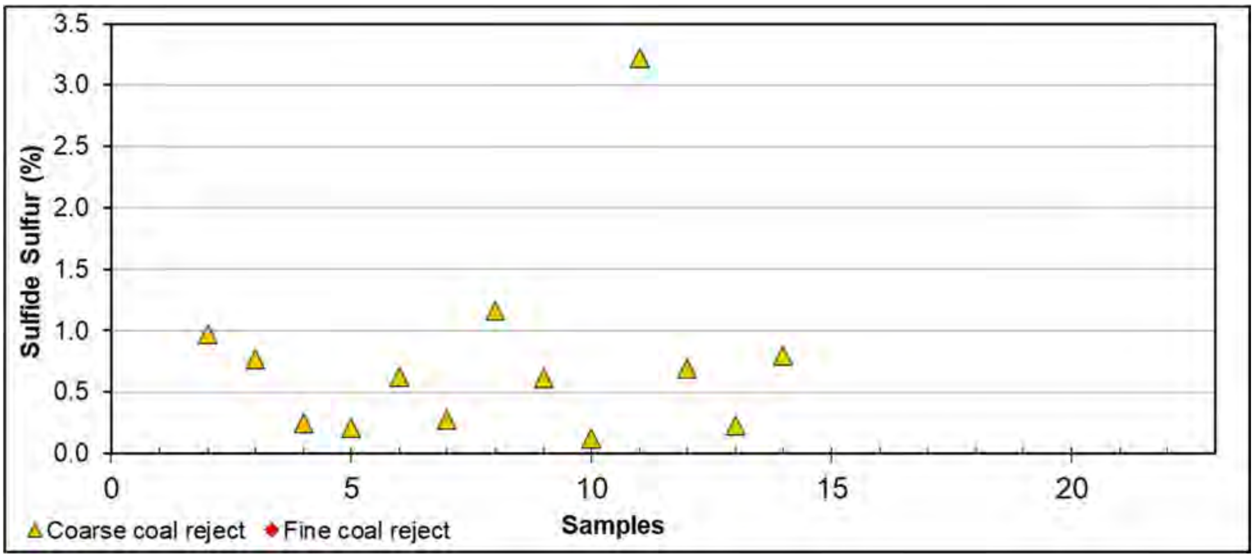


Figure 3.4: Sulfide sulfur results for coal reject

3.1.4 Maximum potential acidity

The Maximum Potential Acidity (MPA) for the reject samples ranges from 3.7 to 128.6 kg H_2SO_4/t, and has a median value of 31.5 kg H_2SO_4/t.

3.1.5 Acid neutralising capacity

The Acid Neutralising Capacity (ANC) for the reject samples ranges from 11.5 to 396.0 kg H_2SO_4/t and has a median value of 68.5 kg H_2SO_4/t (approximately double the median MPA).

3.1.6 Net acid producing potential

The Net Acid Producing Potential (NAPP) is the capacity of a sample to generate acidity (MPA) minus its capacity to neutralise acidity (ANC). The NAPP values for the reject samples range from -351.0 to 72.7 kg H_2SO_4/t, with a negative median value of -33.4 kg H_2SO_4/t (**Figure 3.5**). Sixteen (16) of the 22 coal reject samples have a negative NAPP value and six coal reject samples have a positive NAPP value.

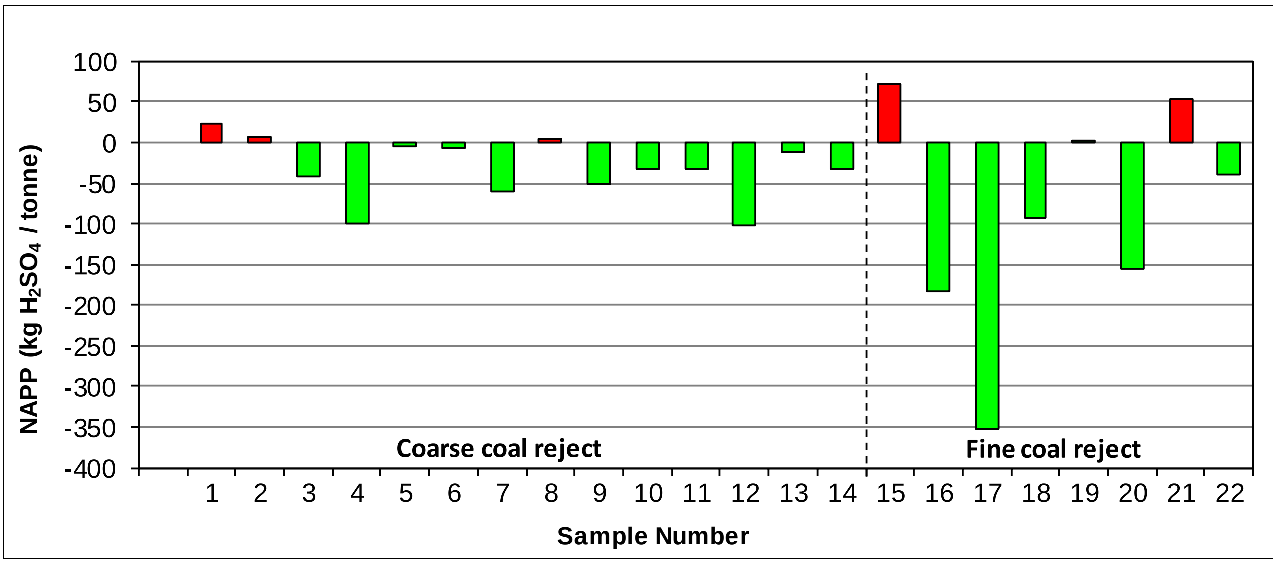


Figure 3.5: NAPP results for coal reject

3.1.7 ANC:MPA ratio

The ANC:MPA ratio of the samples ranges from 0.1 to 9.8, with a median value of 2.7. **Figure 3.6** shows a plot of the ANC versus MPA values for the samples. ANC:MPA ratio lines have been plotted on the graph to illustrate the factor of safety associated with the samples in terms of potential for generation of acid and metalliferous drainage (AMD). Generally, samples with an ANC:MPA ratio of greater than 2 are considered to represent material with a low to negligible risk of acid generation and a high factor of safety in terms of potential for AMD (COA, 2016c; INAP, 2009).

A total of 12 samples fall in the low to negligible risk categories, whilst 5 samples fall in the possible risk category, and 5 samples fall in the increased risk category.

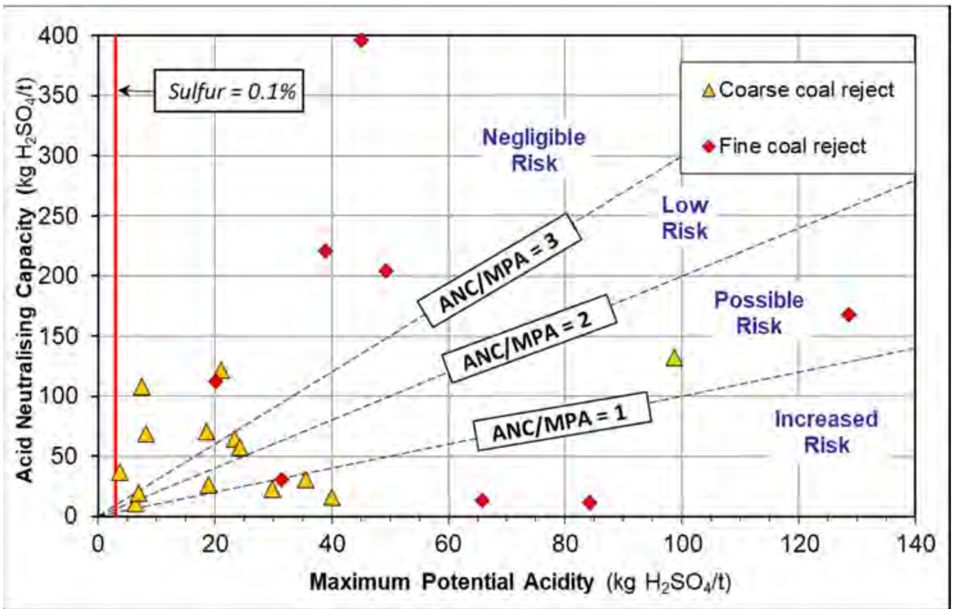


Figure 3.6: ANC vs MPA for coal reject

3.1.8 Geochemical classification

The results of the ABA testing have been used to classify the acid forming nature of the 22 coal reject samples. The classification criteria reflect Australian (COA, 2016c) and international (INAP, 2009) guidelines for the classification of mine waste materials. **Table 3.2** summarises the criteria used by RGS and gives a breakdown of the number of samples in each category.

Table 3.2: Geochemical classification criteria for coal reject

Geochemical Classification	Total Sulfur[1] (%)	NAPP (kg H_2SO_4/t)	ANC:MPA Ratio	No. Samples (n = 22)
Non-Acid Forming	> 0.1	≤ -5	≥ 2	15
Uncertain	> 0.1	> -5 and ≤ +5	≥ 1	2
Potentially Acid Forming (Low Capacity)	> 0.1	> +5 and ≤ +10	< 1	2
Potentially Acid Forming	> 0.1	> +10	< 1	3

The data presented in **Table 3.2** illustrate that 15 of the 22 samples tested (68 %) are classified as non-acid forming (NAF) as a result of the excess ANC present in these samples. Two samples are classified as Uncertain and have a low NAPP value that is negative or close to zero. Two samples are classified as potentially acid forming (low capacity) (PAF-LC) and have a positive NAPP value between 5 and 10 kg H_2SO_4/t. Three samples are classified as PAF and have a positive NAPP value greater than 10 kg H_2SO_4/t .

Whilst there is no strong correlation between the reject material type or coal seam/ply source, two of the three samples classified as PAF were sourced from the AR2 seam/ply and one was sources from the PLU2 seam/ply. Whilst AR seam/plys were included in this assessment, the AR seam coal reject materials make up a small fraction of the overall total coal reject materials likely to be generated at the Project. In addition, two of the three samples classified as PAF represent fine coal reject material which again makes up a relatively small fraction of the total coal reject materials, compared to coarse coal reject materials.

It is expected that blending of the coal reject materials during co-disposal at the Project will result in a bulk coal reject material that is classified as NAF. Most coal reject materials represented by the samples tested have excess ANC and is likely to provide a significant source of buffering to any acidity generated from the small proportion of PAF materials.

3.2 Multi-element concentration in solids

Multi-element assays were carried out on the three composite coal reject samples described in **Section 2.2.1** to identify any elements (metals/metalloids) present in these materials at concentrations that may be of environmental concern with respect to revegetation and surface water/groundwater quality. The total metals/metalloids concentration for individual elements in these materials can be relevant for revegetation activities and/or where the potential exists for human contact (eg. if the material was to be used off-site).

The results from the multi-element tests (total metals/metalloids) are shown in **Table C2** (**Attachment C**). For comparison, guideline values from the National Environmental Protection Measure (NEPM) (NEPC, 2013) are shown for some elements. Where no guideline values are listed, none are specified in the NEPM. All major, minor and trace elements tested returned values below those listed in the NEPM for Health-Based Investigation Level – HIL (C); public open spaces - recreational land use.

3.3 Geochemical abundance index

Total metal/metalloid concentrations in mining waste materials can be compared to the median crustal abundance for un-mineralised soils (Bowen, 1979, COA, 2016c and INAP, 2009). The extent of enrichment is reported as the Geochemical Abundance Index (GAI), which relates the actual concentration in a sample with the median (or average) crustal abundance on a $\log_{10}$ scale. The GAI is expressed in integer increments from 0 to 6, where a GAI value of 0 indicates that the element is present at a concentration less than, or similar to, the median crustal abundance; and a GAI value of 6 indicates approximately a 100-fold enrichment above median crustal abundance (see **Table 3.3**).

Table 3.3: Geochemical Abundance Index values and Enrichment Factors

GAI	Enrichment Factor	GAI	Enrichment Factor
-	Less than 3-fold enrichment	**4**	24 – 48 fold enrichment
1	3 – 6 fold enrichment	**5**	48 – 96 fold enrichment
2	6 – 12 fold enrichment	**6**	Greater than 96 fold enrichment
3	12 – 24 fold enrichment		

As a general rule, a GAI of 3 or greater signifies enrichment that may warrant further examination. This is particularly the case with some environmentally important 'trace' elements, such as arsenic, chromium, cadmium, copper, lead, selenium and zinc, more so than with major rock-forming elements, such as aluminium, calcium, iron, manganese and sodium.

Elements identified as enriched may not necessarily be a concern for revegetation, drainage water quality or public health, but their significance should still be evaluated. While the GAI provides an indication of metals/metalloids that may be enriched relative to the global median crustal abundance, the following points should also be considered:

- The median crustal abundance varies between different literature sources, therefore affecting the calculated GAI values.
- If a sample is shown to be enriched relative to the median crustal abundance, there is no direct correlation that that sample will also leach metals/metalloids at elevated concentrations. The mobility of metals/metalloids is dependent on mineralogy, adsorption/desorption and the environment in which it occurs.
- Whilst some element concentrations can be elevated relative to the median crustal abundance, the nature of an ore deposit means the background levels are generally expected to be elevated.

Similarly, because an element is not enriched does not mean it will never be a concern, because under some conditions (eg. low pH) the solubilities of common environmentally important elements such as aluminium, copper, cadmium, iron and zinc increase significantly.

Table C3 (**Attachment C**) provides total metal/metalloid concentrations for the three composited samples described in **Section 2.2**, and is compared to median crustal abundance (GAI). The GAI results indicate that of the metals/metalloids measured, none are significantly enriched compared to median crustal abundance. Hence, further examination is not considered necessary.

The potential solubility and mobility of any metals/metalloids in the materials was investigated further through water extract tests and the results are presented in **Section 3.4**.

3.4 Water quality static tests

There are no specific regulatory criteria for metal/metalloid concentrations in leachate from mining waste material on mine sites in Queensland. As such, RGS has compared the multi-element results in water extracts from the selected composite samples with the Australian guideline values for livestock drinking water and aquatic freshwater eco-systems (ANZECC and ARMCANZ, 2000). These guidelines are provided for context only and are not intended to be interpreted as "maximum permissible levels" for site water storage or discharge.

It should also be recognized that direct comparison of geochemical data with guideline values can be misleading. For the purpose of this study, guideline values are only provided for broad context and should not be interpreted as arbitrary "maximum" or "trigger" values. Using sample pulps (ground to passing 75 µm) provides a high surface area to solution ratio, which encourages mineral reaction and dissolution of the solid phase. The results on screening tests on water extract solutions is assumed to represent a "worst case" scenario for initial surface runoff and seepage from mining waste materials.

The results from multi-element testing of water extracts (1:5 solid:water) from the samples are presented in **Table C4** (**Attachment C**). The pH of the water extracts ranges from pH 8.0 to 8.5 (median 8.0) and is considered to be slightly alkaline and within the range for 95 % species protection in freshwater aquatic ecosystems as set out in ANZECC and ARMCANZ (2000).

The alkalinity value in the water extract samples is dominated by bicarbonate and significantly exceeds any acidity value, such that the net alkalinity value is strongly positive. This results confirms that bulk coal reject materials represented by the samples tested have excess ANC and should provide a significant source of buffering to any acidity generated from any PAF materials.

The EC in the water extracts ranges from 593 to 1,040 µS/cm (median 865 µS/cm) and is typically moderate. The results confirm that these materials exhibit medium salinity and moderate concentrations of dissolved solids when in contact with water.

The range in concentrations for the major ions in solution in the water extracts are provided in **Table 3.4**. The concentrations for all major ions were well below the water quality guidelines for livestock drinking water.

Table 3.4: Major ion concentrations in solution

Ion	Minimum (mg/L)	Maximum (mg/L)	Median (mg/L)
Calcium (Ca)	10	70	64
Magnesium (Mg)	10	38	34
Potassium (K)	10	16	12
Sodium (Na)	52	108	92
Chloride (Cl)	22	44	38
Fluoride (F)	0.2	0.6	0.4
Sulfate (SO_4)	140	398	286

The concentration of the dissolved trace metals/metalloids tested in the water extracts is generally at or below the laboratory limit of reporting (LoR) for most samples. The exceptions are barium, manganese, molybdenum and silica, although the concentrations are below the applied water quality guideline values (ANZECC & ARMCANZ, 2000), where these exist.

Overall, the results indicate that dissolved metal/metalloid concentrations in initial surface runoff and seepage from the sample materials are unlikely to significantly impact upon the quality of surface and groundwater resources.

3.5 Water quality kinetic tests

As described in **Section 2.2.2** and **Attachment B**, a KLC test program was completed on composite samples representing coarse reject (KLC1) and fine reject (KLC2) materials from the Project. The KLC tests were operated following mining industry guidelines for such tests (AMIRA, 2002; COA, 2016c). The KLC tests commenced in May 2019 and were operated monthly for a period of six months until November 2019.

The KLC test results and trends are presented in **Attachment D** and summarised in this section. The leachate results from the KLC test program are presented alongside the Australian water quality guideline values for livestock drinking water quality (ANZECC & ARMCANZ, 2000). These guidelines are provided for context only and are not intended to be interpreted as "maximum permissible values" for site water storage or discharge. It should be noted that the KLC samples were used as received and have a high surface area for potential geochemical reactions. The ratio of sample to water in the KLC leach tests was approximately 3:1 (w:v); which is more concentrated then that used in the static tests (ie 1:5 w/v). Whilst arbitrary comparisons against water quality guideline concentrations can be useful in some situations and help to provide relevant context, such comparisons cannot be directly extrapolated to the field situation at the Project.

3.5.1 Leachate chemistry

The available KLC test results to date indicate that:

- Leachate from the KLC tests has a pH value in the range 4.90 to 7.22 over the test period. It should be noted that the pH of the deionised water used in the KLC tests over this period has a pH value ranging from 5.45 to 6.01. Apart from the first two leach events for the fine coal reject sample (KLC2) and the final leach event for both samples, the pH of the collected KLC leachate is greater than the pH of the deionised water used in the KLC tests. These results indicate that pH values within bulk co-disposed coal reject materials are likely to be in the pH neutral range, and towards the lower end of the pH range of 6 to 9 for 95 % species protection in freshwater aquatic ecosystems (ANZECC and ARMCANZ, 2000).
- Leachate from the KLC tests has an EC value in the range 1,100 to 3,001 µS/cm, which is fairly consistent throughout the test period. The EC values are generally higher in the fine reject materials (KLC2) compared to the coarse reject material (KLC1).
- The acidity value in leachate from the KLC tests over the test period is low for the coarse reject material (KLC1) and initially higher for the fine reject material (KLC 2). The alkalinity value in leachate from both the coarse and fine reject materials is generally low and results in a variable net alkalinity value over the test period.
- The concentration of major ions in leachate from the KLC tests is dominated by calcium, magnesium sodium, chloride and sulfate (and bicarbonate). The calcium, magnesium and sulfate concentrations typically show a moderately increasing trend over the test period, whereas the sodium and chloride concentrations generally show a reducing trend.
- The sulfate release rate from the KLC samples was relatively steady over the test period, apart from the fifth leachate sample from the fine reject (KLC5), which showed a temporary spike in sulfate release rate before returning to normal levels. The sulfate concentration in leachate from the KLC tests is generally greater than, and less than, the applied guideline value of 1,000 mg/L (ANZECC & ARMCANZ, 2000) for the fine reject material and coarse reject materials, respectively.
- The reject samples used in the KLC tests retain at least ~92.2 % of their inherent total sulfur content after six months of exposure to idealised oxidising conditions, which reflects the relatively slow rate of sulfide oxidation (and low risk of potential acid generation) for these materials.
- The KLC test samples retain at least 97.3 % of their inherent ANC value after six months of exposure to idealised oxidising conditions, which reflects the slow release of alkalinity from these materials.

- The concentrations of trace metals/metalloids in the leachate from the KLC tests is generally low and typically below the laboratory LoR. Most trace metals/metalloids are sparingly soluble at the current pH of the KLC leachate. Exceptions are aluminium, cadmium, copper, manganese selenium and zinc, which can have concentrations in KLC leachate greater than the applied water quality guideline trigger values for aquatic freshwater ecosystems (95 % species protection level) (ANZECC & ARMCANZ, 2000). However, all of the metals/metalloid concentrations are less than the applied livestock drinking water guideline trigger values.

3.5.2 Sulfide oxidation and sulfate generation rates

The sulfate generation rate results obtained for the coal reject samples used in the KLC tests have been used to determine the rate of sulfide oxidation in these materials. Most sulfate salts generated from sulfide reaction involving materials with a relatively low sulfide sulfur concentration are highly soluble, and therefore will be collected in column leachate. The dissolved sulfate (and calcium) concentrations in the KLC leachate are typically much less than the solubility limit of gypsum ($CaSO_4$), for example, which indicates that sulfate generation is not controlled by gypsum dissolution in the KLC test materials. Therefore, the sulfate concentrations and oxidation rate calculations provide reasonable estimates of these parameters and the results align well with existing static and dynamic geochemical data derived from a wide range of mine waste materials (AMIRA, 1995). The sulfate generation rate and associated sulfide oxidation rate for the two KLC tests are shown in **Table 3.5**.

Table 3.5: Sulfate Generation and Sulfide Oxidation Rates for KLC tests on coal reject

KLC Sample Number	Sample Description	Sulfate Generation Rate (mg/kg/week)	Oxidation Rate (kg $O_2/m^3/s$)
KLC1	Coarse Coal Reject	74.5	3.09×10^{-8}
KLC2	Fine Coal Reject	93.6	3.89×10^{-8}

The sulfate generation rate from the KLC samples ranges from 74.5 to 93.6 mg/kg/week indicating that the rate of sulfide oxidation is relatively low in these materials (equivalent to a sulfide oxidation rate ranging from 3.09 to 3.89×10^{-8} kg $O_2/m^3/s$). Mining waste materials with an oxidation rate in the low range (ie., less than 5×10^{-8} kg $O_2/m^3/s$) and a moderate ANC level have an increased factor of safety and are likely to generate leachate that is pH neutral and/or has a low level of acidity (AMIRA, 1995; Bennett *et al*., 2000). Hence, both the coarse and fine reject samples tested fall into this category. Overall, the KLC results reflect the range of material characteristics predicted from the static geochemical test results presented in **Section 3.1**.

Potential implications of these results with respect to the management of coal reject materials at the Project are discussed further in **Section 4.**

4 Discussion

4.1 AMD potential and management

The results of the ABA tests presented in **Section 3.1** indicate that the AMD potential of the coal reject materials is variable. As a bulk material, the coal reject materials are expected to be NAF with excess ANC, that should provide long term buffering to any acid generated. Overall, most coal reject materials have a relatively low risk of acid generation and an increased factor of safety with respect to potential AMD.

If left exposed to oxidising conditions, some of the coal reject materials with elevated total sulfur content may have the potential to generate moderately saline leachate containing an elevated concentration of sulfate. It is therefore recommended that coal reject materials are managed in a way that reduces the risk of connectivity with surface and groundwater resources. In existing Bowen Basin coal mines, this outcome is generally achieved by disposing of these materials either a dedicated co-disposal storage facility or through encapsulation within spoil storage areas, well away from the outside surface of the final rehabilitated landforms. The utilisation of spoil storage areas for coal reject disposal takes advantage of a much larger volume of NAF spoil material with excess ANC. If coal reject materials are left exposed to oxidising conditions for an extended period of time prior to encapsulation, dosing with agricultural limestone (ie. fine limestone) could also be considered as a contingency measure, if warranted.

Notwithstanding the method selected for management of coal reject material, it is recommended that regular collection and monitoring of surface runoff and seepage from storage areas be completed. The potential for connectivity between coal reject materials and any surface water or groundwater resources should also be evaluated.

It is recommended that some representative samples of coal reject materials be generated and subjected to both static and kinetic geochemical testing in the future when bulk materials become available, to verify the expected geochemical nature of these materials. It is likely that the relatively small amount of coal reject material generated at the Project can be safely encapsulated within a much larger volume of NAF spoil material with excess ANC, with little risk of any adverse environmental outcomes. This strategy has successfully been employed at several coal mines within the Bowen Basin.

4.2 Multi-element composition and water quality

4.2.1 Multi-element composition and enrichment

The multi-element concentration of the metals/metalloids present in the coal reject materials are presented in **Sections 3.2** and **3.3**. The results indicate that the sample materials typically have low total metal and metalloid concentrations in solids, mostly below the laboratory limit of reporting (LoR) and all below the applied NEPC (HIL(C)) guideline for soils.

Comparison with median crustal abundance values in un-mineralised soils indicates that the coal reject materials are not significantly enriched with metals/metalloids.

4.2.2 Water quality

The static and kinetic geochemical test results indicate that surface runoff and seepage from coal reject materials is likely to be pH neutral and have a moderate salinity value. The pH of surface runoff and seepage from these materials is likely to be towards the lower end of the pH range (6 to 9) for 95 % species protection in freshwater aquatic ecosystems as set out in ANZECC and ARMCANZ (2000).

The major ion concentrations in surface runoff and seepage from coal reject materials are dominated by calcium, magnesium, sodium, sulfate, chloride (and bicarbonate). The sulfate concentration has the potential to be above the applied livestock drinking water quality guideline criterion of 1,000 mg/L.

The concentration of most trace metals/metalloids tested for water in contact with coal reject materials is generally low, typically below the laboratory LoR, and below the applied water quality guideline criteria. Most trace metals/metalloids are sparingly soluble at the current pH of coal reject materials. Exceptions are the concentrations of aluminium, cadmium, copper, manganese selenium and zinc which can be greater than the applied water quality guideline criteria for aquatic freshwater ecosystems (95 % species protection level) (ANZECC & ARMCANZ, 2000). However, all of the metals/metalloid concentrations are less than the applied livestock drinking water guideline trigger values.

Overall, the static and kinetic geochemical test results indicate that dissolved metal/metalloid concentrations in initial surface runoff and seepage from coal reject materials are unlikely to significantly impact upon the quality of surface and groundwater resources. However, some coal reject materials, if left exposed to oxidising conditions, may have the potential to generate brackish leachate containing elevated concentrations of sulfate and some metals/metalloids compared to applied water quality guideline values. Therefore, coal reject materials should be encapsulated within spoil storage areas, well away from the outside surface of the final rehabilitated landforms. If coal reject materials are left exposed to oxidising conditions for an extended period of time prior to encapsulation, dosing with agricultural limestone (ie. fine limestone) could also be considered as a contingency measure, if warranted.

5 Conclusions and Recommendations

5.1 Conclusions

RGS has completed a geochemical assessment of the coal reject material at the Project. The main findings of the geochemical assessment are:

- The coal reject samples represent materials with a variety of geochemical characteristics ranging from NAF to PAF. As a bulk material, coal reject is expected to be NAF with excess ANC. Overall, most coal reject materials have a relatively low risk of acid generation and an increased factor of safety with respect to potential for AMD.
- Initial and ongoing surface runoff and seepage from coal reject materials is expected to be pH neutral and have a moderate level of salinity. The salinity of leachate from higher sulfur coal reject materials could increase over time if exposed to atmospheric conditions, due to release of sulfate through sulfide oxidation.
- Comparison with guideline values and median crustal abundance in un-mineralised soils indicates that the coal reject materials are not significantly enriched with metals/metalloids.
- Most metals/metalloids are sparingly soluble at the current pH of the leachate from coal reject materials. Dissolved metal/metalloid concentrations in surface runoff and leachate from bulk coal reject materials are expected to be relatively low and unlikely to pose a significant risk to the quality of surface and groundwater resources at relevant storage facilities.

5.2 Recommendations

As a result of the geochemical assessment work completed on coal reject materials at the Project, several recommendations are provided to minimise the risk of any significant environmental harm to the immediate and downstream environment.

- Operational sampling and geochemical testing of representative samples of coal reject material should be used as required when the mine is operational to verify the findings of this report.
- Coal reject materials should be encapsulated in spoil storage areas well away from the outside surface of the final rehabilitated landforms, where there is a low risk of connectivity to surface water or groundwater resources.
- If coal reject materials are left exposed to oxidising conditions for an extended period of time prior to encapsulation, dosing with agricultural limestone (ie. fine limestone) could also be considered as a contingency measure, if warranted.
- Surface water and seepage from the coal reject storage areas should be monitored to ensure that key water quality parameters remain within appropriate criteria. Water quality monitoring parameters should include pH, EC and total suspended solids (TSS) on a quarterly basis and the suite of water quality analyses described in **Table C4** (**Attachment C**) of this report opportunistically and at least on an annual basis.

6 References

AMIRA (1995). Mine Waste Management: *Project P387 Prediction and Identification of Acid Forming Mine Waste*. Australian Minerals Industry Research Association, Report prepared by EGi Pty Ltd, August 1995.

AMIRA (2002). *ARD Test Handbook: Project 387A Prediction and Kinetic Control of Acid Mine Drainage*, Australian Minerals Industry Research Association, Ian Wark Research Institute and Environmental Geochemistry International Pty Ltd, May 2002.

ANZECC & ARMCANZ (2000). *Australian and New Zealand Guidelines for Fresh and Marine Water Quality*, Australian and New Zealand Environment Conservation Council and Agriculture and Resource Management Council of Australia and New Zealand, Canberra.

Australian Standard AS 4969.7 (2008). *Analysis of acid sulfate soil – Dried samples – Methods of test. Method 7: Determination of chromium reducible sulfur (Scr)*. Standards Australia, June 2008.

Bowen, H.J.M. (1979). *Environmental Chemistry of the Elements*. Academic Press, New York.

COA (2016a). *Leading Practice Sustainable Development Program for the Mining Industry - Mine Rehabilitation*. Commonwealth of Australia, Canberra.

COA (2016b). *Leading Practice Sustainable Development Program for the Mining Industry - Mine Closure*. Commonwealth of Australia, Canberra.

COA (2016c). *Leading Practice Sustainable Development Program for the Mining Industry - Managing Acid and Metalliferous Drainage*. Commonwealth of Australia, Canberra.

DEHP (2013). *Application Requirements for Activities with Impacts to Land Guideline.* Queensland Department of Environment and Heritage Protection.

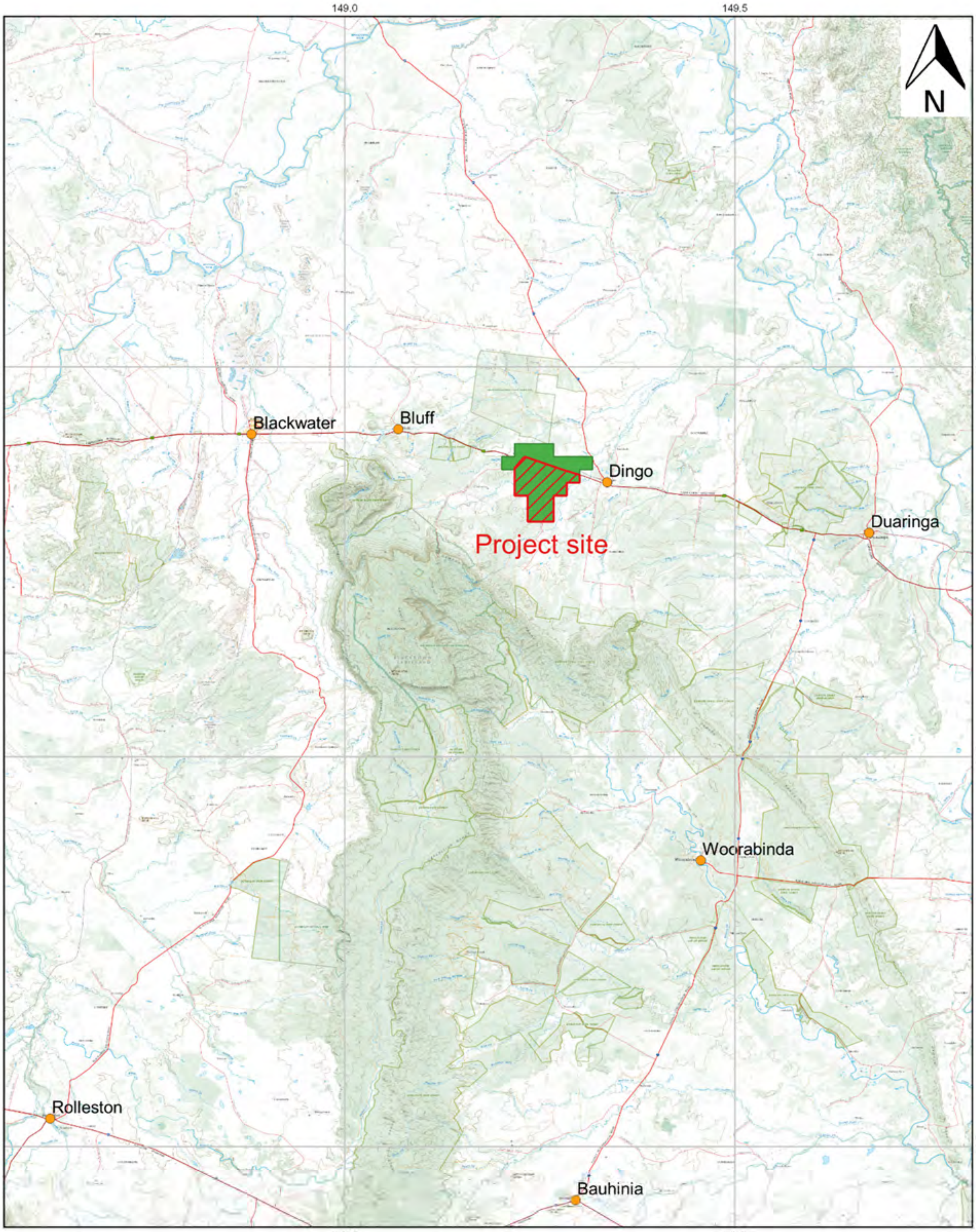
DME (1995). *Draft Technical Guidelines for the Environmental Management of Exploration and Mining in Queensland, Technical Guideline – Assessment and Management of Acid Drainage and Saline/Sodic Wastes*. Queensland Department of Minerals and Energy (DME).

INAP (2009). *Global Acid Rock Drainage Guide (GARD Guide)*. Document prepared by Golder Associates on behalf of the International Network on Acid Prevention (INAP) (http://www.inap.com.au/).

NEPC (2013). *National Environmental Protection (Assessment of Site Contamination) Measure (NEPM), Amendment of Schedule B1-B7 of 1999 version*. National Environmental Protection Council (NEPC).

RGS (2018). *Dingo West Coal Project – Geochemical assessment of mining waste materials*. Document prepared by RGS Environmental Pty Ltd for Magnetic South Limited, 19 March.

Attachment A Figures



Scale: 1:500000	**Figure A1** **Project Location**	**Legend**
0 6 12 km	Gemini Coal Project	MLA Boundary
RGS Environmental Pty Ltd 123 Wynne Street, Sunnybank Hills QLD Tel +61 7 3344 1222	Job Number: 2017002 02/09/2019	EPC 881 Boundary

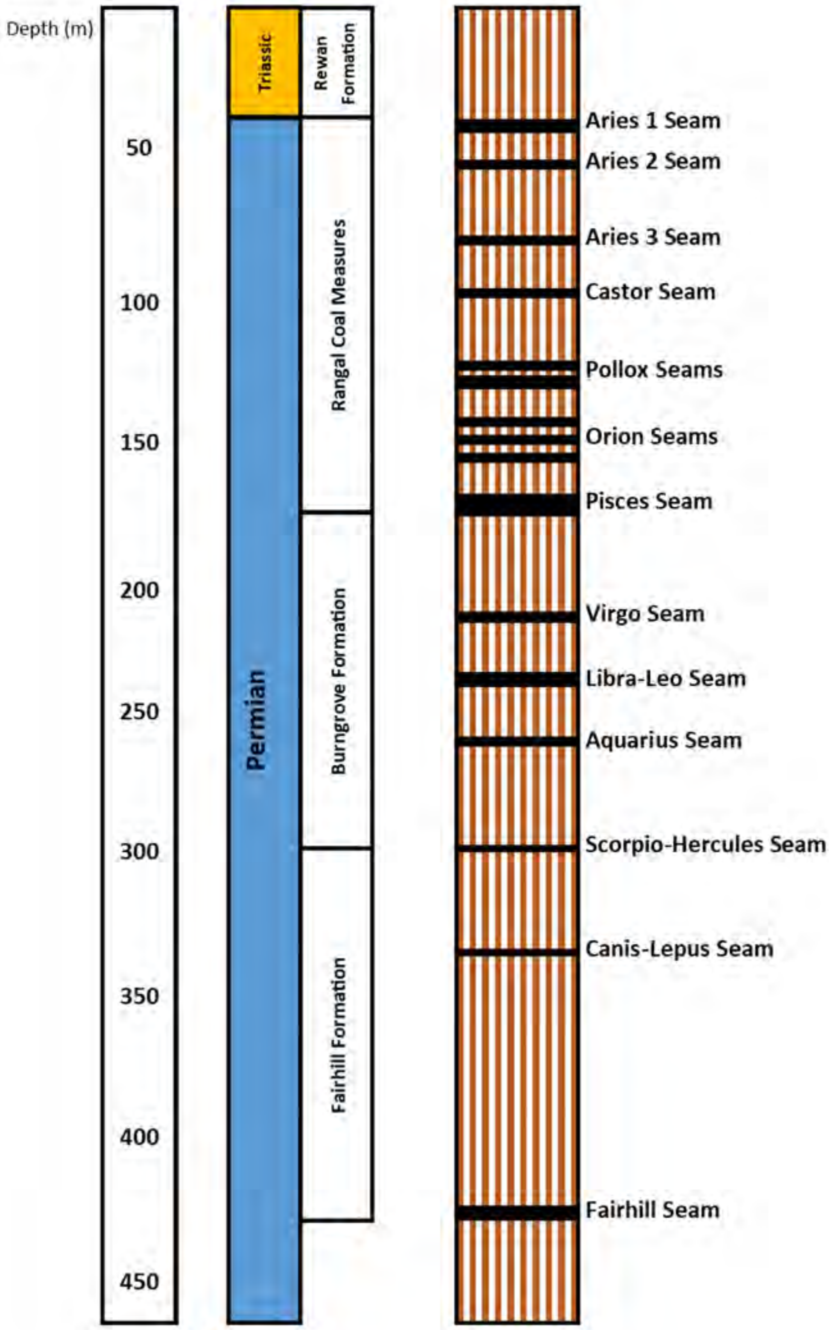


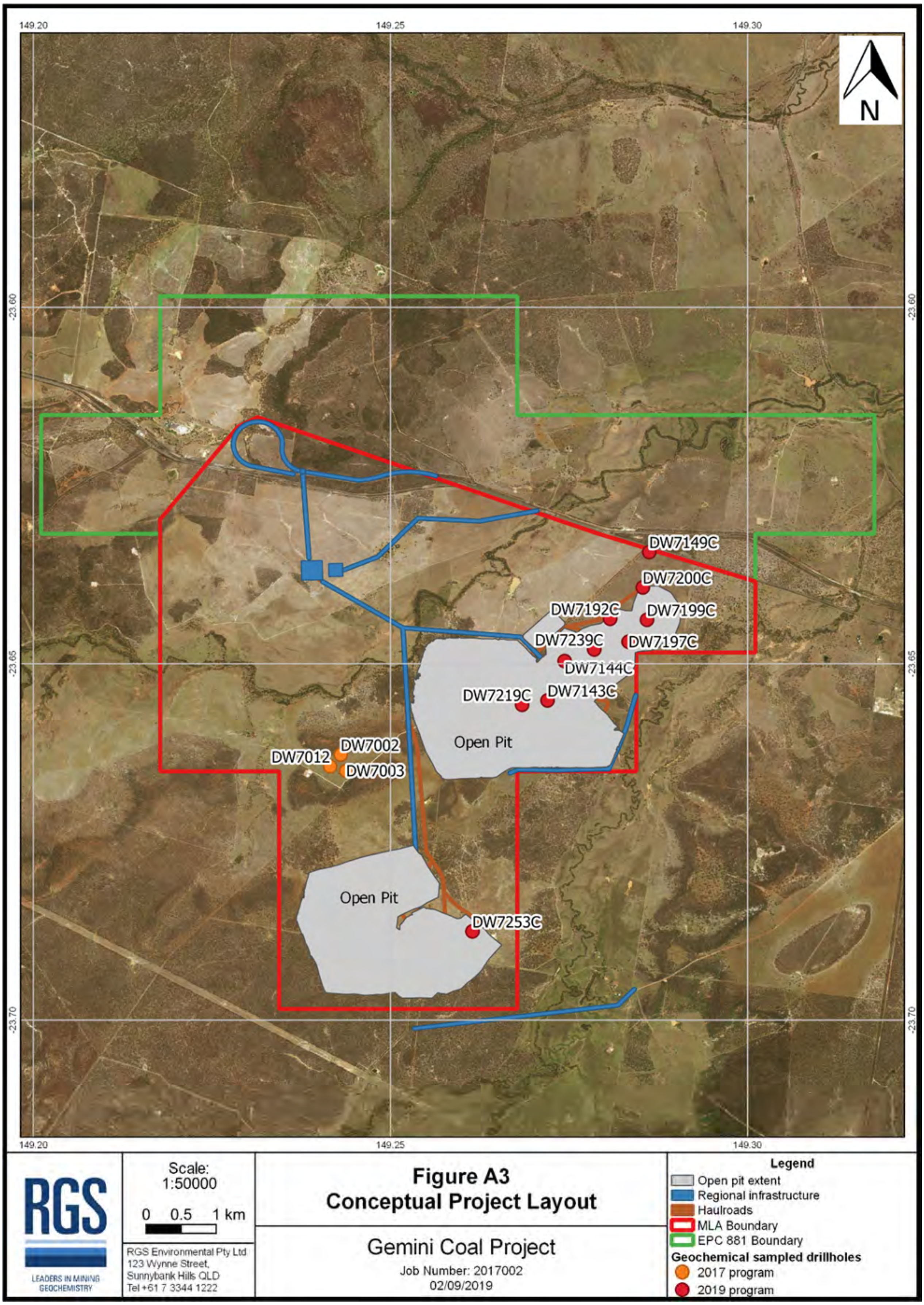
Figure A2

Representative Stratigraphic Column

RGS Environmental Pty Ltd
123 Wynne Street,
Sunnybank Hills QLD
Tel +61 7 3344 1222

Gemini Coal Project

Job Number: 2017002
02/09/2019


149.20
149.25
149.30
-23.60
-23.65
-23.70
N
DW7149C
DW7200C
DW7192C
DW7199C
DW7239C
DW7197C
DW7144C
DW7219C
DW7143C
Open Pit
DW7002
DW7012
DW7003
Open Pit
DW7253C
Scale:
1:50000
0 0.5 1 km
RGS Environmental Pty Ltd
123 Wynne Street,
Sunnybank Hills QLD
Tel +61 7 3344 1222
Figure A3
Conceptual Project Layout
Gemini Coal Project
Job Number: 2017002
02/09/2019
Legend
Open pit extent
Regional infrastructure
Haulroads
MLA Boundary
EPC 881 Boundary
Geochemical sampled drillholes
2017 program
2019 program

Attachment B Geochemical assessment methods for mining waste materials

ACID GENERATION AND PREDICTION

Acid generation is caused by the exposure of sulfide minerals, most commonly pyrite (FeS_2), to atmospheric oxygen and water. Sulfur assay results are used to calculate the maximum acid that could be generated by the sample by either directly determining the pyritic S content or assuming that all sulfur not present as sulfate occurs as pyrite. Pyrite reacts under oxidising conditions to generate acid according to the following overall reaction:

$$FeS_2 + 15/4\ O_2 + 7/2\ H_2O \dashrightarrow Fe(OH)_3 + 2\ H_2SO_4$$

According to this reaction, the maximum potential acidity (MPA) of a sample containing 1%S as pyrite would be 30.6 kg H_2SO_4/t. The chemical components of the acid generation process consist of the above sulfide oxidation reaction and acid neutralization, which is mainly provided by inherent carbonates and to a lesser extent silicate materials. The amount and rate of acid generation is determined by the interaction and overall balance of the acid generation and neutralisation components.

Net Acid Producing Potential

The net acid producing potential (NAPP) is used as an indicator of materials that may be of concern with respect to acid generation. The NAPP calculation represents the balance between the maximum potential acidity (MPA) of a sample, which is derived from the sulfide sulfur content, and the acid neutralising capacity (ANC) of the material, which is determined experimentally. By convention, the NAPP result is expressed in units of kg H_2SO_4/t sample. If the capacity of the solids to neutralise acid (ANC) exceeds their capacity to generate acid (MPA), then the NAPP of the material is negative. Conversely, if the MPA exceeds the ANC, the NAPP of the material is positive. A NAPP assessment involves a series of analytical tests that include:

Determination of pH and EC

pH and EC measured on 1:5 w/w water extract. This gives an indication of the inherent acidity and salinity of the waste material when initially exposed in a waste emplacement area.

Total sulfur content and Maximum Potential Acidity (MPA)

Total sulfur content is determined by the Leco high temperature combustion method. The total sulfur content is then used to calculate the MPA, which assumes that the entire sulfur content is present as reactive pyrite. Direct determination of the pyritic sulfur content can provide a more accurate estimate of the MPA.

Acid neutralising capacity (ANC)

By addition of acid to a known weight of sample, then titration with NaOH to determine the amount of residual acid. The ANC measures the capacity of a sample to react with and neutralise acid. The ANC can be further evaluated by slow acid titration to a set end-point in the Acid Buffering Characteristic Curve (ABCC) test through calculation of the amount of acid consumed and evaluation of the resultant titration curve.

Net Acid Generation (NAG)

The net acid generation (NAG) test involves the addition of hydrogen peroxide to a sample of mine rock or process residue to oxidise reactive sulfide, then measurement of pH and titration of any net acidity produced by the acid generation and neutralisation reactions occurring in the sample. A significant NAG result (*i.e.* final $NAG_{pH} < 4.5$) indicates that the sample is potentially acid forming (PAF) and the test provides a direct measure of the net amount of acid remaining in the sample after all acid generating and acid neutralising reactions have taken place. A $NAG_{pH} > 4.5$ indicates that the sample is non-acid forming (NAF). The NAG test provides a direct assessment of the potential for a material to produce acid after a period of exposure and weathering and is used to refine the results of the theoretical NAPP predictions. The NAG test can be used as a stand-alone test but is recommended that this only be considered after site specific calibration work is carried out. RGS generally avoids use the NAG test at coal mining projects as the high organic content of some materials can cause erroneous results.

ASSESSMENT OF ELEMENT ENRICHMENT AND SOLUBILITY

In mineralised areas it is common to find a suite of enriched elements that have resulted from natural geological processes. Multi-element scans are carried out to identify any elements that are present in a material (or readily leachable from a material) at concentrations that may be of environmental concern with respect to surface water quality, revegetation and public health. The samples are generally analysed for the following elements:

Major elements	Al, Ca, Fe, K, Mg, Na and S.
Minor elements	As, B, Cd, Co, Cr, Cu, F, Hg, Mn, Mo, Ni, Pb, Sb, Se and Zn.

The concentration of these elements in samples can be directly compared with relevant state or national environmental and health based concentration guideline criteria to determine the level of significance. Water extracts are used to determine the immediate element solubilities under the existing sample pH conditions of the sample. The following tests are normally carried out:

Multi-element composition of solids.

Multi-element composition of solid samples determined using a combination of ICP-mass spectroscopy (ICP-MS), ICP-optical emission spectroscopy (OES), and atomic absorption spectrometry (AAS).

Multi-element composition of water extracts (1:5 sample:deionised water).

Multi-element composition of water extracts from solid samples determined using a combination of ICP-mass spectroscopy (ICP-MS), ICP-optical emission spectroscopy (OES), and atomic absorption spectrometry (AAS).

Under some conditions (*eg*. low pH) the solubility and mobility of common environmentally important elements can increase significantly. If element mobility under initial pH conditions is deemed likely and/or subsequent low pH conditions may occur, kinetic leach column test work may be completed on representative samples.

KINETIC LEACH COLUMN TESTS

Kinetic leach column (KLC) tests can be used to provide information on the reaction kinetics of mining waste materials. The major objectives of kinetics tests are to:

- Provide time-dependent data on the kinetics and rate of acid generation and acid neutralising reactions under laboratory controlled (or onsite conditions);
- Investigate metal release and drainage/seepage quality; and
- Assess treatment options such as addition of alkaline materials.

The KLC tests simulate the weathering process that leads to acid and base generation and reaction under laboratory controlled or site conditions. The kinetic tests allow an assessment of the acid forming characteristics and indicate the rate of acid generation, over what period it will occur, and what management controls may be required.

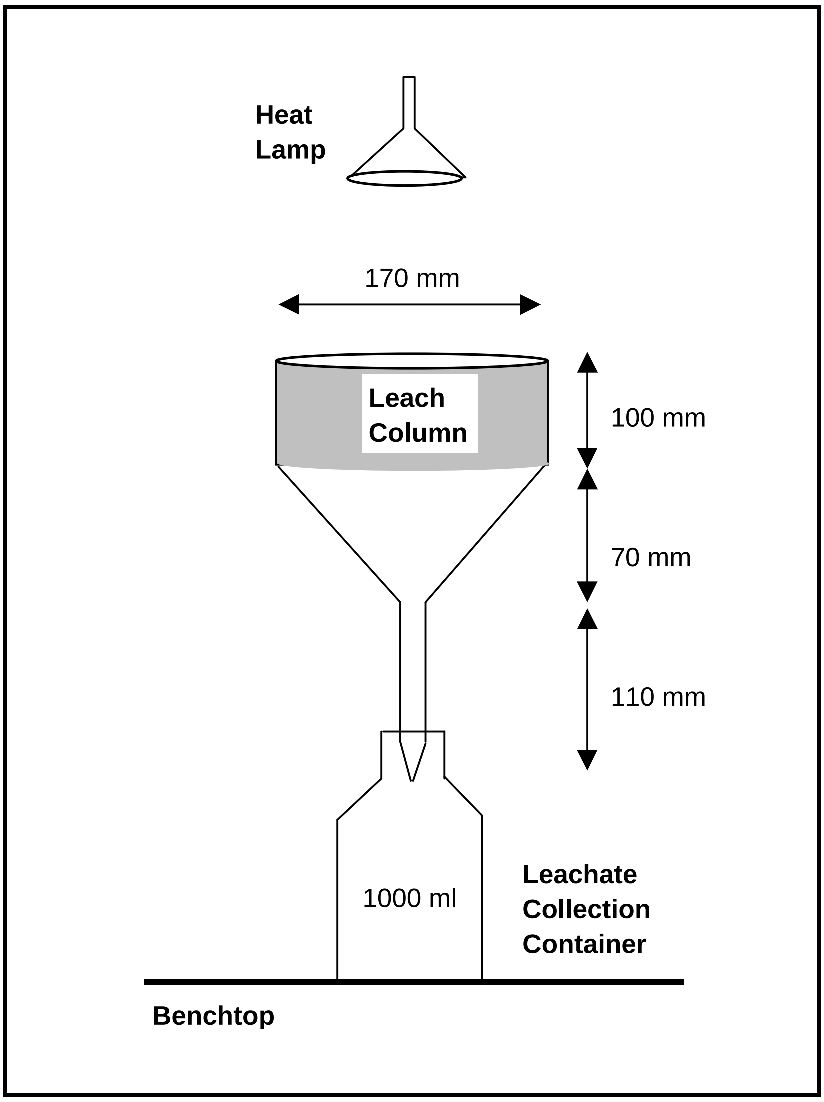
In KLC tests, water is added to a sample and the mixture allowed to leach products and by-products of acid producing and consuming reactions. Samples of leachate are then collected and analysed. Intermittent water application is applied to simulate rainfall and heat lamps are used to simulate sunshine. These tests provide real-time information and may have to continue for months or years. Monitoring includes trends in pH, sulfate, acidity or alkalinity, and metals, for example. The pH of the collected leachate simulates the acid drainage process, acidity or alkalinity levels indicate the rate of acid production and acid neutralisation, and sulfate production can be related to the rate of sulfide oxidation. Metal concentration data provides an assessment of metal solubility and leaching behaviour.

Figure B1 shows the kinetic leach column set up used by RGS adapted from *AMIRA, 2002*. The columns are placed under heat lamps to allow the sample to dry between water additions to ensure adequate oxygen ingress into the sample material.

Approximately 2 kg of sample is accurately weighed and used in the leach columns and depending on the physical nature of the material and particle size can be used on an as-received basis (*i.e.* no crushing as with process residues) or crushed to nominal 5-10 mm particle size (as with waste rock). The sample in the column is initially leached with deionised water at a rate of about 400 ml/kg of sample and the initial leachate from the columns collected and analysed. Subsequent column leaching is carried out at a rate of about 400 ml/kg per month and again collected and analysed. The leaching rate can be varied to better simulate expected site conditions or satisfy test program data requirements. The column must be exposed to drying conditions in between watering events. The residual water content and air void content in the column can be determined by comparing the wet and dry column weights. A heat lamp is generally used above the sample during daylight hours to maintain the leach column surface temperature at about 30^{o}C.

Figure B1

Kinetic Leach Column Setup



Attachment C Static geochemical results

Table C1: Acid Base Account test results for coal reject samples

RGS Sample No.	Sample Name	ALS Sample ID	Sample Lithology	Coal seam	pH[1]	EC[1]	Total S	S_{CR}[2]	MPA[2]	ANC[2]	NAPP[2]	ANC: MPA Ratio	Sample Classification[3]
						(µS/cm)	(%)	(%)	kg H_2SO_4/t				
1	Sample 1	EB1912348001	Coarse coal reject	AR2	6.3	946	1.31		40.1	16.0	24.1	0.4	Potentially Acid Forming
2	Sample 2	EB1912348002	Coarse coal reject	AR3	6.0	1,440	0.94	0.97	29.8	22.6	7.2	0.8	Potentially Acid Forming (LC)
3	Sample 3	EB1912348003	Coarse coal reject	AR3	7.3	1,040	0.78	0.76	23.4	64.6	-41.2	2.8	Non Acid Forming
4	Sample 4	EB1912348004	Coarse coal reject	CAS	7.8	567	0.41	0.25	7.6	108.0	-100.4	14.3	Non Acid Forming
5	Sample 5	EB1912348005	Coarse coal reject	CAS	8.2	919	0.37	0.21	6.5	10.7	-4.2	1.7	Uncertain
6	Sample 6	EB1912348006	Coarse coal reject	CAS	8.2	688	0.99	0.62	18.9	26.3	-7.4	1.4	Non Acid Forming
7	Sample 7	EB1912348007	Coarse coal reject	CAS	7.9	398	0.52	0.27	8.3	68.5	-60.2	8.3	Non Acid Forming
8	Sample 8	EB1912348008	Coarse coal reject	PLU1	5.1	1620	1.77	1.16	35.5	30.3	5.2	0.9	Potentially Acid Forming (LC)
9	Sample 9	EB1912348009	Coarse coal reject	PLU1	8.0	456	0.59	0.61	18.7	70.1	-51.4	3.8	Non Acid Forming
10	Sample 10	EB1912348010	Coarse coal reject	PLU1	7.4	1040	0.23	0.12	3.7	36.3	-32.6	9.8	Non Acid Forming
11	Sample 11	EB1912348011	Coarse coal reject	PLU1	6.6	1300	3.25	3.22	98.6	132.0	-33.4	1.3	Non Acid Forming
12	Sample 12	EB1912348012	Coarse coal reject	PLU1	8.2	418	0.73	0.69	21.0	122.0	-101.0	5.8	Non Acid Forming
13	Sample 13	EB1912348013	Coarse coal reject	PLU2	8.3	774	0.37	0.23	7.0	19.0	-12.0	2.7	Non Acid Forming
14	Sample 14	EB1912348014	Coarse coal reject	PLU2	7.4	1160	0.92	0.80	24.4	57.3	-32.9	2.4	Non Acid Forming
15	Sample 15	EB1912348015	Fine coal reject	AR2	6.2	824	2.75		84.2	11.5	72.7	0.1	Potentially Acid Forming
16	Sample 16	EB1912348016	Fine coal reject	AR3	6.9	1320	1.27		38.9	221.0	-182.1	5.7	Non Acid Forming
17	Sample 17	EB1912348017	Fine coal reject	CAS	7.6	520	1.47		45.0	396.0	-351.0	8.8	Non Acid Forming
18	Sample 18	EB1912348018	Fine coal reject	CAS	7.8	570	0.66		20.2	112.0	-91.8	5.5	Non Acid Forming
19	Sample 19	EB1912348019	Fine coal reject	PLU1	6.4	1120	1.03		31.5	30.6	0.9	1.0	Uncertain
20	Sample 20	EB1912348020	Fine coal reject	PLU1	7.0	647	1.61		49.3	204.0	-154.7	4.1	Non Acid Forming
21	Sample 21	EB1912348021	Fine coal reject	PLU2	5.9	502	2.15		65.8	12.9	52.9	0.2	Potentially Acid Forming
22	Sample 22	EB1912348022	Fine coal reject	PLU2	6.4	1170	4.20		128.6	168.0	-39.4	1.3	Non Acid Forming

1. Current pH, EC, Alkalinity and Acidity provided for 1:5 sample:water extracts
2. Scr = Chromium Reducible Sulfur; MPA = Maximum Potential Acidity; ANC = Acid Neutralising Capacity; and NAPP = Net Acid Producing Potential.
3. Sample classification criteria detail provided in report text.

Table C2: Multi-element test results for coal reject samples

Parameters	Limit of Reporting	NEPC[1] Health-Based Investigation Level (HILs)-C	Composite 1	Composite 2	Composite 3
		ALS Laboratory ID →	EB1912809023	EB1912809024	EB1912809025
		Sample ID →	Coarse-CAS/AR Composite	Coarse-PLU1/PLU2 Composite	Fine-CAS/AR Composite - Fine/PLU1/PLU2 Composite
Major Cations			All units mg/kg		
Calcium (Ca)	50	-	18,100	26,200	61,000
Magnesium (Mg)	50	-	3,780	3,950	5,040
Potassium (K)	50	-	1,490	1,020	1,230
Sodium (Na)	50	-	860	900	490
Major, Minor and Trace Elements			All units mg/kg		
Aluminium (Al)	50	-	6,490	6,500	6,510
Antimony (Sb)	5	-	<5	<5	<5
Arsenic (As)	5	300	21	34	17
Barium (Ba)	10	-	310	180	140
Beryllium (Be)	1	-	<1	<1	<1
Boron (B)	50	20,000	<50	<50	<50
Cadmium (Cd)	1	90	<1	<1	<1
Chromium (Cr)	2	300 **	6	4	12
Cobalt (Co)	2	300	4	2	3
Copper (Cu)	5	17,000	46	42	33
Iron (Fe)	50	-	32,600	41,400	50,500
Lead (Pb)	5	600	15	11	10
Manganese (Mn)	5	19,000	423	1,160	1,030
Mercury (Hg)	0.1	-	0.1	0	0
Molybdenum (Mo)	2	80	2	<2	<2
Nickel (Ni)	2	1,200	7	5	7
Reactive Phosphorus (P)	0.1	-	<0.1	<0.1	<0.1
Selenium (Se)	5	700	<5	<5	<5
Vanadium (V)	5	-	12	14.0	13.0
Zinc (Zn)	5	30,000	44	52	45

Notes: < indicates less than the laboratory limit of reporting (LoR).

** Guideline level for Cr(VI) = 300 mg/kg. Guideline level for Cr(III) = 24% of total Cr.

1. NEPC (2013). National Environmental Protection Council (NEPC). *National Environmental Protection (Assessment of Site Contamination) Measure (NEPM)* , Amendment of Schedule B1-B7 of 1999 version.
Guideline on Investigation Levels for Soil and Groundwater. Health-Based Investigation Level - HIL(C); public open spaces - recreational use.

Table C3: Geochemical Abundance Index results for coal reject samples

	RGS Sample Number →		Composite 1	Composite 2	Composite 3
	ALS Laboratory ID →		EB1912809023	EB1912809024	EB1912809025
	Sample Description →		Coarse-CAS/AR Composite	Coarse-PLU1/PLU2 Composite	Fine-CAS/AR Composite - Fine/PLU1/PLU2 Composite
Parameters	Limit of Reporting	Average Crustal Abundance[1]			
Major Elements	all units in mg/kg		Geochemical Abundance Index		
Calcium (Ca)	50	15,000	0	0	1
Magnesium (Mg)	50	5,000	0	0	0
Potassium (K)	50	14,000	0	0	0
Sodium (Na)	50	5,000	0	0	0
Major, Minor and Trace Elements	all units in mg/kg		Geochemical Abundance Index		
Aluminium (Al)	50	71,000	0	0	0
Antimony (Sb)	5	5	0	0	0
Arsenic (As)	5	6	1	2	1
Barium (Ba)	10	500	0	0	0
Beryllium (Be)	1	6.00	0	0	0
Boron (B)	50	100	0	0	0
Cadmium (Cd)	1	0	0	0	0
Chromium (Cr)	2	70	0	0	0
Cobalt (Co)	2	8	0	0	0
Copper (Cu)	5	30	0	0	0
Iron (Fe)	50	40,000	0	0	0
Lead (Pb)	5	35	0	0	0
Manganese (Mn)	5	1,000	0	0	0
Mercury (Hg)	0.1	0	0	1	0
Nickel (Ni)	2	50	0	0	0
Reactive Phosphorus (P)	0.1	800	0	0	0
Selenium (Se)	5	0.4	2	2	2
Zinc (Zn)	5	90	0	0	0

Notes: GAI's greater than or equal to 3 are highlighted.
1. Average Crustal Abundance values sourced from the "GARD Guide", Chapter 5 (INAP, 2009). When no GARD Guide value is available for particular element, then values are taken from Bowen H.J.M.(1979) Environmental Chemistry of the Elements, pages 60-61.

Table C4: Multi-Element Test results for water extracts from coal reject samples

			RGS Sample Number →	Composite 1	Composite 2	Composite 3
			ALS Laboratory ID →	EB1912809023	EB1912809024	EB1912809025
			Sample ID →	Coarse-CAS/AR Composite	Coarse-PLU1/PLU2 Composite	Fine-CAS/AR Composite - Fine/PLU1/PLU2 Composite
		Water Quality Guidelines:				
Parameters	Limit of Reporting	Aquatic Ecosystems (freshwater)[1]	Livestock Drinking Water[2]			
pH	0.01 pH unit	6 to 9	-	8.5	8.0	8.0
Electrical Conductivity	1 µS/cm	<1,000[#]	3,580[^]	593	1,040	865
Carbonate Alkalinity ($mgCaCO_3/L$)	1 mg/L	-	-	<1	<1	<1
Bicarbonate Alkalinity ($mgCaCO_3/L$)	1 mg/L	-	-	3,320	2,960	13,220
Total Alkalinity ($mgCaCO_3/L$)	1 mg/L	-	-	3,320	2,960	13,220
Acidity ($mgCaCO_3/L$)	1 mg/L	-	-	2	36	24
Net Alkalinity ($mgCaCO_3/L$)	1 mg/L	-	-	3,318	2,924	13,196
Major Ions	All units mg/L			All units mg/L		
Calcium (Ca)	2	-	1,000	10	64	70
Magnesium (Mg)	2	-	-	10	38	34
Potassium (K)	2	-	-	12	10	16
Sodium (Na)	2	-	-	92	108	52
Chloride (Cl)	2	-	-	38	22	44
Fluoride (F)	0.2	-	2	0.6	0.4	0.2
Sulfate (SO_4)	2	-	1,000	140	398	286
Trace Metals/Metalloids	All units mg/L			All units mg/L		
Aluminium (Al)	0.02	0.055	5	<0.02	<0.02	<0.02
Antimony (Sb)	0.002	-	-	<0.002	<0.002	<0.002
Arsenic (As) (trivalent)	0.002	0.024 **	0.5	0.002	<0.002	<0.002
Barium (Ba)	0.002	-	-	0.026	0.022	0.022
Beryllium (Be)	0.002	-	-	<0.002	<0.002	<0.002
Boron (B)	0.2	0.37	5	<0.2	<0.2	<0.2
Cadmium (Cd)	0.002	0.0002	0.01	<0.002	<0.002	<0.002
Chromium (Cr)	0.002	0.001 (hex)*	1 (total)	<0.002	<0.002	<0.002
Cobalt (Co)	0.002	-	-	<0.002	<0.002	<0.002
Copper (Cu)	0.002	0.0014	1	<0.002	<0.002	<0.002
Iron (Fe)	0.2	-	-	<0.2	<0.2	<0.2
Lead (Pb)	0.002	0.0034	0.1	<0.002	<0.002	<0.002
Manganese (Mn)	0.002	1.90	-	0.004	0.588	0.094
Mercury (Hg)	0.0001	0.0001	0.002	<0.0001	<0.0001	<0.0001
Molybdenum (Mo)	0.002	-	0.15	0.036	0.004	0.010
Nickel (Ni)	0.002	0.011	1	<0.002	<0.002	<0.002
Selenium (Se)	0.02	0.011	0.02	<0.02	<0.02	<0.02
Silica (Si)	0.2	-	-	5.0	4.8	5.2
Thorium (Th)	0.002	-	-	<0.002	<0.002	<0.002
Uranium (U)	0.002	-	-	<0.002	<0.002	<0.002
Vanadium (V)	0.02	-	-	<0.02	<0.02	<0.02
Zinc (Zn)	0.01	0.008	20	<0.01	<0.01	<0.01

Notes: < indicates concentration less than the detection limit. Shaded cells exceed applied guideline values.

1. ANZECC & ARMCANZ (2000). Trigger values for aquatic ecosystems (95% species protection level)

2. ANZECC & ARMCANZ (2000). Recommended guideline limits for Livestock Drinking Water.

* Cr (VI) = hexavalent. ** 0.013 mg/Lfor pentavalent Arsenic (V).

\# for still water bodies only, moving rivers at low flow rates should not exceed 2,200µS/cm

^ calculated based on total dissolved solids (TDS) conversion rate of 0.67% of EC. TDS is an approximate measure of inorganic dissolved salts and should not exceed 2,400mg/L for livestock drinking water.

Attachment D Kinetic geochemical results

Gemini Coal Project
KLC1 (Coarse Reject)

Weight (kg)	1.53	**Total S (%)**	0.94	**ANC**	56
pH (1:5)	7.3	**Scr (%)**	0.65	**NAPP**	-27.2
EC (µS/cm)	912	**MPA**	28.8	**ANC:MPA**	1.9

Date				**23-May-19**	**25-Jun-19**	**22-Jul-19**	**27-Aug-19**	**25-Sep-19**	**22-Oct-19**	**26-Nov-19**
Number of Weeks				**0**	**4**	**9**	**13**	**17**	**22**	**26**
Leach Number				**1**	**2**	**3**	**4**	**5**	**6**	**7**
ALS Laboratory Number				EB1913182001	EB1916404001	EB1918950001	EB1922372001	EB1925268001	EB1927982001	EB1931641001
Volume On (L)				1.0	1.0	1.0	1.0	1.0	1.0	1.0
Volume Off (L)				0.552	0.565	0.577	0.621	0.567	0.598	0.469
Cum. Volume (L)				0.55	1.12	1.69	2.31	2.88	3.48	3.95
Pore Volumes				0.4	0.8	1.3	1.7	2.1	2.6	2.9
pH (RGS Measurement)				6.34	5.84	6.83	6.96	6.46	6.02	5.48
pH (ALS Measurement)				6.61	5.88	6.90	6.83	6.18	5.45	5.68
pH (deionised water used in test)				5.73	5.45	5.46	6.01	5.89	5.67	5.87
EC (RGS Measurement) (µS/cm)				1,100	2,312	1,711	1,822	1,843	1,452	1,712
EC (ALS Measurement) (µS/cm)				1,110	2,410	1,860	1,820	2,040	1440	1720
Acidity (mg/L)*				5	15	1	2	3	13	19
Alkalinity (mg/L)*				13	3	7	8	5	3	4
Net Alkalinity (mg/L)*				8	-12	6	6	2	-10	-15
		WQ Guidelines#								
Major Ions (mg/L)	**LoR**	**Aquatic Ecosystem (freshwater)[1]**	**Livestock Drinking Water[2]**							
Calcium (Ca)	1	-	1,000	34	83	75	98	121	112	138
Potassium (K)	1	-	-	5	6	4	7	8	6	8
Magnesium (Mg)	1	-	-	31	120	84	98	114	77	102
Sodium (Na)	1	-	-	164	337	215	212	195	97	99
Chloride (Cl)	1	-	-	41	83	51	42	34	18	24
Fluoride (F)	0.1	-	2	0.2	0.1	0.2	0.2	0.2	0.2	0.2
Sulfate (SO_4)	1	-	1,000	451	1,140	846	861	1,060	700	954
Trace metals/ metalloids	**LoR**			All units mg/L						
Aluminium (Al)	0.01	0.055	5	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.04
Arsenic (As)	0.001	0.024	0.5	<0.001	<0.001	<0.001	0.001	<0.001	<0.001	0.01
Boron (B)	0.05	-	5	0.12	0.06	0.06	0.07	0.08	0.1	0.12
Cadmium (Cd)	0.0001	0.0002	0.01	0.0003	0.0005	0.0002	0.0003	0.0006	0.0006	0.0009
Cobalt (Co)	0.001	-	1	0.025	0.035	0.008	0.012	0.016	0.021	0.025
Chromium (Cr)	0.001	0.001	1	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Copper (Cu)	0.001	0.0014	1	<0.001	<0.001	<0.001	<0.001	<0.001	0.009	0.014
Iron (Fe)	0.05	-	-	1.81	4.6	<0.05	<0.05	0.22	3.17	1.83
Manganese (Mn)	0.001	1.9	-	4.85	2.55	1.06	1.04	1.86	1.85	2.13
Molybdenum (Mo)	0.001	-	0.15	<0.001	<0.001	0.002	0.002	<0.001	<0.001	<0.001
Nickel (Ni)	0.001	-	1	0.022	0.029	0.006	0.013	0.018	0.02	0.023
Lead (Pb)	0.001	0.0034	0.1	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Antimony (Sb)	0.001	-	-	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Selenium (Se)	0.01	0.011	0.02	<0.01	0.02	0.01	0.01	0.01	<0.01	0.01
Vanadium	0.01	-	-	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Zinc (Zn)	0.005	0.008	20	0.020	0.048	0.011	0.023	0.044	0.073	0.096
Total Anions				10.8	26.1	19.2	19.3	23.1	15.1	20.6
Total Cations				11.5	28.8	20.1	22.4	24.1	16.3	19.8
Ionic Balance				3.15	4.9	2.34	7.41	2.07	3.68	2.05
Calculations**										
SO_4 Release Rate				162	420	318	349	392	273	292
Cumulative SO_4 Release				162	582	900	1,249	1,641	1,913	2,205
Ca Release Rate				12	31	28	40	45	44	42
Cumulative Ca Release				12	43	71	111	155	199	241
Mg Release Rate				11	44	32	40	42	30	31
Cumulative Mg Release				11	55	87	127	169	199	230
Residual ANC (%)				99.9	99.4	99.1	98.6	98.1	97.7	97.3
Residual Sulfur (%)				99.4	97.9	96.8	95.6	94.2	93.2	92.2
SO_4/(Ca+Mg) molar ratio				2.2	1.7	1.7	1.4	1.4	1.2	1.3

< indicates less than the limit of reporting. * Acidity and alkalinity data calculated in mg $CaCO_3$/L.
** SO_4, Ca and Mg release rates calculated in mg/kg/flush.
Total S = Total Sulfur; Scr = Chromium Reducible Sulfur; and ANC = Acid Neutralising Capacity.
MPA = Maximum Potential Acidity, and NAPP = Net Acid Producing Potential.
# ANZECC & ARMCANZ (2000). 1. Trigger values for aquatic ecosystems (95 % protection level).
2. Livestock Drinking Water Levels.

Gemini Coal Project
KLC2 (Fine Reject)

Weight (kg)	1.54	**Total S (%)**	1.89	**ANC**	144.5
pH (1:5)	6.80	**Scr (%)**	1.70	**NAPP**	-86.6
EC (µS/cm)	834	**MPA**	57.9	**ANC:MPA**	2.5

Date				**23-May-19**	**25-Jun-19**	**22-Jul-19**	**27-Aug-19**	**25-Sep-19**	**22-Oct-19**	**26-Nov-19**
Number of Weeks				**0**	**4**	**9**	**13**	**17**	**22**	**26**
Leach Number				**1**	**2**	**3**	**4**	**5**	**6**	**7**
ALS Laboratory Number				EB1913182002	EB1916404002	EB1918950002	EB1922372002	EB1925268002	EB1927982002	EB1931641002
Volume On (L)				1.0	1.0	1.0	1.0	1.5	1.0	1.0
Volume Off (L)				0.332	0.328	0.346	0.332	0.915	0.398	0.252
Cum. Volume (L)				0.33	0.66	1.01	1.34	2.25	2.65	2.90
Pore Volumes				0.2	0.5	0.7	1.0	1.7	2.0	2.2
pH (RGS Measurement)				5.31	4.90	7.22	6.84	7.26	6.26	5.63
pH (ALS Measurement)				5.15	4.75	7.18	6.65	7.51	6.02	5.04
pH (deionised water used in test)				5.73	5.45	5.46	6.01	5.89	5.67	5.87
EC (RGS Measurement) (µS/cm)				2,098	2,319	2,790	2,380	3,001	2,152	2,059
EC (ALS Measurement) (µS/cm)				2,090	2,420	3,030	2,450	3,240	2,140	2060
Acidity (mg/L)*				101	110	2	2	11	26	29
Alkalinity (mg/L)*				4	<1	13	9	96	3	2
Net Alkalinity (mg/L)*				-97	-110	11	7	85	-23	-27
Major Ions (mg/L)	**LoR**	**WQ Guidelines[#]**								
		Aquatic Ecosystem (freshwater)[1]	**Livestock Drinking Water[2]**							
Calcium (Ca)	1	-	1,000	110	202	234	292	390	303	302
Potassium (K)	1	-	-	8	7	8	14	12	8	9
Magnesium (Mg)	1	-	-	68	126	161	134	204	123	107
Sodium (Na)	1	-	-	252	190	260	156	152	37	34
Chloride (Cl)	1	-	-	259	141	261	95	112	22	23
Fluoride (F)	0.1	-	2	<0.1	<0.1	0.2	0.2	0.2	<0.1	<0.1
Sulfate (SO_4)	1	-	1,000	726	1,240	1,500	1,300	1,970	1,320	1,220
Trace metals/ metalloids	**LoR**			All units mg/L						
Aluminium (Al)	0.01	0.055	5	0.12	0.07	<0.01	<0.01	<0.01	<0.01	<0.01
Arsenic (As)	0.001	0.024	0.5	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.006
Boron (B)	0.05	-	5	0.13	0.13	0.05	0.12	0.14	0.14	0.12
Cadmium (Cd)	0.0001	0.0002	0.01	0.0006	0.0013	0.0001	0.0008	0.0004	0.0011	0.0012
Cobalt (Co)	0.001	-	1	0.085	0.097	0.006	0.039	0.014	0.057	0.055
Chromium (Cr)	0.001	0.001	1	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Copper (Cu)	0.001	0.0014	1	0.005	0.011	<0.001	<0.001	<0.001	<0.001	<0.001
Iron (Fe)	0.05	-	-	44.5	53.6	<0.05	0.34	0.29	10.2	6.39
Manganese (Mn)	0.001	1.9	-	4.10	5.38	1.67	2.61	2.81	3.19	2.8
Molybdenum (Mo)	0.001	-	0.15	<0.001	<0.001	0.001	<0.001	0.001	<0.001	<0.001
Nickel (Ni)	0.001	-	1	0.096	0.083	0.006	0.039	0.018	0.055	0.051
Lead (Pb)	0.001	0.0034	0.1	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Antimony (Sb)	0.001	-	-	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Selenium (Se)	0.01	0.011	0.02	0.02	0.01	0.02	<0.01	0.02	<0.01	<0.01
Vanadium	0.01	-	-	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Zinc (Zn)	0.005	0.008	20	0.270	0.281	0.007	0.075	0.034	0.170	0.139
Total Anions				22.5	29.8	38.8	29.9	46.1	28.2	26.1
Total Cations				22.2	28.9	36.4	32.7	43.2	27.0	25.6
Ionic Balance				0.56	1.54	3.20	4.50	3.28	2.00	0.98
Calculations**										
SO_4 Release Rate				157	265	338	281	1174	342	200
Cumulative SO_4 Release				157	422	760	1,041	2,216	2,558	2,758
Ca Release Rate				24	43	53	63	232	79	50
Cumulative Ca Release				24	67	120	183	415	494	543
Mg Release Rate				15	27	36	29	122	32	18
Cumulative Mg Release				15	42	78	107	228	260	278
Residual ANC (%)				99.9	99.8	99.6	99.4	98.7	98.4	98.3
Residual Sulfur (%)				99.7	99.3	98.7	98.2	96.1	95.5	95.1
SO_4/(Ca+Mg) molar ratio				1.4	1.3	1.3	1.1	1.1	1.1	1.1

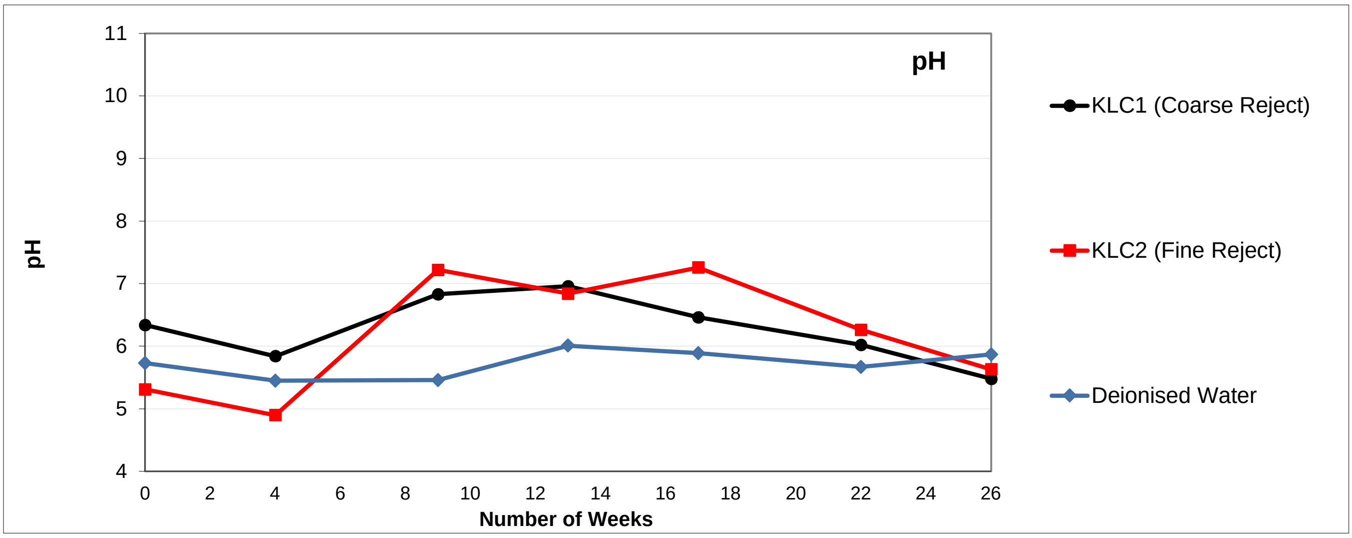
< indicates less than the analytical detection limit. * Acidity and alkalinity data calculated in mg CaCO

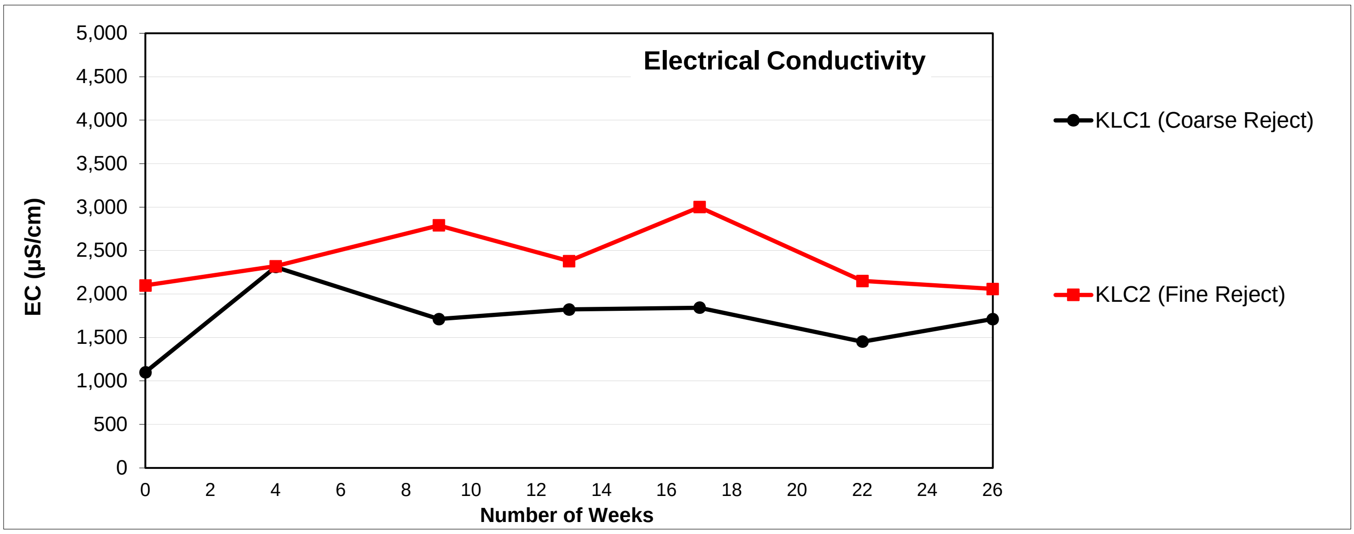
** SO_4, Ca and Mg release rates calculated in mg/kg/flush.

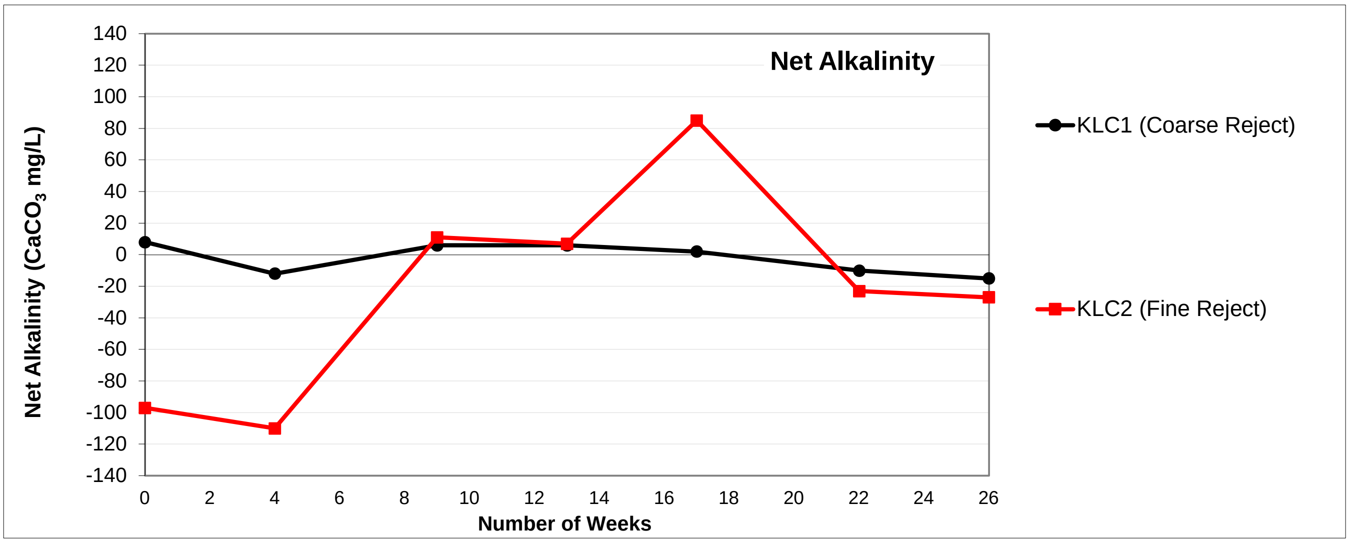
Total S = Total Sulfur; Scr = Chromium Reducible Sulfur; and ANC = Acid Neutralising Capacity.

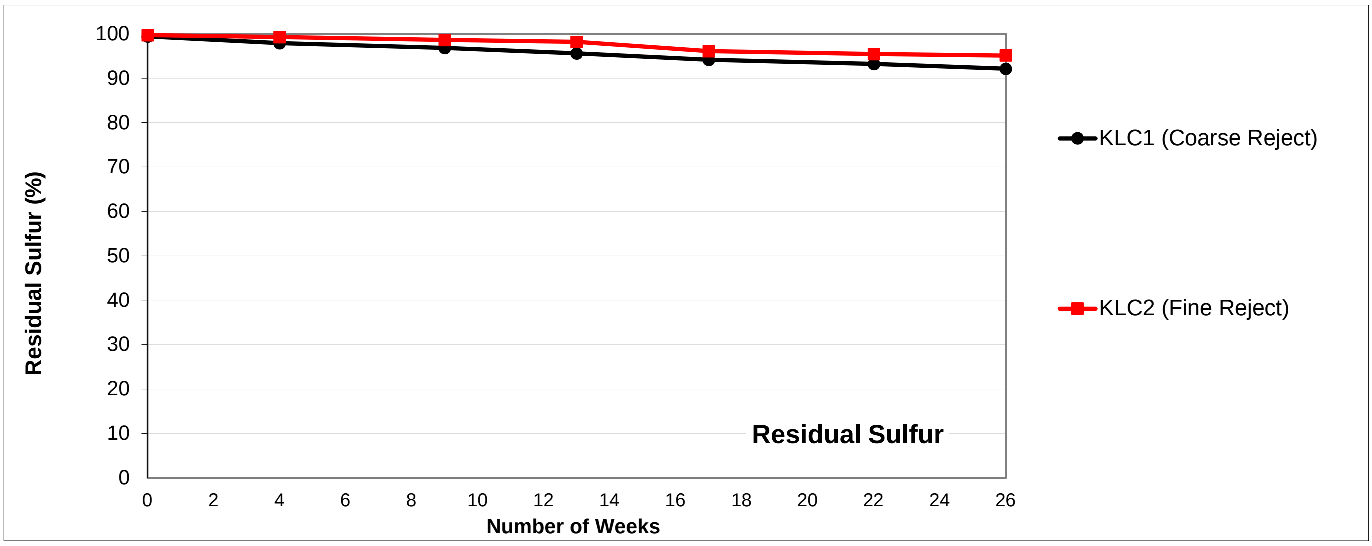
MPA = Maximum Potential Acidity, and NAPP = Net Acid Producing Potential.

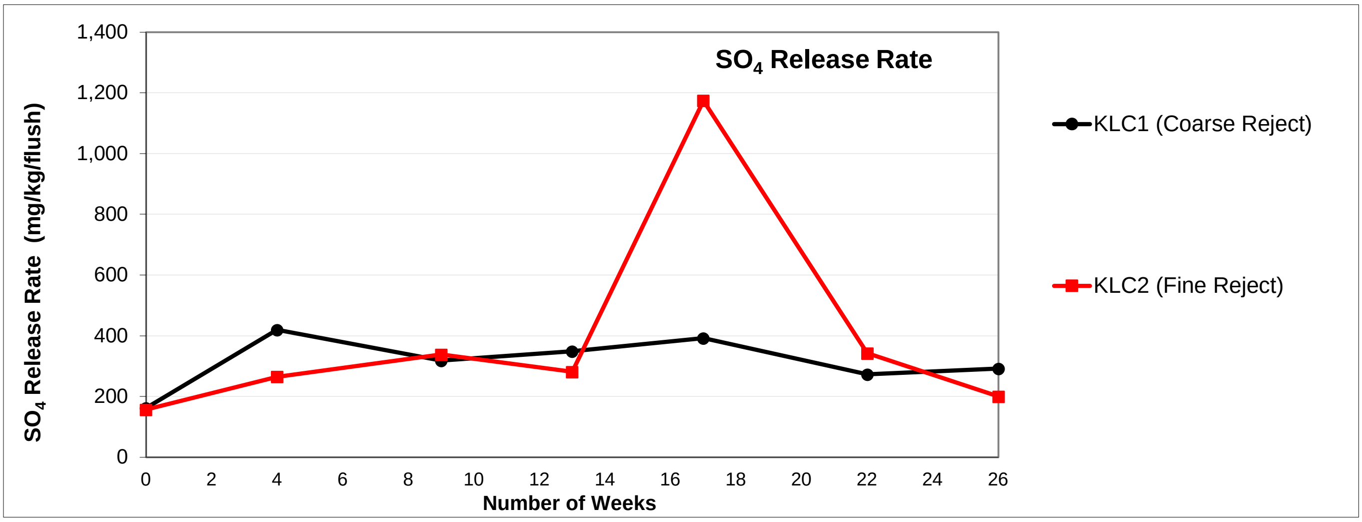
ANZECC & ARMCANZ (2000). 1. Trigger values for aquatic ecosystems (95 % protection level). 2. Livestock Drinking Water Levels.

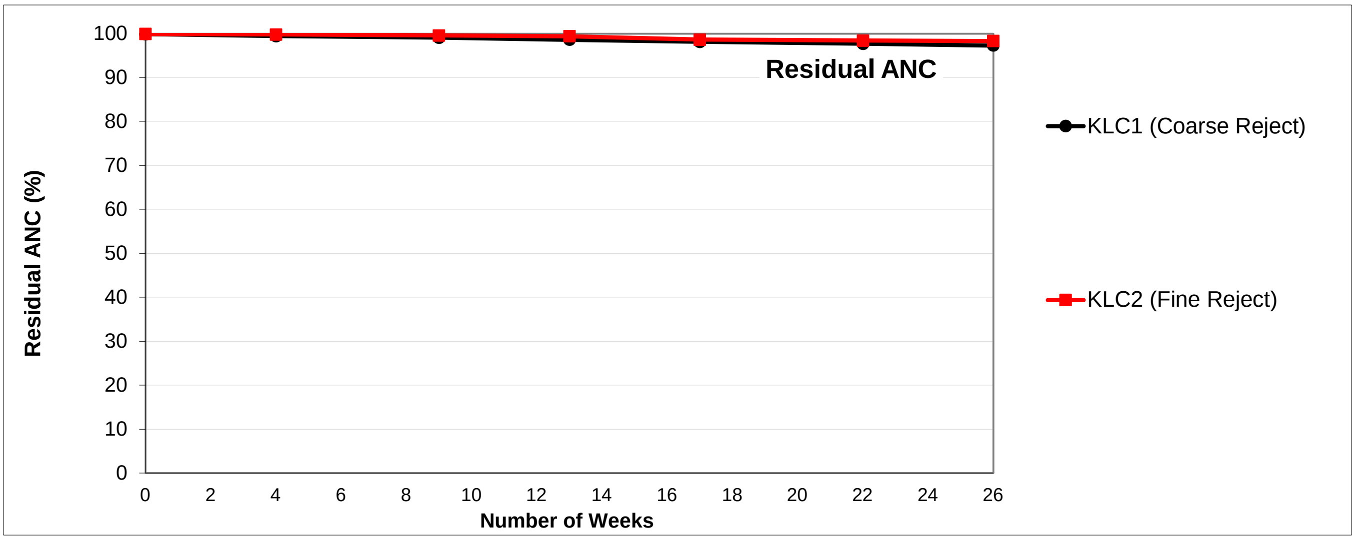

pH
KLC1 (Coarse Reject)
KLC2 (Fine Reject)
Deionised Water
Number of Weeks

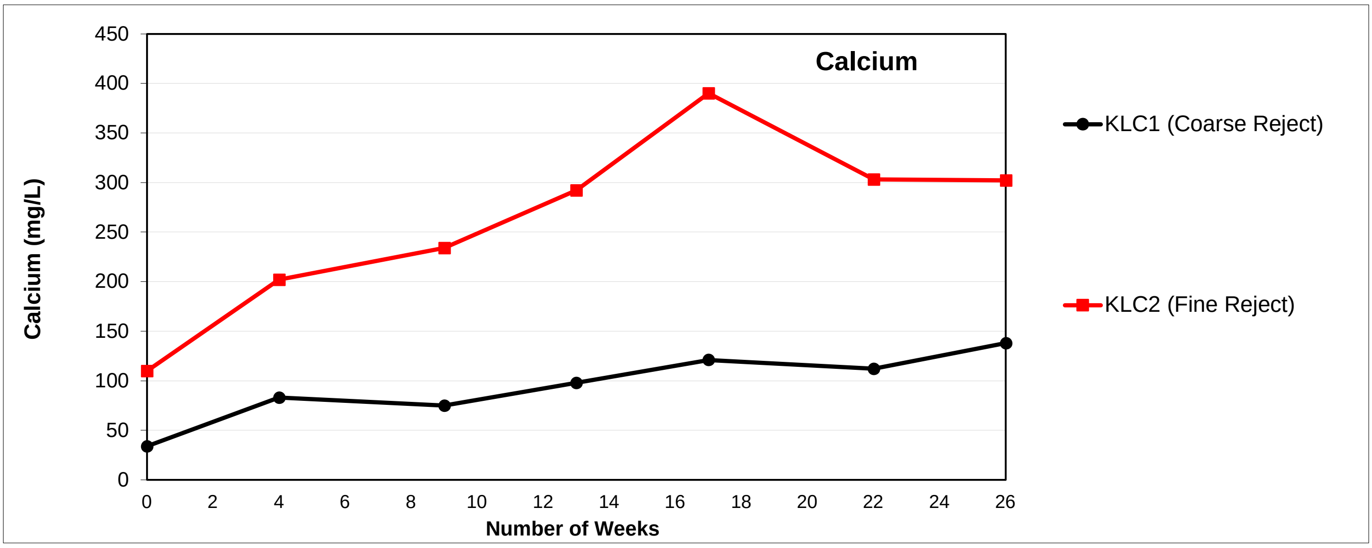

Electrical Conductivity
EC (µS/cm)
KLC1 (Coarse Reject)
KLC2 (Fine Reject)
Number of Weeks

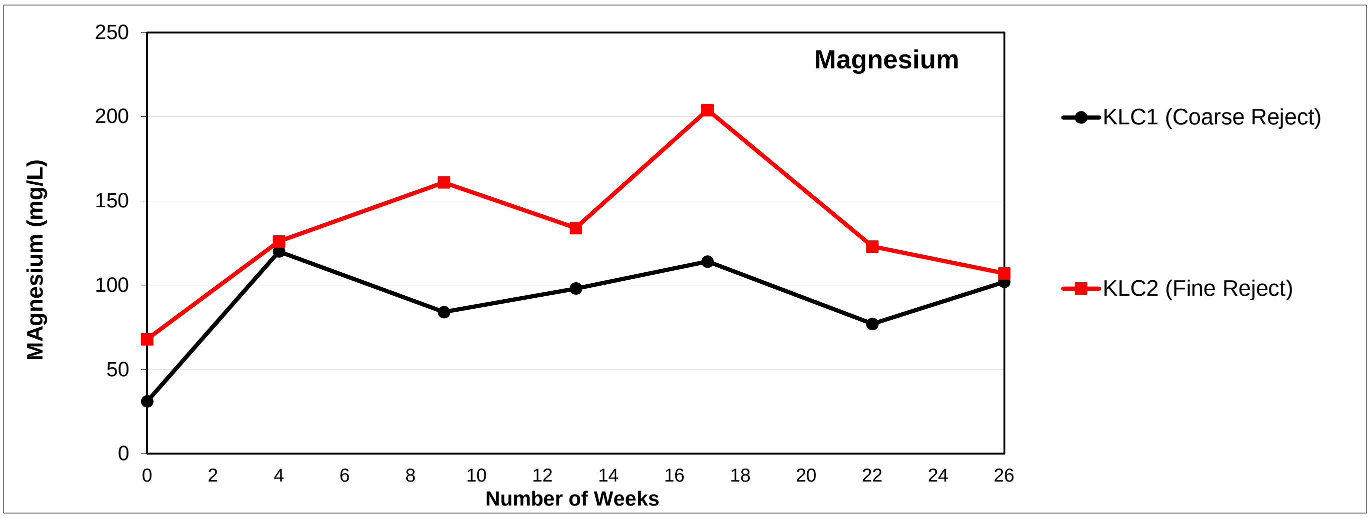

Net Alkalinity
Net Alkalinity (CaCO3 mg/L)
KLC1 (Coarse Reject)
KLC2 (Fine Reject)
Number of Weeks

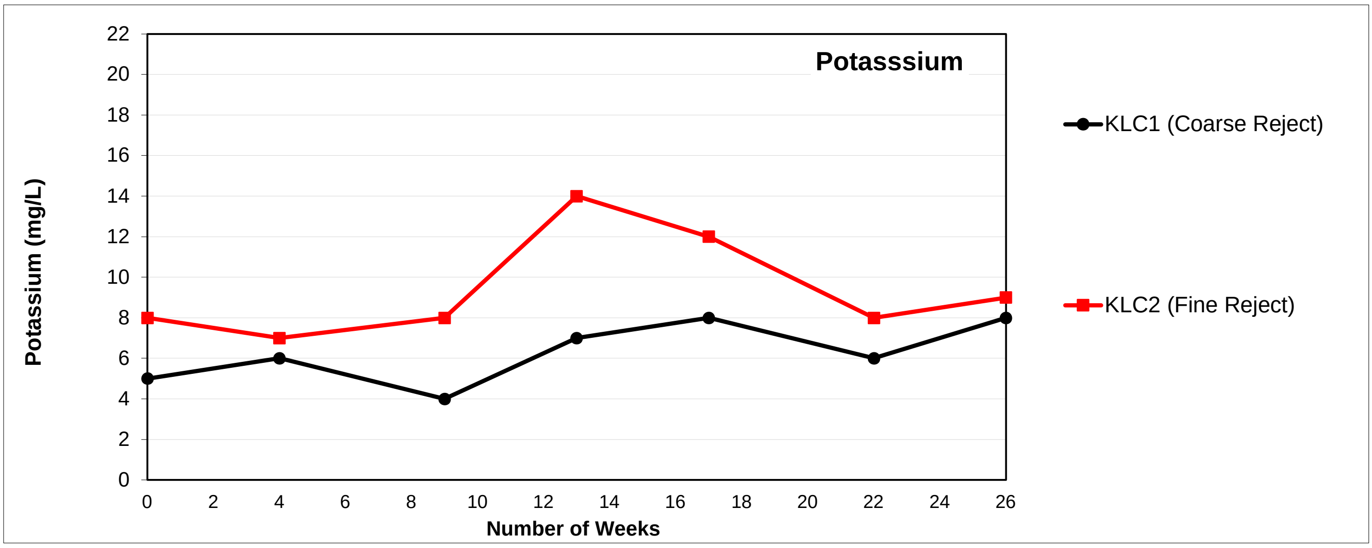

Residual Sulfur
Residual Sulfur (%)
Number of Weeks
KLC1 (Coarse Reject)
KLC2 (Fine Reject)
0
10
20
30
40
50
60
70
80
90
100
0
2
4
6
8
10
12
14
16
18
20
22
24
26

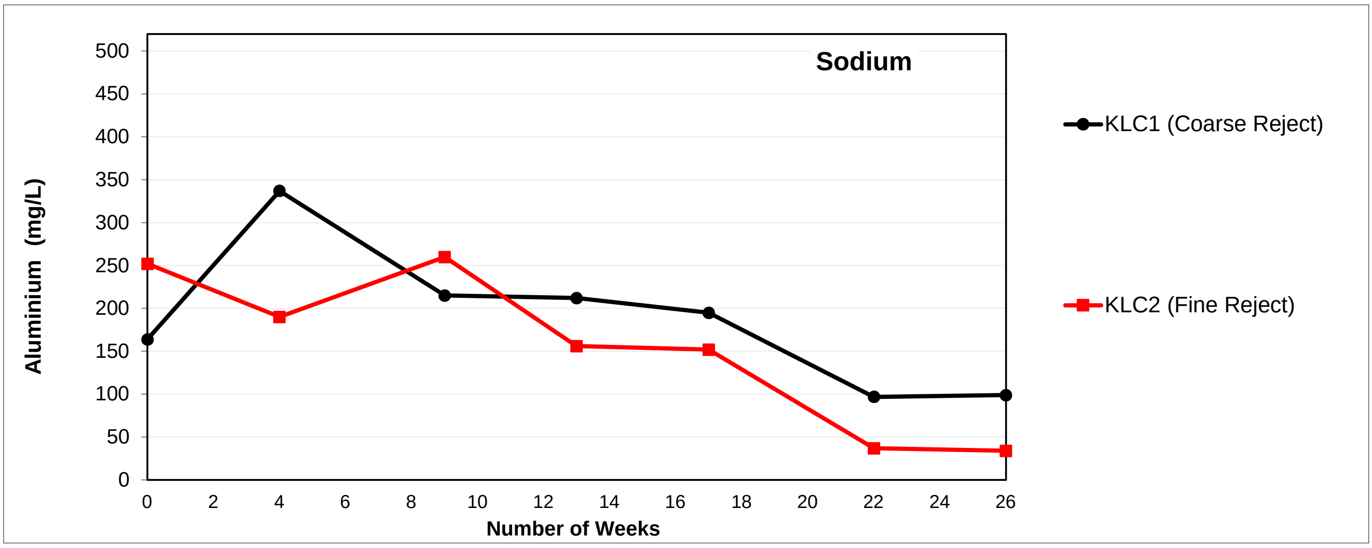

SO4 Release Rate
SO4 Release Rate (mg/kg/flush)
Number of Weeks
KLC1 (Coarse Reject)
KLC2 (Fine Reject)
0
200
400
600
800
1,000
1,200
1,400
0
2
4
6
8
10
12
14
16
18
20
22
24
26

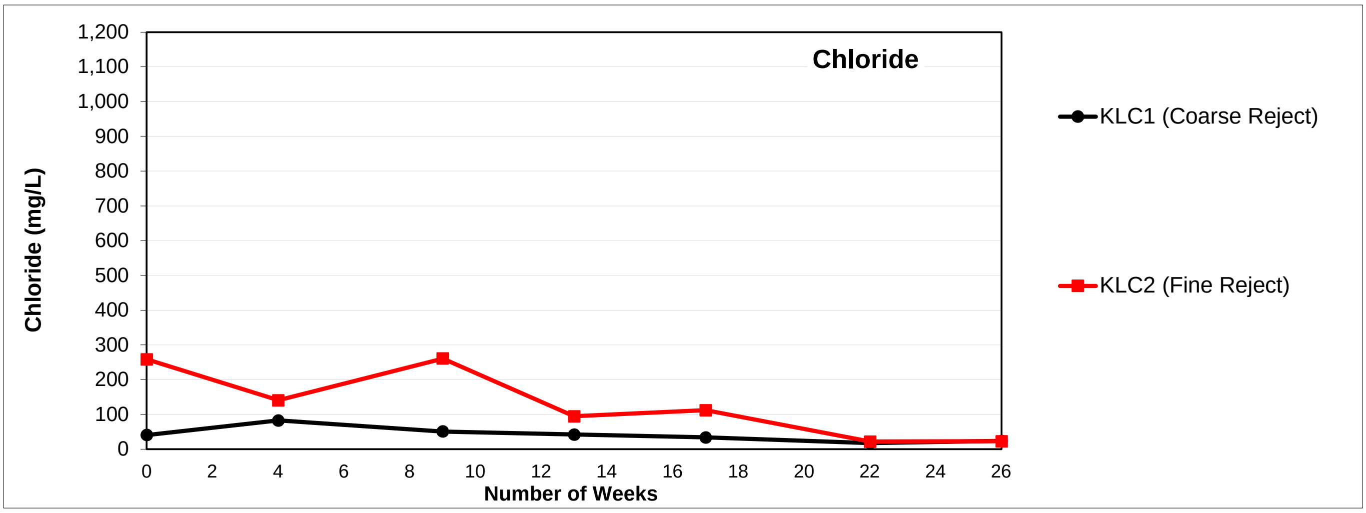

Residual ANC
Residual ANC (%)
Number of Weeks
KLC1 (Coarse Reject)
KLC2 (Fine Reject)
0
10
20
30
40
50
60
70
80
90
100
0
2
4
6
8
10
12
14
16
18
20
22
24
26

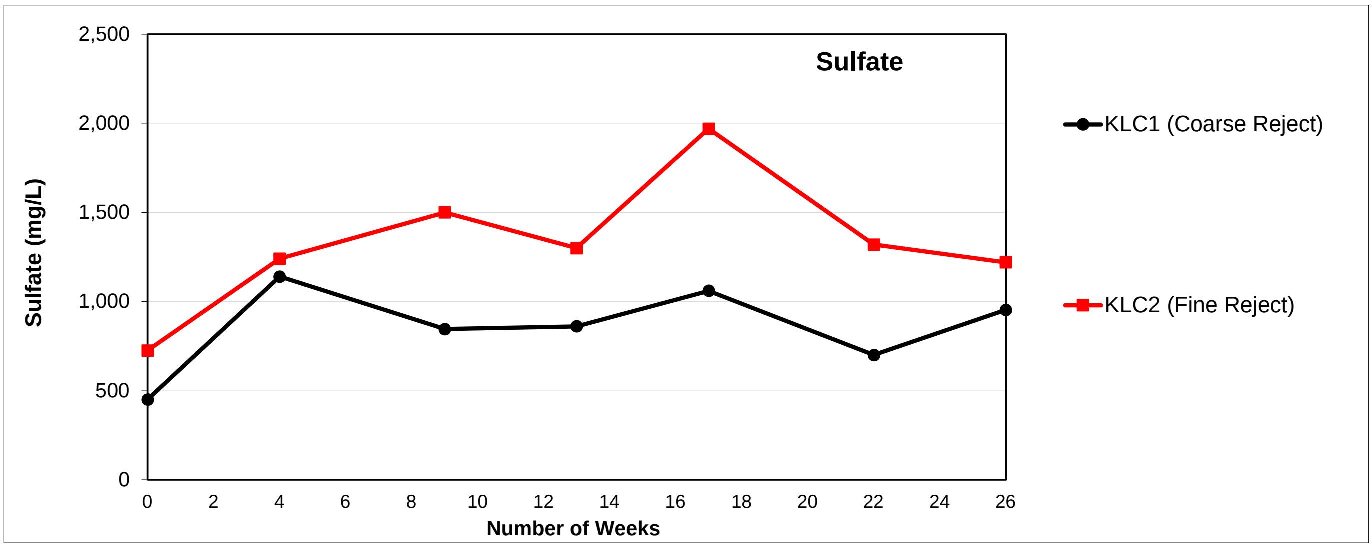

Calcium
Calcium (mg/L)
Number of Weeks
KLC1 (Coarse Reject)
KLC2 (Fine Reject)

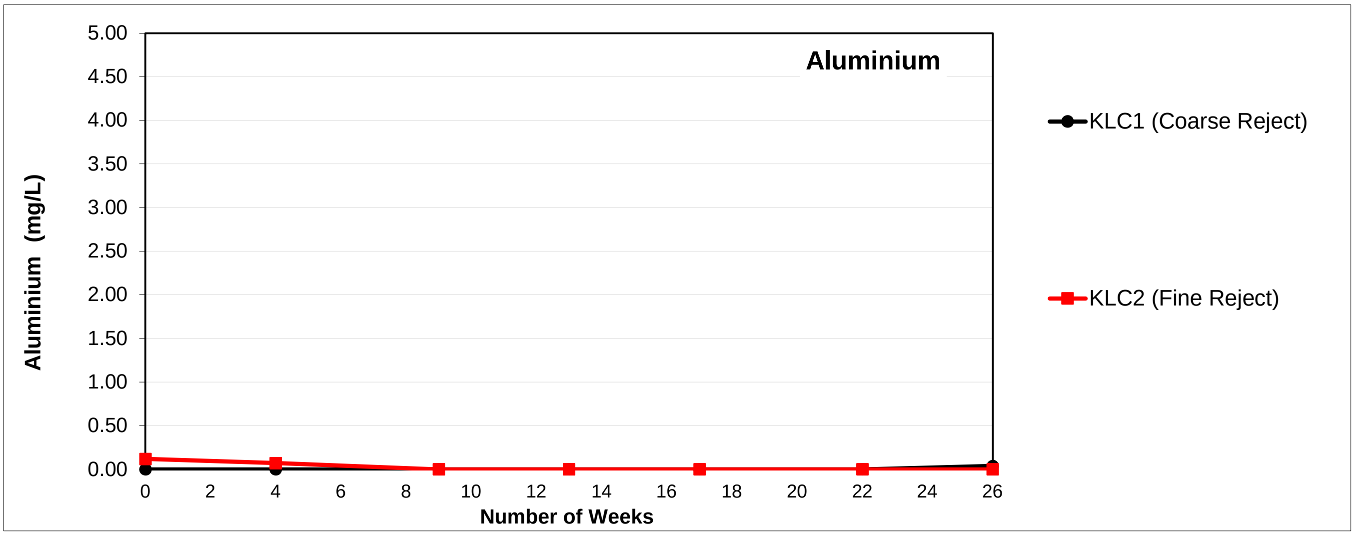

Magnesium
MAgnesium (mg/L)
Number of Weeks
KLC1 (Coarse Reject)
KLC2 (Fine Reject)

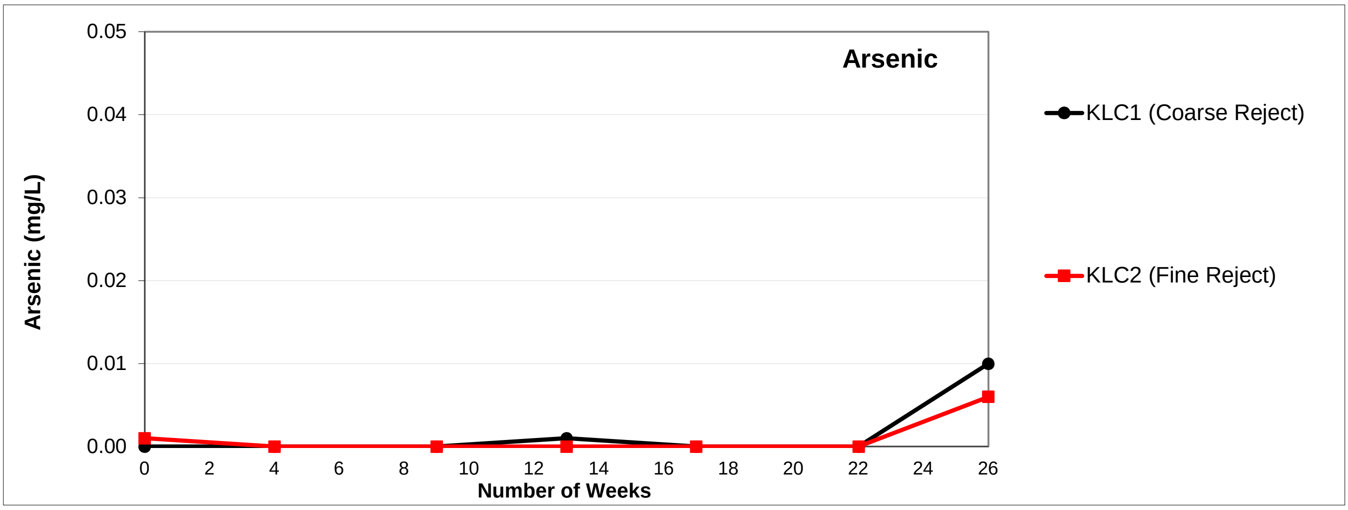

Potasssium
Potassium (mg/L)
Number of Weeks
KLC1 (Coarse Reject)
KLC2 (Fine Reject)

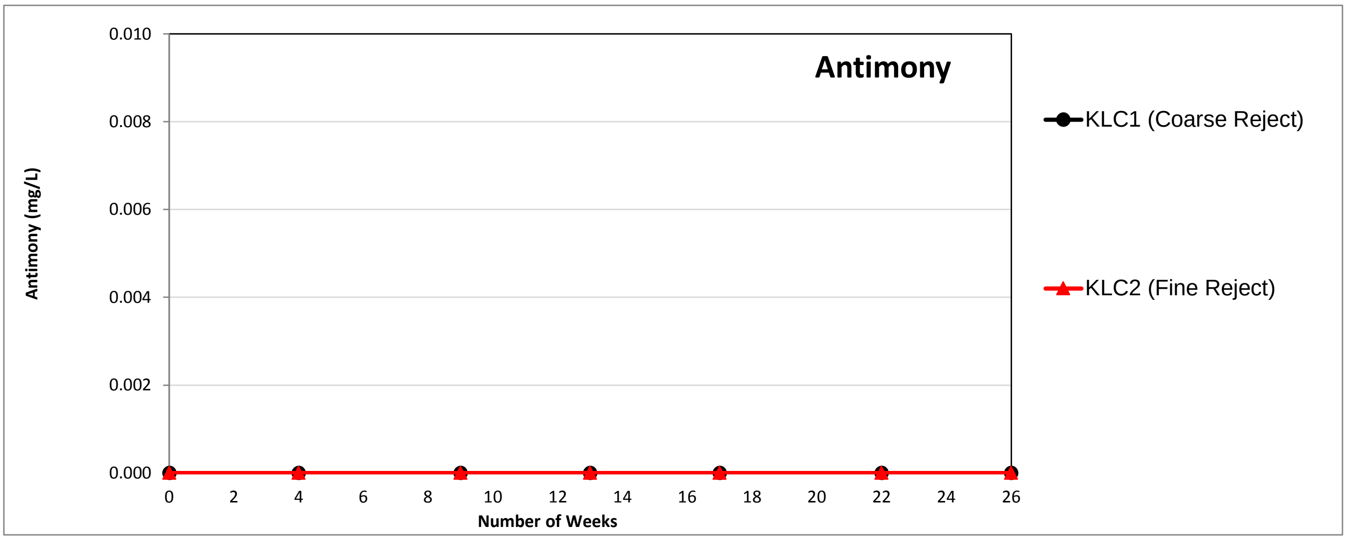

Sodium
Aluminium (mg/L)
500
450
400
350
300
250
200
150
100
50
0
0
2
4
6
8
10
12
14
16
18
20
22
24
26
Number of Weeks
KLC1 (Coarse Reject)
KLC2 (Fine Reject)

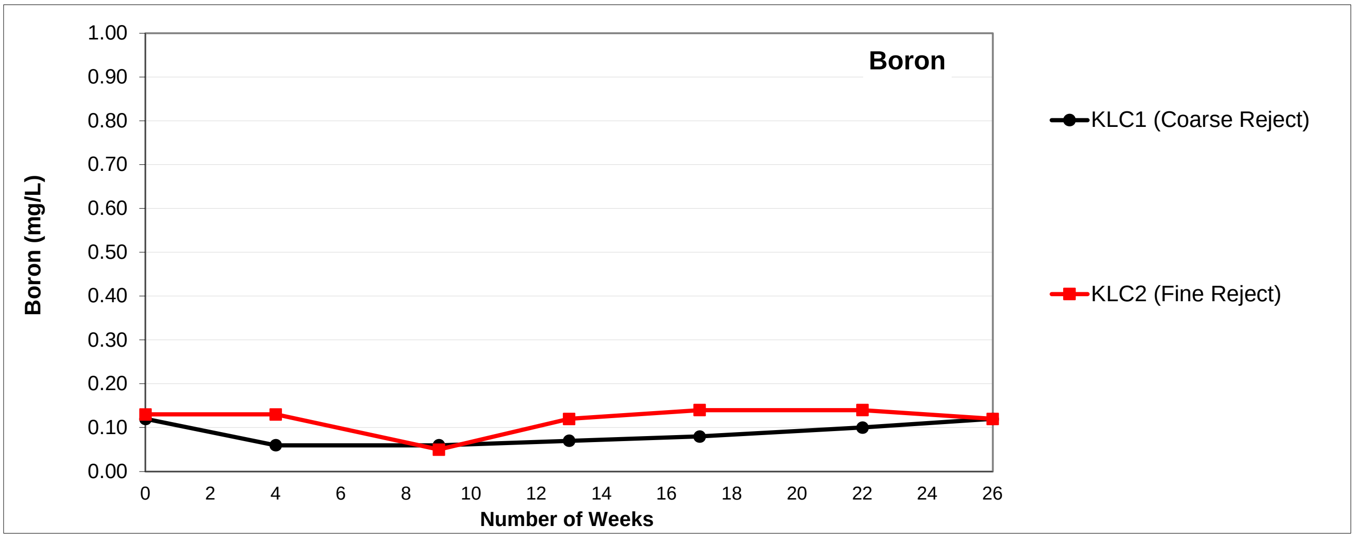

Chloride
Chloride (mg/L)
1,200
1,100
1,000
900
800
700
600
500
400
300
200
100
0
0
2
4
6
8
10
12
14
16
18
20
22
24
26
Number of Weeks
KLC1 (Coarse Reject)
KLC2 (Fine Reject)

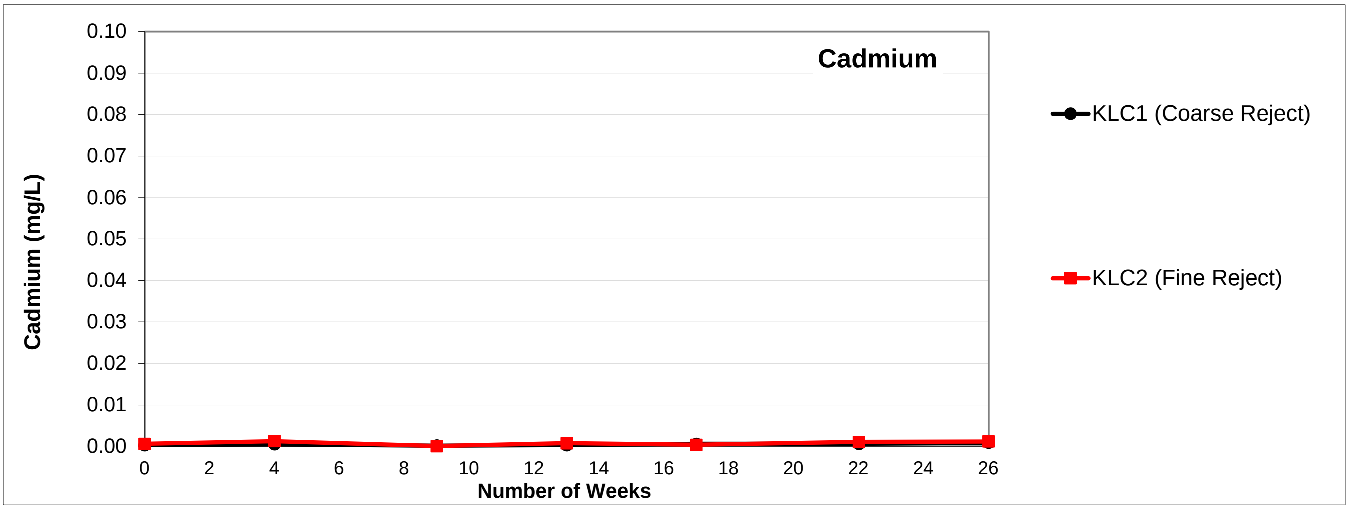

Sulfate
Sulfate (mg/L)
2,500
2,000
1,500
1,000
500
0
0
2
4
6
8
10
12
14
16
18
20
22
24
26
Number of Weeks
KLC1 (Coarse Reject)
KLC2 (Fine Reject)

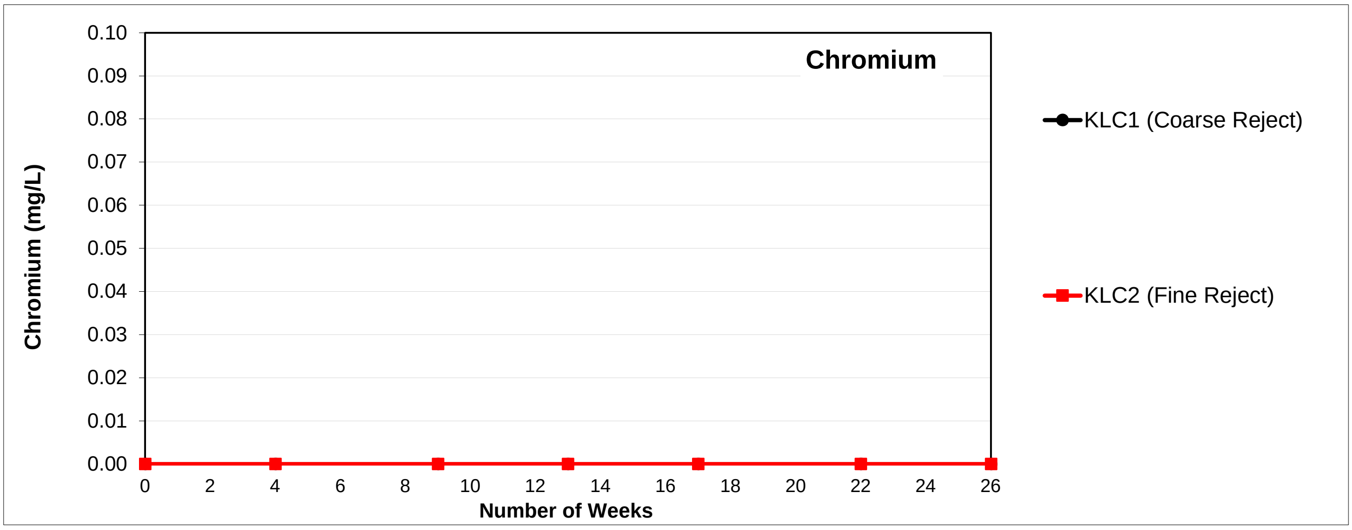

Aluminium
Aluminium (mg/L)
5.00
4.50
4.00
3.50
3.00
2.50
2.00
1.50
1.00
0.50
0.00
0 2 4 6 8 10 12 14 16 18 20 22 24 26
Number of Weeks
KLC1 (Coarse Reject)
KLC2 (Fine Reject)

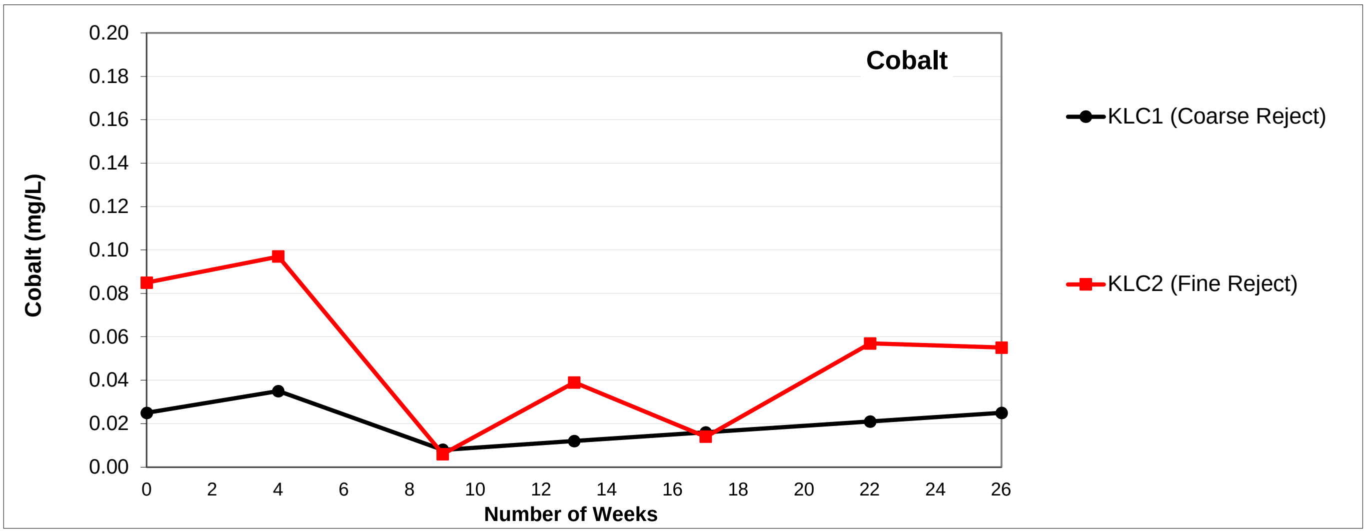

Arsenic
Arsenic (mg/L)
0.05
0.04
0.03
0.02
0.01
0.00
0 2 4 6 8 10 12 14 16 18 20 22 24 26
Number of Weeks
KLC1 (Coarse Reject)
KLC2 (Fine Reject)

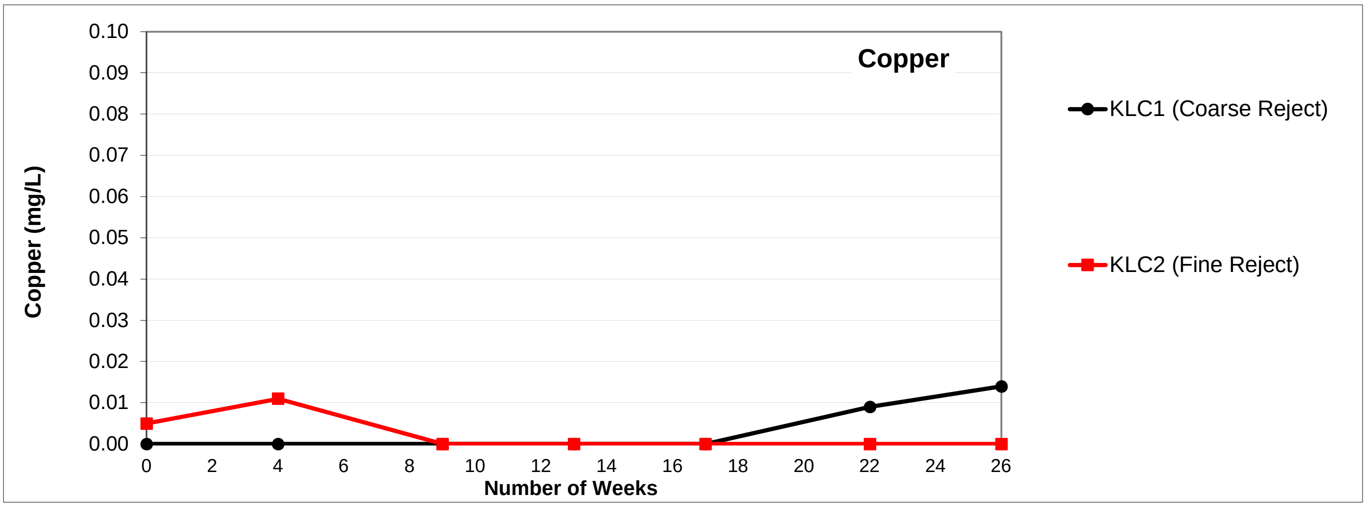

Antimony
Antimony (mg/L)
0.010
0.008
0.006
0.004
0.002
0.000
0 2 4 6 8 10 12 14 16 18 20 22 24 26
Number of Weeks
KLC1 (Coarse Reject)
KLC2 (Fine Reject)

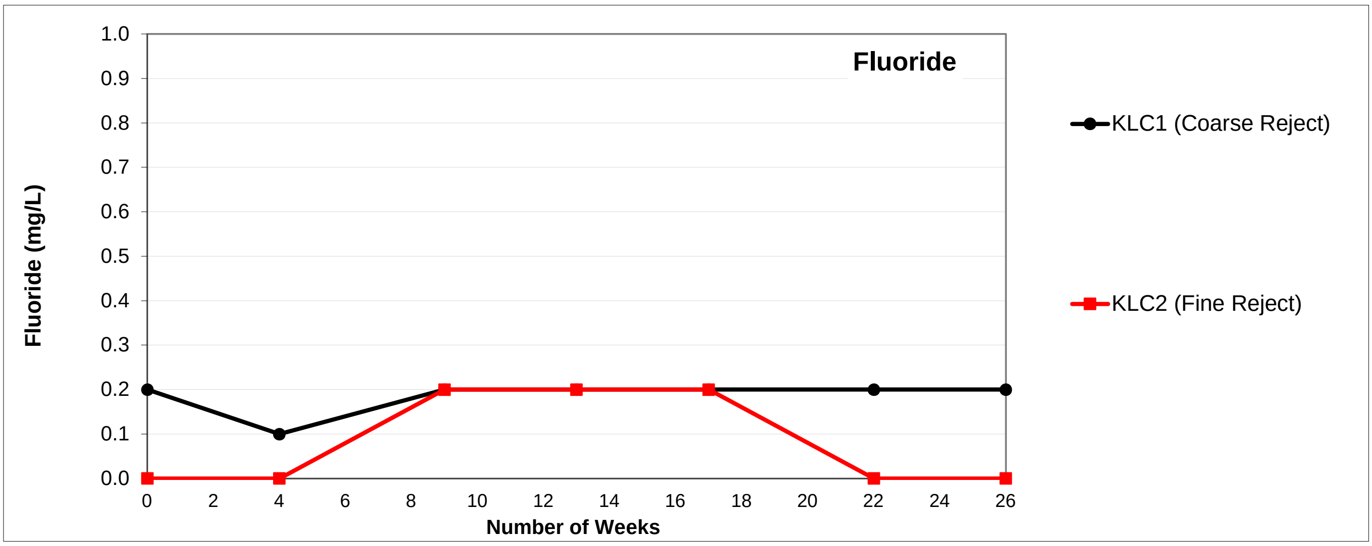

Boron
Boron (mg/L)
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
0
2
4
6
8
10
12
14
16
18
20
22
24
26
Number of Weeks
KLC1 (Coarse Reject)
KLC2 (Fine Reject)

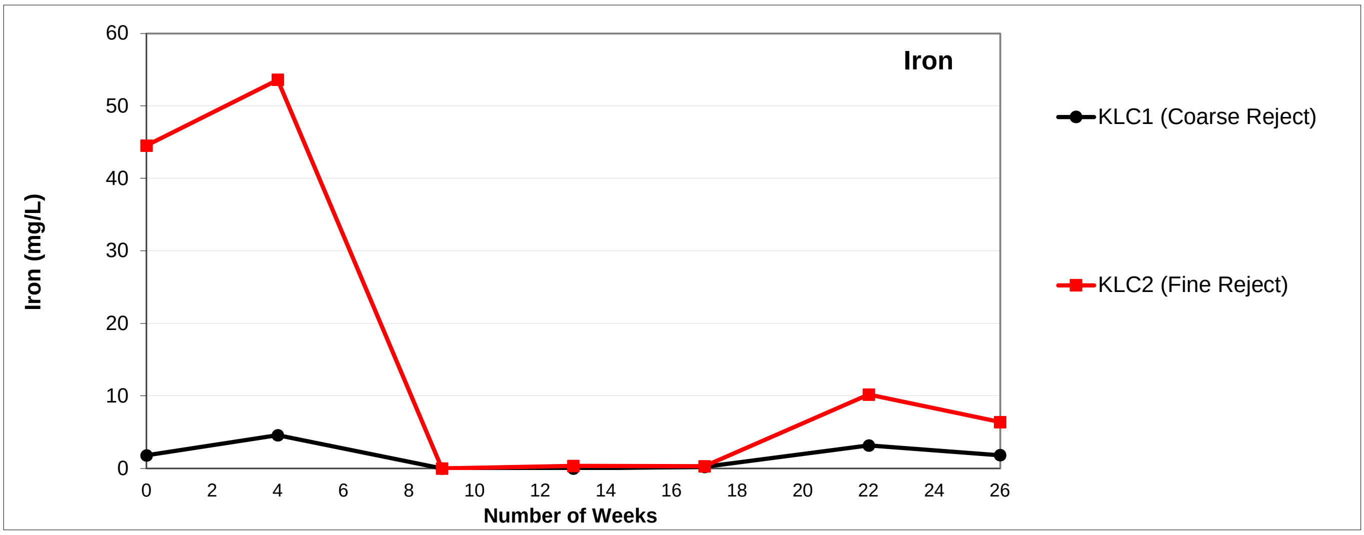

Cadmium
Cadmium (mg/L)
0.10
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0.00
0
2
4
6
8
10
12
14
16
18
20
22
24
26
Number of Weeks
KLC1 (Coarse Reject)
KLC2 (Fine Reject)

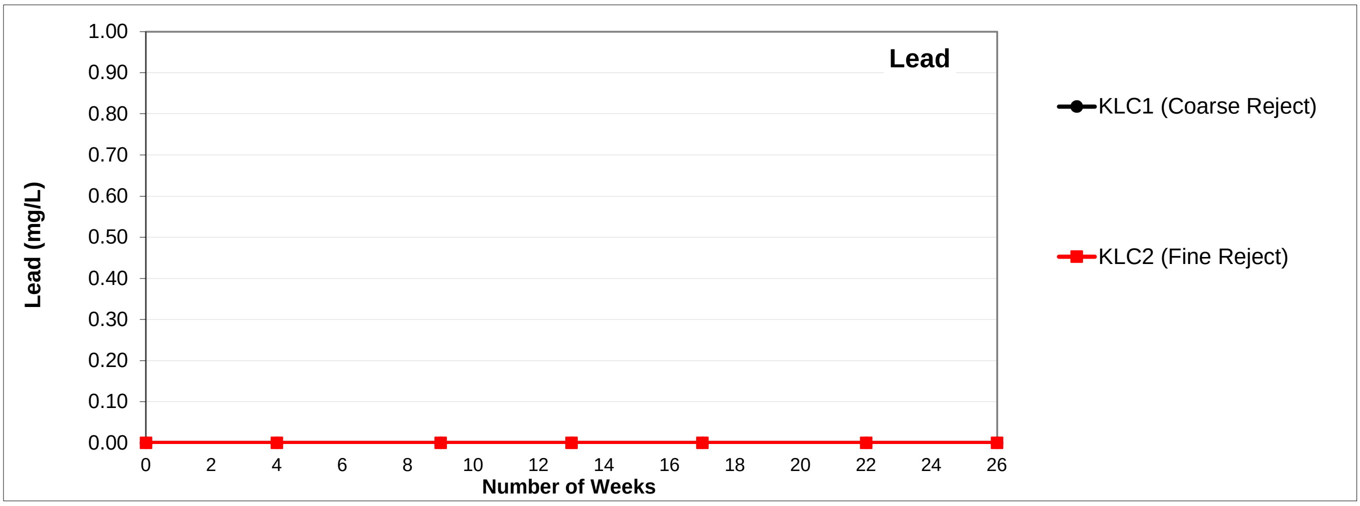

Chromium
Chromium (mg/L)
0.10
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0.00
0
2
4
6
8
10
12
14
16
18
20
22
24
26
Number of Weeks
KLC1 (Coarse Reject)
KLC2 (Fine Reject)

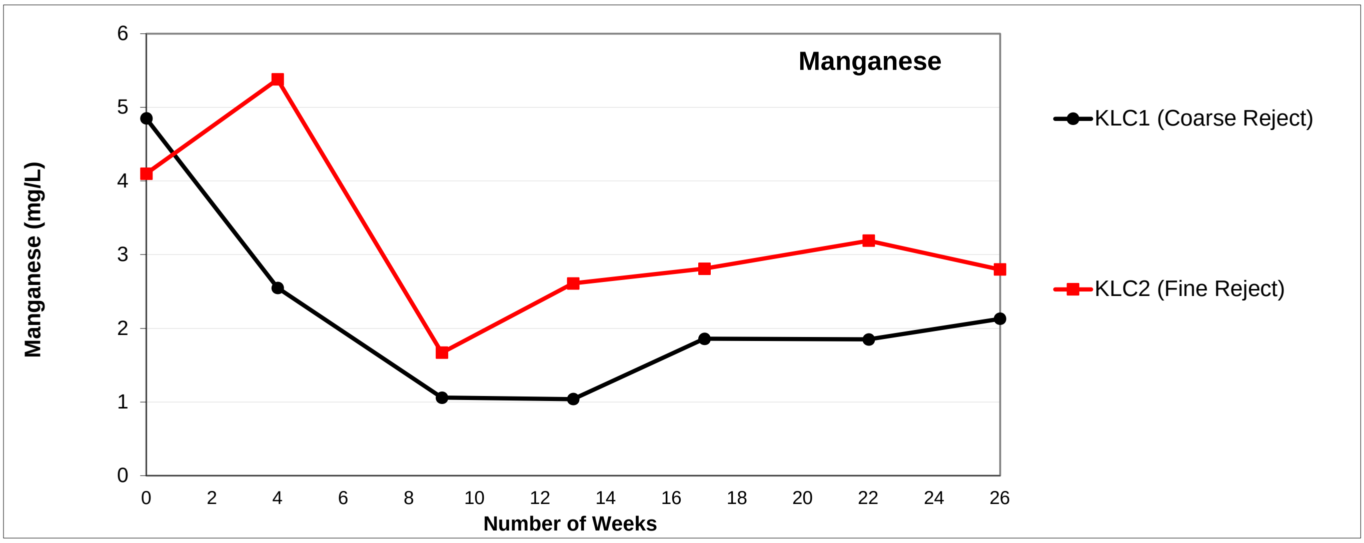

Cobalt
Cobalt (mg/L)
0.20
0.18
0.16
0.14
0.12
0.10
0.08
0.06
0.04
0.02
0.00
0
2
4
6
8
10
12
14
16
18
20
22
24
26
Number of Weeks
KLC1 (Coarse Reject)
KLC2 (Fine Reject)

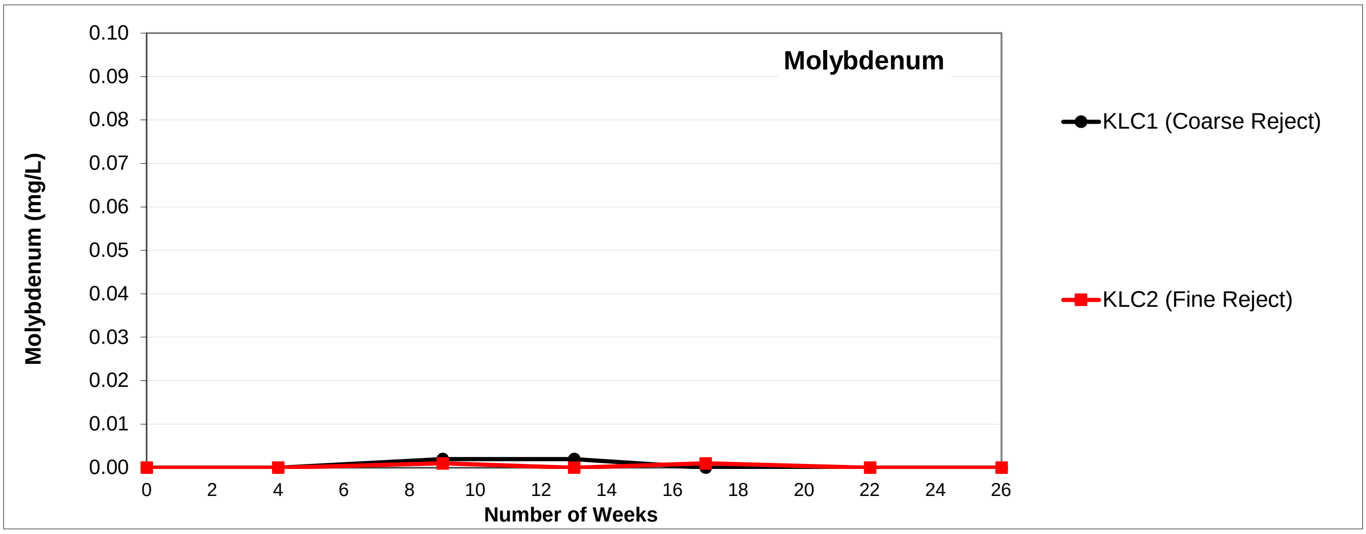

Copper
Copper (mg/L)
0.10
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0.00
0
2
4
6
8
10
12
14
16
18
20
22
24
26
Number of Weeks
KLC1 (Coarse Reject)
KLC2 (Fine Reject)

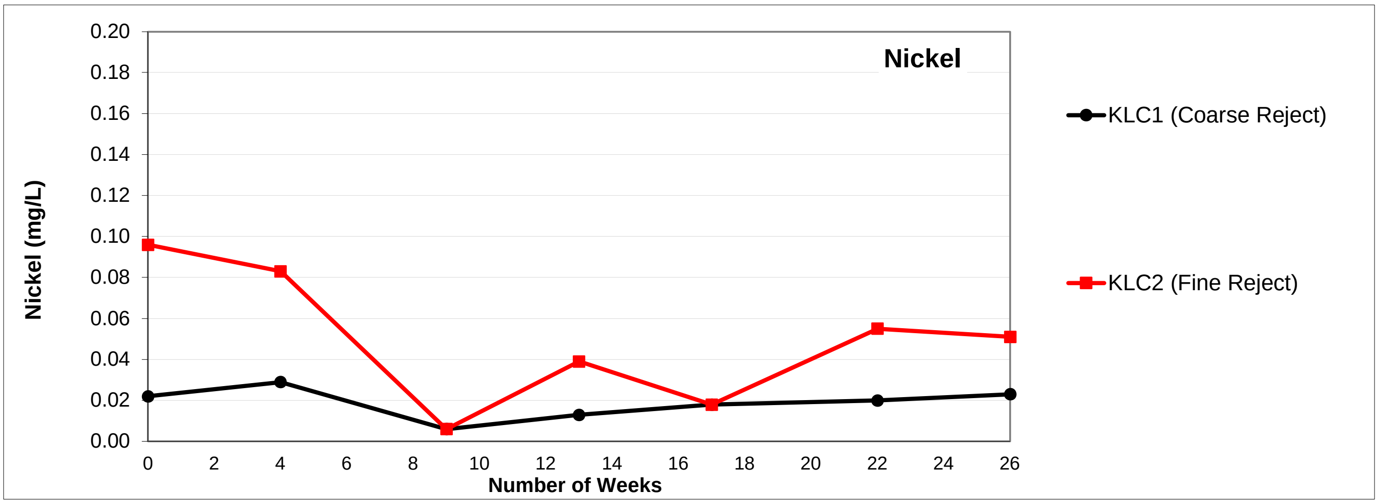

Fluoride
Fluoride (mg/L)
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
0
2
4
6
8
10
12
14
16
18
20
22
24
26
Number of Weeks
KLC1 (Coarse Reject)
KLC2 (Fine Reject)

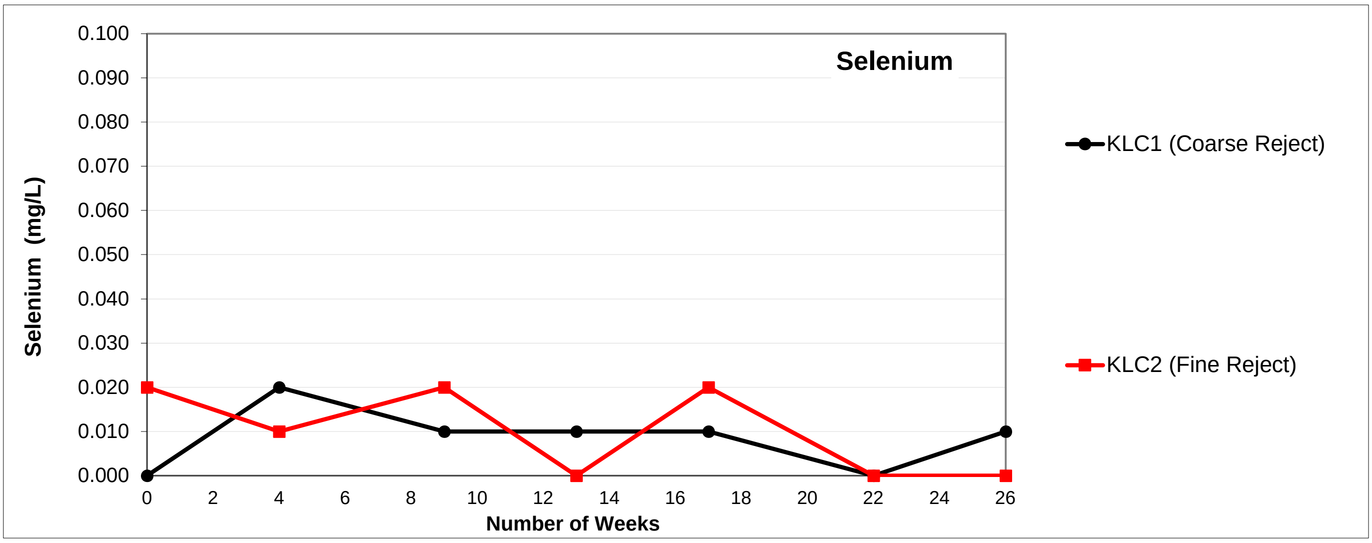

Iron
Iron (mg/L)
Number of Weeks
KLC1 (Coarse Reject)
KLC2 (Fine Reject)

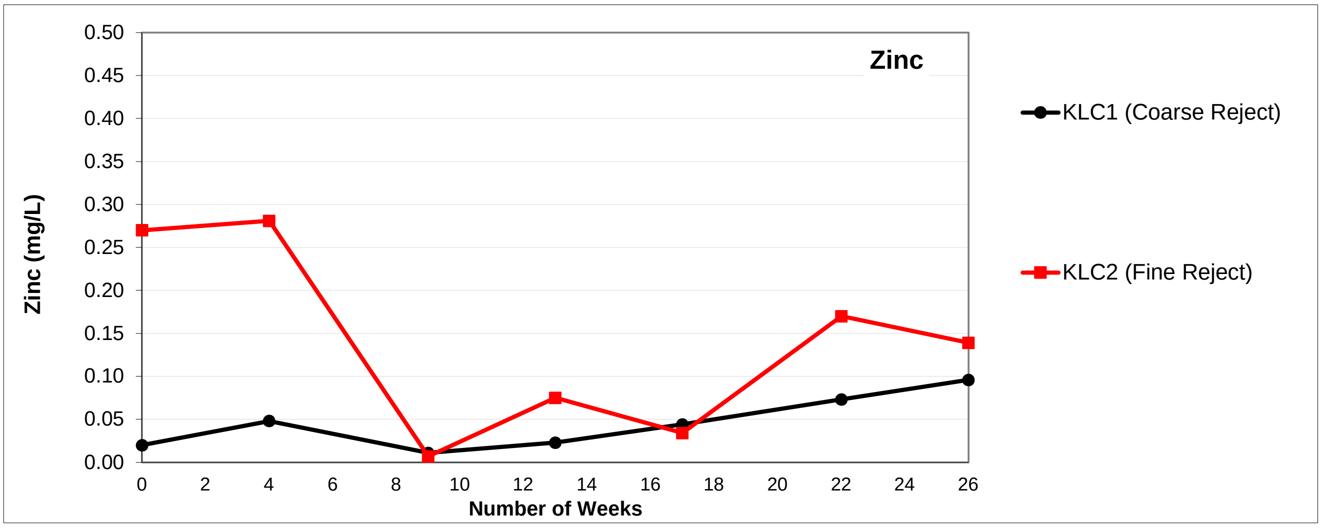

Lead
Lead (mg/L)
Number of Weeks
KLC1 (Coarse Reject)
KLC2 (Fine Reject)


Manganese
Manganese (mg/L)
Number of Weeks
KLC1 (Coarse Reject)
KLC2 (Fine Reject)


Molybdenum
Molybdenum (mg/L)
Number of Weeks
KLC1 (Coarse Reject)
KLC2 (Fine Reject)


Nickel
Nickel (mg/L)
Number of Weeks
KLC1 (Coarse Reject)
KLC2 (Fine Reject)


Selenium
Selenium (mg/L)
Number of Weeks
KLC1 (Coarse Reject)
KLC2 (Fine Reject)


Zinc
Zinc (mg/L)
0.50
0.45
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
0
2
4
6
8
10
12
14
16
18
20
22
24
26
Number of Weeks
KLC1 (Coarse Reject)
KLC2 (Fine Reject)

Attachment E ALS laboratory results

CERTIFICATE OF ANALYSIS

Work Order	: **EB1912348**	Page	: 1 of 7
Client	: **RGS ENVIRONMENTAL PTY LTD**	Laboratory	: Environmental Division Brisbane
Contact	: MR ALAN ROBERTSON	Contact	: Customer Services EB
Address	: PO Box 3091 SUNNYBANK SOUTH QLD, AUSTRALIA 4109	Address	: 2 Byth Street Stafford QLD Australia 4053
Telephone	: +61 07 3344 1222	Telephone	: +61-7-3243 7222
Project	: 2017002 Dingo west	Date Samples Received	: 15-May-2019 14:30
Order number	: 2017002	Date Analysis Commenced	: 15-May-2019
C-O-C number	: ----	Issue Date	: 22-May-2019 13:08
Sampler	: MARY MACELROY		
Site	: ----		
Quote number	: EN/222		
No. of samples received	: 23		
No. of samples analysed	: 23		

Accreditation No. 825
Accredited for compliance with
ISO/IEC 17025 - Testing

This report supersedes any previous report(s) with this reference. Results apply to the sample(s) as submitted. This document shall not be reproduced, except in full.

This Certificate of Analysis contains the following information:

- General Comments
- Analytical Results

Additional information pertinent to this report will be found in the following separate attachments: Quality Control Report, QA/QC Compliance Assessment to assist with Quality Review and Sample Receipt Notification.

Signatories

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

Signatories	*Position*	*Accreditation Category*
Kim McCabe	Senior Inorganic Chemist	Brisbane Acid Sulphate Soils, Stafford, QLD
Kim McCabe	Senior Inorganic Chemist	Brisbane Inorganics, Stafford, QLD
Satishkumar Trivedi	Senior Acid Sulfate Soil Chemist	Brisbane Acid Sulphate Soils, Stafford, QLD

General Comments

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

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

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

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

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

Where a result is required to meet compliance limits the associated uncertainty must be considered. Refer to the ALS Contact for details.

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

- EA031 (Saturated Paste pH): NATA accreditation does not cover the performance of this service.
- EA032 (Saturated Paste EC): NATA accreditation does not cover the performance of this service.
- ASS: EA013 (ANC) Fizz Rating: 0- None; 1- Slight; 2- Moderate; 3- Strong; 4- Very Strong; 5- Lime.

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Client sample ID	Composite 1	Composite 2	Composite 3	Composite 4	Composite 5
			Client sampling date / time	15-May-2019 00:00	15-May-2019 00:00	15-May-2019 00:00	15-May-2019 00:00	15-May-2019 00:00
Compound	CAS Number	LOR	Unit	EB1912348-001	EB1912348-002	EB1912348-003	EB1912348-004	EB1912348-005
				Result	Result	Result	Result	Result
EA009: Nett Acid Production Potential								
Net Acid Production Potential	----	0.5	kg H2SO4/t	24.1	6.2	-40.7	-95.4	0.6
EA013: Acid Neutralising Capacity								
ANC as H2SO4	----	0.5	kg H2SO4 equiv./t	16.0	22.6	64.6	108	10.7
ANC as CaCO3	----	0.1	% CaCO3	1.6	2.3	6.6	11.0	1.1
Fizz Rating	----	0	Fizz Unit	1	1	2	2	1
EA031: pH (saturated paste)								
ø pH (Saturated Paste)	----	0.1	pH Unit	6.3	6.0	7.3	7.8	8.2
EA032: Electrical Conductivity (saturated paste)								
ø Electrical Conductivity (Saturated Paste)	----	1	µS/cm	946	1440	1040	567	919
ED042T: Total Sulfur by LECO								
Sulfur - Total as S (LECO)	----	0.01	%	1.31	0.94	0.78	0.41	0.37

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Client sample ID	Composite 6	Composite 7	Composite 8	Composite 9	Composite 10
			Client sampling date / time	15-May-2019 00:00	15-May-2019 00:00	15-May-2019 00:00	15-May-2019 00:00	15-May-2019 00:00
Compound	CAS Number	LOR	Unit	EB1912348-006	EB1912348-007	EB1912348-008	EB1912348-009	EB1912348-010
				Result	Result	Result	Result	Result
EA009: Nett Acid Production Potential								
Net Acid Production Potential	----	0.5	kg H2SO4/t	**4.0**	**-52.6**	**23.9**	**-52.0**	**-29.3**
EA013: Acid Neutralising Capacity								
ANC as H2SO4	----	0.5	kg H2SO4 equiv./t	**26.3**	**68.5**	**30.3**	**70.1**	**36.3**
ANC as CaCO3	----	0.1	% CaCO3	**2.7**	**7.0**	**3.1**	**7.1**	**3.7**
Fizz Rating	----	0	Fizz Unit	**1**	**2**	**1**	**2**	**1**
EA031: pH (saturated paste)								
ø pH (Saturated Paste)	----	0.1	pH Unit	**8.2**	**7.9**	**5.1**	**8.0**	**7.4**
EA032: Electrical Conductivity (saturated paste)								
ø Electrical Conductivity (Saturated Paste)	----	1	µS/cm	**688**	**398**	**1620**	**456**	**1040**
ED042T: Total Sulfur by LECO								
Sulfur - Total as S (LECO)	----	0.01	%	**0.99**	**0.52**	**1.77**	**0.59**	**0.23**

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Client sample ID	Composite 11	Composite 12	Composite 13	Composite 14	Composite 15
			Client sampling date / time	15-May-2019 00:00	15-May-2019 00:00	15-May-2019 00:00	15-May-2019 00:00	15-May-2019 00:00
Compound	CAS Number	LOR	Unit	EB1912348-011	EB1912348-012	EB1912348-013	EB1912348-014	EB1912348-015
				Result	Result	Result	Result	Result
EA009: Nett Acid Production Potential								
Net Acid Production Potential	----	0.5	kg H2SO4/t	-32.6	-99.7	-7.7	-29.1	72.6
EA013: Acid Neutralising Capacity								
ANC as H2SO4	----	0.5	kg H2SO4 equiv./t	132	122	19.0	57.3	11.5
ANC as CaCO3	----	0.1	% CaCO3	13.5	12.5	1.9	5.8	1.2
Fizz Rating	----	0	Fizz Unit	2	2	1	2	1
EA031: pH (saturated paste)								
ø pH (Saturated Paste)	----	0.1	pH Unit	6.6	8.2	8.3	7.4	6.2
EA032: Electrical Conductivity (saturated paste)								
ø Electrical Conductivity (Saturated Paste)	----	1	µS/cm	1300	418	774	1160	824
ED042T: Total Sulfur by LECO								
Sulfur - Total as S (LECO)	----	0.01	%	3.25	0.73	0.37	0.92	2.75

Analytical Results

Sub-Matrix: SOIL
(Matrix: SOIL)

Compound	CAS Number	LOR	Unit	Composite 16	Composite 17	Composite 18	Composite 19	Composite 20
Client sampling date / time				15-May-2019 00:00	15-May-2019 00:00	15-May-2019 00:00	15-May-2019 00:00	15-May-2019 00:00
				EB1912348-016	EB1912348-017	EB1912348-018	EB1912348-019	EB1912348-020
				Result	Result	Result	Result	Result
EA009: Nett Acid Production Potential								
Net Acid Production Potential	----	0.5	kg H2SO4/t	-182	-351	-91.8	0.9	-155
EA013: Acid Neutralising Capacity								
ANC as H2SO4	----	0.5	kg H2SO4 equiv./t	221	396	112	30.6	204
ANC as CaCO3	----	0.1	% CaCO3	22.5	40.4	11.5	3.1	20.8
Fizz Rating	----	0	Fizz Unit	3	4	2	1	3
EA031: pH (saturated paste)								
ø pH (Saturated Paste)	----	0.1	pH Unit	6.9	7.6	7.8	6.4	7.0
EA032: Electrical Conductivity (saturated paste)								
ø Electrical Conductivity (Saturated Paste)	----	1	µS/cm	1320	520	570	1120	647
ED042T: Total Sulfur by LECO								
Sulfur - Total as S (LECO)	----	0.01	%	1.27	1.47	0.66	1.03	1.61

Work Order : EB1912348
Client : RGS ENVIRONMENTAL PTY LTD
Project : 2017002 Dingo west

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Client sample ID	Composite 21	Composite 22	pH and EC - DI Water	----	----
			Client sampling date / time	15-May-2019 00:00	15-May-2019 00:00	15-May-2019 00:00	----	----
Compound	CAS Number	LOR	Unit	EB1912348-021	EB1912348-022	EB1912348-023	--------	--------
				Result	Result	Result	----	----
EA002: pH 1:5 (Soils)								
pH Value	----	0.1	pH Unit	----	----	5.1	----	----
EA009: Nett Acid Production Potential								
Net Acid Production Potential	----	0.5	kg H2SO4/t	52.9	-39.5	----	----	----
EA010: Conductivity (1:5)								
Electrical Conductivity @ 25°C	----	1	µS/cm	----	----	<1	----	----
EA013: Acid Neutralising Capacity								
ANC as H2SO4	----	0.5	kg H2SO4 equiv./t	12.9	168	----	----	----
ANC as CaCO3	----	0.1	% CaCO3	1.3	17.1	----	----	----
Fizz Rating	----	0	Fizz Unit	1	3	----	----	----
EA031: pH (saturated paste)								
ø pH (Saturated Paste)	----	0.1	pH Unit	5.9	6.4	----	----	----
EA032: Electrical Conductivity (saturated paste)								
ø Electrical Conductivity (Saturated Paste)	----	1	µS/cm	502	1170	----	----	----
ED042T: Total Sulfur by LECO								
Sulfur - Total as S (LECO)	----	0.01	%	2.15	4.20	----	----	----

CERTIFICATE OF ANALYSIS

Work Order	: **EB1913397**	Page	: 1 of 5
Client	: **RGS ENVIRONMENTAL PTY LTD**	Laboratory	: Environmental Division Brisbane
Contact	: MR ALAN ROBERTSON	Contact	: Customer Services EB
Address	: PO Box 3091 SUNNYBANK SOUTH QLD, AUSTRALIA 4109	Address	: 2 Byth Street Stafford QLD Australia 4053
Telephone	: +61 07 3344 1222	Telephone	: +61-7-3243 7222
Project	: 2017002 Dingo west	Date Samples Received	: 24-May-2019 17:30
Order number	:	Date Analysis Commenced	: 29-May-2019
C-O-C number	: ----	Issue Date	: 29-May-2019 13:28
Sampler	: AMANDA CLEMENTS		
Site	: ----		
Quote number	: EN/222		
No. of samples received	: 15		
No. of samples analysed	: 15		

Accreditation No. 825
Accredited for compliance with
ISO/IEC 17025 - Testing

This report supersedes any previous report(s) with this reference. Results apply to the sample(s) as submitted. This document shall not be reproduced, except in full.

This Certificate of Analysis contains the following information:

- General Comments
- Analytical Results

Additional information pertinent to this report will be found in the following separate attachments: Quality Control Report, QA/QC Compliance Assessment to assist with Quality Review and Sample Receipt Notification.

Signatories

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

Signatories	*Position*	*Accreditation Category*
Ben Felgendrejeris	Senior Acid Sulfate Soil Chemist	Brisbane Acid Sulphate Soils, Stafford, QLD

General Comments

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

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

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

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

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

Where a result is required to meet compliance limits the associated uncertainty must be considered. Refer to the ALS Contact for details.

Key : CAS Number = CAS registry number from database maintained by Chemical Abstracts Services. The Chemical Abstracts Service is a division of the American Chemical Society.

LOR = Limit of reporting

^ = This result is computed from individual analyte detections at or above the level of reporting

ø = ALS is not NATA accredited for these tests.

~ = Indicates an estimated value.

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Client sample ID	Composite 2	Composite 3	Composite 4	Composite 5	Composite 6
			Client sampling date / time	24-May-2019 00:00	24-May-2019 00:00	24-May-2019 00:00	24-May-2019 00:00	24-May-2019 00:00
Compound	CAS Number	LOR	Unit	EB1913397-001	EB1913397-002	EB1913397-003	EB1913397-004	EB1913397-005
				Result	Result	Result	Result	Result
EA026 : Chromium Reducible Sulfur								
Chromium Reducible Sulphur	----	0.005	%	**0.973**	**0.763**	**0.247**	**0.211**	**0.618**

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Client sample ID	Composite 7	Composite 8	Composite 9	Composite 10	Composite 11
			Client sampling date / time	24-May-2019 00:00	24-May-2019 00:00	24-May-2019 00:00	24-May-2019 00:00	24-May-2019 00:00
Compound	CAS Number	LOR	Unit	EB1913397-006	EB1913397-007	EB1913397-008	EB1913397-009	EB1913397-010
				Result	Result	Result	Result	Result
EA026 : Chromium Reducible Sulfur								
Chromium Reducible Sulphur	----	0.005	%	**0.270**	**1.16**	**0.609**	**0.121**	**3.22**

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Client sample ID	Composite 12	Composite 13	Composite 14	KLC1	KLC2
			Client sampling date / time	24-May-2019 00:00	24-May-2019 00:00	24-May-2019 00:00	24-May-2019 00:00	24-May-2019 00:00
Compound	CAS Number	LOR	Unit	EB1913397-011	EB1913397-012	EB1913397-013	EB1913397-014	EB1913397-015
				Result	Result	Result	Result	Result
EA026 : Chromium Reducible Sulfur								
Chromium Reducible Sulphur	----	0.005	%	**0.686**	**0.229**	**0.796**	**0.651**	**1.70**

CERTIFICATE OF ANALYSIS

Work Order	: **EB1912809**	Page	: 1 of 6
Client	: **RGS ENVIRONMENTAL PTY LTD**	Laboratory	: Environmental Division Brisbane
Contact	: MR ALAN ROBERTSON	Contact	: Customer Services EB
Address	: PO Box 3091 SUNNYBANK SOUTH QLD, AUSTRALIA 4109	Address	: 2 Byth Street Stafford QLD Australia 4053
Telephone	: +61 07 3344 1222	Telephone	: +61-7-3243 7222
Project	: 2017002 Dingo west	Date Samples Received	: 20-May-2019 16:41
Order number	:	Date Analysis Commenced	: 04-Jun-2019
C-O-C number	: ----	Issue Date	: 07-Jun-2019 15:51
Sampler	: ----		
Site	: ----		
Quote number	: EN/222		
No. of samples received	: 26		
No. of samples analysed	: 4		

Accreditation No. 825
Accredited for compliance with
ISO/IEC 17025 - Testing

This report supersedes any previous report(s) with this reference. Results apply to the sample(s) as submitted. This document shall not be reproduced, except in full.

This Certificate of Analysis contains the following information:

- General Comments
- Analytical Results

Additional information pertinent to this report will be found in the following separate attachments: Quality Control Report, QA/QC Compliance Assessment to assist with Quality Review and Sample Receipt Notification.

Signatories

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

Signatories	*Position*	*Accreditation Category*
Mark Hallas	Senior Inorganic Chemist	Brisbane Inorganics, Stafford, QLD
Tom Maloney	Senior Inorganic Chemist	Brisbane Acid Sulphate Soils, Stafford, QLD
Tom Maloney	Senior Inorganic Chemist	Brisbane Inorganics, Stafford, QLD

General Comments

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

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

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

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

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

Where a result is required to meet compliance limits the associated uncertainty must be considered. Refer to the ALS Contact for details.

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

- ED037 (Alkalinity): NATA accreditation does not cover the performance of this service.
- ED038 (Acidity): NATA accreditation does not cover the performance of this service.

Analytical Results

Sub-Matrix: **PULP**
(Matrix: **SOIL**)

Compound	CAS Number	LOR	Unit	Coarse-CAS/AR Composite	Coarse-PLU1/PLU2 Composite	Fine-CAS/AR Composite - Fine/PLU1/PLU2 Composite	----	----
			Client sampling date / time	15-May-2019 00:00	15-May-2019 00:00	15-May-2019 00:00	----	----
				EB1912809-023	EB1912809-024	EB1912809-025	--------	--------
				Result	Result	Result	----	----
ED037: Alkalinity								
Total Alkalinity as CaCO3	----	1	mg/kg	**16600**	**14800**	**66100**	----	----
Bicarbonate Alkalinity as CaCO3	71-52-3	1	mg/kg	**16600**	**14800**	**66100**	----	----
Carbonate Alkalinity as CaCO3	3812-32-6	1	mg/kg	<5	<5	<5	----	----
ED038A: Acidity								
Acidity	----	1	mg/kg	**12**	**178**	**119**	----	----
ED040S : Soluble Sulfate by ICPAES								
Sulfate as SO4 2-	14808-79-8	10	mg/kg	**700**	**1990**	**1430**	----	----
Silica	7631-86-9	1	mg/kg	**25**	**24**	**26**	----	----
ED045G: Chloride by Discrete Analyser								
Chloride	16887-00-6	10	mg/kg	**190**	**110**	**220**	----	----
ED093S: Soluble Major Cations								
Calcium	7440-70-2	10	mg/kg	**50**	**320**	**350**	----	----
Magnesium	7439-95-4	10	mg/kg	**50**	**190**	**170**	----	----
Sodium	7440-23-5	10	mg/kg	**460**	**540**	**260**	----	----
Potassium	7440-09-7	10	mg/kg	**60**	**50**	**80**	----	----
ED093T: Total Major Cations								
Sodium	7440-23-5	50	mg/kg	**860**	**900**	**490**	----	----
Potassium	7440-09-7	50	mg/kg	**1490**	**1020**	**1230**	----	----
Calcium	7440-70-2	50	mg/kg	**18100**	**26200**	**61000**	----	----
Magnesium	7439-95-4	50	mg/kg	**3780**	**3950**	**5040**	----	----
EG005(ED093)S : Soluble Metals by ICPAES								
Boron	7440-42-8	1	mg/kg	<1	<1	<1	----	----
Iron	7439-89-6	1	mg/kg	<1	<1	<1	----	----
EG005(ED093)T: Total Metals by ICP-AES								
Aluminium	7429-90-5	50	mg/kg	**6490**	**6500**	**6510**	----	----
Antimony	7440-36-0	5	mg/kg	<5	<5	<5	----	----
Arsenic	7440-38-2	5	mg/kg	**21**	**34**	**17**	----	----
Barium	7440-39-3	10	mg/kg	**310**	**180**	**140**	----	----
Beryllium	7440-41-7	1	mg/kg	<1	<1	<1	----	----
Boron	7440-42-8	50	mg/kg	<50	<50	<50	----	----
Cadmium	7440-43-9	1	mg/kg	<1	<1	<1	----	----
Chromium	7440-47-3	2	mg/kg	**6**	**4**	**12**	----	----

Analytical Results

Sub-Matrix: **PULP**
(Matrix: **SOIL**)

			Client sample ID	Coarse-CAS/AR Composite	Coarse-PLU1/PLU2 Composite	Fine-CAS/AR Composite - Fine/PLU1/PLU2 Composite	----	----
			Client sampling date / time	15-May-2019 00:00	15-May-2019 00:00	15-May-2019 00:00	----	----
Compound	CAS Number	LOR	Unit	EB1912809-023	EB1912809-024	EB1912809-025	--------	--------
				Result	Result	Result	----	----
EG005(ED093)T: Total Metals by ICP-AES - Continued								
Cobalt	7440-48-4	2	mg/kg	**4**	**2**	**3**	----	----
Copper	7440-50-8	5	mg/kg	**46**	**42**	**33**	----	----
Iron	7439-89-6	50	mg/kg	**32600**	**41400**	**50500**	----	----
Lead	7439-92-1	5	mg/kg	**15**	**11**	**10**	----	----
Manganese	7439-96-5	5	mg/kg	**423**	**1160**	**1030**	----	----
Molybdenum	7439-98-7	2	mg/kg	**2**	<2	<2	----	----
Nickel	7440-02-0	2	mg/kg	**7**	**5**	**7**	----	----
Selenium	7782-49-2	5	mg/kg	<5	<5	<5	----	----
Vanadium	7440-62-2	5	mg/kg	**12**	**14**	**13**	----	----
Zinc	7440-66-6	5	mg/kg	**44**	**52**	**45**	----	----
EG020S: Soluble Metals by ICPMS								
Arsenic	7440-38-2	0.01	mg/kg	**0.01**	<0.01	<0.01	----	----
Selenium	7782-49-2	0.1	mg/kg	<0.1	<0.1	<0.1	----	----
Barium	7440-39-3	0.01	mg/kg	**0.13**	**0.11**	**0.11**	----	----
Beryllium	7440-41-7	0.01	mg/kg	<0.01	<0.01	<0.01	----	----
Cadmium	7440-43-9	0.01	mg/kg	<0.01	<0.01	<0.01	----	----
Cobalt	7440-48-4	0.01	mg/kg	<0.01	<0.01	<0.01	----	----
Chromium	7440-47-3	0.01	mg/kg	<0.01	<0.01	<0.01	----	----
Thorium	7440-29-1	0.01	mg/kg	<0.01	<0.01	<0.01	----	----
Copper	7440-50-8	0.01	mg/kg	<0.01	<0.01	<0.01	----	----
Manganese	7439-96-5	0.01	mg/kg	**0.02**	**2.94**	**0.47**	----	----
Molybdenum	7439-98-7	0.01	mg/kg	**0.18**	**0.02**	**0.05**	----	----
Nickel	7440-02-0	0.01	mg/kg	<0.01	<0.01	<0.01	----	----
Lead	7439-92-1	0.01	mg/kg	<0.01	<0.01	<0.01	----	----
Antimony	7440-36-0	0.01	mg/kg	<0.01	<0.01	<0.01	----	----
Uranium	7440-61-1	0.01	mg/kg	<0.01	<0.01	<0.01	----	----
Zinc	7440-66-6	0.05	mg/kg	<0.05	<0.05	<0.05	----	----
Vanadium	7440-62-2	0.1	mg/kg	<0.1	<0.1	<0.1	----	----
Aluminium	7429-90-5	0.1	mg/kg	<0.1	<0.1	<0.1	----	----
EG035S: Soluble Mercury by FIMS								
Mercury	7439-97-6	0.0005	mg/kg	<0.0005	<0.0005	<0.0005	----	----
EG035T: Total Recoverable Mercury by FIMS								

Analytical Results

Sub-Matrix: PULP (Matrix: SOIL)			Client sample ID	Coarse-CAS/AR Composite	Coarse-PLU1/PLU2 Composite	Fine-CAS/AR Composite - Fine/PLU1/PLU2 Composite	----	----
			Client sampling date / time	15-May-2019 00:00	15-May-2019 00:00	15-May-2019 00:00	----	----
Compound	CAS Number	LOR	Unit	EB1912809-023	EB1912809-024	EB1912809-025	--------	--------
				Result	Result	Result	----	----
EG035T: Total Recoverable Mercury by FIMS - Continued								
Mercury	7439-97-6	0.1	mg/kg	**0.1**	**0.2**	**0.1**	----	----
EK040S: Fluoride Soluble								
Fluoride	16984-48-8	1	mg/kg	**3**	**2**	**1**	----	----
EK071G: Reactive Phosphorus as P by discrete analyser								
Reactive Phosphorus as P	14265-44-2	0.1	mg/kg	<0.1	<0.1	<0.1	----	----

Analytical Results

Sub-Matrix: SOIL
(Matrix: SOIL)

			Client sample ID	pH and EC of deionised water	----	----	----	----
			Client sampling date / time	15-May-2019 00:00	----	----	----	----
Compound	CAS Number	LOR	Unit	EB1912809-026	--------	--------	--------	--------
				Result	----	----	----	----
EA002: pH 1:5 (Soils)								
pH Value	----	0.1	pH Unit	**5.5**	----	----	----	----
EA010: Conductivity (1:5)								
Electrical Conductivity @ 25°C	----	1	µS/cm	<1	----	----	----	----

CERTIFICATE OF ANALYSIS

Work Order	: **EB1915057**	Page	: 1 of 2
Client	: **AUSTAR GOLD LTD**	Laboratory	: Environmental Division Brisbane
Contact	: ALAN @ RGS	Contact	: Customer Services EB
Address	: Level 8 46 Edward Street Brisbane QLD 4000	Address	: 2 Byth Street Stafford QLD Australia 4053
Telephone	: ----	Telephone	: +61-7-3243 7222
Project	: ----	Date Samples Received	: 11-Jun-2019 13:53
Order number	:	Date Analysis Commenced	: 15-Jun-2019
C-O-C number	: ----	Issue Date	: 17-Jun-2019 11:14
Sampler	: ----		
Site	: ----		
Quote number	: EN/333		
No. of samples received	: 5		
No. of samples analysed	: 5		

Accreditation No. 825
Accredited for compliance with
ISO/IEC 17025 - Testing

This report supersedes any previous report(s) with this reference. Results apply to the sample(s) as submitted. This document shall not be reproduced, except in full.

This Certificate of Analysis contains the following information:

- General Comments
- Analytical Results

Additional information pertinent to this report will be found in the following separate attachments: Quality Control Report, QA/QC Compliance Assessment to assist with Quality Review and Sample Receipt Notification.

Signatories

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

Signatories	*Position*	*Accreditation Category*
Kim McCabe	Senior Inorganic Chemist	Brisbane Acid Sulphate Soils, Stafford, QLD

General Comments

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

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

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

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

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

Where a result is required to meet compliance limits the associated uncertainty must be considered. Refer to the ALS Contact for details.

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

Analytical Results

Sub-Matrix: **PULP**
(Matrix: **SOIL)**

			Client sample ID	**Coarse-CAS/AR Composite**	**Coarse-PLU1/PLU2 Composite**	**Fine-CAS/AR Composite/Fine-PLU1/ PLU2 Composite**
			Client sampling date / time	20-May-2019 00:00	20-May-2019 00:00	20-May-2019 00:00
Compound	*CAS Number*	*LOR*	*Unit*	**EB1915057-001**	**EB1915057-002**	**EB1915057-003**
				Result	Result	Result
EA002: pH 1:5 (Soils)						
pH Value	----	0.1	pH Unit	**8.5**	**8.0**	**8.0**
EA010: Conductivity (1:5)						
Electrical Conductivity @ 25°C	----	1	µS/cm	**593**	**1040**	**865**

ALS Environmental

CERTIFICATE OF ANALYSIS

Work Order	: **EB1913182**	Page	: 1 of 4
Client	: **RGS ENVIRONMENTAL PTY LTD**	Laboratory	: Environmental Division Brisbane
Contact	: MS AMANDA CLEMENTS	Contact	: Customer Services EB
Address	: PO Box 3091 SUNNYBANK SOUTH QLD, AUSTRALIA 4109	Address	: 2 Byth Street Stafford QLD Australia 4053
Telephone	: ----	Telephone	: +61-7-3243 7222
Project	: 2017002 Dingo West	Date Samples Received	: 23-May-2019 15:40
Order number	:	Date Analysis Commenced	: 24-May-2019
C-O-C number	: ----	Issue Date	: 29-May-2019 09:12
Sampler	: ----		
Site	: ----		
Quote number	: EN/222		
No. of samples received	: 2		
No. of samples analysed	: 2		

NATA

Accreditation No. 825
Accredited for compliance with
ISO/IEC 17025 - Testing

This report supersedes any previous report(s) with this reference. Results apply to the sample(s) as submitted. This document shall not be reproduced, except in full.

This Certificate of Analysis contains the following information:

- General Comments
- Analytical Results

Additional information pertinent to this report will be found in the following separate attachments: Quality Control Report, QA/QC Compliance Assessment to assist with Quality Review and Sample Receipt Notification.

Signatories

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

Signatories	*Position*	*Accreditation Category*
Kim McCabe	Senior Inorganic Chemist	Brisbane Inorganics, Stafford, QLD

General Comments

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

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

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

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

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

Where a result is required to meet compliance limits the associated uncertainty must be considered. Refer to the ALS Contact for details.

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

- Sodium Adsorption Ratio (where reported): Where results for Na, Ca or Mg are <LOR, a concentration at half the reported LOR is incorporated into the SAR calculation. This represents a conservative approach for Na relative to the assumption that <LOR = zero concentration and a conservative approach for Ca & Mg relative to the assumption that <LOR is equivalent to the LOR concentration.

Analytical Results

Sub-Matrix: WATER (Matrix: WATER)			Client sample ID	KLC 1	KLC 2	----	----	----
			Client sampling date / time	23-May-2019 00:00	23-May-2019 00:00	----	----	----
Compound	CAS Number	LOR	Unit	EB1913182-001	EB1913182-002	--------	--------	--------
				Result	Result	----	----	----
EA005P: pH by PC Titrator								
pH Value	----	0.01	pH Unit	**6.61**	**5.15**	----	----	----
EA010P: Conductivity by PC Titrator								
Electrical Conductivity @ 25°C	----	1	µS/cm	**1110**	**2090**	----	----	----
ED037P: Alkalinity by PC Titrator								
Hydroxide Alkalinity as CaCO3	DMO-210-001	1	mg/L	<1	<1	----	----	----
Carbonate Alkalinity as CaCO3	3812-32-6	1	mg/L	<1	<1	----	----	----
Bicarbonate Alkalinity as CaCO3	71-52-3	1	mg/L	**13**	**4**	----	----	----
Total Alkalinity as CaCO3	----	1	mg/L	**13**	**4**	----	----	----
ED038A: Acidity								
Acidity as CaCO3	----	1	mg/L	**5**	**101**	----	----	----
ED041G: Sulfate (Turbidimetric) as SO4 2- by DA								
Sulfate as SO4 - Turbidimetric	14808-79-8	1	mg/L	**451**	**726**	----	----	----
ED045G: Chloride by Discrete Analyser								
Chloride	16887-00-6	1	mg/L	**41**	**259**	----	----	----
ED093F: Dissolved Major Cations								
Calcium	7440-70-2	1	mg/L	**34**	**110**	----	----	----
Magnesium	7439-95-4	1	mg/L	**31**	**68**	----	----	----
Sodium	7440-23-5	1	mg/L	**164**	**252**	----	----	----
Potassium	7440-09-7	1	mg/L	**5**	**8**	----	----	----
EG020F: Dissolved Metals by ICP-MS								
Aluminium	7429-90-5	0.01	mg/L	<0.01	**0.12**	----	----	----
Antimony	7440-36-0	0.001	mg/L	<0.001	<0.001	----	----	----
Arsenic	7440-38-2	0.001	mg/L	<0.001	**0.001**	----	----	----
Cadmium	7440-43-9	0.0001	mg/L	**0.0003**	**0.0006**	----	----	----
Chromium	7440-47-3	0.001	mg/L	<0.001	<0.001	----	----	----
Cobalt	7440-48-4	0.001	mg/L	**0.025**	**0.085**	----	----	----
Copper	7440-50-8	0.001	mg/L	<0.001	**0.005**	----	----	----
Lead	7439-92-1	0.001	mg/L	<0.001	<0.001	----	----	----
Manganese	7439-96-5	0.001	mg/L	**4.85**	**4.10**	----	----	----
Molybdenum	7439-98-7	0.001	mg/L	<0.001	<0.001	----	----	----
Nickel	7440-02-0	0.001	mg/L	**0.022**	**0.096**	----	----	----
Selenium	7782-49-2	0.01	mg/L	<0.01	**0.02**	----	----	----
Vanadium	7440-62-2	0.01	mg/L	<0.01	<0.01	----	----	----
Zinc	7440-66-6	0.005	mg/L	**0.020**	**0.270**	----	----	----

Analytical Results

Sub-Matrix: WATER (Matrix: WATER)			Client sample ID	KLC 1	KLC 2	----	----	----
			Client sampling date / time	23-May-2019 00:00	23-May-2019 00:00	----	----	----
Compound	CAS Number	LOR	Unit	EB1913182-001	EB1913182-002	--------	--------	--------
				Result	Result	----	----	----
EG020F: Dissolved Metals by ICP-MS - Continued								
Boron	7440-42-8	0.05	mg/L	**0.12**	**0.13**	----	----	----
Iron	7439-89-6	0.05	mg/L	**1.81**	**44.5**	----	----	----
EK040P: Fluoride by PC Titrator								
Fluoride	16984-48-8	0.1	mg/L	**0.2**	<0.1	----	----	----
EN055: Ionic Balance								
ø Total Anions	----	0.01	meq/L	**10.8**	**22.5**	----	----	----
ø Total Cations	----	0.01	meq/L	**11.5**	**22.2**	----	----	----
ø Ionic Balance	----	0.01	%	**3.15**	**0.56**	----	----	----

ALS Environmental

CERTIFICATE OF ANALYSIS

Work Order	: **EB1916404**	Page	: 1 of 4
Client	: **RGS ENVIRONMENTAL PTY LTD**	Laboratory	: Environmental Division Brisbane
Contact	: MS AMANDA CLEMENTS	Contact	: Customer Services EB
Address	: PO Box 3091 SUNNYBANK SOUTH QLD, AUSTRALIA 4109	Address	: 2 Byth Street Stafford QLD Australia 4053
Telephone	: ----	Telephone	: +61-7-3243 7222
Project	: 2017002 Dingo west	Date Samples Received	: 25-Jun-2019 14:50
Order number	: 2017002	Date Analysis Commenced	: 26-Jun-2019
C-O-C number	: ----	Issue Date	: 02-Jul-2019 14:44
Sampler	: MARY MACILROY		
Site	: ----		
Quote number	: EN/222		
No. of samples received	: 2		
No. of samples analysed	: 2		

ilac-MRA NATA
Accreditation No. 825
Accredited for compliance with
ISO/IEC 17025 - Testing

This report supersedes any previous report(s) with this reference. Results apply to the sample(s) as submitted. This document shall not be reproduced, except in full.

This Certificate of Analysis contains the following information:

- General Comments
- Analytical Results

Additional information pertinent to this report will be found in the following separate attachments: Quality Control Report, QA/QC Compliance Assessment to assist with Quality Review and Sample Receipt Notification.

Signatories

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

Signatories	*Position*	*Accreditation Category*
Kim McCabe	Senior Inorganic Chemist	Brisbane Inorganics, Stafford, QLD

General Comments

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

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

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

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

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

Where a result is required to meet compliance limits the associated uncertainty must be considered. Refer to the ALS Contact for details.

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

- Sodium Adsorption Ratio (where reported): Where results for Na, Ca or Mg are <LOR, a concentration at half the reported LOR is incorporated into the SAR calculation. This represents a conservative approach for Na relative to the assumption that <LOR = zero concentration and a conservative approach for Ca & Mg relative to the assumption that <LOR is equivalent to the LOR concentration.

Analytical Results

Sub-Matrix: WATER (Matrix: WATER)			Client sample ID	KLC 1	KLC 2	----	----	----
			Client sampling date / time	25-Jun-2019 00:00	25-Jun-2019 00:00	----	----	----
Compound	CAS Number	LOR	Unit	EB1916404-001	EB1916404-002	--------	--------	--------
				Result	Result	----	----	----
EA005P: pH by PC Titrator								
pH Value	----	0.01	pH Unit	**5.88**	**4.75**	----	----	----
EA010P: Conductivity by PC Titrator								
Electrical Conductivity @ 25°C	----	1	µS/cm	**2410**	**2420**	----	----	----
ED037P: Alkalinity by PC Titrator								
Hydroxide Alkalinity as CaCO3	DMO-210-001	1	mg/L	<1	<1	----	----	----
Carbonate Alkalinity as CaCO3	3812-32-6	1	mg/L	<1	<1	----	----	----
Bicarbonate Alkalinity as CaCO3	71-52-3	1	mg/L	**3**	<1	----	----	----
Total Alkalinity as CaCO3	----	1	mg/L	**3**	<1	----	----	----
ED038A: Acidity								
Acidity as CaCO3	----	1	mg/L	**15**	**110**	----	----	----
ED041G: Sulfate (Turbidimetric) as SO4 2- by DA								
Sulfate as SO4 - Turbidimetric	14808-79-8	1	mg/L	**1140**	**1240**	----	----	----
ED045G: Chloride by Discrete Analyser								
Chloride	16887-00-6	1	mg/L	**83**	**141**	----	----	----
ED093F: Dissolved Major Cations								
Calcium	7440-70-2	1	mg/L	**83**	**202**	----	----	----
Magnesium	7439-95-4	1	mg/L	**120**	**126**	----	----	----
Sodium	7440-23-5	1	mg/L	**337**	**190**	----	----	----
Potassium	7440-09-7	1	mg/L	**6**	**7**	----	----	----
EG020F: Dissolved Metals by ICP-MS								
Aluminium	7429-90-5	0.01	mg/L	<0.01	**0.07**	----	----	----
Antimony	7440-36-0	0.001	mg/L	<0.001	<0.001	----	----	----
Arsenic	7440-38-2	0.001	mg/L	<0.001	<0.001	----	----	----
Cadmium	7440-43-9	0.0001	mg/L	**0.0005**	**0.0013**	----	----	----
Chromium	7440-47-3	0.001	mg/L	<0.001	<0.001	----	----	----
Copper	7440-50-8	0.001	mg/L	<0.001	**0.011**	----	----	----
Cobalt	7440-48-4	0.001	mg/L	**0.035**	**0.097**	----	----	----
Nickel	7440-02-0	0.001	mg/L	**0.029**	**0.083**	----	----	----
Lead	7439-92-1	0.001	mg/L	<0.001	<0.001	----	----	----
Zinc	7440-66-6	0.005	mg/L	**0.048**	**0.281**	----	----	----
Manganese	7439-96-5	0.001	mg/L	**2.55**	**5.38**	----	----	----
Molybdenum	7439-98-7	0.001	mg/L	<0.001	<0.001	----	----	----
Selenium	7782-49-2	0.01	mg/L	**0.02**	**0.01**	----	----	----
Vanadium	7440-62-2	0.01	mg/L	<0.01	<0.01	----	----	----

Analytical Results

Sub-Matrix: WATER (Matrix: WATER)			Client sample ID	KLC 1	KLC 2	----	----	----
			Client sampling date / time	25-Jun-2019 00:00	25-Jun-2019 00:00	----	----	----
Compound	CAS Number	LOR	Unit	EB1916404-001	EB1916404-002	--------	--------	--------
				Result	Result	----	----	----
EG020F: Dissolved Metals by ICP-MS - Continued								
Boron	7440-42-8	0.05	mg/L	**0.06**	**0.13**	----	----	----
Iron	7439-89-6	0.05	mg/L	**4.60**	**53.6**	----	----	----
EK040P: Fluoride by PC Titrator								
Fluoride	16984-48-8	0.1	mg/L	**0.1**	<0.1	----	----	----
EN055: Ionic Balance								
ø **Total Anions**	----	0.01	meq/L	**26.1**	**29.8**	----	----	----
ø **Total Cations**	----	0.01	meq/L	**28.8**	**28.9**	----	----	----
ø **Ionic Balance**	----	0.01	%	**4.90**	**1.54**	----	----	----

CERTIFICATE OF ANALYSIS

Work Order	: **EB1918950**	Page	: 1 of 4
Client	: **RGS ENVIRONMENTAL PTY LTD**	Laboratory	: Environmental Division Brisbane
Contact	: MS AMANDA CLEMENTS	Contact	: Customer Services EB
Address	: PO Box 3091 SUNNYBANK SOUTH QLD, AUSTRALIA 4109	Address	: 2 Byth Street Stafford QLD Australia 4053
Telephone	: ----	Telephone	: +61-7-3243 7222
Project	: 2017002 Dingo west	Date Samples Received	: 22-Jul-2019 03:05
Order number	: 2017002	Date Analysis Commenced	: 23-Jul-2019
C-O-C number	: ----	Issue Date	: 30-Jul-2019 11:19
Sampler	: MARY MACELROY		
Site	: ----		
Quote number	: EN/222		
No. of samples received	: 2		
No. of samples analysed	: 2		

Accreditation No. 825
Accredited for compliance with
ISO/IEC 17025 - Testing

This report supersedes any previous report(s) with this reference. Results apply to the sample(s) as submitted. This document shall not be reproduced, except in full.

This Certificate of Analysis contains the following information:

- General Comments
- Analytical Results

Additional information pertinent to this report will be found in the following separate attachments: Quality Control Report, QA/QC Compliance Assessment to assist with Quality Review and Sample Receipt Notification.

Signatories

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

Signatories	*Position*	*Accreditation Category*
Kim McCabe	Senior Inorganic Chemist	Brisbane Inorganics, Stafford, QLD

General Comments

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

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

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

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

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

Where a result is required to meet compliance limits the associated uncertainty must be considered. Refer to the ALS Contact for details.

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

- Sodium Adsorption Ratio (where reported): Where results for Na, Ca or Mg are <LOR, a concentration at half the reported LOR is incorporated into the SAR calculation. This represents a conservative approach for Na relative to the assumption that <LOR = zero concentration and a conservative approach for Ca & Mg relative to the assumption that <LOR is equivalent to the LOR concentration.

Analytical Results

Sub-Matrix: WATER (Matrix: WATER)			Client sample ID	KLC 1	KLC 2	----	----	----
			Client sampling date / time	22-Jul-2019 00:00	22-Jul-2019 00:00	----	----	----
Compound	CAS Number	LOR	Unit	EB1918950-001	EB1918950-002	--------	--------	--------
				Result	Result	----	----	----
EA005P: pH by PC Titrator								
pH Value	----	0.01	pH Unit	**6.90**	**7.18**	----	----	----
EA010P: Conductivity by PC Titrator								
Electrical Conductivity @ 25°C	----	1	µS/cm	**1860**	**3030**	----	----	----
ED037P: Alkalinity by PC Titrator								
Hydroxide Alkalinity as CaCO3	DMO-210-001	1	mg/L	<1	<1	----	----	----
Carbonate Alkalinity as CaCO3	3812-32-6	1	mg/L	<1	<1	----	----	----
Bicarbonate Alkalinity as CaCO3	71-52-3	1	mg/L	**7**	**13**	----	----	----
Total Alkalinity as CaCO3	----	1	mg/L	**7**	**13**	----	----	----
ED038A: Acidity								
Acidity as CaCO3	----	1	mg/L	**1**	**2**	----	----	----
ED041G: Sulfate (Turbidimetric) as SO4 2- by DA								
Sulfate as SO4 - Turbidimetric	14808-79-8	1	mg/L	**846**	**1500**	----	----	----
ED045G: Chloride by Discrete Analyser								
Chloride	16887-00-6	1	mg/L	**51**	**261**	----	----	----
ED093F: Dissolved Major Cations								
Calcium	7440-70-2	1	mg/L	**75**	**234**	----	----	----
Magnesium	7439-95-4	1	mg/L	**84**	**161**	----	----	----
Sodium	7440-23-5	1	mg/L	**215**	**260**	----	----	----
Potassium	7440-09-7	1	mg/L	**4**	**8**	----	----	----
EG020F: Dissolved Metals by ICP-MS								
Aluminium	7429-90-5	0.01	mg/L	<0.01	<0.01	----	----	----
Antimony	7440-36-0	0.001	mg/L	<0.001	<0.001	----	----	----
Arsenic	7440-38-2	0.001	mg/L	<0.001	<0.001	----	----	----
Cadmium	7440-43-9	0.0001	mg/L	**0.0002**	**0.0001**	----	----	----
Chromium	7440-47-3	0.001	mg/L	<0.001	<0.001	----	----	----
Copper	7440-50-8	0.001	mg/L	<0.001	<0.001	----	----	----
Cobalt	7440-48-4	0.001	mg/L	**0.008**	**0.006**	----	----	----
Nickel	7440-02-0	0.001	mg/L	**0.006**	**0.006**	----	----	----
Lead	7439-92-1	0.001	mg/L	<0.001	<0.001	----	----	----
Zinc	7440-66-6	0.005	mg/L	**0.011**	**0.007**	----	----	----
Manganese	7439-96-5	0.001	mg/L	**1.06**	**1.67**	----	----	----
Molybdenum	7439-98-7	0.001	mg/L	**0.002**	**0.001**	----	----	----
Selenium	7782-49-2	0.01	mg/L	**0.01**	**0.02**	----	----	----
Vanadium	7440-62-2	0.01	mg/L	<0.01	<0.01	----	----	----

Analytical Results

Sub-Matrix: WATER (Matrix: WATER)			Client sample ID	KLC 1	KLC 2	----	----	----
			Client sampling date / time	22-Jul-2019 00:00	22-Jul-2019 00:00	----	----	----
Compound	CAS Number	LOR	Unit	EB1918950-001	EB1918950-002	--------	--------	--------
				Result	Result	----	----	----
EG020F: Dissolved Metals by ICP-MS - Continued								
Boron	7440-42-8	0.05	mg/L	**0.06**	**0.05**	----	----	----
Iron	7439-89-6	0.05	mg/L	<0.05	<0.05	----	----	----
EK040P: Fluoride by PC Titrator								
Fluoride	16984-48-8	0.1	mg/L	**0.2**	**0.2**	----	----	----
EN055: Ionic Balance								
ø **Total Anions**	----	0.01	meq/L	**19.2**	**38.8**	----	----	----
ø **Total Cations**	----	0.01	meq/L	**20.1**	**36.4**	----	----	----
ø **Ionic Balance**	----	0.01	%	**2.34**	**3.20**	----	----	----

ALS Environmental

CERTIFICATE OF ANALYSIS

Work Order	: **EB1922372**	Page	: 1 of 4
Client	: **RGS ENVIRONMENTAL PTY LTD**	Laboratory	: Environmental Division Brisbane
Contact	: MS VERONICA CANALES	Contact	: Customer Services EB
Address	:	Address	: 2 Byth Street Stafford QLD Australia 4053
Telephone	: +61 07 3344 1222	Telephone	: +61-7-3243 7222
Project	: Dingo West Template	Date Samples Received	: 27-Aug-2019 15:20
Order number	:	Date Analysis Commenced	: 27-Aug-2019
C-O-C number	: 3548	Issue Date	: 03-Sep-2019 16:56
Sampler	: CARSTEN EMRICH		
Site	: Dingo West Template L4		
Quote number	: BN/1234/19		
No. of samples received	: 2		
No. of samples analysed	: 2		

NATA
Accreditation No. 825
Accredited for compliance with
ISO/IEC 17025 - Testing

This report supersedes any previous report(s) with this reference. Results apply to the sample(s) as submitted. This document shall not be reproduced, except in full.

This Certificate of Analysis contains the following information:

- General Comments
- Analytical Results

Additional information pertinent to this report will be found in the following separate attachments: Quality Control Report, QA/QC Compliance Assessment to assist with Quality Review and Sample Receipt Notification.

Signatories

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

Signatories	*Position*	*Accreditation Category*
Kim McCabe	Senior Inorganic Chemist	Brisbane Inorganics, Stafford, QLD

General Comments

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

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

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

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

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

Where a result is required to meet compliance limits the associated uncertainty must be considered. Refer to the ALS Contact for details.

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

- Sodium Adsorption Ratio (where reported): Where results for Na, Ca or Mg are <LOR, a concentration at half the reported LOR is incorporated into the SAR calculation. This represents a conservative approach for Na relative to the assumption that <LOR = zero concentration and a conservative approach for Ca & Mg relative to the assumption that <LOR is equivalent to the LOR concentration.

Analytical Results

Sub-Matrix: WATER (Matrix: WATER)			Client sample ID	KLC-1	KLC-2	----	----	----
			Client sampling date / time	27-Aug-2019 12:37	27-Aug-2019 12:38	----	----	----
Compound	CAS Number	LOR	Unit	EB1922372-001	EB1922372-002	--------	--------	--------
				Result	Result	----	----	----
EA005P: pH by PC Titrator								
pH Value	----	0.01	pH Unit	**6.83**	**6.65**	----	----	----
EA010P: Conductivity by PC Titrator								
Electrical Conductivity @ 25°C	----	1	µS/cm	**1820**	**2450**	----	----	----
ED037P: Alkalinity by PC Titrator								
Hydroxide Alkalinity as CaCO3	DMO-210-001	1	mg/L	<1	<1	----	----	----
Carbonate Alkalinity as CaCO3	3812-32-6	1	mg/L	<1	<1	----	----	----
Bicarbonate Alkalinity as CaCO3	71-52-3	1	mg/L	**8**	**9**	----	----	----
Total Alkalinity as CaCO3	----	1	mg/L	**8**	**9**	----	----	----
ED038A: Acidity								
Acidity as CaCO3	----	1	mg/L	**2**	**2**	----	----	----
ED041G: Sulfate (Turbidimetric) as SO4 2- by DA								
Sulfate as SO4 - Turbidimetric	14808-79-8	1	mg/L	**861**	**1300**	----	----	----
ED045G: Chloride by Discrete Analyser								
Chloride	16887-00-6	1	mg/L	**42**	**95**	----	----	----
ED093F: Dissolved Major Cations								
Calcium	7440-70-2	1	mg/L	**98**	**292**	----	----	----
Magnesium	7439-95-4	1	mg/L	**98**	**134**	----	----	----
Sodium	7440-23-5	1	mg/L	**212**	**156**	----	----	----
Potassium	7440-09-7	1	mg/L	**7**	**14**	----	----	----
EG020F: Dissolved Metals by ICP-MS								
Aluminium	7429-90-5	0.01	mg/L	<0.01	<0.01	----	----	----
Antimony	7440-36-0	0.001	mg/L	<0.001	<0.001	----	----	----
Arsenic	7440-38-2	0.001	mg/L	**0.001**	<0.001	----	----	----
Cadmium	7440-43-9	0.0001	mg/L	**0.0003**	**0.0008**	----	----	----
Chromium	7440-47-3	0.001	mg/L	<0.001	<0.001	----	----	----
Copper	7440-50-8	0.001	mg/L	<0.001	<0.001	----	----	----
Cobalt	7440-48-4	0.001	mg/L	**0.012**	**0.039**	----	----	----
Nickel	7440-02-0	0.001	mg/L	**0.013**	**0.039**	----	----	----
Lead	7439-92-1	0.001	mg/L	<0.001	<0.001	----	----	----
Zinc	7440-66-6	0.005	mg/L	**0.023**	**0.075**	----	----	----
Manganese	7439-96-5	0.001	mg/L	**1.04**	**2.61**	----	----	----
Molybdenum	7439-98-7	0.001	mg/L	**0.002**	<0.001	----	----	----
Selenium	7782-49-2	0.01	mg/L	**0.01**	<0.01	----	----	----
Vanadium	7440-62-2	0.01	mg/L	<0.01	<0.01	----	----	----

Analytical Results

Sub-Matrix: WATER (Matrix: WATER)			Client sample ID	KLC-1	KLC-2	----	----	----
			Client sampling date / time	27-Aug-2019 12:37	27-Aug-2019 12:38	----	----	----
Compound	CAS Number	LOR	Unit	EB1922372-001	EB1922372-002	--------	--------	--------
				Result	Result	----	----	----
EG020F: Dissolved Metals by ICP-MS - Continued								
Boron	7440-42-8	0.05	mg/L	**0.07**	**0.12**	----	----	----
Iron	7439-89-6	0.05	mg/L	<0.05	**0.34**	----	----	----
EK040P: Fluoride by PC Titrator								
Fluoride	16984-48-8	0.1	mg/L	**0.2**	**0.2**	----	----	----
EN055: Ionic Balance								
ø Total Anions	----	0.01	meq/L	**19.3**	**29.9**	----	----	----
ø Total Cations	----	0.01	meq/L	**22.4**	**32.7**	----	----	----
ø Ionic Balance	----	0.01	%	**7.41**	**4.50**	----	----	----

ALS Environmental

CERTIFICATE OF ANALYSIS

Work Order	: **EB1925268**	Page	: 1 of 4
Client	: **RGS ENVIRONMENTAL PTY LTD**	Laboratory	: Environmental Division Brisbane
Contact	: MR ALAN ROBERTSON	Contact	: Customer Services EB
Address	: PO Box 3091 SUNNYBANK SOUTH QLD, AUSTRALIA 4109	Address	: 2 Byth Street Stafford QLD Australia 4053
Telephone	: +61 07 3344 1222	Telephone	: +61-7-3243 7222
Project	: Dingo West - 2017002	Date Samples Received	: 25-Sep-2019 15:51
Order number	:	Date Analysis Commenced	: 26-Sep-2019
C-O-C number	: 4384	Issue Date	: 02-Oct-2019 16:02
Sampler	: MARY MACELROY, VERONICA CANALES		
Site	: Dingo West L-5		
Quote number	: BN/1234/19		
No. of samples received	: 2		
No. of samples analysed	: 2		

NATA

Accreditation No. 825
Accredited for compliance with
ISO/IEC 17025 - Testing

This report supersedes any previous report(s) with this reference. Results apply to the sample(s) as submitted. This document shall not be reproduced, except in full.

This Certificate of Analysis contains the following information:

- General Comments
- Analytical Results

Additional information pertinent to this report will be found in the following separate attachments: Quality Control Report, QA/QC Compliance Assessment to assist with Quality Review and Sample Receipt Notification.

Signatories

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

Signatories	*Position*	*Accreditation Category*
Kim McCabe	Senior Inorganic Chemist	Brisbane Inorganics, Stafford, QLD

General Comments

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

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

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

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

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

Where a result is required to meet compliance limits the associated uncertainty must be considered. Refer to the ALS Contact for details.

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

- Sodium Adsorption Ratio (where reported): Where results for Na, Ca or Mg are <LOR, a concentration at half the reported LOR is incorporated into the SAR calculation. This represents a conservative approach for Na relative to the assumption that <LOR = zero concentration and a conservative approach for Ca & Mg relative to the assumption that <LOR is equivalent to the LOR concentration.

Analytical Results

Sub-Matrix: WATER (Matrix: WATER)			Client sample ID	KLC-1	KLC-2	----	----	----
			Client sampling date / time	25-Sep-2019 10:25	25-Sep-2019 10:25	----	----	----
Compound	CAS Number	LOR	Unit	EB1925268-001	EB1925268-002	--------	--------	--------
				Result	Result	----	----	----
EA005P: pH by PC Titrator								
pH Value	----	0.01	pH Unit	6.18	7.51	----	----	----
EA010P: Conductivity by PC Titrator								
Electrical Conductivity @ 25°C	----	1	µS/cm	2040	3240	----	----	----
ED037P: Alkalinity by PC Titrator								
Hydroxide Alkalinity as CaCO3	DMO-210-001	1	mg/L	<1	<1	----	----	----
Carbonate Alkalinity as CaCO3	3812-32-6	1	mg/L	<1	<1	----	----	----
Bicarbonate Alkalinity as CaCO3	71-52-3	1	mg/L	5	96	----	----	----
Total Alkalinity as CaCO3	----	1	mg/L	5	96	----	----	----
ED038A: Acidity								
Acidity as CaCO3	----	1	mg/L	3	11	----	----	----
ED041G: Sulfate (Turbidimetric) as SO4 2- by DA								
Sulfate as SO4 - Turbidimetric	14808-79-8	1	mg/L	1060	1970	----	----	----
ED045G: Chloride by Discrete Analyser								
Chloride	16887-00-6	1	mg/L	34	112	----	----	----
ED093F: Dissolved Major Cations								
Calcium	7440-70-2	1	mg/L	121	390	----	----	----
Magnesium	7439-95-4	1	mg/L	114	204	----	----	----
Sodium	7440-23-5	1	mg/L	195	152	----	----	----
Potassium	7440-09-7	1	mg/L	8	12	----	----	----
EG020F: Dissolved Metals by ICP-MS								
Aluminium	7429-90-5	0.01	mg/L	<0.01	<0.01	----	----	----
Antimony	7440-36-0	0.001	mg/L	<0.001	<0.001	----	----	----
Arsenic	7440-38-2	0.001	mg/L	<0.001	<0.001	----	----	----
Cadmium	7440-43-9	0.0001	mg/L	0.0006	0.0004	----	----	----
Chromium	7440-47-3	0.001	mg/L	<0.001	<0.001	----	----	----
Copper	7440-50-8	0.001	mg/L	<0.001	<0.001	----	----	----
Cobalt	7440-48-4	0.001	mg/L	0.016	0.014	----	----	----
Nickel	7440-02-0	0.001	mg/L	0.018	0.018	----	----	----
Lead	7439-92-1	0.001	mg/L	<0.001	<0.001	----	----	----
Zinc	7440-66-6	0.005	mg/L	0.044	0.034	----	----	----
Manganese	7439-96-5	0.001	mg/L	1.86	2.81	----	----	----
Molybdenum	7439-98-7	0.001	mg/L	<0.001	0.001	----	----	----
Selenium	7782-49-2	0.01	mg/L	0.01	0.02	----	----	----
Vanadium	7440-62-2	0.01	mg/L	<0.01	<0.01	----	----	----

Analytical Results

Sub-Matrix: **WATER** (Matrix: **WATER**)			Client sample ID	**KLC-1**	**KLC-2**	**----**	**----**	**----**
			Client sampling date / time	25-Sep-2019 10:25	25-Sep-2019 10:25	----	----	----
Compound	CAS Number	LOR	Unit	**EB1925268-001**	**EB1925268-002**	**--------**	**--------**	**--------**
				Result	Result	----	----	----
EG020F: Dissolved Metals by ICP-MS - Continued								
Boron	7440-42-8	0.05	mg/L	**0.08**	**0.14**	**----**	**----**	**----**
Iron	7439-89-6	0.05	mg/L	**0.22**	**0.29**	**----**	**----**	**----**
EK040P: Fluoride by PC Titrator								
Fluoride	16984-48-8	0.1	mg/L	**0.2**	**0.2**	**----**	**----**	**----**
EN055: Ionic Balance								
ø **Total Anions**	----	0.01	meq/L	**23.1**	**46.1**	**----**	**----**	**----**
ø **Total Cations**	----	0.01	meq/L	**24.1**	**43.2**	**----**	**----**	**----**
ø **Ionic Balance**	----	0.01	%	**2.07**	**3.28**	**----**	**----**	**----**

CERTIFICATE OF ANALYSIS

Work Order	: **EB1927982**	Page	: 1 of 4
Client	: **RGS ENVIRONMENTAL PTY LTD**	Laboratory	: Environmental Division Brisbane
Contact	: MS VERONICA CANALES	Contact	: Customer Services EB
Address	: PO Box 3091 SUNNYBANK SOUTH QLD, AUSTRALIA 4109	Address	: 2 Byth Street Stafford QLD Australia 4053
Telephone	: +61 07 3344 1222	Telephone	: +61-7-3243 7222
Project	: Dingo West Template	Date Samples Received	: 22-Oct-2019 16:15
Order number	:	Date Analysis Commenced	: 22-Oct-2019
C-O-C number	: 5180	Issue Date	: 29-Oct-2019 10:35
Sampler	: VERONICA CANALES		
Site	: Digno West- L5		
Quote number	: BN/1234/19		
No. of samples received	: 2		
No. of samples analysed	: 2		

Accreditation No. 825
Accredited for compliance with
ISO/IEC 17025 - Testing

This report supersedes any previous report(s) with this reference. Results apply to the sample(s) as submitted. This document shall not be reproduced, except in full.

This Certificate of Analysis contains the following information:

- General Comments
- Analytical Results

Additional information pertinent to this report will be found in the following separate attachments: Quality Control Report, QA/QC Compliance Assessment to assist with Quality Review and Sample Receipt Notification.

Signatories

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

Signatories	*Position*	*Accreditation Category*
Kim McCabe	Senior Inorganic Chemist	Brisbane Inorganics, Stafford, QLD

General Comments

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

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

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

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

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

Where a result is required to meet compliance limits the associated uncertainty must be considered. Refer to the ALS Contact for details.

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

- Sodium Adsorption Ratio (where reported): Where results for Na, Ca or Mg are <LOR, a concentration at half the reported LOR is incorporated into the SAR calculation. This represents a conservative approach for Na relative to the assumption that <LOR = zero concentration and a conservative approach for Ca & Mg relative to the assumption that <LOR is equivalent to the LOR concentration.

Analytical Results

Sub-Matrix: WATER (Matrix: WATER)			Client sample ID	KLC-1	KLC-2	----	----	----
			Client sampling date / time	22-Oct-2019 14:24	22-Oct-2019 14:24	----	----	----
Compound	CAS Number	LOR	Unit	EB1927982-001	EB1927982-002	--------	--------	--------
				Result	Result	----	----	----
EA005P: pH by PC Titrator								
pH Value	----	0.01	pH Unit	**5.45**	**6.02**	----	----	----
EA010P: Conductivity by PC Titrator								
Electrical Conductivity @ 25°C	----	1	µS/cm	**1440**	**2140**	----	----	----
ED037P: Alkalinity by PC Titrator								
Hydroxide Alkalinity as CaCO3	DMO-210-001	1	mg/L	<1	<1	----	----	----
Carbonate Alkalinity as CaCO3	3812-32-6	1	mg/L	<1	<1	----	----	----
Bicarbonate Alkalinity as CaCO3	71-52-3	1	mg/L	**3**	**3**	----	----	----
Total Alkalinity as CaCO3	----	1	mg/L	**3**	**3**	----	----	----
ED038A: Acidity								
Acidity as CaCO3	----	1	mg/L	**13**	**26**	----	----	----
ED041G: Sulfate (Turbidimetric) as SO4 2- by DA								
Sulfate as SO4 - Turbidimetric	14808-79-8	1	mg/L	**700**	**1320**	----	----	----
ED045G: Chloride by Discrete Analyser								
Chloride	16887-00-6	1	mg/L	**18**	**22**	----	----	----
ED093F: Dissolved Major Cations								
Calcium	7440-70-2	1	mg/L	**112**	**303**	----	----	----
Magnesium	7439-95-4	1	mg/L	**77**	**123**	----	----	----
Sodium	7440-23-5	1	mg/L	**97**	**37**	----	----	----
Potassium	7440-09-7	1	mg/L	**6**	**8**	----	----	----
EG020F: Dissolved Metals by ICP-MS								
Aluminium	7429-90-5	0.01	mg/L	<0.01	<0.01	----	----	----
Antimony	7440-36-0	0.001	mg/L	<0.001	<0.001	----	----	----
Arsenic	7440-38-2	0.001	mg/L	<0.001	<0.001	----	----	----
Cadmium	7440-43-9	0.0001	mg/L	**0.0006**	**0.0011**	----	----	----
Chromium	7440-47-3	0.001	mg/L	<0.001	<0.001	----	----	----
Copper	7440-50-8	0.001	mg/L	**0.009**	<0.001	----	----	----
Cobalt	7440-48-4	0.001	mg/L	**0.021**	**0.057**	----	----	----
Nickel	7440-02-0	0.001	mg/L	**0.020**	**0.055**	----	----	----
Lead	7439-92-1	0.001	mg/L	<0.001	<0.001	----	----	----
Zinc	7440-66-6	0.005	mg/L	**0.073**	**0.170**	----	----	----
Manganese	7439-96-5	0.001	mg/L	**1.85**	**3.19**	----	----	----
Molybdenum	7439-98-7	0.001	mg/L	<0.001	<0.001	----	----	----
Selenium	7782-49-2	0.01	mg/L	<0.01	<0.01	----	----	----
Vanadium	7440-62-2	0.01	mg/L	<0.01	<0.01	----	----	----

Analytical Results

Sub-Matrix: WATER (Matrix: WATER)			Client sample ID	KLC-1	KLC-2	----	----	----
			Client sampling date / time	22-Oct-2019 14:24	22-Oct-2019 14:24	----	----	----
Compound	CAS Number	LOR	Unit	EB1927982-001	EB1927982-002	--------	--------	--------
				Result	Result	----	----	----
EG020F: Dissolved Metals by ICP-MS - Continued								
Boron	7440-42-8	0.05	mg/L	**0.10**	**0.14**	----	----	----
Iron	7439-89-6	0.05	mg/L	**3.17**	**10.2**	----	----	----
EK040P: Fluoride by PC Titrator								
Fluoride	16984-48-8	0.1	mg/L	**0.2**	<0.1	----	----	----
EN055: Ionic Balance								
ø Total Anions	----	0.01	meq/L	**15.1**	**28.2**	----	----	----
ø Total Cations	----	0.01	meq/L	**16.3**	**27.0**	----	----	----
ø Ionic Balance	----	0.01	%	**3.68**	**2.00**	----	----	----

CERTIFICATE OF ANALYSIS

Work Order	: **EB1931641**	Page	: 1 of 4
Client	: **RGS ENVIRONMENTAL PTY LTD**	Laboratory	: Environmental Division Brisbane
Contact	: MARY MACELROY	Contact	: Customer Services EB
Address	: Level 7 380 QUEEN STREET BRISBANE QLD, AUSTRALIA 4000	Address	: 2 Byth Street Stafford QLD Australia 4053
Telephone	: +61 07 3344 1222	Telephone	: +61-7-3243 7222
Project	: Dingo West - 2017002	Date Samples Received	: 26-Nov-2019 17:07
Order number	:	Date Analysis Commenced	: 27-Nov-2019
C-O-C number	: 6193	Issue Date	: 04-Dec-2019 09:59
Sampler	: ALAN ROBERTSON, MARY MACELROY		
Site	: Dingo West L-Flush 7		
Quote number	: BN/1234/19		
No. of samples received	: 2		
No. of samples analysed	: 2		

Accreditation No. 825
Accredited for compliance with
ISO/IEC 17025 - Testing

This report supersedes any previous report(s) with this reference. Results apply to the sample(s) as submitted. This document shall not be reproduced, except in full.

This Certificate of Analysis contains the following information:

- General Comments
- Analytical Results

Additional information pertinent to this report will be found in the following separate attachments: Quality Control Report, QA/QC Compliance Assessment to assist with Quality Review and Sample Receipt Notification.

Signatories

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

Signatories	*Position*	*Accreditation Category*
Kim McCabe	Senior Inorganic Chemist	Brisbane Inorganics, Stafford, QLD

General Comments

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

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

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

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

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

Where a result is required to meet compliance limits the associated uncertainty must be considered. Refer to the ALS Contact for details.

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

- Sodium Adsorption Ratio (where reported): Where results for Na, Ca or Mg are <LOR, a concentration at half the reported LOR is incorporated into the SAR calculation. This represents a conservative approach for Na relative to the assumption that <LOR = zero concentration and a conservative approach for Ca & Mg relative to the assumption that <LOR is equivalent to the LOR concentration.

Analytical Results

Sub-Matrix: WATER (Matrix: WATER)			Client sample ID	KLC-1	KLC-2	----	----	----
			Client sampling date / time	26-Nov-2019 14:21	26-Nov-2019 14:22	----	----	----
Compound	CAS Number	LOR	Unit	EB1931641-001	EB1931641-002	--------	--------	--------
				Result	Result	----	----	----
EA005P: pH by PC Titrator								
pH Value	----	0.01	pH Unit	**5.68**	**5.04**	----	----	----
EA010P: Conductivity by PC Titrator								
Electrical Conductivity @ 25°C	----	1	µS/cm	**1720**	**2060**	----	----	----
ED037P: Alkalinity by PC Titrator								
Hydroxide Alkalinity as CaCO3	DMO-210-001	1	mg/L	<1	<1	----	----	----
Carbonate Alkalinity as CaCO3	3812-32-6	1	mg/L	<1	<1	----	----	----
Bicarbonate Alkalinity as CaCO3	71-52-3	1	mg/L	**4**	**2**	----	----	----
Total Alkalinity as CaCO3	----	1	mg/L	**4**	**2**	----	----	----
ED038A: Acidity								
Acidity as CaCO3	----	1	mg/L	**19**	**29**	----	----	----
ED041G: Sulfate (Turbidimetric) as SO4 2- by DA								
Sulfate as SO4 - Turbidimetric	14808-79-8	1	mg/L	**954**	**1220**	----	----	----
ED045G: Chloride by Discrete Analyser								
Chloride	16887-00-6	1	mg/L	**24**	**23**	----	----	----
ED093F: Dissolved Major Cations								
Calcium	7440-70-2	1	mg/L	**138**	**302**	----	----	----
Magnesium	7439-95-4	1	mg/L	**102**	**107**	----	----	----
Sodium	7440-23-5	1	mg/L	**99**	**34**	----	----	----
Potassium	7440-09-7	1	mg/L	**8**	**9**	----	----	----
EG020F: Dissolved Metals by ICP-MS								
Aluminium	7429-90-5	0.01	mg/L	**0.04**	<0.01	----	----	----
Antimony	7440-36-0	0.001	mg/L	<0.001	<0.001	----	----	----
Arsenic	7440-38-2	0.001	mg/L	**0.010**	**0.006**	----	----	----
Cadmium	7440-43-9	0.0001	mg/L	**0.0009**	**0.0012**	----	----	----
Chromium	7440-47-3	0.001	mg/L	<0.001	<0.001	----	----	----
Copper	7440-50-8	0.001	mg/L	**0.014**	<0.001	----	----	----
Cobalt	7440-48-4	0.001	mg/L	**0.025**	**0.055**	----	----	----
Nickel	7440-02-0	0.001	mg/L	**0.023**	**0.051**	----	----	----
Lead	7439-92-1	0.001	mg/L	<0.001	<0.001	----	----	----
Zinc	7440-66-6	0.005	mg/L	**0.096**	**0.139**	----	----	----
Manganese	7439-96-5	0.001	mg/L	**2.13**	**2.80**	----	----	----
Molybdenum	7439-98-7	0.001	mg/L	<0.001	<0.001	----	----	----
Selenium	7782-49-2	0.01	mg/L	**0.01**	<0.01	----	----	----
Vanadium	7440-62-2	0.01	mg/L	<0.01	<0.01	----	----	----

Analytical Results

Sub-Matrix: **WATER** (Matrix: **WATER**)			Client sample ID	**KLC-1**	**KLC-2**	**----**	**----**	**----**
			Client sampling date / time	26-Nov-2019 14:21	26-Nov-2019 14:22	----	----	----
Compound	*CAS Number*	*LOR*	*Unit*	**EB1931641-001**	**EB1931641-002**	**--------**	**--------**	**--------**
				Result	Result	----	----	----
EG020F: Dissolved Metals by ICP-MS - Continued								
Boron	7440-42-8	0.05	mg/L	**0.12**	**0.12**	----	----	----
Iron	7439-89-6	0.05	mg/L	**1.83**	**6.39**	----	----	----
EK040P: Fluoride by PC Titrator								
Fluoride	16984-48-8	0.1	mg/L	**0.2**	<0.1	----	----	----
EN055: Ionic Balance								
ø **Total Anions**	----	0.01	meq/L	**20.6**	**26.1**	----	----	----
ø **Total Cations**	----	0.01	meq/L	**19.8**	**25.6**	----	----	----
ø **Ionic Balance**	----	0.01	%	**2.05**	**0.98**	----	----	----

RGS

LEADERS IN MINING GEOCHEMISTRY

Appendix I Soil and Land Suitability Assessment

GEMINI PROJECT
SOIL AND LAND SUITABILITY ASSESSMENT

PREPARED FOR

MAGNETIC SOUTH PTY LTD

JULY 2019

BRISBANE OFFICE
Suite 5, 1 Swann Road
Taringa, QLD 4068
P +61 7 3217 8772

CAIRNS OFFICE
PO Box 4887
Cairns, QLD 4879
P +61 7 4057 9402

E info@aarc.net.au
AARC.NET.AU

ACN. 620 818 920
ABN. 71 620 818 920

AARC Environmental Solutions Pty Ltd

Document History and Status

Issue	Rev.	Issued To	Qty	Date	Reviewed	Approved
1	0	MS	1	22/09/19	GB	GB

Author: Zoe Maskell & Steven Griffiths
Project Manager: Gareth Bramston
Name of Client: Magnetic South Pty Ltd
Name of Project: Gemini Project
Title of Document: Soil and Land Suitability Assessment
Document Version: Final

Opinions and judgments expressed herein, which are based on our understanding and interpretation of current regulatory standards, should not be construed as legal opinions. Information obtained from interviews and contained in the documentation has been assumed to be correct and complete. AARC Environmental Solutions Pty Ltd does not accept any liability for misrepresentation of information or for items not visible, accessible, nor able to be inspected at the sites at the time of the site visits.

INDEX

1.0 INTRODUCTION ... 1
1.1 SCOPE OF STUDY ... 1
1.2 PROJECT BACKGROUND ... 2
1.3 LOCAL WATERWAYS AND TOPOGRAPHY ... 2
1.4 CURRENT LAND USE ... 2
1.5 REGIONAL GEOLOGY ... 5
1.5.1 Solid Geology ... 5
1.5.2 Surface Geology ... 5
1.6 REGIONAL CLIMATE ... 8
1.7 LAND SYSTEMS ... 8
1.7.1 Dingo Land System ... 9
1.7.2 Melbadale ... 9
2.0 RELEVANT LEGISLATION, POLICY AND GUIDELINES ... 10
2.1 REGIONAL PLANNING INTERESTS ACT 2014 (QLD) ... 10
2.2 GUIDELINES ... 10
3.0 SOIL SURVEY METHODOLOGY ... 11
3.1 DESKTOP ANALYSIS ... 11
3.2 SURVEY DESIGN ... 11
3.3 FIELD INVESTIGATIONS ... 12
3.4 LABORATORY ANALYSIS ... 12
3.5 CHARACTERISATION OF SOIL MANAGEMENT UNITS ... 13
4.0 SOIL SURVEY RESULTS ... 14
4.1 ANDERSON SOIL MANAGEMENT UNIT ... 16
4.2 BARRY SOIL MANAGEMENT UNIT ... 19
4.3 CHARLEVUE SOIL MANAGEMENT UNIT ... 22
4.4 COOINDA SOIL MANAGEMENT UNIT ... 25
4.5 ELLESMERE SOIL MANAGEMENT UNIT ... 28
4.6 GEOFFREY SOIL MANAGEMENT UNIT ... 31
4.7 JAMES SOIL MANAGEMENT UNIT ... 35
4.8 KOSH SOIL MANAGEMENT UNIT ... 38

4.9 NAMOI SOIL MANAGEMENT UNIT 41
4.10 NIGEL SOIL MANAGEMENT UNIT 44
4.11 NORMANBY SOIL MANAGEMENT UNIT 47
4.12 WALLACE SOIL MANAGEMENT UNIT 51
5.0 LAND SUITABILITY 54
5.1 CATTLE GRAZING 55
5.1.1 Water Availability 55
5.1.2 Nutrient Deficiency 56
5.1.3 Soil Physical Factors 57
5.1.4 Salinity 58
5.1.5 Rockiness 58
5.1.6 Microrelief 59
5.1.7 pH 60
5.1.8 Exchangeable Sodium Percentage (ESP) 60
5.1.9 Wetness 61
5.1.10 Water Erosion 61
5.1.11 Flooding 62
5.1.12 Vegetation Regrowth (management limitation) 63
5.1.13 Summary of Land suitability for Cattle Grazing 64
5.2 DRYLAND CROPPING 67
5.2.1 Water Erosion 67
5.2.2 Erosion hazard, Subsoil Erodibility 68
5.2.3 Soil Water Availability 69
5.2.4 Narrow Moisture Range 69
5.2.5 Surface Condition 70
5.2.6 Rockiness 71
5.2.7 Microrelief 72
5.2.8 Wetness 72
5.2.9 Summary of Land Suitability for Dryland Cropping 74
6.0 SOIL HANDLING RECOMMENDATIONS 77
6.1 TOPSOIL SUITABILITY AND STRIPPING 77
6.2 TOPSOIL STOCKPILING 80
6.3 TOPSOIL PLACEMENT 81
7.0 POTENTIAL IMPACTS AND MANAGEMENT 83
7.1 LAND SUITABILITY 83
7.2 EROSION 84
7.3 EROSION OF REHABILITED LANDFORMS 84
7.4 SOIL DEGRADATION 85

8.0 REFERENCES 87

LIST OF FIGURES

Figure 1 Project Location 3
Figure 2 Waterways and Topography associated with the Project..4
Figure 3 Solid Geology..6
Figure 4 Surface Geology 7
Figure 5 Mean temperature and rainfall data for the region 8
Figure 6 Distribution of Soil Management Units..15
Figure 7 Cattle Grazing Land Suitability Classes..66
Figure 8 Dryland Cropping Land Suitability Classes 76

LIST OF TABLES

Table 1 Survey Site Numbers for SLSA 2018 11
Table 2 Area of Soil Management Units 14
Table 3 Anderson Soil Unit Description 16
Table 4 Chemical Properties of the Anderson SMU 17
Table 5 Surface Soil (0-10 cm) Properties of the Anderson SMU 18
Table 6 Barry Soil Unit Description..19
Table 7 Chemical Properties of the Barry SMU..20
Table 8 Surface Soil (0-10cm) Properties of the Barry SMU..21
Table 9 Charlevue Soil Unit Description 22
Table 10 Chemical Properties of the Charlevue SMU 23
Table 11 Surface Soil (0-10 cm) Properties of the Charlevue SMU 24
Table 12 Cooinda Soil Unit Description 25
Table 13 Chemical Properties of the Cooinda SMU 26
Table 14 Surface Soil (0-10cm) Properties of the Cooinda SMU 27
Table 15 Ellesmere Soil Unit Description 28
Table 16 Chemical Properties of the Ellesmere SMU 29
Table 17 Surface Soil (0-10 cm) Properties of the Ellesmere SMU 30
Table 18 Geoffrey Soil Unit Description..31
Table 19 Chemical Properties of the Geoffrey SMU 33
Table 20 Surface Soil (0-10cm) Properties of the Geoffrey SMU..33
Table 21 James Soil Unit Description..35

Table 22 Chemical Properties of the James SMU 36
Table 23 Surface Soil (0-10 cm) Properties of the James SMU 37
Table 24 Kosh Soil Unit Description 38
Table 25 Chemical Properties of the Kosh SMU 39
Table 26 Surface Soil (0-10 cm) Properties of the Kosh SMU 40
Table 27 Namoi Soil Unit Description 41
Table 28 Chemical Properties of the Namoi SMU 42
Table 29 Surface Soil (0-10 cm) Properties of the Namoi SMU 43
Table 30 Nigel Soil Unit Description 44
Table 31 Chemical Properties of the Nigel SMU 45
Table 32 Surface Soil (0-10 cm) Properties of the Nigel SMU 46
Table 33 Normanby Soil Unit Description 47
Table 34 Chemical Properties of the Normanby SMU 48
Table 35 Surface Soil (0-10 cm) Properties of the Normanby SMU 49
Table 36 Wallace Soil Unit Description 51
Table 37 Chemical Properties of the Wallace SMU 52
Table 38 Surface Soil (0-10 cm) Properties of the Wallace SMU 53
Table 39 Agricultural and Conservation Land Classes 54
Table 40 Plant Available Water Capacity 56
Table 41 Land Suitability Classes for Cattle Grazing based on Nutrient Status 57
Table 42 Land Suitability Classes for Cattle Grazing based on Soil Physical Factors 57
Table 43 Land Suitability Classes for Cattle Grazing based on Salinity 58
Table 44 Land Suitability Classes for Cattle Grazing 59
Table 45 Land Suitability Classes for Cattle Grazing based on microrelief 59
Table 46 Land Suitability Classes for Cattle Grazing based on pH 60
Table 47 Land Suitability Classes for Cattle Grazing based on ESP 60
Table 48 Land Suitability Classes for Cattle Grazing based on Wetness 61
Table 49 Land Suitability Classes for Cattle Grazing based on Water Erosion 62
Table 50 Land Suitability Classes for Cattle Grazing based on Flooding 62
Table 51 Land Suitability Classes for Cattle Grazing based on Vegetation 63
Table 52 Summary of Land Suitability Limitations for Cattle Grazing 64
Table 53 Land Suitability Classes for Dryland Cropping based on Water Erosion 67
Table 54 Land Suitability Classes for Dryland Cropping based on Erosion Hazard and Subsoil Erodibility 68
Table 55 Land Suitability Classes for Dryland Cropping based on Soil Water Availability 69
Table 56 Land Suitability Classes for Dryland Cropping based on Narrow Moisture Range 70
Table 57 Land Suitability Classes for Dryland Cropping based on Surface Condition 70
Table 58 Land Suitability Classes for Dryland Cropping based on Rockiness 71
Table 59 Land Suitability Classes for Dryland Cropping based on Microrelief 72
Table 60 Land Suitability Classed for Dryland Cropping based on Wetness 72

Table 61 Summary of Land Suitability Limitations for Dryland Cropping 74
Table 62 Maximum Topsoil Stripping Depths for all Soil Management Units..............................77
Table 63 Estimated Soil Volumes 81
Table 64 Summary of the Size and Suitability Classes for all SMUs 83

LIST OF PHOTO PLATES

Photo Plate 1 Anderson SMU Vegetation 16
Photo Plate 2 Barry SMU Vegetation 19
Photo Plate 3 Charlevue SMU Vegetation 22
Photo Plate 4 Cooinda SMU Vegetation 25
Photo Plate 5 Ellesmere SMU Vegetation...28
Photo Plate 6 Geoffrey SMU Vegetation (showing cleared and vegetated sections)........................31
Photo Plate 7 James SMU Vegetation 35
Photo Plate 8 Kosh SMU Vegetation (cleared) 38
Photo Plate 9 Namoi SMU Vegetation 41
Photo Plate 10 Nigel SMU Vegetation 44
Photo Plate 11 Normanby SMU Vegetation 47
Photo Plate 12 Wallace SMU Vegetation..51

LIST OF APPENDICES

Appendix A Lab Results ....A
Appendix B Soil Profile Data ....B
Appendix C Soil Observation Data C

LIST OF ABBREVIATIONS

%	-	Percentage
<	-	less than
>	-	greater than
°C	-	Degrees Celsius
AARC	-	AARC Environmental Solutions Pty Ltd
ALS	-	Australian Laboratory Services
BoM	-	Bureau of Meteorology
Ca	-	Calcium
Ca/Mg	-	Calcium/Magnesium Ratio
CEC	-	Cation Exchange Capacity
CH4	-	Methane
cm	-	Centimetre(s)
CO2	-	Carbon Dioxide
Cu	-	Copper
DME	-	Department of Mines and Energy
DNRM	-	Department of Natural Resources and Mining
dS/m	-	deciSiemens(s) per metre
DSITI	-	Department of Science, Information Technology and Innovation
EC	-	Electrical Conductivity
EPC	-	Exploration Permit Coal
ESP	-	Exchangeable Sodium Percentage
GPS	-	Global Positioning System
ha	-	Hectare(s)
Iron	-	Fe
K	-	Potassium

km	-	Kilometre(s)
km^2	-	Kilometre(s) squared
m	-	metre(s)
m2	-	metre(s) squared
m3	-	metre(s) cubed
Magnetic South	-	Magnetic South Pty Ltd
MCA	-	Mineral Council of Australia
meq/100g	-	milliequivalent(s) per 100 grams
Mg	-	Magnesium
mg/kg	-	milligram(s) per kilogram
mm	-	Millimetre(s)
Mn	-	Manganese
N2O	-	Nitrous oxide
Na	-	Sodium
NATA	-	National Association of Testing Authorities
PAWC	-	Plant Available Water Capacity
ppm	-	Parts per million
PSA	-	Particle Size Analysis
ROM	-	Run of Mine
RPI Act	-	*Regional Planning Interests Act 2014 (Qld)*
RPI Regulation	-	Regional Planning Interests Regulation 2014
SILO	-	Scientific Information for Land Owners
SC Act	-	*Soil Conservation Act 1986 (Qld)*
SCL	-	Strategic Cropping Land
SLSA	-	Soil and Land Suitability Assessment
SMU	-	Soil Management Units
Taunton national Park	-	Taunton National Park (Scientific)
The Project	-	Gemini Project

tpa	-	tonnes per annum
V:H	-	vertical to horizontal ratio
Zn	-	Zinc

1.0 INTRODUCTION

AARC Environmental Solutions Pty Ltd (AARC) was commissioned by Magnetic South Pty Ltd (Magnetic South) to conduct a Soil and Land Suitability Assessment (SLSA) for the Gemini Project (the Project).

An assessment of the Project's soil and land suitability values was conducted within Exploration Permit Coal (EPC) 881 near Dingo in Central Queensland. This assessment forms part of the supporting studies required for the Project's Environmental Authority (EA) Application.

The Project is a greenfield, open-cut metallurgical mine approval, proposing production of Pulverised Coal Injection (PCI) coal for export to the international steel making industry.

This SLSA documents the nature and distribution of major soil types in the target area and assesses their suitability for land uses such as cattle grazing and cropping. This assessment establishes baseline environmental characteristics and values relating to land use and suitability and makes recommendations for the management of soil resources.

1.1 SCOPE OF STUDY

The objectives of the SLSA were to:

- Describe the agricultural use of the land of the Project and the surrounding area, including any crop rotations;

- Describe, map and illustrate soil types and profiles according to the *Australian Soil and Land Survey Field Handbook* (NCST 2009), *Guidelines for Surveying Soil and Land Resources* (McKenzie et. al. 2008) and *Australian Soil Classification* (Isbell 2002);

- Identify soils that would require specialised management due to wetness, erosivity, depth, acidity, salinity or other features;

- Identify soil management units from representative samples down the soil profile, based on their physical and chemical properties;

- Describe and map land suitability classes of the potentially affected area in accordance with the *Guidelines for Agricultural Land Evaluation in Queensland – Second Edition (Draft)* (DSITI & DNRM 2015), and the *Regional Land Suitability Frameworks for Queensland Guidelines for Agricultural Land Evaluation in Queensland – Second Edition (Draft)* (DSITI & DNRM 2013);

- Assess the potential impacts of the Project on the soil and land use values and provide recommended mitigation measures to minimise negative impacts; and

- Include the findings in a stand-alone report suitable for reference in the Project's EA Application.

1.2 PROJECT BACKGROUND

The Project is situated in the Bowen Basin, Central Queensland, approximately 3 kilometres (km) west of the township of Dingo, 110 km east of Emerald, and 125 km south-west of Rockhampton (Figure 1). The study area is contained within the bounds of EPC 881.

The Project is proposed to be an open-cut coal mine with an anticipated life of 25 years from grant of the mining lease (ML); with this term including initial construction, mine operation and rehabilitation activities.

1.3 LOCAL WATERWAYS AND TOPOGRAPHY

The Project lies within the Fitzroy River Basin, which encompasses an area of 142,545 square kilometres (km^2) and contains the Comet, Connors, Dawson, Don, Nogoa and Mackenzie Rivers, which make up its six sub-catchment areas (BoM 2018; DES 2018).

The Project lies within the Mackenzie River sub-catchment, which covers a total area of 12,985 km^2, and is situated in the centre of the Fitzroy River catchment. The major water body associated with the Project site is Charlevue Creek, which dissects the EPC in a north-easterly direction. This creek begins within the boundaries of Blackdown Tablelands National Park, flowing north-east before joining with Springton Creek and the Fitzroy River, eventually reaching the Pacific Ocean approximately 46 km north of Gladstone. Two significantly smaller creeks, Stanley and Springton, cross the Project boundaries in the north-west and south-east respectively. These two creeks also eventually converge with the Mackenzie River. Associated tributaries, dams and drainage features also appear across the site. Figure 2 displays the extent of the watercourses associated with the study area.

Topography of the land varies from flat to undulating hills, with elevation within the study area ranging between 120 metres (m) and 150 m above sea level. The landscape is influenced by the presence of Charlevue Creek and its associated flood plains, which have relatively lower elevations than the surrounding landscape of undulating hills. The topography of the Project is representative of the surrounding region.

1.4 CURRENT LAND USE

The land within the Project boundary is currently used for low intensity cattle grazing and resource exploration activities. There is one highway (Capricorn) and five publicly gazetted roads (Charlevue, Cooinda, Red Hill, Normanby, and Ellesmere) dissecting the area.

.

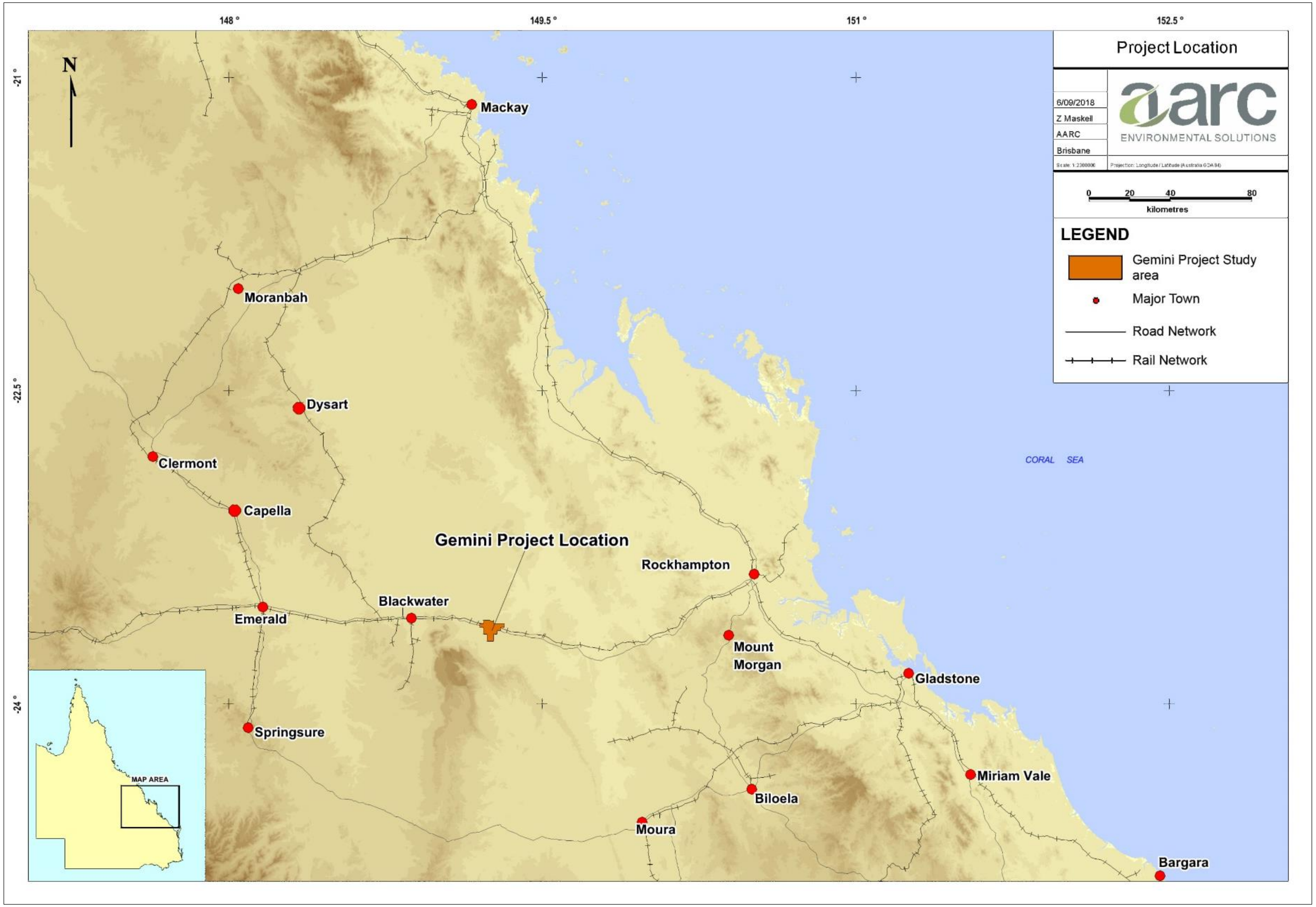


Figure 1 Project Location

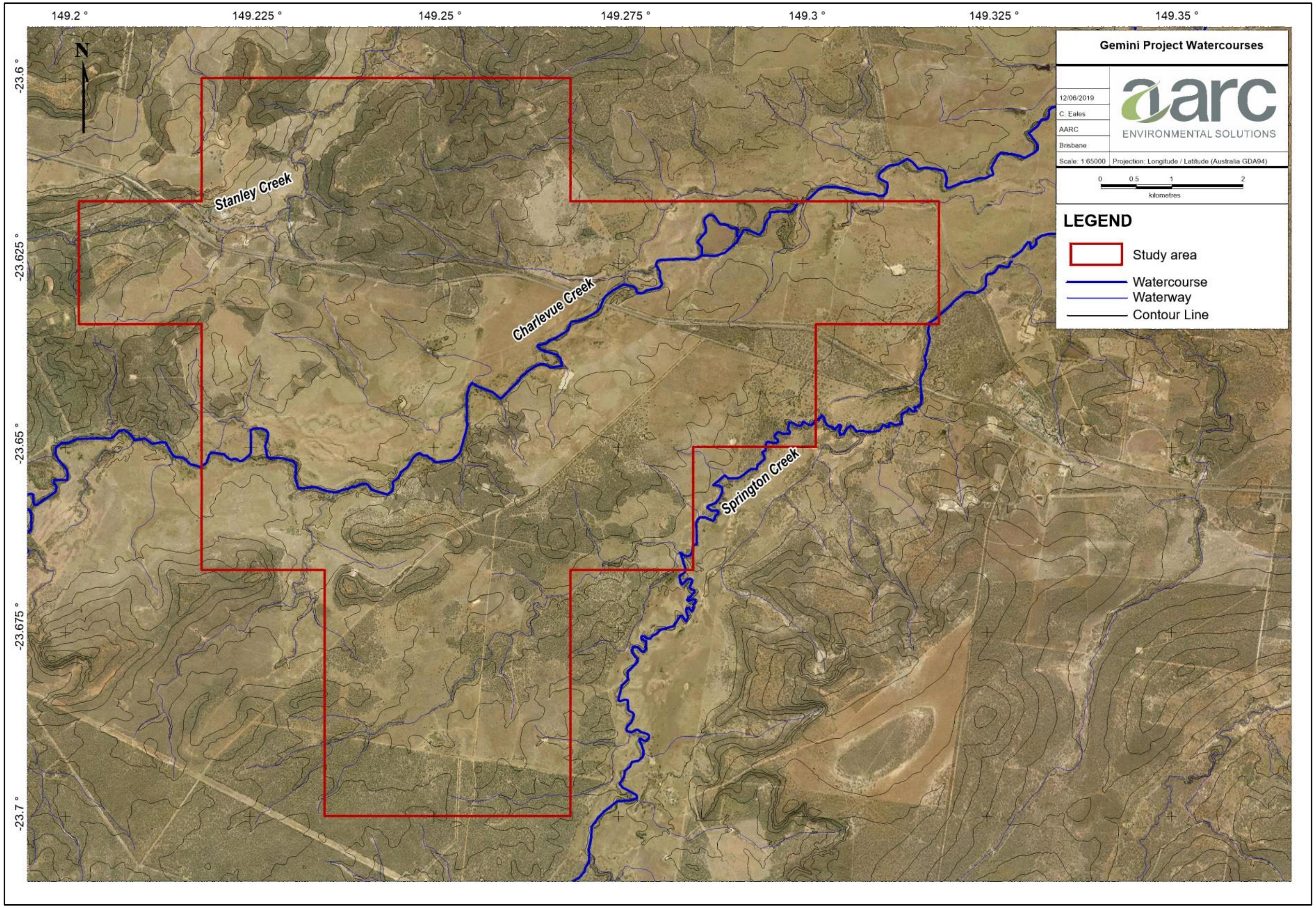


Figure 2 Waterways and Topography associated with the Project

1.5 REGIONAL GEOLOGY

The geology of the Dingo area is dominated by its position within the Bowen Basin. The Bowen Basin is one of Queensland's largest depositional zones, forming through a period of rifting and subsidence lasting from the Early Permian to Mid-Triassic. The area surrounding the Project is dominated by clastic sedimentary rocks of marine and lacustrine origin, including sandstones, conglomerates, mudstones, siltstones and coal (Geoscience Australia 2018).

The coastal and inland depositional environments which created these deposits allowed for the formation of extensive coal seams throughout the Bowen Basin, with the anoxic deposition of organic matter subsequently compacted and de-volatised through compression and increased temperatures (Brooks & Smith 1969).

Generally, coal seams found in the east-central part of the basin contain higher quality coking coal deposits, with rank falling below coking range farther south and west (Hutton 2009). The high-quality coal measures found at within the Gemini Project are of Permian age, and are generally located less than 60 m from the surface (Mutton 2003).

1.5.1 Solid Geology

The following solid geology map units were identified within the Project area.

- Rangal Coal Measures (Pwj) – Late Permian sedimentary unit comprised of sandstone, siltstone, mudstone, coal, tuff and conglomerate;

- Gyranda Subgroup (Pwy) – Late Permian sedimentary unit comprised of siltstone and shale with minor tuff and volcanilithic sandstone and rare coal (lower part - Banana Formation); calcareous sandstone, mudstone and siltstone (upper part - Wiseman Formation); and

- Rewan Group (Rr) – Early Triassic – Middle Triassic sedimentary unit comprised of lithic sandstone, pebbly lithic sandstone, green to reddish brown mudstone and minor volcanilithic pebble conglomerate (at base).

These map units are displayed below in Figure 3.

1.5.2 Surface Geology

The following surface geology map units were identified within the Project area.

- Qa-QLD (Qa) – Quaternary clay, silt, sand and gravel; flood-plain alluvium

- Td-QLD (Td) – Tertiary duricrusted palaeosols at the top of deep weathering profiles, including ferricrete and silcrete; duricrusted old land surfaces.

- Duaringa Formation (Tu) – Eocene-Oligocene mudstone, sandstone, conglomerate, siltstone, oil shale, lignite and basalt.

- Gyranda Subgroup (Pwy) – Late Permian sedimentary unit comprised of siltstone and shale with minor tuff and volcanilithic sandstone and rare coal (lower part - Banana Formation); calcareous sandstone, mudstone and siltstone (upper part - Wiseman Formation);

These map units are displayed below in Figure 4.

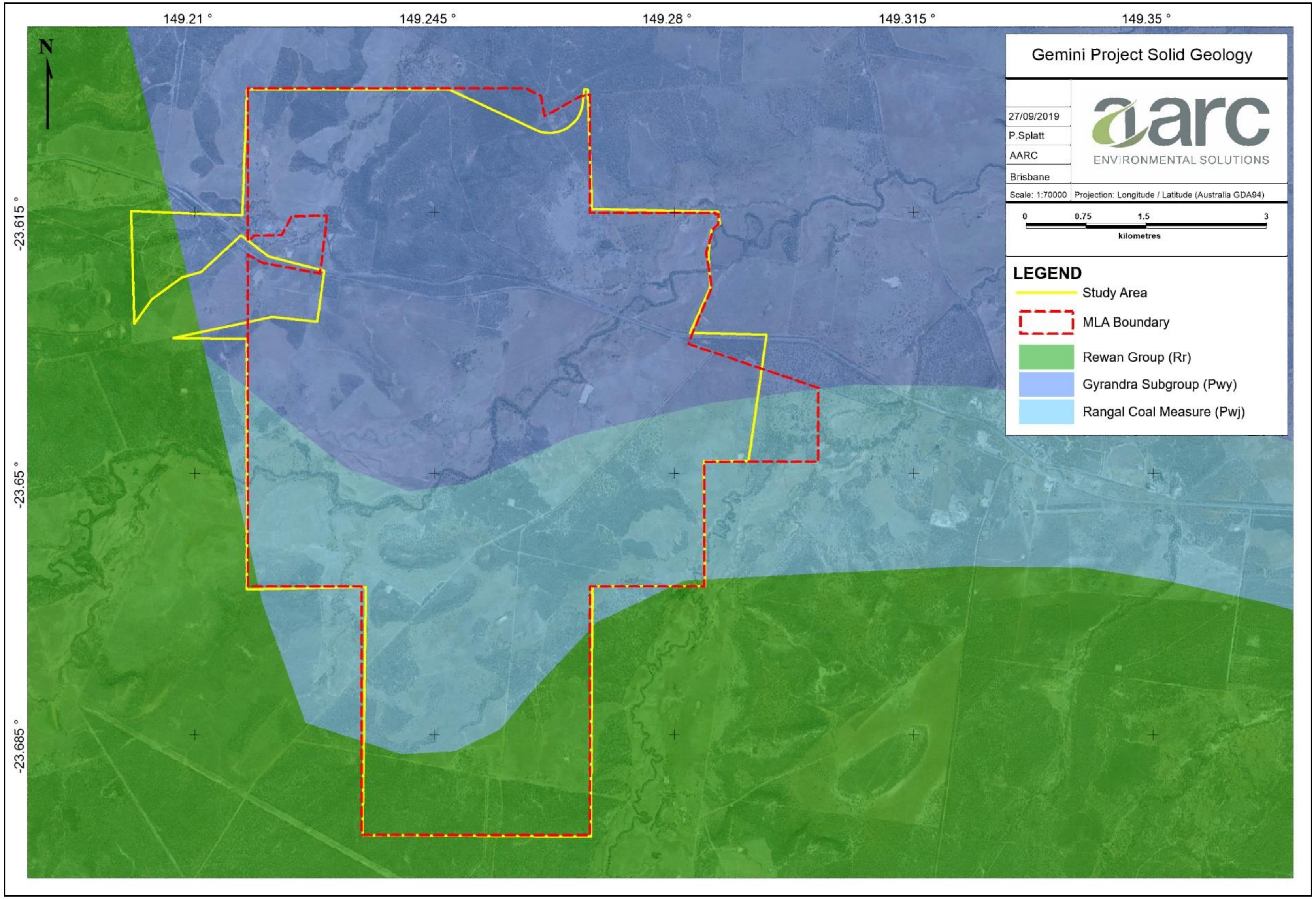


Figure 3 Solid Geology

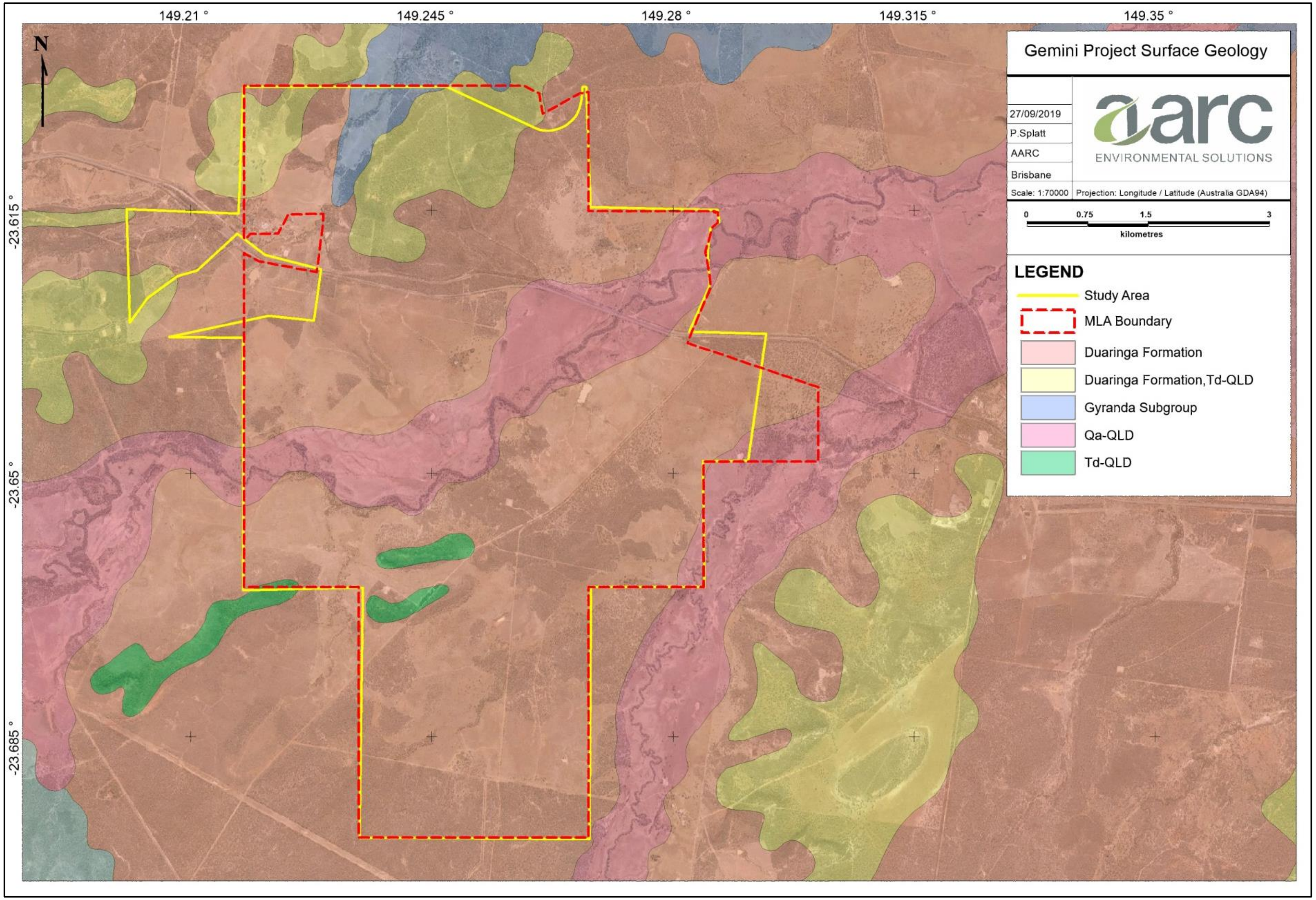


Figure 4 Surface Geology

1.6 REGIONAL CLIMATE

The regional climate is classified as semi-arid, characterised with warm dry summers and warm winters. Climate data for the Project has been sourced from Scientific Information for Land Owners (SILO) climate database (Queensland Government), which operates by interpolating data from the Commonwealth Bureau of Meteorology (BoM) into a single point data drill. SILO was selected to obtain the data, instead of weather station data from BoM, due to the significant distance between the Project and the closest weather station located in Blackwater Water Treatment Plant weather station approximately 50 km away, which only recorded weather data between 1995 and 2008.

Figure 5 shows average temperature and rainfall registered in the area from January 1999, to present. The data indicates the annual mean rainfall for the region is highest between December and March with the maximum average registering in December (111.5 millimetres (mm)).

The hottest months typically occur between October and March while the coldest months occur between May and September. The highest mean maximum temperature typically occurs in December (34.2 degrees Celsius (°C)) and the lowest mean minimum temperature in July (8.5°C). The mean annual maximum temperature for the region is 29.8°C and the mean annual minimum temperature is 16 °C.

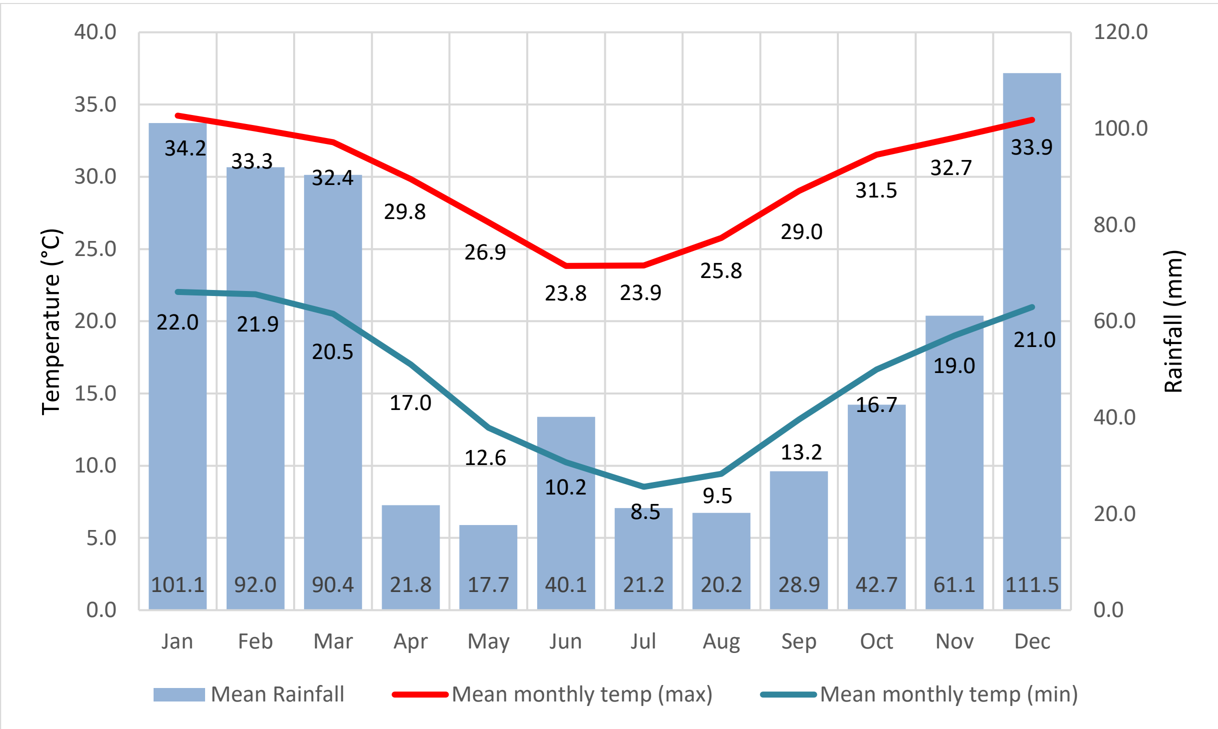


Figure 5 Mean temperature and rainfall data for the region

1.7 LAND SYSTEMS

The General Report on Lands of the Dawson-Fitzroy Area (Speck et. al. 1967) mapped at a scale of 1:80,000 indicated the study area contains the Dingo Land System and the Melbadale Land System.

1.7.1 Dingo Land System

The Dingo Land System is characterised by fluvial plains surrounding significant waterways. It is mostly composed of stable flood plains traversed by a branching pattern of drainage floors. The majority of deposits are weathered alluvium, with slopes of coarser or finer textured alluvium (depending on flow patterns). Channels can be up to 30 m wide and 3 m deep, with fringing riparian vegetation. Main drainage floors can then extend 800 m outwards, with deep texture contrast sandy loams over mottled clays, and open spaces of *Eucalyptus tereticornis* (Blue gum) and *Eucalyptus crebra* (Narrow-leaved ironbark) with sparse shrubs. Large plains surround drainage features (up to 3 km wide) which can contain either deep texture contrast soils with *Eucalyptus populnea* (Poplar box) woodlands, or deep layered soils on alluvium with woodlands of Blue gum and Narrow-leaved ironbark. Slopes within this land unit are usually the result of strongly gilgaied shrink-swell clays, forming depressions of finer soil textures with *Acacia harpophylla* (Brigalow) scrub.

Geology in this unit is comprised of weathered Quaternary alluvium.

1.7.2 Melbadale

The Melbadale Land System in characterised by the shallow dissection of weathered tertiary land surfaces, forming undulating plains dominated by complex depositional mid and lower slopes, with minor lateritic upper slopes in some places. This land system features moderately dense branching drainage patterns, with local relief usually less than 15 m. Depending on the steepness of terrain, upper slopes are often dominated by deep loamy red earths (gentle slopes) with *Eucalyptus crebra*, or shallow fine sandy loams (steep terrain) with *Acacia shirleyi* (lancewood) forests. Mid to lower slopes are often associated with deep texture contrast soils of loamy sands overlying mottled sandy clays, with grassy woodlands of open-spaced narrow-leaved ironbark and shrubs. Lower slopes are often associated with deep light to medium clays, with tall forests of narrow-leaved ironbark. Tributaries have variable soil textures depending on slope, though stratified loams and texture contrast soils are common.

Geology in this land system is comprised of Quaternary to Late Tertiary colluvial/alluvium, laterised tertiary sandstone, conglomerate, and shale.

2.0 RELEVANT LEGISLATION, POLICY AND GUIDELINES

Relevant legislation, and supporting policy and guidelines, relevant to the assessment of soil and land suitability values on the Project are discussed below.

2.1 REGIONAL PLANNING INTERESTS ACT 2014 (QLD)

The *Regional Planning Interests Act 2014 (Qld)* (RPI Act) aims to identify areas of Queensland that are of regional interests because they contribute, or are likely to contribute, to Queensland's economic, social and environmental prosperity. The RPI Act also aims to give effect to the policies about matters of State interest stated in regional plans and effectively manage impact of resource activities on the areas of regional interest and the coexistence of the two and other regulated activities such as highly productive agricultural activities.

Areas of regional interest that the RPI Act aims to protect are classified as:

- Living areas in regional communities (Priority Living Areas);
- High-quality agricultural areas from dislocation (Priority Agricultural Areas);
- Strategic cropping areas; and
- Regionally important environmental areas (Strategic Environmental Areas).

Detailed description of what constitutes each type of area of regional interest are addressed in Section 8 – 11 of the Act and the Regional Planning Interests Regulation 2014 (RPI Regulation). The RPI Act and RPI Regulation seeks to strike an appropriate balance between protecting priority land uses and delivering a diverse and prosperous economic future for our regions.

There are no areas of regional interest within the study area. Bluff is located just over 6 km to the west is mapped as a Priority Living Area and the nearest SCAs are about 5 km to the north and north-east.

2.2 GUIDELINES

Below is a summary of all relevant guidelines and resources pertaining to the assessment of soil and land suitability for the Project. These guidelines form the basis of the methodology and requirements around these assessments.

- *Australian Soil and Land Survey Field Handbook* (NCST 2009),
- *The Australian Soil Classification Revised Edition* (Isbell 2002);
- *Guidelines for Agricultural Land Evaluation in Queensland – Second Edition* (DSITI & DNRM 2015);
- *Guidelines for Surveying Soil and Land Resources* (McKenzie et al. 2008);
- *Regional Land Suitability Frameworks for Queensland Guidelines for Agricultural Land Evaluation in Queensland – Second Edition* (DSITI & DNRM 2013); and
- *Technical Guidelines for the Environmental Management of Exploration and Mining in Queensland – Land Suitability Assessment Techniques* (DME 1995).

3.0 SOIL SURVEY METHODOLOGY

3.1 DESKTOP ANALYSIS

Desktop analysis was conducted prior to field sampling. This analysis was comprised of background research and evaluation of available information for the study area. Resources used included:

- The Digital Atlas of Australian Soils (BRS, 1991). Australian soils were mapped at a scale of 1:2,000,000. Although this scale is broad it provided a good foundation for understanding the soils that may be present in the Project region.

- Government maps featuring regional topography, geology, contour data, and watercourse locations was used to help refine mapping boundaries, particularly where soil types were a function of gradient.

- Reference information for land systems: *Lands of the Dawson-Fitzroy Area, Queensland* (Speck et al. 1967).

- Reference Information for regional geology: *Geology of the Bowen Basin, Queensland* (Dickins & Malone 1973).

- Reference information for land management: *Understanding and Managing Soils in the Central Highlands* (DPI, 1993).

3.2 SURVEY DESIGN

Methodologies employed throughout this study followed procedures detailed in the *Australian Soil and Land Survey Field Handbook* (NCST, 2009) and the *Guidelines for Surveying Soil and Land Resources* (McKenzie et. al. 2008). The soil survey was based on a free-survey technique with soil profile and observation sites located to best represent all soil types present in the Project.

For this site, a scale between 1:25,000 to 1:100,000 was deemed most appropriate. This scale was selected based on information contained within the *Guidelines for Surveying Soil and Land Resources* (McKenzie et. al. 2008). The final mapping scale for the Project site fell within the specified range.

To achieve a mapping scale of 1:25,000 to 1:100,000, McKenzie et. al. (2008) suggest a minimum recommended sampling density of 1 site per 25 ha with data collection comprising detailed soil profile descriptions (15 to 35 percent (%) of sites), representative profile sampling for lab analysis (1 to 5%) and mapping observations sites (55 to 83%).

The number of sites surveyed for the SLSA (Table 1) exceeded these minimum requirements.

Table 1 Survey Site Numbers for SLSA 2018

Survey Site	Scale	Detailed Soil Profiles	Representative Profiles for Analysis	Mapping Observations	Total
Gemini (6,240 ha)	1:70,000	60	12	180	252

3.3 FIELD INVESTIGATIONS

Field sampling at the Project was undertaken from 20th to 29th of June 2018, consisting of both primary sampling sites (profiles) and secondary visual assessments (observations).

During the survey, sampling site locations were determined using desktop analysis, land management units, landform and vehicle access. Visual assessments were conducted continually whilst traversing the landscape to confirm major soil types and boundaries between soil units. Each site location was recorded using a Global Positioning System (GPS).

Detailed soil profiles were undertaken at 60 sites within the Project boundaries. A jack hammer operated soil corer was used to excavate cores to a maximum depth of 120 centimetres (cm). Soil samples were collected from profiles at standard depths of 0-10, 20-30, 50-60, 80-90, and 110-120 cm where possible. Samples were sealed in clean, plastic zip-lock bags and labelled with the site number, date, depth of sampling, and the initials of the sampler.

Parameters recorded included micro-relief, permeability, drainage, substrate, site disturbance, landform (slope %, relief, elevation, morphological type, landform element and landform pattern), runoff, erosion, SC fragments, rock outcrops, surface condition and dominant vegetation type. Soil profile morphology was described in the field in terms of horizon type, horizon depth, boundary, colour, mottles, texture, coarse fragments, structure, segregations, consistency, and field pH.

3.4 LABORATORY ANALYSIS

Soil profiles from 12 representative sites were selected for analysis through Australian Laboratory Services (ALS) for National Association of Testing Authorities (NATA) approved physical and chemical analyses. All standard depths at the chosen sites were utilised in chemical analysis. Samples were analysed to:

- Confirm the classification of the described soil profile;
- Assist in the description of soil characteristics;
- Assist in the determination of land suitability classes;
- Assist in the determination of topsoil and subsoil as a suitable topdressing media; and
- Assist in the identification of soils that would require specialised management.

Physical and chemical parameters analysed for all samples included:

- pH;
- Electrical Conductivity (EC);
- Moisture Content;
- Chloride (Soluble);
- Exchangeable Cations (Calcium(Ca), Magnesium (Mg), Sodium (Na), Potassium (K));
- Cation Exchange Capacity (CEC); and
- Exchangeable Sodium Percentage (ESP).

Additional physical and chemical parameters analysed for topsoil samples included:

- Organic Matter (%);
- Particle Size Analysis (PSA);
- Extractable Trace Elements/Metals (Iron (Fe), Copper (Cu), Zinc (Zn), Manganese (Mn));
- Boron ($CaCl_2$ extractable);
- N as Nitrate;
- Sulphate (water soluble S as SO_4);
- Phosphorus and Potassium (Colwell); and
- Emerson Class.

3.5 CHARACTERISATION OF SOIL MANAGEMENT UNITS

Soil classification was undertaken using the methodologies specified in *The Australian Soil Classification* (Isbell 2002). Soil Management Units (SMUs) were then described based on the soils' physical and chemical attributes, and land attributes in accordance with the *Guidelines for Surveying Soil and Land Resources* (McKenzie et. al. 2008).

Typically, each SMU was described in terms of its soil profile class, defined as a group of similar soils, having soil profile properties in common. The soils' attributes/limitations were then interpreted using the *Guidelines for Agricultural Land Evaluation in Queensland – Second Edition* (DSITI & DNRM, 2015) to determine their suitability for cattle grazing and broadacre cropping. SMUs were mapped at a scale of 1:70,000 across the Project.

4.0 SOIL SURVEY RESULTS

Within the Project, a total of 12 SMUs were described. Table 2 provides an overview of each SMU and its extent within the Project. The spatial distribution of the SMUs is depicted in Figure 6.

Ratings and categories outlined in the CSIRO publications *Interpreting Soil Test Results – Third Edition* (Hazelton & Murphy 2016) and *Soil Chemical Methods of Australasia* (Rayment & Lyons 2011) were used to assist in interpretation of the SMU physical and chemical properties.

Table 2 Area of Soil Management Units

SMU	Surface Area (ha)	Percent of Study Area (%)
Anderson	37.8	0.61
Barry	156.5	2.54
Charlevue	232.9	3.77
Cooinda	34.9	0.57
Ellesmere	14.6	0.24
Geoffrey	4,079	66.10
James	145.2	2.35
Kosh	927.6	15.03
Namoi	177.6	2.89
Nigel	286.4	4.64
Normanby	48.5	0.79
Wallace	32.0	0.52
Total Area	**6,171.3**	**100**

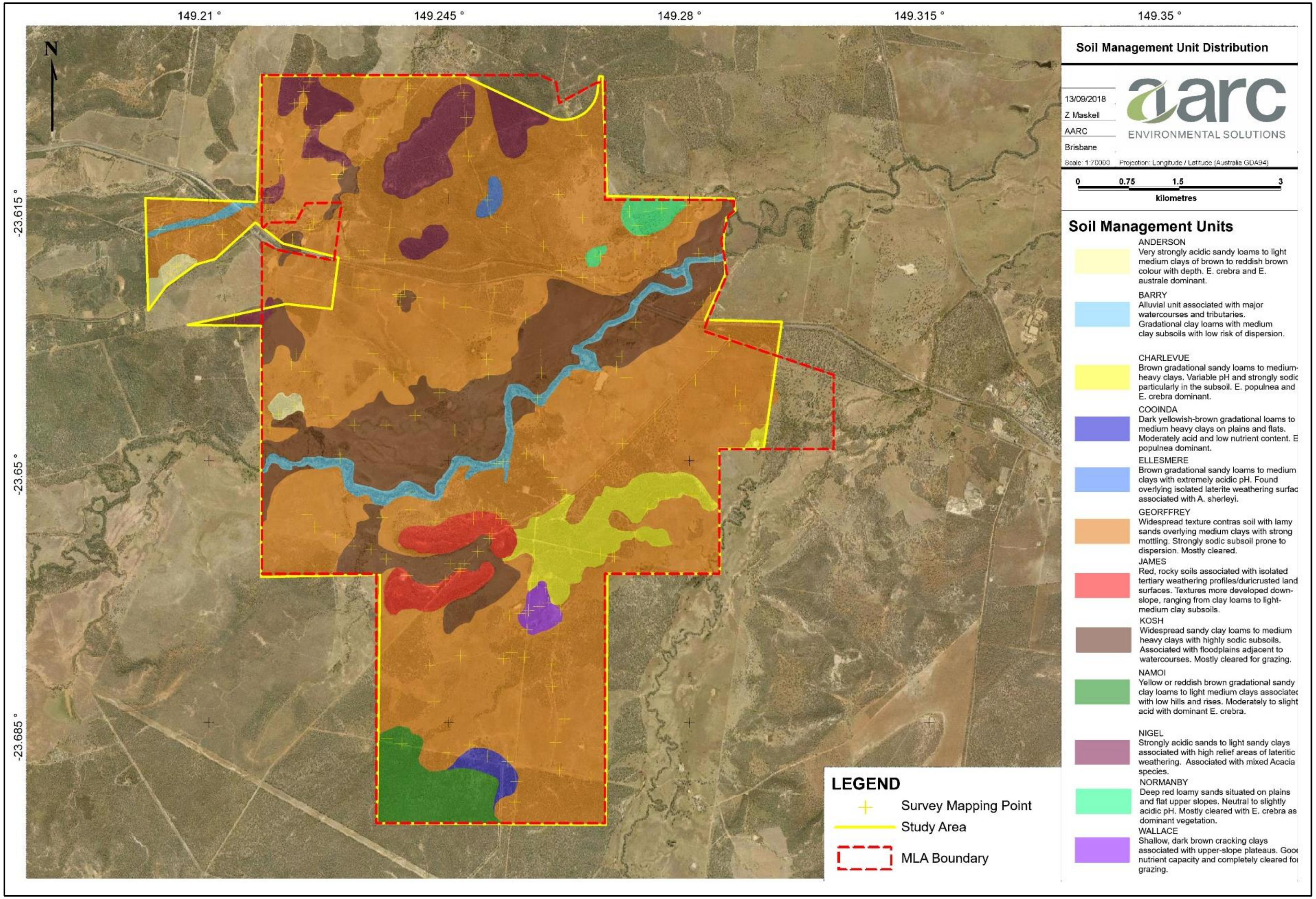


Figure 6 Distribution of Soil Management Units

4.1 ANDERSON SOIL MANAGEMENT UNIT

Soil Unit Description: Hard setting soil unit associated with isolated hills. Soil textures grade from loams at the surface, to light medium clays with depth, sometimes exhibiting red mottling. Vegetation associated with this unit includes *Eucalyptus crebra*, *Corymbia clarksoniana*, and *Acacia rhodoxylon* with *Erythroxylum australe* in the shrub layer.

Australian Soil Classification: Red Kurosol.

Photo Plate 1 Anderson SMU Vegetation

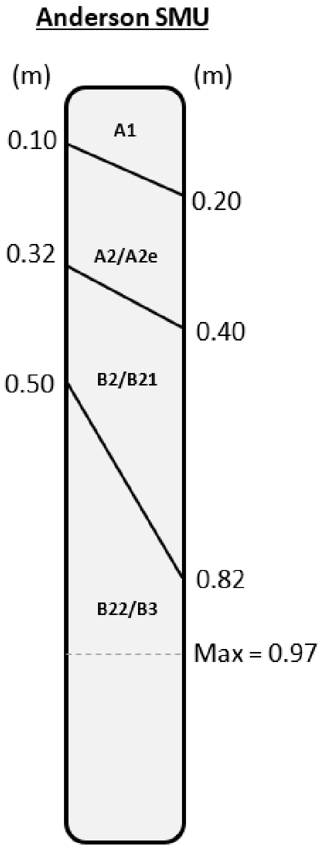
Table 3 Anderson Soil Unit Description

Parameter	Soil Unit Description
Profile Site Numbers	DP37, DP26
Observation Site Numbers	DO55, DO75
Landform	Isolated hills
Land System	Melbadale
Slope	1 to 6%
Geology	Rewan Group (Rr) – Early Triassic – Middle Triassic sedimentary unit comprised of lithic sandstone, pebbly lithic sandstone, green to reddish brown mudstone and minor volcanilithic pebble conglomerate (at base)
Vegetation	*Eucalyptus crebra, Corymbia clarksoniana,* and *Acacia rhodoxylon* with *Erythroxylon australe* in the shrub layer.
Runoff	Moderate to Rapid
Permeability	Slowly to moderately permeable
Drainage	Imperfectly to moderately well drained

Profile Description Representative Sites: DP37 and DP26.

The **surface soil** (A1) is a reddish brown to dark greyish brown (5YR4/4, 10YR3/2) sandy loam to clay loam with massive structure. It has a field pH of 4.5, demonstrating a gradual change to;

The **lower surface soil** (A2/A2e) is a reddish brown (5YR4/4) sandy loam to light medium clay with some profiles exhibiting conspicuous bleaching. It has massive to weak polyhedral structure and a field pH of 4.5 to 5.0. Sub-rounded to rounded coarse fragments make up 1 to 20% of this soil horizon. Clear or gradual change to;



The **subsoil** (B2/B21) is a brown to yellowish red (10YR5/3, 5YR4/6) light to light medium clay with weak lenticular to moderate polyhedral structure. It can exhibit red mottles, and has angular course fragments making up to 20% of the horizon. This horizon has a field pH of 5.5, with a gradual change to;

The **lower subsoil** can present as two different horizons depending on slope. B22 is a light brownish grey (10YR6/2) medium clay with strong angular blocky structure with red mottles. B3 is a yellowish red (5YR4/6) light clay with massive structure, and a small amount of 2-6 mm diameter rounded coarse fragments. The pH in these horizons ranges from 5.5 to 5.8.

<u>Chemical and Physical Analysis</u>

Table 4 Chemical Properties of the Anderson SMU

Representative site: DP26									
Depth (m)	**pH**		**EC**		**Cl**	**ESP%**		**Moisture (%)**	**Emerson Class No.**
	#	**Rate**	**dS/m**	**Rate**	**mg/kg**	**%**	**Rate**		
0-0.1	4.6	Very strongly acid	0.064	Very low	30	3.7	Non-sodic	1	3
0.2-0.3	4.7	Very strongly acid	0.028	Very low	10	2.6	Non-sodic	4.3	4
0.5-0.6	4.8	Very strongly acid	0.02	Very low	10	4.5	Non-sodic	8.2	4

Depth (m)	**CEC**		**Exchangeable Cations (meq/100g)**				**Ca/Mg Ratio**
	meq / 100g	**Rate**	**Ca**	**Mg**	**K**	**Na**	
0-0.1	2.7	Very low	0.7	0.2	0.4	<0.1	3.5
0.2-0.3	2.8	Very low	0.4	0.2	0.2	<0.1	2.0
0.5-0.6	4.2	Very low	0.2	1	<0.1	<0.1	0.2
Percentage in Topsoil			25.93%	7.41%	14.81%	3.70%	-

Key: meq/100g milliequivalent per 100 grams
dS/m deciSiemens per metre
mg/kg milligrams per kilogram

The Anderson SMU has a very strongly acidic pH throughout the profile, ranging from 4.6 in the topsoil, to 4.8 in the lower subsoil. EC and chloride results indicate that at all depths, salinity is very low, with EC ranging from 0.064 deciSiemens per metre (dS/m) in the topsoil, to 0.02 dS/m in the subsoil layer. Chloride concentrations reflected this result, decreasing with depth from 30 milligrams per kilogram (mg/kg) to 10 mg/kg, both well below toxic limits.

CEC is considered very low throughout the profile, though increases from 2.7 milliequivalent per 100 grams (meq/100g) in the topsoil, to 4.2 meq/100g in the subsoil layer. This may be attributed to the high amount of sand in this Exchangeable cation concentrations reflect the low CEC, with calcium (Ca), magnesium (Mg), potassium (K) and sodium (Na) presenting with <1.0 meq/100g) at all depths. Cation percentages are also below appropriate levels, except potassium, which presents within the appropriate range.

The Ca/Mg ratio in the topsoil is between 1 and 4 (low calcium), though this is considered appropriate for sandy soils. This ratio falls to 0.2 in the lower subsoil (Ca deficient). Due to the low clay content of this soil, the low Ca/Mg ratio seen here isn't likely to increase the risk of dispersion in this soil unit.

Table 5 Surface Soil (0-10 cm) Properties of the Anderson SMU

Particle Size Analysis %				Emerson Class No.	Nitrate (mg/kg)	Sulphate (mg/kg)	Organic Matter (%)
Gravel	**Sand**	**Silt**	**Clay**				
10	66	13	11	3	10.2	20	3.3

Extractable Nutrients (mg/kg)			Extractable Metals (mg/kg)			
P	**K**	**B**	**Cu**	**Fe**	**Mn**	**Zn**
11	<200	0.6	<1.00	296	5.46	<1.00

Key: < less than

The surface soil (A1) was dominated by sand (66%), with 10% gravel, 13% silt, and 11% clay. It lacks true structure (massive), and is non-sodic, with a Ca/Mg ratio of 3.5, and an organic matter content of 3.3%. This information paired with the topsoil's Emerson Class Number of 3, indicates that this soil has favourable chemistry, and is unlikely to suffer from dispersion. The high concentration of coarse particles (sand and gravel) may mean this SMU has the tendency to slump under pressure, as it lacks the binding capacity provided by higher clay percentages.

Nutrient levels are variable, with nitrate concentration (10.2 mg/kg) within the guideline range for supporting plant life, while phosphorous (11 mg/kg) and potassium (<200 mg/kg) are not. Boron (0.6 mg/kg) and sulphate (20 mg/kg) concentrations are acceptable, though extractable metals are generally too low (copper and zinc) or too high (iron), with only manganese within the appropriate range for plant life. Acidic pH values in the topsoil will limit the availability of these nutrients to plants, by impacting solubility and speciation. In addition to this, high iron levels can lead to plant toxicity and inefficiency in photosynthesis (Connolly & Guerinot, 2002).

4.2 BARRY SOIL MANAGEMENT UNIT

Soil Unit Description: Hard setting soil associated with rivers, drainage lines and levees. Surface soils in this unit are comprised of clay loams to medium clays, grading into light or medium clays at variable depths. Dominant vegetation includes *Eucalyptus tessellaris, Eucalyptus populnea* and *Eucalyptus tereticornis,* with *Lysiphyllum hookeri*, *Cassia spinarum* and *Cassia brewsteri* in the shrub layer.

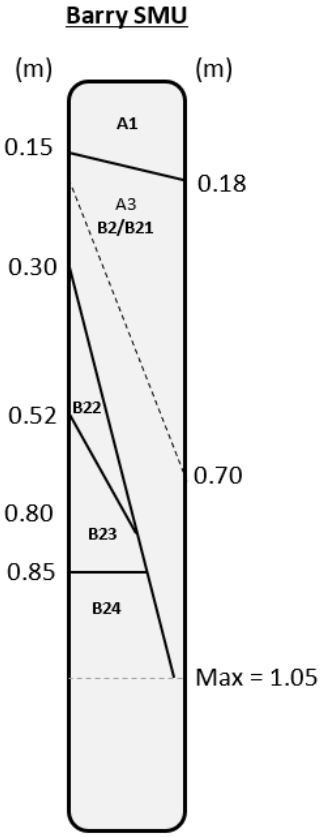
Australian Soil Classification: Brown Dermosol.

Photo Plate 2 Barry SMU Vegetation

Table 6 Barry Soil Unit Description

Parameter	Soil Unit Description
Profile Site Numbers	DP14, DP29, DP36
Observation Site Numbers	DO45, DO79, DO203
Landform	Alluvial plains and levees
Land System	Dingo
Slope	2 to 3%
Geology	Qa-QLD (Qa) – Quaternary clay, silt, sand and gravel; flood-plain alluvium
Vegetation	*Eucalyptus tessellaris, Eucalyptus populnea* and *Eucalyptus tereticornis*, with *Lysiphyllum hookeri, Cassia spinarum* and *Cassia brewsteri* in the shrub layer.
Runoff	Moderate to Rapid
Permeability	Moderately to highly permeable
Drainage	Moderately well drained

Profile Description – Representative Sites: DP14, DP29 and DP36



The **surface soil** (A/A1) is a dark reddish brown (5YR3/4, 7.5YR4/3) clay loam to medium clay with weak to moderate polyhedral or platy structure. It has a field pH of 6.0 to 6.5, with a gradual change to either A3 or B2;

The **lower surface soil** (A3) was not present at all profile sites. It is a reddish brown (5YR4/4) sandy clay loam with massive structure and a field pH of 6.5. Gradual change to;

The **upper subsoil** (B2/B21) is a dark reddish brown to brown (5YR3/3, 7.5YR4/4) sandy light medium clay to medium heavy clay, with weak to moderate structure. It has a field pH of 6.0 to 6.5, with a gradual change to;

The **subsoil** (B22) is a brown to dark brown (7.5YR4/4, 7.5YR3/2) clay loam to medium clay, which can either extend to great depths in the profile, or grade into the subsoil horizons. It has moderate polyhedral structure and a field pH of 6.0 to 6.5. Gradual change to;

The **mid-subsoil** (B23) is a brown (7.5YR4/4) light clay with moderate platy structure and a field pH of 6.5. Clear change to;

The **lower-subsoil** (B24) is a dark brown (7.5YR3/3) light medium clay with moderate polyhedral structure and a field pH of 6.5.

Chemical and Physical Analysis

Table 7 Chemical Properties of the Barry SMU

Representative site: DP14									
Depth (m)	pH		EC		Cl	ESP%		Moisture (%)	Emerson Class No.
	#	Rate	dS/m	Rate	mg/kg	%	Rate		
0-0.1	6.5	Slightly acid	0.063	Very low	20	0.3	Non-sodic	2.3	3
0.2-0.3	6.8	Neutral	0.012	Very low	<10	0.5	Non-sodic	5.1	4
0.5-0.6	6.9	Neutral	0.01	Very low	<10	0.7	Non-sodic	4.3	3
0.8-0.9	7.2	Neutral	0.012	Very low	<10	1	Non-sodic	7.2	3

Depth (m)	CEC		Exchangeable Cations (meq/100g)				Ca/Mg Ratio
	meq / 100g	Rate	Ca	Mg	K	Na	
0-0.1	12.5	Moderate	6.4	5.2	0.9	<0.1	1.2
0.2-0.3	11.3	Low	6.1	4.9	0.2	<0.1	1.2
0.5-0.6	10.4	Low	5.5	4.6	0.2	<0.1	1.2
0.8-0.9	18	Moderate	10	7.5	0.3	0.2	1.3

Percentage in Topsoil	51.20%	41.60%	7.20%	0.30%	-

The Barry SMU has a slightly acidic pH (6.5) which increases gradually with depth, becoming neutral at 0.2 m (6.8), and increasing to pH 7.2 with depth. EC is very low throughout the profile, ranging from 0.063 dS/m in the topsoil, to 0.012 dS/m in the lower subsoil. Chloride concentrations reflect this result, ranging from 20 mg/kg to <10 mg/kg mg/kg with depth.

CEC varies with depth from moderate in the topsoil, to low in the mid-stratum, to moderate in the lower subsoil. This result is reflected in the concentrations of exchangeable cations, which are higher in the topsoil and lower subsoil than they are in the mid-level horizons. Ca, Mg, K and Na are all within the desirable range for plant growth, at all depths. Throughout the profile, calcium dominates magnesium, with a Ca/Mg ratio of 1.2 to 1.3 at all depths. This assists in decreasing any risk of dispersion in the soil, though plants could benefit from additional calcium.

ESP is considered non-sodic at all depths, ranging from 0.3% in the topsoil layer to 1.0% in the lower subsoil. This is beneficial for plant life and ensures that the unit should remain relatively stable when wet. This conclusion is supported by the unit's Emerson Class Numbers, which vary from 3 to 4 throughout the profile, suggesting that if left undisturbed, this unit should not become dispersive.

Table 8 Surface Soil (0-10cm) Properties of the Barry SMU

Particle Size Analysis %				Emerson Class No.	Nitrate (mg/kg)	Sulphate (mg/kg)	Organic Matter (%)
Gravel	**Sand**	**Silt**	**Clay**				
2	42	42	14	3	1.7	<10	3.3

Extractable Nutrients (mg/kg)			Extractable Metals (mg/kg)			
P	**K**	**B**	**Cu**	**Fe**	**Mn**	**Zn**
64	596	0.4	<1.00	53.4	37.2	2.88

The surface soil (A/A1) is dominated by sand (42%) and silt (42%), with 14% clay and 2% gravel. It has weak to moderate structure and is hard setting. The surface soil is non-sodic, with a Ca/Mg ratio of 1.2, and a high organic matter content of 3.3%. This information paired with the topsoil's Emerson Class Number of 3 suggests that the surface soil is unlikely to suffer from dispersion when wetted. The water-holding capacity of the topsoil is relatively good, due to the organic matter content and presence of clay sized particles. This is evidenced by the increase in moisture content with depth (as seen in Table 7).

Nutrient levels are variable, with deficient nitrate (1.7 mg/kg), and adequate concentrations of phosphorous (64 mg/kg) and potassium (569 mg/kg). Boron (0.4 mg/kg) and sulphate (<10 mg/kg) are both below guideline levels for supporting plant life. Extractable metal concentrations also vary in their suitability. While zinc is at an appropriate concentration (2.88 mg/kg), manganese (37.2 mg/kg) and iron (53.4 mg/kg) are both slightly higher than desirable, while copper is below detectable concentration (<1.0 mg/kg). These variable nutrient and metals concentrations are likely to limit the types of vegetation supported by the Barry SMU.

4.3 CHARLEVUE SOIL MANAGEMENT UNIT

Soil Unit Description: Hard setting soil associated with plains and rises. Textures within this unit grade from sandy clay loams or light clays in the surface soil, to medium heavy clays in the subsoil horizons. Dominant vegetation includes *Eucalyptus populnea* and *Eucalyptus crebra,* with *Flindersia dissosperma* (sometimes dominant) and *Cassia spinarum* in the shrub layer.

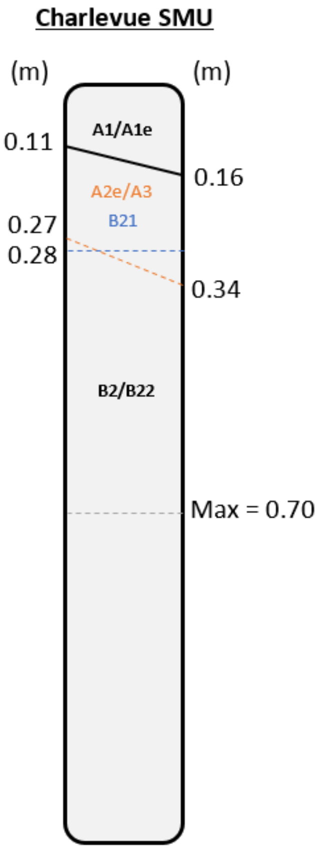
Australian Soil Classification: Red or Brown Dermosol

Photo Plate 3 Charlevue SMU Vegetation

Table 9 Charlevue Soil Unit Description

Parameter	Soil Unit Description
Profile Site Numbers	DP6, DP10, DP11
Observation Site Numbers	DO6, DO24, DO25, DO27, DO244
Landform	Plains and rises
Land System	Melbadale
Slope	1 to 3%
Geology	Qa-QLD (Qa) – Quaternary clay, silt, sand and gravel; flood-plain alluvium
Vegetation	*Eucalyptus populnea* and *Eucalyptus crebra*, with *Flindersia dissosperma* and *Cassia spinarum* in the shrub layer.
Runoff	Very slow to rapid
Permeability	Slowly permeable
Drainage	Poorly drained

Profile Description – Representative Sites: DP6, DP10 and DP11



The **surface soil** (A1/A1e) is a dark brown to brown (7.5YR3/3, 7.5YR4/3, 10YR3/3) sandy clay loam to light medium clay, with weak to moderate structure. It may exhibit conspicuous bleaching, and has a field pH of 5.5 to 5.8. Clear or sharp change to;

The **lower surface soil** (A2e/A3) was not present as all profile sites. It is a light to medium clay with moderate structure, sometimes exhibiting conspicuous bleaching. Field pH is 5.5 to 6.0, with a sharp or abrupt change to;

The **upper subsoil** (B21) was only present at one profile site. It is a dark brown (7.5YR3/4) medium clay with weak lenticular structure and a field pH of 6.5. Clear change to;

The **lower subsoil** (B2/B22) is a reddish or yellowish brown (5YR4/4, 10YR4/6) medium heavy clay with weak to moderate structure. It has a field pH of 6.5 to 7.0.

Chemical and Physical Analysis

Table 10 Chemical Properties of the Charlevue SMU

Representative site: DP6									
Depth (m)	**pH**		**EC**		**Cl**	**ESP%**		**Moisture (%)**	**Emerson Class No.**
	#	**Rate**	**dS/m**	**Rate**	**mg/kg**	**%**	**Rate**		
0-0.1	5.4	Strongly acid	0.28	Medium	420	19.8	Strongly sodic	9.1	4
0.2-0.3	6.4	Slightly acid	0.43	Medium	680	15.1	Strongly sodic	11.8	2
0.5-0.6	7.9	Moderately alkaline	0.46	High	630	29.4	Strongly sodic	10.7	1
Depth (m)	**CEC**			**Exchangeable Cations (meq/100g)**				**Ca/Mg Ratio**	
	meq / 100g	**Rate**		**Ca**	**Mg**	**K**	**Na**		
0-0.1	6.3	Low		1.7	3.1	0.1	1.2	0.5	
0.2-0.3	11.4	Low		3.2	6.4	<0.1	1.7	0.5	
0.5-0.6	13.1	Moderate		2.7	6.5	<0.2	3.8	0.4	
Percentage in Topsoil				26.98%	49.21%	1.59%	19.80%	-	

The Charlevue SMU has a variable pH, ranging from 5.4 (strongly acid) in the topsoil to 7.9 (moderately alkaline) in the lower subsoil. EC is medium in the surface soil (0.28 to 0.43 dS/m), and increases to high in the subsoil (0.46 dS/m). Chloride is considered to be high from 0.2 m depth downwards (>600 mg/kg), which can cause toxicity by interfering with plants' osmotic capacity.

CEC increases with depth, ranging from low (6.3 meq/100g) in the topsoil, to moderate (13.1 meq/100g) in the subsoil layer. This result is reflected in the concentrations of exchangeable cations, which also generally increase with depth. Potassium concentrations were lower than desirable, and though calcium and magnesium fell within the appropriate concentration ranges, necessary percentages were unbalanced throughout the profile. In the topsoil, exchangeable cations are dominated by magnesium at 49.21%, which translates to a Ca/Mg ratio of 0.5. Subsoil layers see a decrease in this ratio, with magnesium (6.5 meq/100g) dominating over calcium (2.7 meq/100g). Due to the high clay content of this soil, this is likely to increase the risk of dispersion in this soil unit.

ESP is considered strongly sodic throughout the profile, ranging from 19.8% in the topsoil layer to 29.4% in the lower subsoil. Due to the high clay content in this soil, this is likely to increase the dispersive tendencies of the unit with depth. This result is reflected in the unit's Emerson Class Numbers, which range from 4 in the surface soil (non-dispersive) to 1 in the lower subsoil (highly dispersive).

Table 11 Surface Soil (0-10 cm) Properties of the Charlevue SMU

Particle Size Analysis %				Emerson Class No.	Nitrate (mg/kg)	Sulphate (mg/kg)	Organic Matter (%)
Gravel	Sand	Silt	Clay				
5	54	38	3	4	0.4	20	1

Extractable Nutrients (mg/kg)			Extractable Metals (mg/kg)			
P	K	B	Cu	Fe	Mn	Zn
12	<200	0.8	<1.00	29.7	5.45	<1.00

The surface soil (A1/A1e) for the Charlevue SMU is dominated by sand (54%) and silt (38%), with 5% gravel and 3% clay. It has weak to moderate structure, and a hard setting surface condition. The topsoil is strongly sodic, with a Ca/Mg ratio of 0.5, and an organic matter content of 1.0%. This information would usually suggest that dispersion would be a considerable risk for the topsoil, though chemical results presented an Emerson Class Number of 4 (non-dispersive). This is likely due to the high sand content in the topsoil layer, which decreases with depth as clay content (and dispersive tendency) increases.

Nutrient levels in the topsoil layer are generally poor, with nitrate (0.4 mg/kg), phosphorous (12 mg/kg) and potassium (<200 mg/kg) below suitable levels. Sulphate (20 mg/kg) and boron (0.8 mg/kg) are within acceptable ranges for supporting plant life. Extractable metals vary in their suitability. Both copper and zinc are below reportable amounts, while manganese (5.45 mg/kg) and iron (29.7 mg/kg) are present in suitable concentrations.

Strongly acidic soils such as these can limit the availability of these nutrients to plants, by affecting their solubility, speciation, and toxicity.

4.4 COOINDA SOIL MANAGEMENT UNIT

Soil Unit Description: Hard setting soil associated with plains. Texture development within this unit is gradual, changing from a sandy clay loam in the topsoil, to a sandy light clay at mid-depth, and a medium heavy clay in the deeper subsoil. Dominant vegetation includes *Eucalyptus populnea* and *Flindersia dissosperma* (sometimes dominant), with *Cassia spinarum* in the shrub layer.

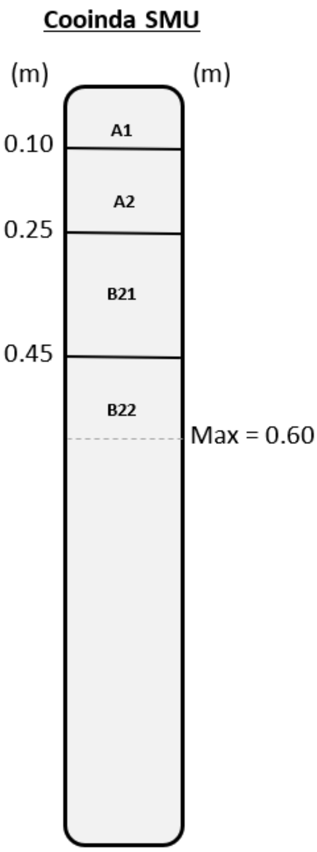
Australian Soil Classification: Brown Dermosol

Photo Plate 4 Cooinda SMU Vegetation

Table 12 Cooinda Soil Unit Description

Parameter	Soil Unit Description
Profile Site Numbers	DP2
Observation Site Numbers	N/A
Landform	Plains and flats
Land System	Melbadale
Slope	2%
Geology	Qa-QLD (Qa) – Quaternary clay, silt, sand and gravel; flood-plain alluvium
Vegetation	Eucalyptus populnea and Flindersia dissosperma (sometimes dominant), with Cassia spinarum in the shrub layer.
Runoff	Moderate
Permeability	Slowly permeable
Drainage	Imperfectly drained

Profile Description – Representative Sites: DP2



The **surface soil** (A1) is a dark yellowish brown (10YR3/6) sandy clay loam with strong play structure. It has a small percentage (<2%) of small sub-rounded coarse fragments. The field pH is 6.0. Clear change to;

The **lower surface soil** (A2) is a dark brown (7.5YR3/4) sandy light clay with moderate polyhedral structure. It also has a small percentage (<2%) of small sub-rounded coarse fragments, with a field pH of 5.5. Gradual change to;

The **upper subsoil** (B21) is a dark yellowish brown (10YR4/4) sandy light clay with moderate polyhedral structure. It has a small percentage (<2%) of small sub-rounded coarse fragments (these are consistent throughout the entire profile), with a field pH of 6.0. Sharp change to;

The **lower subsoil** (B22) is a dark yellowish brown (10YR4/6) medium heavy clay with moderate lenticular structure. It has a small percentage (<2%) of small sub-rounded coarse fragments, with a field pH of 7.0.

Chemical and Physical Analysis

Table 13 Chemical Properties of the Cooinda SMU

Representative site: DP2									
Depth (m)	**pH**		**EC**		**Cl**	**ESP%**		**Moisture (%)**	**Emerson Class No.**
	#	**Rate**	**dS/m**	**Rate**	**mg/kg**	**%**	**Rate**		
0-0.1	5.6	Moderately acid	0.015	Very low	<10	0.9	Non-sodic	4.2	3
0.2-0.3	5.7	Moderately acid	0.013	Very low	10	2.1	Non-sodic	6.0	3
0.5-0.6	6.8	Neutral	0.043	Very low	40	10.9	Sodic	10.0	3
Depth (m)	**CEC**			**Exchangeable Cations (meq/100g)**				**Ca/Mg Ratio**	
	meq / 100g		**Rate**	**Ca**	**Mg**	**K**	**Na**		
0-0.1	4.4		Very low	1.9	2.0	0.4	<0.1	1.0	
0.2-0.3	4.6		Very low	1.5	2.6	0.2	<0.1	0.6	
0.5-0.6	9.8		Low	1.9	6.7	0.1	1.1	0.3	
Percentage in Topsoil				43.18%	45.45%	9.09%	0.9%	-	

The pH of the Cooinda SMU ranges from moderately acid (5.6) in the topsoil, to neutral (6.8) in the lower subsoil. EC is very low throughout the profile, with topsoil values of 0.015 dS/m, increasing to 0.043 dS/m in the subsoil. Chloride levels reflect EC, increasing from less than 10 mg/kg to 40 mg/kg with depth.

CEC increases down the soil profile, ranging from very low (4.4 meq/100g) in the topsoil to low (9.8 meq/100g) in the subsoil. An increase in clay content with depth likely contributes to this increase in CEC. Exchangeable cations are dominated by magnesium and calcium in the topsoil, then magnesium in the subsoil, resulting in a Ca/Mg ratio that decreases with depth from 1.0 to 0.3. Magnesium concentrations (meq/100g) are within acceptable ranges at all depths, though all other cations are either too low (calcium and potassium) or too high (sodium) to be considered appropriate for healthy plant growth.

ESP ranges from non-sodic (0.9%) in the topsoil layer, to sodic (10.9%) in the lower subsoil. Due to the moderate clay content within this soil, this ESP may impact the dispersive tendencies of the soil unit. This result is reflected in the unit's Emerson Class Numbers, which remain at the same level throughout the profile (3), suggesting that the soil unit may become dispersive if physically disturbed.

Table 14 Surface Soil (0-10cm) Properties of the Cooinda SMU

Particle Size Analysis %				Emerson Class No.	Nitrate (mg/kg)	Sulphate (mg/kg)	Organic Matter (%)
Gravel	Sand	Silt	Clay				
7	51	30	12	3	1.2	<10	1
Extractable Nutrients (mg/kg)				Extractable Metals (mg/kg)			
P	K	B		Cu	Fe	Mn	Zn
15	<200	0.4		<1.00	76.9	61.6	1.82

The surface soil (A1) for the Cooinda SMU is dominated by sand (51%), with 30% silt, 12% clay, and 7% gravel. It has a strong platy structure and is hard setting. The topsoil is non-sodic, with a Ca/Mg ratio of 1.0, and an organic matter content of 1.0%. This information paired with the topsoil's Emerson Class Number of 3 suggests that the soil may suffer from dispersion if physically disturbed. The mixture of particle sizes seen here will assist in stabilising the topsoil horizon, as pore spaces between sand grains may be infilled with the sand and silt fractions.

Nutrient levels are low, with nitrate (1.2 mg/kg), phosphorous (15 mg/kg) and potassium (<200 mg/kg) all below the guideline levels for plant life. Boron (0.4 mg/kg) and sulphate (<10 mg/kg) were also lower than desired. Extractable metals were found below suitable concentrations with zinc (1.82 mg/kg) the only trace element detected within the desirable range. Iron (76.9 mg/kg) and manganese (61.6 mg/kg) were both high enough to potentially impact plant health, while copper (<1.0 mg/kg) was below the desirable concentration.

4.5 ELLESMERE SOIL MANAGEMENT UNIT

Soil Unit Description: Hard setting soil associated with isolated hills of weathered tertiary surfaces (laterite). Textures within this unit grade from fine sandy loams in the surface soil to medium clays in the subsoil horizons. Dominant vegetation is *Acacia shirleyi*, with *Erythroxylon australe* in the shrub layer.

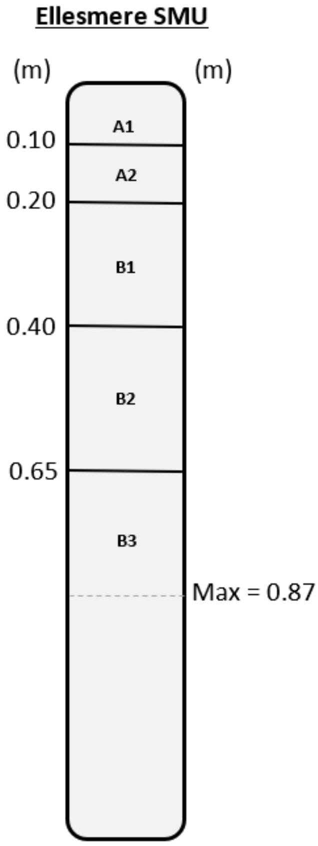
Australian Soil Classification: Red Dermosol.

Photo Plate 5 Ellesmere SMU Vegetation

Table 15 Ellesmere Soil Unit Description

Parameter	Soil Unit Description
Profile Site Numbers	DP40
Observation Site Numbers	N/A
Landform	Isolated hills
Land System	Melbadale
Slope	3-5%
Geology	Gyranda Subgroup (Pwy) – Late Permian sedimentary unit comprised of siltstone and shale with minor tuff and volcanilithic sandstone (lower part)
Vegetation	*Acacia shirleyi*, with *Erythroxylon australe* in the shrub layer.
Runoff	Slow
Permeability	Slowly permeable
Drainage	Moderately well drained

Profile Description – Representative Sites: DP40



The **surface soil** (A1) is a dark brown (7.5YR3/4) fine sandy loam with moderate platy structure. It has a field pH of 5.0, with a gradual change to;

The **lower surface soil** (A2) is a dark brown (7.5YR3/4) sandy clay loam with grainy structure. It has a field pH is 4.5, with a gradual change to;

The **upper subsoil** (B1) is a brown (7.5YR4/4) light clay with grainy structure and a field pH of 4.5. Gradual change to;

The **mid-subsoil** (B2) is a yellowish red (5YR4/6) medium clay with moderate polyhedral structure. It has a field pH of 5.5, with a clear change to;

The **lower subsoil** (B3) is a light brown (7.5YR6/3) medium clay with moderate polyhedral structure. It has a field pH of 5.5.

Chemical and Physical Analysis

Table 16 Chemical Properties of the Ellesmere SMU

Representative site: DP40									
Depth (m)	**pH**		**EC**		**Cl**	**ESP%**		**Moisture (%)**	**Emerson Class No.**
	#	**Rate**	**dS/m**	**Rate**	**mg/kg**	**%**	**Rate**		
0-0.1	4.6	Very strongly acid	0.02	Very low	<10	<0.1	Non-sodic	1.4	3
0.2-0.3	4.6	Very strongly acid	0.011	Very low	<10	6.4	Sodic	3.4	3
0.5-0.6	5.1	Strongly acid	0.017	Very low	<10	10.5	Sodic	11.8	4
0.8-0.9	5.5	Strongly acid	0.026	Very low	<10	13.8	Sodic	10.0	4

Depth (m)	**CEC**		**Exchangeable Cations (meq/100g)**				**Ca/Mg Ratio**
	meq / 100g	**Rate**	**Ca**	**Mg**	**K**	**Na**	
0-0.1	2.3	Very low	0.4	0.2	0.2	<0.1	2
0.2-0.3	2.2	Very low	<0.1	0.2	0.1	<0.1	<0.1
0.5-0.6	5.7	Very low	<0.1	1.7	0.1	0.2	<0.1
0.8-0.9	6.9	Low	<0.1	3.4	0.1	0.6	<0.1
Percentage in Topsoil			17.39%	8.70%	8.70%	<0.1	-

The Ellesmere SMU is a highly acidic soil unit, ranging from 4.6 (very strongly acid) in the topsoil to 5.5 (strongly acid) in the lower subsoil layer. EC is very low throughout the profile, changing from 0.02 dS/m in the topsoil, to 0.026 dS/m in the lower subsoil. Chloride concentrations are very low, consistently presenting at <10 mg/kg.

CEC increases progressively with depth, ranging from very low in the topsoil (2.3 meq/100g) to low in the subsoil (6.9 meq/100g). Corresponding exchangeable cation concentrations are also low, the only values within the appropriate range being magnesium in the bottom two horizons, and potassium in the topsoil. Calcium dominated magnesium in the surface soil layer (Ca/Mg = 2.0), though this was reversed in the subsoil (Ca/Mg = <0.1), where Mg comprises 49.28% of the exchangeable cations, with Ca below reportable levels. These low levels of exchangeable cations may be limiting plant growth.

While sodium concentrations are within the commonly measured levels at all depths, ESP ranges from <0.1% (non-sodic) in the topsoil layer to 13.8% (sodic) in the lower subsoil, becoming sodic at 0.2 m depth. This unit has a moderate clay content in the subsoil layers, though has a very low/low CEC. For this reason, the impact of sodicity is less pronounced than it would be in a soil with high CEC, as sodium atoms cannot effectively separate the clay particles within the soil. This interpretation is reflected in the unit's Emerson Class Numbers, which range from 3 in the surface soil (dispersive if disturbed) to 4 in the subsoil layers (non-dispersive).

Table 17 Surface Soil (0-10 cm) Properties of the Ellesmere SMU

Particle Size Analysis %				Emerson Class No.	Nitrate (mg/kg)	Sulphate (mg/kg)	Organic Matter (%)
Gravel	Sand	Silt	Clay				
3	68	19	10	3	1.6	<10	5

Extractable Nutrients (mg/kg)			Extractable Metals (mg/kg)			
P	K	B	Cu	Fe	Mn	Zn
6	532	0.4	<1.00	327	3.13	<1.00

The surface soil (A1) is dominated by sand (68%), with 19% silt, 10% clay, and 3% gravel. It has a moderate, platy structure and is hard setting. The topsoil is non-sodic, with a Ca/Mg ratio of 2.0, and a high organic matter content of 5%. This information paired with the topsoil's Emerson Class Number of 3, suggests that the surface soil is unlikely to suffer from dispersion if it is not physically disturbed.

Nutrient levels for this SMU are variable. Nitrate (1.6 mg/kg) and phosphorous (6 mg/kg) were both below desirable levels, while potassium (535 mg/kg) was extremely high for both grazing and cropping land uses. Both sulphate (<10 mg/kg) and boron (0.4 mg/kg) were lower than desired. Extractable metals were generally unsuitable, with only manganese (3.13 mg/kg) within the appropriate range. Copper and zinc were both below reportable levels, while iron (327 mg/kg) concentrations were significantly elevated.

Elevated iron levels such as these can cause toxicity to plants and limit their photosynthetic efficiency. They can also limit the uptake of phosphorous, which is already below the ideal concentration. In addition to this, acidic pH values such as those seen in this SMU can limit the availability of all metals and nutrients to plants, by increasing toxicity, reducing solubility and altering elemental speciation.

4.6 GEOFFREY SOIL MANAGEMENT UNIT

Soil Unit Description: This unit consists of texture contrast soils with soft surface conditions, associated with undulating plains and rises. Textures range from loamy sands to sandy light clays, overlying sandy medium clays with conspicuous orange or red mottling. Where these soils were exposed due to insufficient groundcover, extensive washouts and large erosion gullies were observed. In these areas, overland flow had removed coarse sandy material, leaving the easily eroded clays exposed to surface runoff. The Geoffrey SMU was often cleared, though when present dominant vegetation included *Eucalyptus crebra*, *Melaleuca leucadendra*, *Casuarina cunninghamiana* and *Corymbia clarksoniana*, with *Alphitonia excelsa*, *Petalostigma pubecens*, and *Acacia rhodoxylon* in the shrub layer.

Australian Soil Classification: Brown Sodosol.

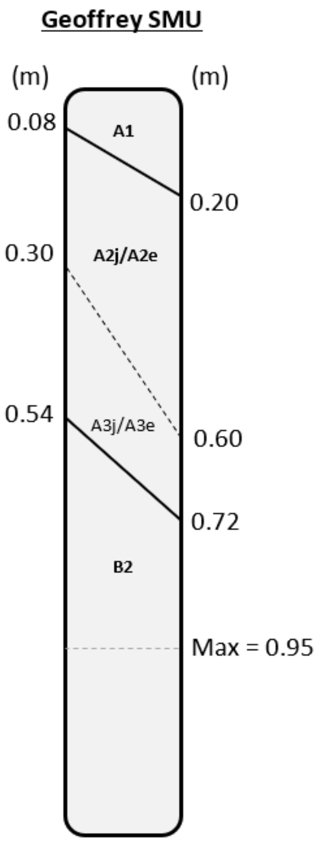
Photo Plate 6 Geoffrey SMU Vegetation (showing cleared and vegetated sections)

Table 18 Geoffrey Soil Unit Description

Parameter	Soil Unit Description
Profile Site Numbers	DP1, DP5, DP7, DP8, DP9, DP12, DP13, DP15, DP18, DP19, DP20, DP30, DP32, DP33, DP38, DP39, DP42, DP44, DP45, DP49, DP53, DP54, DP55, DP56, DP57, DP58
Observation Site Numbers	DO2, DO3, DO9, DO11-DO14, DO22, DO29, DO30, DO33, DO46, DO51-DO53, DO58, DO59, DO61-DO65, DO70, DO71, DO77, DO78, DO80-DO82, DO86, DO88-DO94, DO103, DO109, DO111-DO116, DO200, DO213, DO216-DO218, DO221, DO226-DO230, DO232, DO238-DO241, DO245-DO247, DO249, DO251, DO252, DO254, DO256-DO258, DO260-DO263, DO265
Landform	Undulating plains and hills
Land System	Melbadale
Slope	1 to 5%
Geology	Duaringa Formation (Tu) – Eocene-Oligocene mudstone, sandstone, conglomerate, siltstone, oil shale, lignite and basalt

Parameter	Soil Unit Description
Vegetation	*Eucalyptus crebra, Melaleuca leucadendra, Casuarina cunninghamiana* and *Corymbia clarksoniana*, with *Alphitonia excelsa*, *Petalostigma pubecens*, and Acacia rhodoxylon in the shrub layer.
Runoff	Slow to Rapid
Permeability	Very slowly permeable
Drainage	DP1, DP5, DP7, DP8, DP9, DP12, DP13, DP15, DP18, DP19, DP20, DP30, DP32, DP33, DP38, DP39, DP42, DP44, DP45, DP49, DP53, DP54, DP55, DP56, DP57, DP58

Profile Description – Representative Sites: DP1, DP5, DP7, DP30, DP32



The **surface soil** (A1) is a pale brown to brown (10YR6/3, 7.5YR4/4, 7.5YR4/3) sand to fine sandy loam with massive or grainy structure. This horizon has a field pH of 5.5 to 6.0, with a gradual change to;

The **mid-surface soil** (A2j/A2e) is a brown (7.5YR4/3, 7.5YR5/4, 10YR5/3) sand to fine sandy clay loam with sporadic or conspicuous bleaching. It has a massive to grainy structure and a field pH of 5.5 to 6.0. At some sites, this horizon had an abrupt change to B2, though at other sites had a gradual change to;

The **lower surface soil** (A3j/A3e) was not present at all sites. It is a sporadically or conspicuously bleached pale brown to pink (10YR6/3, 5YR7/3) sand to light sand. It has a grainy structure with a field pH of 6.0 to 6.5. Where present, this horizon has an abrupt change to;

The **subsoil** (B2) is very easy to differentiate from the overlying horizons. It is a yellowish brown to greyish brown (10YR6/4, 10YR5/2, 10YR4/6) medium clay, with moderate lenticular structure. Field pH is 6.0 to 7.5. This horizon continues to great depths, and exhibits distinct yellow, orange and red mottles.

Chemical and Physical Analysis

Table 19 Chemical Properties of the Geoffrey SMU

Representative site: DP1										
Depth (m)	**pH**		**EC**		**Cl**	**ESP%**		**Moisture (%)**	**Emerson Class No.**	
	#	**Rate**	**dS/m**	**Rate**	**mg/kg**	**%**	**Rate**			
0-0.1	5.8	Moderately acid	0.026	Very low	20	1.0	Non-sodic	2.7	4	
0.2-0.3	5.6	Moderately acid	0.006	Very low	<10	1.8	Non-sodic	0.8	4	
0.5-0.6	6.0	Moderately acid	0.004	Very low	<10	8.2	Sodic	0.8	4	
0.8-0.9	8.1	Moderately alkaline	0.137	Low	110	22.1	Strongly sodic	9.0	1	
Depth (m)	**CEC**			**Exchangeable Cations (meq/100g)**				**Ca/Mg Ratio**		
	meq / 100g		**Rate**	**Ca**	**Mg**	**K**	**Na**			
0-0.1	1.7		Very low	0.7	0.7	0.3	<0.1	1.0		
0.2-0.3	0.8		Very low	0.2	0.2	0.2	<0.1	1.0		
0.5-0.6	0.4		Very low	0.1	0.2	<0.1	<0.1	0.5		
0.8-0.9	8.8		Low	0.9	5.9	<0.2	2.0	<0.2		
Percentage in Topsoil				41.18%	41.18%	17.65%	1.00%	-		

Due to the stark difference in textures between the topsoil and subsoil layers, pH for the Geoffrey SMU changes quite dramatically down the soil profile. Sandy, massive horizons (0.0 to 0.6 m) are moderately acid, with pH increasing with depth from 5.8 to 6.0. The clay B2 horizon has a pH value over two units higher (8.1) and is classified as 'moderately alkaline'. This is likely due to the increased CEC of the clay in the B2 horizon compared with the sand in the upper horizons (A1, A2 and A3). In addition to this, salts are held in the subsoil layers, resulting in an increase in EC, chloride, and sodicity (evidenced by the ESP) in the B2 layer.

The clay-rich subsoil present a higher CEC, due to its elevated clay content. It is likely that if exposed, the subsoil (B2) would become dispersive, while the surface soil horizons (A1, A2 and A3) would remain non-dispersive. This interpretation is supported by the unit's Emerson Class numbers, which change from 4 (non-dispersive) for the topsoil layers, to 1 (extremely dispersive) for the subsoil. The dispersive tendencies of the B2 horizon may be further exacerbated by the low Ca/Mg ratio in this layer (<0.2).

Low concentrations of exchangeable cations were observed in this unit. In the surface soil, calcium and magnesium were relatively equally represented, though concentrations of these cations were extremely limited. Increased levels of some of the major cations were observed in the subsoil, these were dominated by magnesium (67.1%) and sodium (22.1%), with calcium and potassium at similar levels to observed levels in the A horizons. These low levels of calcium in comparison to magnesium in the B2 horizon further increases the susceptibility of this layer to dispersion upon wetting.

The Geoffrey soil unit also lends itself to storage of water above the B2 horizon due to the low permeability of the clay sub-soil layers..

Table 20 Surface Soil (0-10cm) Properties of the Geoffrey SMU

Particle Size Analysis %	Emerson	Nitrate	Sulphate	Organic

Gravel	Sand	Silt	Clay	Class No.	(mg/kg)	(mg/kg)	Matter (%)
1	65	25	9	4	3	<10	1.8
Extractable Nutrients (mg/kg)			Extractable Metals (mg/kg)				
P	K	B	Cu	Fe	Mn	Zn	
8	<200	0.2	<1.00	166	16.0	2.16	

The surface soil (A1) is dominated by sand (65%) with 25% silt, 9% clay, and 1% gravel. It has grainy texture, and a soft surface condition. The topsoil is non-sodic, with a Ca/Mg ratio of 1.0, and an organic matter content of 1.8%. The soil has an Emerson Class of 4, indicating that the topsoil unit is unlikely to become dispersive when wetted. Sandy soils such as these are often less susceptible to erosion, due to the large particle size of the sand grains, and their low CEC.

Topsoil nutrients for the Geoffrey SMU are generally quite limited, with nitrate (3 mg/kg), phosphorous (8 mg/kg) and potassium (<200 mg/kg) below desirable levels. Boron (0.2 mg/kg) and sulphate (<10 mg/kg) are also lower than guideline recommendations for suitable plant growth medium. For extractable metals, manganese (16.0 mg/kg) and zinc (2.16 mg/kg) are within the desirable range, though iron (166 mg/kg) is elevated, and copper (<1.0 mg/kg) is below reportable levels. These low levels of nutrients are likely due to the low CEC and leaching capacity of sand, paired with the nutrient content of the parent material.

4.7 JAMES SOIL MANAGEMENT UNIT

Soil Unit Description: Hard setting red soils associated with hills and rises. Textures within this unit vary depending on slope, with lesser developed soils found on crests (sandy clay loams to clay loams) and more developed/deeper soils found on mid slopes (clay loams to light medium clays). Dominant vegetation includes *Acacia rhodoxylon, Eucalyptus crebra,* and *Corymbia clarksoniana.*

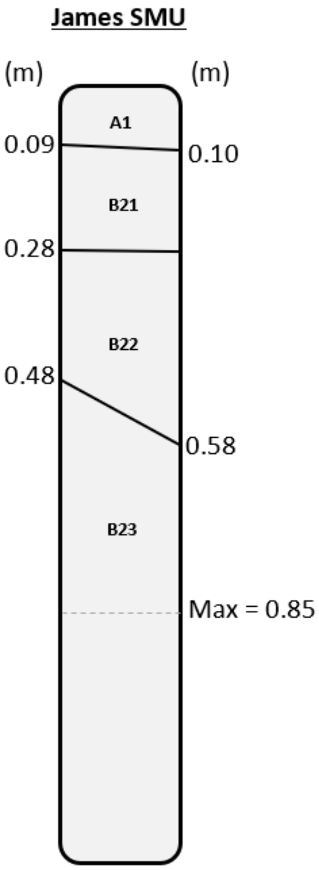
Australian Soil Classification: Red Dermosol.

Photo Plate 7 James SMU Vegetation

Table 21 James Soil Unit Description

Parameter	Soil Unit Description
Profile Site Numbers	DP17, DP16.1
Observation Site Numbers	DO39, DO40, DO42, DO253
Landform	Hills and rises
Land System	Melbadale
Slope	4 to 6%
Geology	Td-QLD (Td) – Tertiary duricrusted palaeosols at the top of deep weathering profiles, including ferricrete and silcrete; duricrusted old land surfaces.
Vegetation	*Acacia rhodoxylon, Eucalyptus crebra,* and *Corymbia clarksoniana*.
Runoff	Moderate to rapid
Permeability	Moderately permeable
Drainage	Moderately to well drained

Profile Description – Representative Sites: DP17 & DP16.1



The **surface soil** (A1) is a dark reddish brown (5YR3/4) sandy clay loam to clay loam with weak to moderate platy structure. Profiles with higher relief may have a small number of sub-rounded coarse fragments. This horizon has a pH of 6.0, with a gradual change to;

The **upper subsoil** (B21) varies in texture depending on relief within the landscape. Profiles with high relief (crests) exhibit a dark red (2.5YR3/6) clay loam, with a grainy structure and a significant amount (10-20%) of small sub-rounded coarse fragments. Lower relief profiles (slopes) are a dark reddish-brown (5YR3/4) light medium clay with weak angular blocky structure and no coarse fragments. Both variations of this horizon have a pH of 6.0, with a gradual change to;

The **mid-subsoil** (B22) is also variable in texture depending on relief. High relief (crest) examples are dark red in colour (2.5YR3/6) with a clay loam texture and a large amount (50-90%) of small sub-rounded coarse fragments. Lower relief profiles (slopes) are also dark red in colour (2.5YR3/6) with light clay texture, and no coarse fragments. Both versions of this horizon have a pH of 6.0, and moderate structure, with lower relief profiles gradually changing to;

The **lower subsoil** (B23) is only present on the lower slopes of the James SMU, where deeper clays have had the opportunity to develop. It is dark red in colour (2.5YR3/6), with a light medium clay texture, moderate lenticular structure and no coarse fragments. Field pH is 6.5.

Chemical and Physical Analysis

Table 22 Chemical Properties of the James SMU

Representative site: DP17									
Depth (m)	**pH**		**EC**		**Cl**	**ESP%**		**Moisture (%)**	**Emerson Class No.**
	#	**Rate**	**dS/m**	**Rate**	**mg/kg**	**%**	**Rate**		
0-0.1	6.2	Slightly acid	0.013	Very low	<10	0.4	Non-sodic	1.5	8
0.2-0.3	6.1	Slightly acid	0.006	Very low	<10	0.7	Non-sodic	7.0	3
0.5-0.6	6.4	Slightly acid	0.015	Very low	<10	1.4	Non-sodic	10.2	4

Depth (m)	**CEC**		**Exchangeable Cations (meq/100g)**				**Ca/Mg Ratio**
	meq / 100g	**Rate**	**Ca**	**Mg**	**K**	**Na**	
0-0.1	4.3	Very low	2.0	1.8	0.4	<0.1	1.1
0.2-0.3	5.9	Very low	3.1	2.4	0.3	<0.1	1.3
0.5-0.6	5.8	Very low	2.4	3.2	<0.1	<0.1	0.8
Percentage in Topsoil			46.51%	41.86%	9.30%	0.40%	-

pH in the James SMU is slightly acidic throughout the profile, with very little variation. It increases gradually with depth from 6.2 in the topsoil, to 6.4 in the lower subsoil. EC is very low at all depths, ranging from 0.013 dS/m in the topsoil to 0.015 dS/m in the subsoil. Chloride levels reflect this result, presenting at <10 mg/kg throughout the profile.

CEC remains fairly consistent with depth, ranging from 4.3 meq/100g (very low) in the topsoil to 5.8 meq/100g (very low) in the subsoil. Despite this, concentrations of available cations are within the acceptable ranges, with the exception of potassium in the lower subsoil, which is below reportable levels. In the topsoil, exchangeable cations are dominated by calcium (46.51%) and magnesium (41.86%) in roughly equal amounts (Ca/Mg = 1.1). The mid-stratum layer sees this ratio increase to 1.3, before dropping in the subsoil layer to 0.8.

ESP is considered non-sodic throughout the profile, ranging from 0.4% in the topsoil layer to 1.4% in the lower subsoil. This ESP isn't likely to impact the dispersive tendencies of the soil unit. This interpretation is confirmed by the unit's Emerson Class Numbers, which range from 8 (non-dispersive) in the surface soil, to 3 (dispersive if disturbed) in the mid-stratum, to 4 (non-dispersive) in the subsoil layer.

Table 23 Surface Soil (0-10 cm) Properties of the James SMU

Particle Size Analysis %				Emerson Class No.	Nitrate (mg/kg)	Sulphate (mg/kg)	Organic Matter (%)
Gravel	Sand	Silt	Clay				
6	56	21	17	8	1.1	<10	2.8
Extractable Nutrients (mg/kg)			**Extractable Metals (mg/kg)**				
P	**K**	**B**	**Cu**	**Fe**	**Mn**	**Zn**	
14	<200	0.3	<1.00	21.4	18.7	<1.00	

The surface soil (A1) is dominated by sand (56%) with 21% silt, 17% clay, and 6% gravel. It has moderate, platy structure, and a hard setting surface. The topsoil is non-sodic, with a Ca/Mg ratio of 1.1, and an organic matter content of 2.8%. This favourable chemistry combination, paired with the topsoil's Emerson Class Number of 8, suggests that the surface soil is unlikely to suffer from dispersion. The water-holding capacity of the topsoil is relatively poor, due to the lack of clay sized particles. This is evidenced by the increase in moisture content with depth (as seen in Table 22).

Nutrient availability within the James SMU is generally limited. Nitrate (1.1 mg/kg), phosphorous (14 mg/kg) and potassium (<200 mg/kg) are all well below the desirable concentrations, with sulphate (<10 mg/kg) and boron (0.3 mg/kg) also low. Extractable metals vary in concentration. While, iron (21.4 mg/kg) and manganese (18.7 mg/kg) are both within the suitable range for plant life, copper and zinc are below reportable levels.

It is noted that the soil profile examined here represents a mid-slope site on the James SMU, with profiles higher in the landscape (e.g. hill crests) typically possessing shallower subsoils, lower CECs and reduced nutrient concentrations.

4.8 KOSH SOIL MANAGEMENT UNIT

Soil Unit Description: Hard setting soil associated with alluvial plains, plains and low rises. Textures within this unit are gradational, changing from sandy clay loams and light clays in the topsoil, to medium heavy clays in the lower subsoil. Commonly, this unit was cleared for grazing, with regrowth consisting of scrub species including *Vachellia nilotica*, *Cassia spinarum, Capparis lasiantha, Cassia brewsteri*, and various Eucalyptus shrubs. When present, vegetation included *Eucalyptus tereticornis, Acacia hemiglauca, Acacia salicina, Lysiphyllum hookeri, Eucalyptus crebra* and *Eucalyptus populnea*.

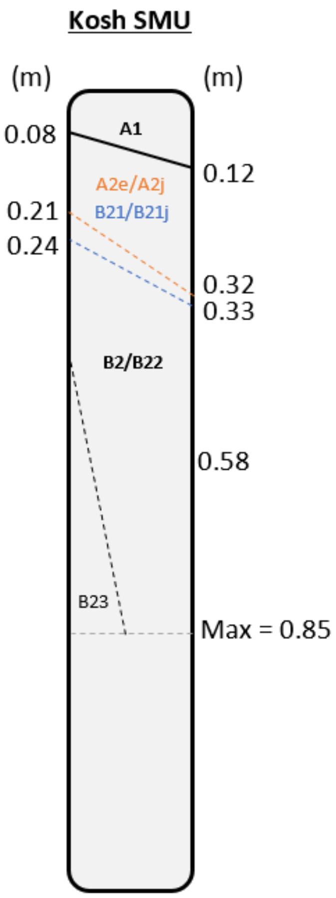
Australian Soil Classification: Brown Dermosol

Photo Plate 8 Kosh SMU Vegetation (cleared)

Table 24 Kosh Soil Unit Description

Parameter	Soil Unit Description
Profile Site Numbers	DP16.2, DP21, DP22, DP23, DP25, DP27, DP31, DP34, DP35, DP41, DP47, DP59
Observation Site Numbers	DO34, DO35, DO37, DO38, DO67, DO73, DO201, DO204, DO231, DO250, DO255
Landform	Alluvial plains, plains and rises
Land System	Dingo
Slope	1 to 4%
Geology	Qa-QLD (Qa) – Quaternary clay, silt, sand and gravel; flood-plain alluvium
Vegetation	Cleared - *Vachellia nilotica, Cassia spinarum, Capparis lasiantha, Cassia brewsteri* Vegetated - *Eucalyptus tereticornis, Acacia hemiglauca, Acacia salicina, Lysiphyllum hookeri, Eucalyptus crebra* and *Eucalyptus populnea*.
Runoff	Very slow to rapid
Permeability	Slowly permeable
Drainage	Poorly drained

Profile Description – Representative Sites: DP23, DP34, DP35, DP47



The **surface soil** (A1) is a brown to dark reddish brown (7.5YR4/3, 10YR3/3, 5YR3/3) sandy clay-loam to medium clay with weak to massive structure. Field pH of 6.0 to 6.5, with clear/gradual change to;

The **lower surface soil** (A2e/A2j) is a sporadically or conspicuously bleached horizon present at approximately half of the profile sites. It is a pale brown to brown (10YR6/3, 7.5YR4/3) sandy clay-loam to medium clay that usually has massive structure (though can be weak angular blocky), with a field pH of 6.0 to 7.0. When present, this layer has a clear or gradual change to;

The **upper subsoil** (B21/B21j) was not present at all sites. When present this horizon can exhibit sporadic bleaching. It is a brown to dark reddish brown (7.5YR4/4, 5YR3/2) medium heavy clay with weak to moderate angular blocky structure. This horizon has a field pH of 6.0 to 7.0, with a clear or gradual change to;

The **subsoil** (B2/B22) is variable in colour, presenting as a dark brown, dark reddish, or yellowish brown colour (7.5YR3/3, 5YR3/3, 10YR5/6). Soil texture is a medium heavy clay, with moderate lenticular structure. pH gradually increased with depth at all sites, ranging from 7.0 to 9.0, sometimes within the same soil profile. This layer can extend to great depths, otherwise exhibiting a gradual change to;

The **lower subsoil** (B23) was only observed at two sites. It is a dark brown (7.5YR3/4) medium heavy clay with moderate lenticular structure, and a field pH ranging from 6.5 to 7.5 (increasing with depth).

Chemical and Physical Analysis

Table 25 Chemical Properties of the Kosh SMU

Representative site: DP34									
Depth (m)	pH		EC		Cl	ESP%		Moisture (%)	Emerson Class No.
	#	Rate	dS/m	Rate	mg/kg	%	Rate		
0-0.1	6.3	Slightly acid	0.036	Very Low	<10	0.6	Non-sodic	2.8	4
0.2-0.3	7.7	Slightly alkaline	0.083	Very Low	60	13.2	Sodic	7.1	2
0.5-0.6	8.5	Strongly alkaline	0.415	Medium	490	19.5	Strongly sodic	9.0	2

Depth (m)	CEC		Exchangeable Cations (meq/100g)				Ca/Mg Ratio
	meq / 100g	Rate	Ca	Mg	K	Na	
0-0.1	6.8	Low	4.4	1.7	0.6	<0.1	2.6
0.2-0.3	13.3	Moderate	4.4	6.9	0.2	1.8	0.6
0.5-0.6	17.4	Moderate	4.1	9.7	<0.2	3.4	0.4
Percentage in Topsoil			64.71%	25.00%	8.82%	0.60%	-

The pH within the Kosh SMU is highly variable, changing from 6.3 (slightly acid) in the topsoil to 8.5 (strongly alkaline) in the lower subsoil. EC follows a similar pattern, changing from very low between 0.0 and 0.3 m depth, to medium in the subsoil. Chloride concentration also increases significantly with depth, ranging from <10 mg/kg in the topsoil, to 490 mg/kg in the subsoil layer. High chloride concentrations such as these can impact a plant's osmotic capacity, impacting its ability to access water and nutrients.

CEC increases with depth from low (6.8 meq/100g) to moderate (17.4 meq/100g), likely due to the increased clay content in the subsoil layers. Exchangeable cations within the topsoil are dominated by calcium (64.71%) and magnesium (25.00%), with potassium at 8.82%. These concentrations and ratios are considered appropriate for plant growth, though become less so with depth. While calcium remains relatively consistent throughout the profile, magnesium and sodium concentrations continue to increase, eventually contributing to 55.75% and 19.5% of the total CEC, respectively. The Ca/Mg ratio drops from 2.6 in the topsoil, to 0.4 in the lower subsoil layer. This is detrimental to the ability of the soil to maintain its integrity upon exposure, significantly increasing the subsoil's potential erodibility.

ESP for this SMU increases progressively with depth, changing from non-sodic (0.6%) in the topsoil to strongly sodic (19.5%) in the lower subsoil. Due to the high clay content in the lower horizons, the elevated ESP observed here is likely to impact the dispersive tendencies of the soil unit. This interpretation is reflected in the sample's Emerson Class Numbers, which range from 4 in the surface soil (non-dispersive) to 2 in the subsoil (moderately dispersive).

It is likely that subsoils in this unit would be considerably erosive.

Table 26 Surface Soil (0-10 cm) Properties of the Kosh SMU

Particle Size Analysis %				Emerson Class No.	Nitrate (mg/kg)	Sulphate (mg/kg)	Organic Matter (%)
Gravel	Sand	Silt	Clay				
4	63	24	9	4	2.5	<10	4

Extractable Nutrients (mg/kg)			Extractable Metals (mg/kg)			
P	K	B	Cu	Fe	Mn	Zn
13	<200	0.4	<1.00	32.4	17.5	1.20

The topsoil layer (A1) for the Kosh SMU is dominated by sand-sized particles (63%), with 24% silt, 9% clay, and 4% gravel. It has a weak structure, with a hard setting surface. The surface soil is non-sodic, with a Ca/Mg ratio of 2.6, and an organic matter content of 4%. This means the topsoil has favourable chemistry in terms of dispersion, evidenced by the unit's Emerson Class of 4 (non-dispersive). This topsoil is particularly significant for this SMU, as it protects the underlying sodic clay from erosion.

Nutrient content within this topsoil is quite poor. Nitrate (2.5 mg/kg), phosphorous (13 mg/kg) and potassium (<200 mg/kg) are all below suitable levels, as are sulphate (<10 mg/kg) and boron (0.4 mg/kg). Extractable metal concentrations are adequate, with only copper below the required concentration.

4.9 NAMOI SOIL MANAGEMENT UNIT

Soil Unit Description: Hard setting soil associated with hills and rises. Textures within this unit are gradational, changing from a sandy clay loam in the topsoil to a light medium clay in the subsoil. Dominant vegetation includes *Eucalyptus crebra,* with *Heteropogon contortus* and juvenile Acacia species.

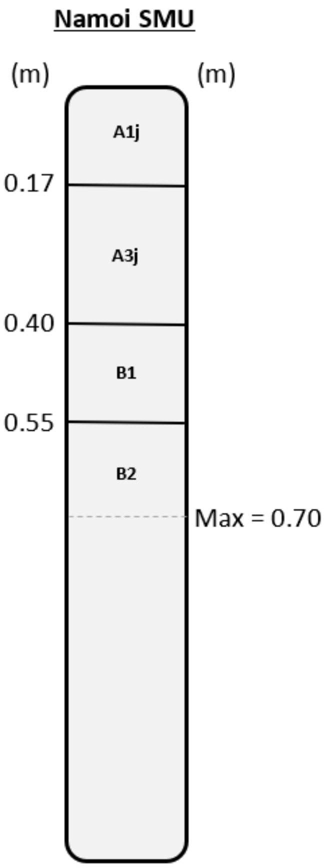
Australian Soil Classification: Red Dermosol

Photo Plate 9 Namoi SMU Vegetation

Table 27 Namoi Soil Unit Description

Parameter	Soil Unit Description
Profile Site Numbers	DP3
Observation Site Numbers	DO1
Landform	Hills and rises
Land System	Melbadale
Slope	4%
Geology	Rewan Group (Rr) – Early Triassic – Middle Triassic sedimentary unit comprised of lithic sandstone, pebbly lithic sandstone, green to reddish brown mudstone and minor volcanilithic pebble conglomerate (at base)
Vegetation	*Eucalyptus crebra*, with *Heteropogon contortus* and juvenile Acacia species.
Runoff	Rapid
Permeability	Slowly permeable
Drainage	Moderately well drained

Profile Description – Representative Sites: DP3.



The **surface soil** (A1j) is a dark brown (7.5YR3/4) sandy clay-loam with sporadic bleaching. It has a moderate lenticular structure, and a field pH of 5.0. Clear change to;

The **lower surface soil** (A3j) is a reddish brown (5YR4/4) sandy clay-loam+ with sporadic bleaching. It has a weak angular blocky structure, and a field pH of 5.5. Gradual change to;

The **upper subsoil** (B1) is a yellowish red (5YR4/6) light clay with weak angular blocky structure, and a field pH of 6.0. Gradual change to;

The **lower subsoil** (B2) is a yellowish red (5YR5/8) light medium clay with moderate polyhedral structure, and a field pH of 6.5. It may contain a small number (<2%) of subangular coarse fragments and faint red mottling.

Chemical and Physical Analysis

Table 28 Chemical Properties of the Namoi SMU

Representative site: DP3									
Depth (m)	**pH**		**EC**		**Cl**	**ESP%**		**Moisture (%)**	**Emerson Class No.**
	#	**Rate**	**dS/m**	**Rate**	**mg/kg**	**%**	**Rate**		
0-0.1	5.7	Moderately acid	0.011	Very Low	<10	0.6	Non-sodic	2.8	3
0.2-0.3	5.5	Strongly acid	0.008	Very Low	<10	1.8	Non-sodic	3.2	3
0.5-0.6	6.1	Slightly acid	0.007	Very Low	<10	4.1	Non-sodic	6.6	3

Depth (m)	**CEC**		**Exchangeable Cations (meq/100g)**				**Ca/Mg Ratio**
	meq / 100g	**Rate**	**Ca**	**Mg**	**K**	**Na**	
0-0.1	2.0	Very low	1.0	0.6	0.2	<0.1	1.7
0.2-0.3	1.9	Very low	0.8	0.8	<0.1	<0.1	1.0
0.5-0.6	3.0	Very low	0.7	2.1	<0.1	0.1	0.3
Percentage in Topsoil			50.00%	30.00%	10.00%	0.60%	-

The Namoi SMU has a pH that is most acidic in the upper subsoil (5.5), with a moderately acidic topsoil (5.7), and a slightly acidic lower subsoil (6.1). EC is very low at all depths, ranging from 0.01 dS/m in the topsoil, to 0.007 dS/m in the subsoil horizon. Chloride concentration reflects this result, presenting at <10 mg/kg at all depths.

CEC is also very low throughout the profile, changing from 2.0 meq/100g in the surface horizons, to 3.0 meq/100g in the subsoil layer. Exchangeable cations were found at concentrations below desirable, with calcium at 1.0 mg/kg, and magnesium at 0.6 mg/kg. Topsoil potassium however (0.2 mg/kg), meets the required concentration. Calcium levels decrease with depth, while magnesium increases, such that the lower subsoil has a Ca/Mg ratio of 0.3. This could exacerbate soil dispersion if ESP was high, though in this case should not reduce soil cohesion. Overall, exchangeable cation concentrations do not reflect the optimal ranges expected of a healthy soil, which may be affecting plant health within this SMU.

ESP is considered non-sodic throughout the profile, ranging from 0.6 to 4.1% with depth. The entire profile has an Emerson Class of 3, meaning that the soil should remain non-dispersive unless it is physically disturbed.

Table 29 Surface Soil (0-10 cm) Properties of the Namoi SMU

Particle Size Analysis %				Emerson Class No.	Nitrate (mg/kg)	Sulphate (mg/kg)	Organic Matter (%)
Gravel	Sand	Silt	Clay				
3	64	21	12	3	1.7	<10	0.8

Extractable Nutrients (mg/kg)			Extractable Metals (mg/kg)			
P	K	B	Cu	Fe	Mn	Zn
7	<200	0.2	<1.00	86.3	43.7	2.09

The surface soil (A1j) has a high concentration of sand (64%), with 21% silt, 12% clay, and 3% gravel. It has moderate, lenticular structure, and is hard setting. The topsoil is non-sodic, with a Ca/Mg ratio of 1.7, and an organic matter content of 0.8%. Low organic matter levels combined with high sand percentages, means that the topsoil for Namoi is likely to have a low water holding capacity. The Emerson Class Number is 3, meaning that the surface soil horizon may become dispersive when wetted, if physically disturbed through stripping or tillage.

Nutrient levels are generally low, with nitrate (1.7 mg/kg), phosphorous (7 mg/kg) and potassium (<200 mg/kg) all below the desirable concentrations. Sulphate (<10 mg/kg) and boron (0.2 mg/kg) are also lower than expected for soils supporting plant growth. Extractable metals are generally unsuitable, with only zinc (2.09 mg/kg) within the acceptable range. Variable concentrations of nutrients and metals could limit vegetation type and plant growth within the Namoi SMU.

4.10 NIGEL SOIL MANAGEMENT UNIT

Soil Unit Description: Hard setting soil associated with isolated high relief areas of tertiary land surface. Textures within this unit are rudimentary, grading from sands to sandy light clays. Vegetation is variable between sites, but includes *Acacia shirleyi, Acacia rhodoxylon, Eucalyptus crebra, Melaleuca leucadendra, Corymbia clarksoniana,* and *Eucalyptus tessellaris.*

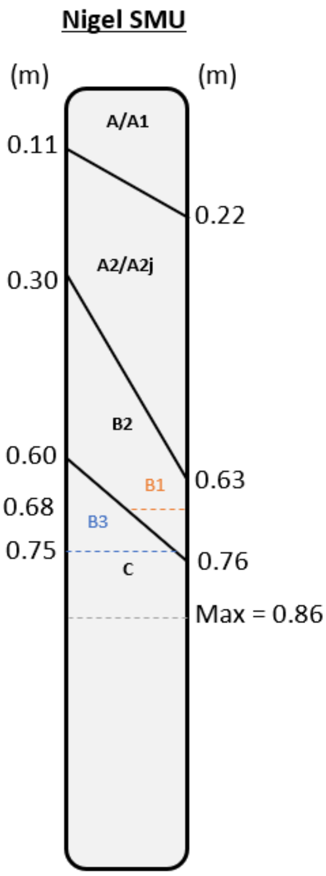
Australian Soil Classification: Brown Kandosol

Photo Plate 10 Nigel SMU Vegetation

Table 30 Nigel Soil Unit Description

Parameter	Soil Unit Description
Profile Site Numbers	DP43, DP51, DP52
Observation Site Numbers	DO83, DO101, DO107
Landform	Hills and rises
Land System	Melbadale
Slope	3 to 5%
Geology	Gyranda Subgroup (Pwy) – Late Permian sedimentary unit comprised of siltstone and shale with minor tuff and volcanilithic sandstone and rare coal (lower part - Banana Formation) (weathered to laterite)
Vegetation	*Acacia shirleyi, Acacia rhodoxylon, Eucalyptus crebra, Melaleuca leucadendra, Corymbia clarksoniana,* and *Eucalyptus tessellaris.*
Runoff	Very slow to rapid
Permeability	Slowly permeable
Drainage	Poorly drained

Profile Description – Representative Sites: DP43, DP51 & DP52



The **surface soil** (A/A1) is a dark brown to greyish brown (10YR3/3, 7.5YR3/4, 10YR4/4) sand to loamy sand with massive structure. It has a field pH of 4.8 to 5.5, with a clear or gradual change to;

The **lower surface soil** (A2/A2j) is a dark red to yellowish-red (2.5YR3/6, 5YR4/6, 5YR3/3) sand to clayey sand, which often demonstrates sporadic bleaching. It has a massive/grainy structure and a field pH ranging from 5.0 to 5.5. This horizon exhibits a clear or gradual change to;

The **upper subsoil** (B1) was only present at one profile site. It is a red (2.5YR4/6) loamy sand with grainy structure and a field pH of 5.5. When present, this horizon has a clear change to the C horizon, though when absent, A2/A2j grades gradually to;

The **subsoil** (B2) is a yellowish brown (10YR4/6, 10YR5/6) soil with a clayey sand to sandy light clay texture. Structure in this horizon is weak to massive, with field pH values of 5.5. This unit can have a clear or gradual change to the C horizon, or;

The **lower subsoil** (B3) was only present at one site. It was a dark yellowish brown (10YR4/6) clayey sand with massive structure and a field pH of 6.0. It contained a small amount (<2%) of manganiferous nodules.

The **parent material** (C) was comprised of laterite pebbles with a pH ranging from 5.5 to 6.0.

Chemical and Physical Analysis

Table 31 Chemical Properties of the Nigel SMU

Representative site: DP52									
Depth (m)	pH		EC		Cl	ESP%		Moisture (%)	Emerson Class No.
	#	Rate	dS/m	Rate	mg/kg	%	Rate		
0-0.1	4.4	Extremely acid	0.038	Very Low	10	1.3	Non-sodic	7.3	4
0.2-0.3	4.6	Very strongly acid	0.01	Very Low	<10	<0.1	Non-sodic	2.3	4
0.5-0.6	4.6	Very strongly acid	0.01	Very Low	<10	<0.1	Non-sodic	2.3	4

Depth (m)	CEC		Exchangeable Cations (meq/100g)				Ca/Mg Ratio
	meq / 100g	Rate	Ca	Mg	K	Na	
0-0.1	2.8	Very low	0.8	0.4	0.2	<0.1	2.0
0.2-0.3	1.7	Very low	<0.1	<0.1	0.1	<0.1	<0.1
0.5-0.6	1.6	Very low	<0.1	<0.1	<0.1	<0.1	<0.1
Percentage in Topsoil			28.57%	14.29%	7.14%	1.30%	-

The Nigel SMU has an extremely low pH throughout the profile, ranging from 4.4 (extremely acidic) in the topsoil to 4.6 (strongly acidic) in the subsoil layers. EC is very low at all depths, a result reflected in chloride results, which are consistently less than or equal to 10 mg/kg.

CEC is also very low, ranging from 2.8 mg/kg in the topsoil to 1.6 mg/kg in the subsoil. This has resulted in very low concentrations of exchangeable cations. Calcium ranges from 0.8 in the topsoil, to <0.1 in the subsoil layers. Magnesium was measured at 0.4 meq/100g in the topsoil, and 0.1 meq/100g in the lower subsoil. Optimal potassium levels should be >0.2 meq/100g, and though this level was met in the topsoil, the concentration dropped to <0.1 meq/100g in the subsoil horizons.

ESP is considered non-sodic at all depths, ranging from 1.3 % in the topsoil layer to <0.1% in the lower subsoil. Therefore, the unit is unlikely to become dispersive when wetted. This interpretation is reflected in the unit's Emerson Class Numbers, which were calculated at 4 for all horizons (non-dispersive).

In addition to this, low pH values can reduce the CEC of the soil, and affect the solubility, availability, and potential toxicity of various macro and micronutrients to plant roots. This means that even if they are present in the soil, some elements (such as calcium, magnesium, and potassium) will become less available to plant roots below a pH of 5.0 and may even become damaging to vegetation (Hazelton & Murphy, 2016).

Table 32 Surface Soil (0-10 cm) Properties of the Nigel SMU

Particle Size Analysis %				Emerson Class No.	Nitrate (mg/kg)	Sulphate (mg/kg)	Organic Matter (%)
Gravel	Sand	Silt	Clay				
1	76	17	6	4	11.2	<10	4.6
Extractable Nutrients (mg/kg)				**Extractable Metals (mg/kg)**			
P	**K**	**B**		**Cu**	**Fe**	**Mn**	**Zn**
7	<200	0.2		<1.00	331	3.21	<1.00

The surface soil (A/A1) for the Nigel SMU is dominated by sand (76%) with 17% silt, 6% clay and 1% gravel. It is hard setting and has a massive structure. The topsoil is non-sodic, with a Ca/Mg ratio of 2.0, and a relatively high organic matter content of 4.6%. This indicates that the soil is unlikely to disperse upon wetting, shown by the surface soil's Emerson Class Number of 4 (non-dispersive). Although dispersion is not likely to become an issue, this structureless topsoil indicates that the soil may slake upon wetting, losing air filled porosity and allowing it to collapse under its own weight.

Nutrient levels are generally poor, with nitrate present at optimum levels (11.2 mg/kg), while phosphorous (7 mg/kg) and potassium (<200 mg/kg) outside of the guideline levels for supporting plant life. Boron (0.2 mg/kg) and sulphate (<10 mg/kg) are also lower than desired and may be causing nutrient deficiency.

Extractable metals are quite unbalanced, with copper and zinc at <1.00 mg/kg, and iron much higher than expected in a healthy soil. At 3.21 mg/kg, manganese is the only trace element within the desirable range.

This SMU is characterised by extremely low nutrient levels, exacerbated by limited availability to plant roots caused by the extremely acidic pH throughout the profile. The physical characteristics of this soil, however, are considered suitable in terms of stability.

4.11 NORMANBY SOIL MANAGEMENT UNIT

Soil Unit Description: Deep red earth with soft surface condition, associated with plains, and the flat areas of upper slopes. Textures within this unit are relatively consistent throughout the profile, ranging from loamy sands to sandy light medium clays. Vegetation is mostly cleared, but when present includes *Eucalyptus crebra* and *Alectryon oleifolius.*

Australian Soil Classification: Red Kandosol

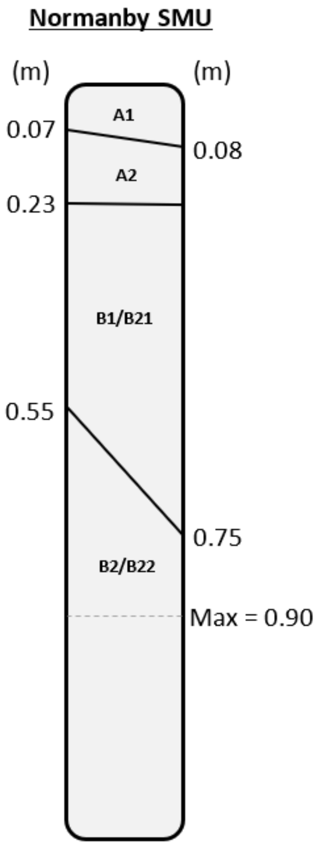
Photo Plate 11 Normanby SMU Vegetation

Table 33 Normanby Soil Unit Description

Parameter	Soil Unit Description
Profile Site Numbers	DP48, DP50
Observation Site Numbers	DO208
Landform	Plains and upper slopes
Land System	Melbadale
Slope	2 to 3%
Geology	Duaringa Formation (Tu) – Eocene-Oligocene mudstone, sandstone, conglomerate, siltstone, oil shale, lignite and basalt (iron-rich)
Vegetation	Cleared with *Eucalyptus crebra* and *Alectryon oleifolius.*
Runoff	Slow
Permeability	Moderately to highly permeable

Drainage	Moderately to well drained

Profile Description – Representative Sites: DP48 & DP50



The **surface soil** (A1) is a reddish brown (2.5YR4/4, 5YR4/3) loamy sand to sandy loam, with grainy structure. It has a field pH of 6.0 to 6.5 and a clear or gradual change to;

The **lower surface soil** (A2) is a reddish brown to dark reddish brown (2.5YR3/3, 2.5YR4/3) loamy sand to sandy loam with a grainy/massive structure. It has a field pH of 6.0 to 6.5, and a gradual change to;

The **upper subsoil** (B1/B21) is a red (10R4/6, 2.5YR4/6) loamy sand to sandy loam. It has massive/grainy structure and a pH ranging from 6.0 to 6.5. Gradual change to;

The **lower subsoil** (B2/B22) is a red to dark red (10YR4/6, 2.5YR3/6) sandy loam to sandy light medium clay. It has weak lenticular structure and a field pH ranging from 6.0 to 7.0.

Chemical and Physical Analysis

Table 34 Chemical Properties of the Normanby SMU

Representative site: DP50									
Depth (m)	pH		EC		Cl	ESP%		Moisture (%)	Emerson Class No.
	#	Rate	dS/m	Rate	mg/kg	%	Rate		
0-0.1	6.7	Neutral	0.036	Very Low	<10	<0.1	Non-Sodic	6.1	4
0.2-0.3	6.6	Neutral	0.006	Very Low	<10	<0.1	Non-Sodic	1.7	4
0.5-0.6	6.1	Slightly Acid	0.003	Very Low	<10	<0.1	Non-Sodic	1.5	4

Depth (m)	CEC		Exchangeable Cations (meq/100g)				Ca/Mg Ratio
	meq / 100g	Rate	Ca	Mg	K	Na	
0-0.1	2.4	Very Low	1.3	0.6	0.4	<0.1	2.2

0.2-0.3	2.1	Very Low	1.4	0.4	0.3	<0.1	3.5
0.5-0.6	1.6	Very Low	0.9	0.5	<0.1	<0.1	1.8
Percentage in Topsoil			54.17%	25.00%	16.67%	4.17%	-

The Normanby soil unit has a neutral to slightly acidic pH throughout the soil profile, decreasing with depth from 6.7 to 6.1. EC is very low throughout the profile, ranging from 0.036 dS/m in the topsoil to 0.003 dS/m in the subsoil. Chloride levels reflect this result, presenting at less than 10 mg/kg at all depths.

CEC measurements are considered very low, ranging from 2.4 meq/100g to 1.6 meq/100g with depth. Exchangeable cation concentrations reflected this result, with calcium, magnesium and potassium concentrations below the desirable level at all depths. The ratios between each cation, however, were appropriate. In addition to this, calcium dominated magnesium at all depths, the Ca/Mg ratio ranging from 2.2 in the topsoil, to 3.5 in the mid-stratum, to 1.8 in the lower subsoil, further reducing the likelihood that this SMU will suffer from dispersion

Of the exchangeable cations, very little was sodium, with ESP values consistently below reportable levels (<0.1%), indicating that the soil is likely to be non-dispersive. This interpretation is supported by the unit's Emerson Class Numbers, which are considered non-dispersive (4) at all depths.

Although this soil is non-dispersive and suitable in terms of pH and salinity, the low levels of exchangeable cations limit the soil in terms of its ability to provide a suitable medium for plant growth. In addition to this, the high sand content within this SMU puts it at risk of slumping if the slope angle is too high.

Table 35 Surface Soil (0-10 cm) Properties of the Normanby SMU

Particle Size Analysis %				Emerson Class No.	Nitrate (mg/kg)	Sulphate (mg/kg)	Organic Matter (%)
Gravel	Sand	Silt	Clay				
1	83	9	7	4	10.3	<10	1.1

Extractable Nutrients (mg/kg)			Extractable Metals (mg/kg)			
P	K	B	Cu	Fe	Mn	Zn
6	275	<0.2	<1.00	29.1	13.0	<1.00

The surface soil (A1) for the Normanby unit is dominated by sand (83%) with 9% silt, 7% clay and 1% gravel. It had a grainy structure, and a soft surface condition. The topsoil is non-sodic, with a Ca/Mg ratio of 2.2, and an organic matter content of 1.1%. This information, paired with the topsoil's Emerson Class Number of 4, suggests that the surface soil is unlikely to become dispersive when wetted. The red colour of the soil indicates that drainage and permeability are both highly active in this soil unit.

Nutrient levels within this soil are generally low. Nitrate concentration is within the acceptable bounds at 10.3 mg/kg, as is potassium at 275 mg/kg. Phosphorous, boron and sulphate, however, are all below the desirable level, potentially causing nutrient deficiency. Extractable metal concentrations vary in their suitability, with copper and zinc below reportable levels, and iron and manganese within the appropriate range for plant life.

The limited nutrient holding capacity of this soil can be attributed to its low clay content and low organic matter levels.

4.12 WALLACE SOIL MANAGEMENT UNIT

Soil Unit Description: Shallow, self-mulching, cracking clay associated with upper slope flats. Textures within this unit grade from medium heavy clays to heavy clays, with the B3/C horizon met at approximately 0.24 m depth. The Wallace SMU is extensively cleared, with the boundary of the unit corresponding to an increase in standing vegetation. The dominant grass species is likely *Aristida latifolia*, with confirmation required during the wet season when an accurate identification can be made.

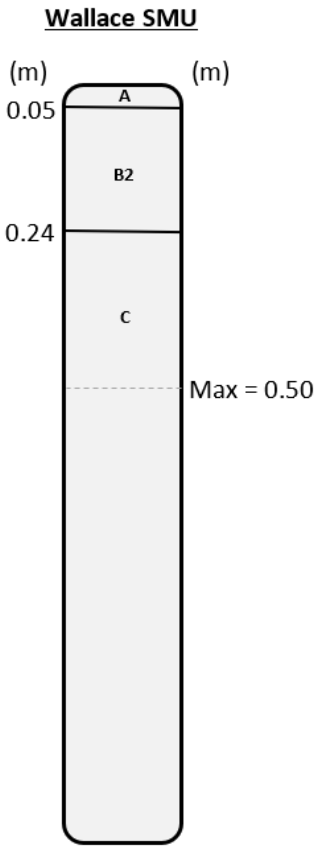
Australian Soil Classification: Black Vertosol.

Photo Plate 12 Wallace SMU Vegetation

Table 36 Wallace Soil Unit Description

Parameter	Soil Unit Description
Profile Site Numbers	DP4
Observation Site Numbers	DO5, DO18, DO248
Landform	Flats on upper slopes
Land System	Melbadale
Slope	1%
Geology	Qa-QLD (Qa) – Quaternary clay, silt, sand and gravel; flood-plain alluvium
Vegetation	Cleared with *Aristida latifolia* (unconfirmed)
Runoff	Slow
Permeability	Moderately permeable
Drainage	Moderately well drained

Profile Description – Representative Sites: DP4



The **surface soil** (A) is a very dark brown (7.5YR2.5/2) medium heavy clay with weak lenticular structure and a pH of 6.5. Gradual change to;

The **subsoil** (B2) is a very dark brown (7.5YR2.5/2) heavy clay with moderate sub-angular blocky structure. It has a small amount (<2%) of sub-angular coarse fragments, and a field pH of 6.5. Clear change to;

The **parent material** (C) is a dark grey (7.5YR4/1) rocky material of sedimentary origin, with a field pH of 6.5.

Chemical and Physical Analysis

Table 37 Chemical Properties of the Wallace SMU

Representative site: DP4									
Depth (m)	**pH**		**EC**		**Cl**	**ESP%**		**Moisture (%)**	**Emerson Class No.**
	#	**Rate**	**dS/m**	**Rate**	**mg/kg**	**%**	**Rate**		
0-0.1	6.8	Neutral	0.09	Low	30	0.3	Non-sodic	5.4	3
0.2-0.3	7.4	Slightly alkaline	0.038	Very Low	10	0.6	Non-sodic	13.8	4

Depth (m)	**CEC**		**Exchangeable Cations (meq/100g)**				**Ca/Mg Ratio**
	meq / 100g	**Rate**	**Ca**	**Mg**	**K**	**Na**	
0-0.1	39	High	18.7	18.3	1.8	0.1	1.0
0.2-0.3	44	Very high	27.3	16.1	0.3	0.3	1.7
Percentage in Topsoil			47.95%	46.92%	4.62%	0.30%	-

The Wallace SMU is a well-rounded soil unit, which would be appropriate for an agricultural land use, but for its shallow soil depth. Soil pH ranges from 6.8 in the topsoil (neutral) to 7.4 in the subsoil (slightly alkaline). Salinity in this soil is not a concern, with EC ranging from low (0.09 dS/m) to very low (0.038 dS/m), with chloride well below toxic levels.

The high clay content and organic matter in this soil is associated with an elevated CEC, ranging from high in the topsoil (39 meq/100g) to very high in the subsoil (44 meq/100g). This has resulted in relatively high concentrations of available cations, dominated by calcium (18.7 to 27.3 meq/100g) and magnesium (18.3 to 16.1 meq/100g), with suitable levels of potassium (1.8 to 0.3 meq/100g). Calcium was present in higher quantities than magnesium at all depths, with the Ca/Mg ratio ranging from 1.0 to 1.7. This reduces the likelihood of any dispersive tendencies within the soil.

ESP is extremely low and considered non-sodic throughout the profile, ranging from 0.3% to 0.6%, meaning that this soil in unlikely to become dispersive upon wetting. Emerson Class numbers support this fact, ranging from 3 in the surface soil (dispersive if physically disturbed) to 4 in the subsoil (non-dispersive).

Water-holding capacity appears to increase with depth and clay content, as evidenced by the increase in moisture % with depth seen in Table 37.

Table 38 Surface Soil (0-10 cm) Properties of the Wallace SMU

Particle Size Analysis %				Emerson Class No.	Nitrate (mg/kg)	Sulphate (mg/kg)	Organic Matter (%)
Gravel	Sand	Silt	Clay				
4	14	52	30	3	6.6	10	4.1

Extractable Nutrients (mg/kg)			Extractable Metals (mg/kg)			
P	K	B	Cu	Fe	Mn	Zn
169	652	0.5	1.61	63.4	53.4	1.02

The surface soil (A) for the Wallace SMU is dominated by silt sized particles (52%), with 30% clay, 14% sand, and 4% gravel. It has a weak lenticular structure, and a fine, self-mulching surface. The topsoil is non-sodic, with a Ca/Mg ratio of 1.0, and an organic matter content of 4.1%. This information paired with the soil's Emerson Class Number of 3, suggests that is will remain non-dispersive unless physically disturbed. This potential dispersion is likely influenced by the relatively low Ca/Mg ratio of the topsoil unit.

Nutrient levels in this topsoil are generally good. Nitrate (6.6 mg/kg) was outside of the acceptable bounds for agriculture, though phosphorous (169 mg/kg), potassium (652 mg/kg), boron (0.5 mg/kg) and sulphate (10 mg/kg) were well within the desired concentrations. For the extractable metals, only zinc (1.02 mg/kg) was found to be at an appropriate level, with copper (1.61 mg/kg) lower than desired, and iron (63.4 mg/kg) and manganese (53.4 mg/kg) higher than necessary.

High clay content, low sodicity, and desirable nutrient concentrations make this unit one of the best growth mediums in the survey area. This fact is observable in the field as the SMU area supports a healthy sward of highly palatable grass species that are rare or absent in most other SMUs. The shallow soil depth and low nitrate concentration are both limiting factors for agricultural use of this soil, though as grazing land it is highly suitable.

5.0 LAND SUITABILITY

The aim of this land suitability assessment is to evaluate the suitability of the Project for agricultural land uses including cattle grazing and dryland cropping, prior to the development of the mine. Land suitability assessment considers environmental factors including climate, soils, geology, geomorphology, erosion, topography and the effects of past land use. The classification does not always represent the current land use. Rather, it indicates the potential of the land to be used for a range of agricultural activities.

The assessment for land suitability (cattle grazing and dryland cropping) has been carried out in accordance with the methodologies described in:

- DSITI & DNRM (2015). *Guidelines for Agricultural Land Evaluation in Queensland* (2nd edition). Queensland Government, Brisbane, Queensland; and
- DSITI & DNRM (2013). *Regional Land Suitability Frameworks for Queensland*, Chapter 10 – Suitability Framework for the Inland Fitzroy and Southern Burdekin area. Queensland Government. Brisbane, Queensland.

The five land suitability classes used for assessing the land are defined in Table 39. Land is considered less suitable as the severity of limitations for a land use increase. The land suitability class reflects the score of the most limiting attribute for a given SMU. An increase in limitations may reflect either:

- Reduced potential for production; and/or
- Increased inputs to achieve and acceptable level of production;
- Increased inputs to prepare the land for successful production; and/or
- Increased inputs required to prevent land degradation.

Table 39 Agricultural and Conservation Land Classes

Agricultural Land Class	Type	Description
Class 1	Agricultural	**Suitable land** with negligible limitations. This is highly productive land requiring only simple management practices to maintain economic production.
Class 2	Agricultural	**Suitable land** with minor limitations which either reduce production or require more than the simple management practices of class 1 land to maintain economic production.
Class 3	Agricultural	**Suitable land** with moderate limitations which either further lower production or require more than those management practices of class 2 land to maintain economic production.
Class 4	Agricultural	**Marginal land**, which is presently considered unsuitable due to severe limitations. The long-term significance of these limitations on the proposed land use is unknown or not quantified. The use of this land is dependent upon undertaking additional studies to determine whether the effect of the limitation(s) can be reduced to achieve sustained economic production.
Class 5	Agricultural	**Unsuitable land** with extreme limitations that preclude its use.

Key: green shading suitable
red shading unsuitable

5.1 CATTLE GRAZING

Limitations for the assessment of grazing land suitability on improved pastures as outlined in the *Land Suitability Assessment Technique* (DME 1995) Guidelines (Table 2.2 and 2.3) are:

- Water availability;
- Nutrient deficiency;
- Soil physical factors;
- Salinity;
- Rockiness;
- Micro relief;
- pH;
- ESP;
- Wetness;
- Topography;
- Water erosion;
- Flooding; and
- Vegetation

Numerous parameters outlined in this assessment require calculation of the 'rootzone'. The rootzone is the depth to hard or weathered rock, or the depth to a significant salt bulge within the soil profile. A depth of 0.6 m has been assumed as the rootzone for any profile in which weathered rock, and/or a salt bulge was absent as outlined in the guidelines (DME 1995).

Class 1 and **class 2** land is considered suitable for grazing improved pastures with maximum grazing productivity achieved in most seasons. **Class 3** land is considered suitable for grazing improved pastures however it is less productive than **Classes 1** and **2**. **Class 4** land is categorised as marginal for grazing improved pastures although it is largely considered suitable for grazing native pastures of variable quality. **Class 5** land is unsuitable for any form of pasture improvement and is limited to low productivity grazing of native pastures. Due to the poor soil quality **Class 5** land may require destocking in poor seasons.

5.1.1 Water Availability

Plant available water capacity (PAWC) for each soil management unit was calculated with reference to Table 2.3 of the *Technical Guidelines for the Environmental Management of Exploration and Mining in Queensland – Land Suitability Assessment Techniques* (DME 1995). PAWC cut-off levels for each of the land suitability classes are as follows:

Class 1: >125 mm

Class 2: 100-125 mm

Class 3: 75-100 mm

Class 4: 50-75 mm

Class 5: <50 mm

These cut-off levels are not based on a specific species of pasture, but on pasture as a general land use. The soils are assessed on the depth to weathered rock, or other root inhibiting factor such as a salt bulge or significant sodicity. The availability of water in soils is vital for both plants and soil organisms as they require water to survive.

Table 40 Plant Available Water Capacity

Soil Management Unit	Limiting Features	PAWC (mm)	Land Suitability Class
Anderson	Gradational earth reaching 75-125 cm depth with no weathered rock/salt bulge (no rock/salt layer reached at 97cm).	100-125	2
Barry	Gradational earths reaching >125 cm depth with no weathered rock/salt layer (no rock/salt layer reached at 105 cm – alluvial units typically deep and non-sodic).	125-150	1
Charlevue	Gradational earth reaching 50-75 cm depth with no weathered rock/salt layer (EC >0.9 dS/m or Cl >900 mg/kg) (max core depth 70 cm).	75-100	3
Cooinda	Gradational earth reaching 50-75cm depth with no weathered rock/salt layer (EC >0.9 dS/m or Cl >900 mg/kg) (max core depth 60 cm).	75-100	3
Ellesmere	Gradational earth reaching 75-125cm depth with no weathered rock/salt layer (EC >0.9 dS/m or Cl >900 mg/kg) (max core depth 60 cm).	100-125	2
Geoffrey	Sands and sandy loams 45-90 cm deep	75-100	3
James	Gradational earths reaching 75-125 cm depth with no weathered rock/salt layer (EC >0.9 dS/m or Cl >900 mg/kg) (max core depth 85 cm).	100-125	2
Kosh	Non-cracking clay reaching 75-125 cm depth with no weathered rock/salt layer (EC >0.9 dS/m or Cl >900 mg/kg) (max core depth 85 cm).	100-125	2
Namoi	Non-cracking clay reaching 75-125cm depth with no weathered rock/salt layer (EC >0.9 dS/m or Cl >900 mg/kg) (max core depth 70cm).	100-125	2
Nigel	Clayey sands with 75-125 cm depth to weathered rock (parent material at 76 cm).	100-125	2
Normanby	Loamy sands >90 cm deep.	75-100	3
Wallace	Cracking clays with alkaline pH, and 20-40 cm depth to weathered or hard rock.	75-100	3

Key: > greater than

5.1.2 Nutrient Deficiency

The nutrient status of each Soil Management Unit identified has been assessed against Table 2.2 of the *Technical Guidelines for the Environmental Management of Exploration and Mining in Queensland – Land Suitability Assessment Techniques* (DME 1995). The land suitability classes identified for each Soil Management Unit are presented in Table 41. Note that bicarbonate P was only analysed within the topsoil layer (0-10 cm). Soil nutrients are vital for plant and animal growth and metabolism.

Table 41 Land Suitability Classes for Cattle Grazing based on Nutrient Status

Soil Management Unit	Limiting Features	Land Suitability Class
Anderson	Eucalypt vegetation and downs with bicarbonate P >10 mg/kg.	2
Barry	Eucalypt vegetation and downs with bicarbonate P >10 mg/kg.	2
Charlevue	Eucalypt vegetation and downs with bicarbonate P >10 mg/kg.	2
Cooinda	Eucalypt vegetation and downs with bicarbonate P >10 mg/kg.	2
Ellesmere	Other soils with Bicarbonate P 5-10 mg/kg.	3
Geoffrey	Other soils with Bicarbonate P 5-10 mg/kg.	3
James	Eucalypt vegetation and downs with bicarbonate P >10 mg/kg.	2
Kosh	Eucalypt vegetation and downs with bicarbonate P >10 mg/kg.	2
Namoi	Other soils with Bicarbonate P 5-10 mg/kg.	3
Nigel	Soil overlying rock at shallow depth, with bicarbonate P 5-10 mg/kg.	4
Normanby	Sands and loams at least 0.75 m deep with bicarbonate P 5-10 ppm.	4
Wallace	Former scrub soils with bicarbonate P >10 mg/kg.	1

Key: ppm parts per million

5.1.3 Soil Physical Factors

Table 2.2 of the *Technical Guidelines for the Environmental Management of Exploration and Mining in Queensland – Land Suitability Assessment Techniques* (DME 1995) has been used to assess the physical factors of each Soil Management Unit identified. Results are presented in Table 42. The physical condition of soils plays a direct role with seed germination and emergence. Adverse conditions such as hard setting or crusting of surface soils reduces plant establishment through creating a barrier, reducing seed soil contact.

Table 42 Land Suitability Classes for Cattle Grazing based on Soil Physical Factors

Soil Management Unit	Limiting Features	Land Suitability Class
Anderson	Rigid soils with a hard setting surface when dry	2
Barry	Rigid soils with a hard setting surface when dry	2
Charlevue	Rigid soils with a hard setting surface when dry	2
Cooinda	Rigid soils with a hard setting surface when dry	2
Ellesmere	Rigid soils with a hard setting surface when dry	2
Geoffrey	Rigid soils with a loose, soft or firm surface when dry.	1
James	Rigid soils with a hard setting surface when dry	2
Kosh	Rigid soils with a hard setting surface when dry	2
Namoi	Rigid soils with a hard setting surface when dry	2

Soil Management Unit	Limiting Features	Land Suitability Class
Nigel	Rigid soils with a hard setting surface when dry	2
Normanby	Rigid soils with a loose, soft or firm surface when dry.	1
Wallace	Cracking clays with coarse peds (>10 mm)	3

5.1.4 Salinity

Table 2.2 of the *Technical Guidelines for the Environmental Management of Exploration and Mining in Queensland – Land Suitability Assessment Techniques* (DME 1995) has been used to determine the land suitability class against salinity parameters. Given salinity can inhibit plant growth; the highest EC recorded is considered the most limiting factor and dictates the rating given to each Soil Management Unit. The results are provided in Table 43. Significant levels of salinity present in the rootzone can negatively impact plant growth and production.

Table 43 Land Suitability Classes for Cattle Grazing based on Salinity

Soil Management Unit	Limiting Features	Land Suitability Class
Anderson	Rootzone EC <0.15 mS/cm, Rootzone Cl <300 ppm	1
Barry	Rootzone EC <0.15 mS/cm, Rootzone Cl <300 ppm	1
Charlevue	Rootzone EC 0.15-0.3 mS/cm, and rootzone Cl 300-600 mg/kg	2
Cooinda	Rootzone EC <0.15 mS/cm, Rootzone Cl <300 ppm	1
Ellesmere	Rootzone EC <0.15 mS/cm, Rootzone Cl <300 ppm	1
Geoffrey	Rootzone EC <0.15 mS/cm, Rootzone Cl <300 ppm	1
James	Rootzone EC <0.15 mS/cm, Rootzone Cl <300 ppm	1
Kosh	Rootzone EC <0.15 mS/cm, Rootzone Cl <300 ppm	1
Namoi	Rootzone EC <0.15 mS/cm, Rootzone Cl <300 ppm	1
Nigel	Rootzone EC <0.15 mS/cm, Rootzone Cl <300 ppm	1
Normanby	Rootzone EC <0.15 mS/cm, Rootzone Cl <300 ppm	1
Wallace	Rootzone EC <0.15 mS/cm, Rootzone Cl <300 ppm	1

5.1.5 Rockiness

The land suitability for each Soil Management Unit based on rockiness was assessed in regard to Table 2.2 of the *Technical Guidelines for the Environmental Management of Exploration and Mining in Queensland – Land Suitability Assessment Techniques* (DME 1995). Results are presented in Table 44. The impacts of rockiness are more extreme for cropping than for grazing. In regard to grazing, rock outcrops reduce the area available to grow pasture, indirectly impacting the carrying capacity of the land.

Table 44 Land Suitability Classes for Cattle Grazing

Soil Management Unit	Limiting Features	Land Suitability Class
Anderson	<20% course surface gravel and rock outcrop	1
Barry	<20% course surface gravel and rock outcrop	1
Charlevue	<20% course surface gravel and rock outcrop	1
Cooinda	<20% course surface gravel and rock outcrop	1
Ellesmere	<20% course surface gravel and rock outcrop	1
Geoffrey	<20% course surface gravel and rock outcrop	1
James	20 to 50% course surface gravel and rock outcrop	2
Kosh	<20% course surface gravel and rock outcrop	1
Namoi	<20% course surface gravel and rock outcrop	1
Nigel	<20% course surface gravel and rock outcrop	1
Normanby	<20% course surface gravel and rock outcrop	1
Wallace	<20% course surface gravel and rock outcrop	1

5.1.6 Microrelief

The microrelief for each Soil Management Unit identified has been assessed against Table 2.2 of the *Technical Guidelines for the Environmental Management of Exploration and Mining in Queensland – Land Suitability Assessment Techniques* (DME 1995), presented in Table 45. Microrelief refers to local relief (up to several metres) around the plane of the land (NCST 2009). Impacts of microrelief on the suitability of land for cattle grazing are only experienced when soil is severely melon holed. Ponding of water in the depressions can reduce pasture yield, indirectly impacting the land's carrying capacity.

Table 45 Land Suitability Classes for Cattle Grazing based on microrelief

Soil Management Unit	Limiting Features	Land Suitability Class
Anderson	Melon holes cover <20% surface area	1
Barry	Melon holes cover <20% surface area	1
Charlevue	Melon holes cover <20% surface area	1
Cooinda	Melon holes cover <20% surface area	1
Ellesmere	Melon holes cover <20% surface area	1
Geoffrey	Melon holes cover <20% surface area	1
James	Melon holes cover <20% surface area	1
Kosh	Melon holes cover <20% surface area	1
Namoi	Melon holes cover <20% surface area	1
Nigel	Melon holes cover <20% surface area	1
Normanby	Melon holes cover <20% surface area	1
Wallace	Melon holes cover <20% surface area	1

5.1.7 pH

The land suitability class for pH has been assessed against Table 2.2 of the *Technical Guidelines for the Environmental Management of Exploration and Mining in Queensland – Land Suitability Assessment Techniques* (DME 1995), and presented in Table 46. Soil pH determines the availability of nutrients for plant intake. Where the soil material is strongly acidic, problems with aluminium and manganese toxicity may occur, limiting root growth and plant productivity. Strongly acidic soils may require input of lime or dolomite to increase soil pH. Strongly alkaline soils will restrict the availability of some elements (Fe, Cu, Zn) and may be an indicator of sodicity. Ameliorates may be added to the soil to correct pH and increase nutrient availability.

Table 46 Land Suitability Classes for Cattle Grazing based on pH

Soil Management Unit	Limiting Features	Land Suitability Class
Anderson	pH 4.5-5.0	3
Barry	pH 6.6-8.0	2
Charlevue	pH 5.6-6.6	1
Cooinda	pH 5.6-6.6	1
Ellesmere	pH 4.5-5.0	3
Geoffrey	pH 5.6-6.6	1
James	pH 5.6-6.6	1
Kosh	pH 6.6-8.0	2
Namoi	pH 5.6-6.6	1
Nigel	pH 4.5-5.0	3
Normanby	pH 5.6-6.6	1
Wallace	pH 6.6-8.0	2

5.1.8 Exchangeable Sodium Percentage (ESP)

The ESP of each Soil Management Unit identified has been assessed against Table 2.2 of the *Technical Guidelines for the Environmental Management of Exploration and Mining in Queensland – Land Suitability Assessment Techniques* (DME 1995). ESP is used to determine the erosion potential of soils. The land suitability class identified for each Soil Management Unit based on ESP in the upper 100 mm of soil is presented in Table 47.

Table 47 Land Suitability Classes for Cattle Grazing based on ESP

Soil Management Unit	Limiting Features	Land Suitability Class
Anderson	ESP (10 cm) <5%	1
Barry	ESP (10 cm) <5%	1
Charlevue	ESP (10 cm) 15-30%	4
Cooinda	ESP (10 cm) <5%	1
Ellesmere	ESP (10 cm) <5%	1
Geoffrey	ESP (10 cm) <5%	1
James	ESP (10 cm) <5%	1

Soil Management Unit	Limiting Features	Land Suitability Class
Kosh	ESP (10 cm) <5%	1
Namoi	ESP (10 cm) <5%	1
Nigel	ESP (10 cm) <5%	1
Normanby	ESP (10 cm) <5%	1
Wallace	ESP (10 cm) <5%	1

5.1.9 Wetness

The land suitability class identified for each Soil Management Unit based on wetness has been assessed against Table 2.2 of the *Technical Guidelines for the Environmental Management of Exploration and Mining in Queensland – Land Suitability Assessment Techniques* (DME 1995), and is presented in Table 48. The wetness limitation refers to any excess water both in or on the soil profile. The adverse effects of excess water include reducing plant growth, impeding oxygen supply to plant roots (possibly leading to denitrification) and increased risk of plant disease.

Table 48 Land Suitability Classes for Cattle Grazing based on Wetness

Soil Management Unit	Limiting Features	Land Suitability Class
Anderson	Elevated plains	1
Barry	Undulating terrain	1
Charlevue	Rigid soils with strongly sodic subsoil (ESP≥15) within 60 cm of the surface	2
Cooinda	Elevated plains	1
Ellesmere	Undulating terrain	1
Geoffrey	Undulating terrain	1
James	Undulating terrain	1
Kosh	Rigid soils with strongly sodic subsoil (ESP≥15) within 60 cm of the surface	2
Namoi	Elevated plains	1
Nigel	Elevated plains	1
Normanby	Elevated plains	1
Wallace	Elevated plains	1

5.1.10 Water Erosion

The land suitability class identified for each Soil Management Unit based on water erosion has been assessed against Table 2.2 of the *Technical Guidelines for the Environmental Management of Exploration and Mining in Queensland – Land Suitability Assessment Techniques* (DME 1995), and presented in Table 49. Erosion of topsoil reduces the productivity of the land through the loss of key nutrients in the soil's upper horizons.

Table 49 Land Suitability Classes for Cattle Grazing based on Water Erosion

Soil Management Unit	Limiting Features	Land Suitability Class
Anderson	Slopes 3-12% on non-sodic rigid soils	2
Barry	Slopes <3% on non-sodic rigid soils	1
Charlevue	Slopes 1-3% on sodic rigid soils	2
Cooinda	Slopes <3% on non-sodic rigid soils	1
Ellesmere	Slopes 3-12% on non-sodic rigid soils	2
Geoffrey	Slopes 3-12% on non-sodic rigid soils	2
James	Slopes 3-12% on non-sodic rigid soils	2
Kosh	Slopes 3-12% on non-sodic rigid soils	2
Namoi	Slopes 3-12% on non-sodic rigid soils	2
Nigel	Slopes 3-12% on non-sodic rigid soils	2
Normanby	Slopes <3% on non-sodic rigid soils	1
Wallace	Slopes <3% on non-sodic rigid soils	1

5.1.11 Flooding

The land suitability class identified for each Soil Management Unit based on flooding risk has been assessed against Table 2.2 of the *Technical Guidelines for the Environmental Management of Exploration and Mining in Queensland – Land Suitability Assessment Techniques* (DME 1995), and is presented in Table 50. Flooding may result in plant death or reduced growth. In severe cases were land is inundated for a prolonged period stock loss and loss of grazing production may also occur.

Table 50 Land Suitability Classes for Cattle Grazing based on Flooding

Soil Management Unit	Limiting Features	Land Suitability Class
Anderson	No flooding	1
Barry	Periodic flooding	2
Charlevue	No flooding	1
Cooinda	No flooding	1
Ellesmere	No flooding	1
Geoffrey	Periodic flooding	2
James	No flooding	1
Kosh	Periodic flooding	2
Namoi	No flooding	1
Nigel	No flooding	1
Normanby	No flooding	1
Wallace	No flooding	1

5.1.12 Vegetation Regrowth (management limitation)

The land suitability class identified for each Soil Management Unit based on vegetation regrowth has been assessed against Table 2.2 of the *Technical Guidelines for the Environmental Management of Exploration and Mining in Queensland – Land Suitability Assessment Techniques* (DME 1995), and is presented in Table 51. Vegetation communities may contain poisonous species or woody weeds that will limit the productivity of grazing pastures to varying degrees and increase the need for land management. The density of tree species and presence of a woody shrub layer may also limit the carrying capacity of the land.

Table 51 Land Suitability Classes for Cattle Grazing based on Vegetation

Soil Management Unit	Limiting Features	Land Suitability Class
Anderson	Eucalypt woodlands with wattle understorey	4
Barry	Mountain coolabah and ironbark open woodlands	1
Charlevue	Box and ironbark woodlands without wattle understorey	2
Cooinda	Box woodlands without wattle understorey	2
Ellesmere	Acacia scrub without melonholes	1
Geoffrey	Bloodwood and ironbark open woodlands	1
James	Box and ironbark woodlands with wattle understorey	4
Kosh	Box and ironbark woodlands without wattle understorey (cleared)	2
Namoi	Ironbark open woodlands	1
Nigel	Acacia scrub without melonholes	1
Normanby	Ironbark open woodlands	1
Wallace	(cleared)	-

5.1.13 Summary of Land suitability for Cattle Grazing

Table 52 Summary of Land Suitability Limitations for Cattle Grazing

Limitation	Anderson	Barry	Charlevue	Cooinda	Ellesmere	Geoffrey	James	Kosh	Namoi	Nigel	Normanby	Wallace
Water availability	2	1	3	3	2	3	2	2	2	2	3	3
Nutrient deficiency	2	2	2	2	3	3	2	2	3	4	4	1
Soil physical factors	2	2	2	2	2	1	2	2	2	2	1	3
Salinity	1	1	2	1	1	1	1	1	1	1	1	1
Rockiness	1	1	1	1	1	1	2	1	1	1	1	1
Microrelief	1	1	1	1	1	1	1	1	1	1	1	1
pH	3	2	1	1	3	1	1	2	1	3	1	2
ESP (10cm) %	1	1	4	1	1	1	1	1	1	1	1	1
Wetness	1	1	2	1	1	1	1	2	1	1	1	1
Water Erosion	2	1	2	1	2	2	2	2	2	2	1	1
Flooding	1	2	1	1	1	2	1	2	1	1	1	1
Vegetation Regrowth	4	1	2	2	1	1	4	2	1	1	1	-
Overall Suitability Rating	4	2	4	3	3	3	4	2	3	4	4	3

Key: green shading suitable
red shading unsuitable

On the Project, the suitability of land for cattle grazing is most limited by nutrient deficiency, ESP, and vegetation. Low nutrient levels and high sodicity in the soils may limit livestock production through a reduction in pasture growth and nutritive value of pasture species. Vegetation regrowth species can also impact the suitability of the land if they contain woody or poisonous species. In addition to this, high density regrowth and a woody shrub layer may reduce the carrying capacity of the land, making it unsuitable for grazing.

While no Class 1 land was identified for the Project, examination of the land suitability limitations for cattle grazing (Table 52) indicate 1084.1 ha of the Project is suitable for cattle grazing with minor limitations (Class 2), while 4338 ha is suitable for cattle grazing with moderate limitations (Class 3). The remaining area (750.8 ha) was comprised of Class 4 land, with no Class 5 land identified.

SMUs Barry and Kosh are classified as Class 2 land which is suitable for cattle grazing with minor limitations. In most seasons, younger cattle on Class 2 land will perform well, with minimal inputs required (e.g. fertiliser, land preparation or maintenance) to achieve a weight grade similar to cattle raised on Class 1 land. Land graded as Class 3 (SMUs Cooinda, Ellesmere, Geoffrey, Namoi and Wallace) may require some inputs to achieve this same weight grade, with emphasis on remediating nutrient deficiency and hard setting soil surfaces.

SMUs Anderson, Charlevue, James, Nigel and Normanby are classified as Class 4 land, which is considered suitable for improved pastures (though with severe limitations). Class 4 land will generally require significant inputs in the form of fertiliser or land management, which may not be justified given the limited benefits this land can offer. Given changes to knowledge, economics or technology this land could be sustainably managed, though does not currently hold significant economic value for improved pastures. These areas may be suitable for grazing native pastures of variable quality, though would likely have a reduced output when compared with land Classes 1, 2 and 3.

Figure 7 shows the distribution of land suitability classes for cattle grazing across the Project.

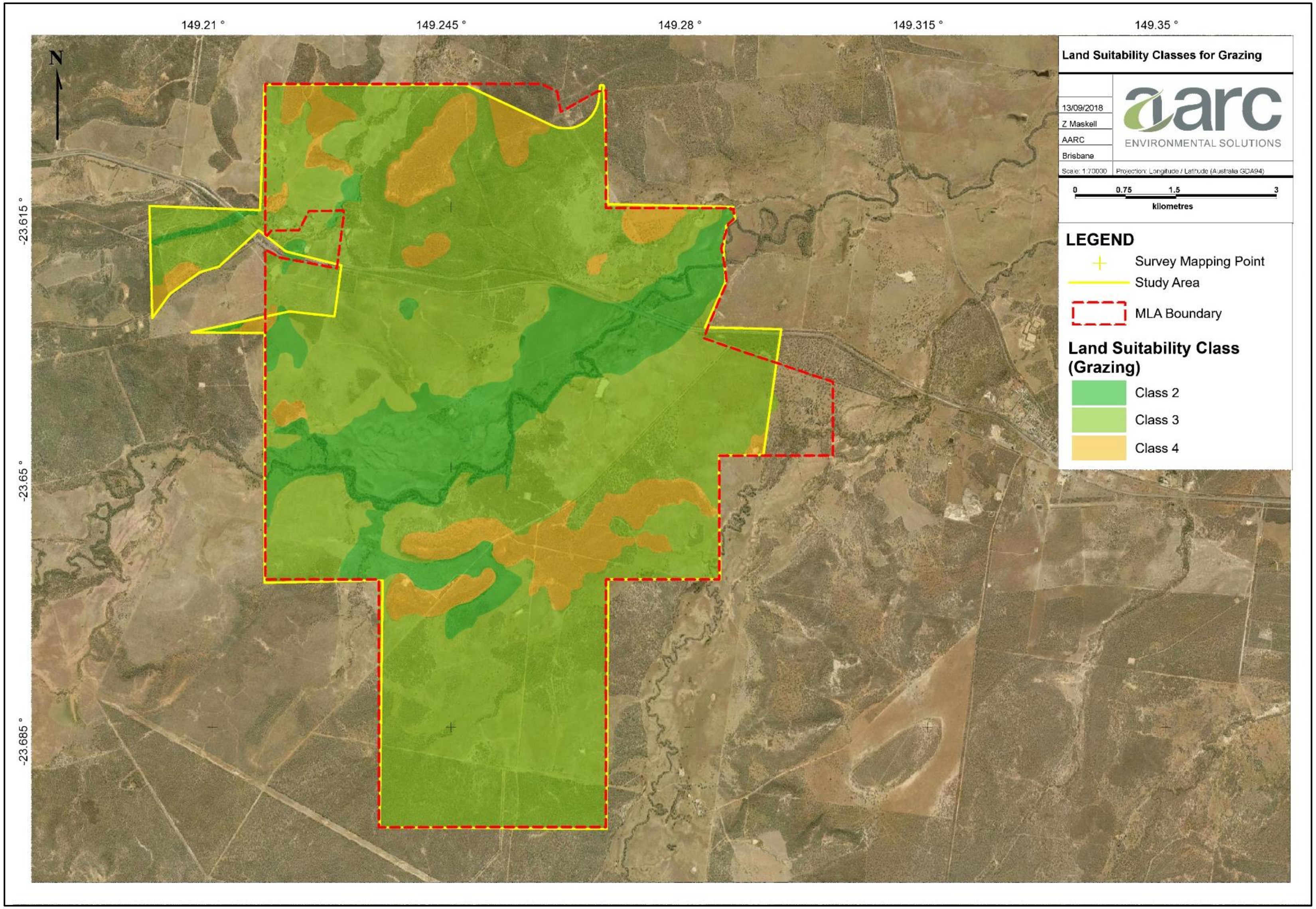


Figure 7 Cattle Grazing Land Suitability Classes

5.2 DRYLAND CROPPING

The Project lies within the Inland Fitzroy and Southern Burdekin area. Limitations for the assessment of dryland cropping suitability are specific to the Projects region and include:

- Water Erosion;
- Erosion hazard, subsoil erodibility;
- Soil water availability;
- Narrow moisture range;
- Surface conditions;
- Rockiness;
- Microrelief; and
- Wetness.

Several of these limitations contain subclasses based on the varying land management practices required for different crops. This suitability assessment will present findings based on the lowest land suitability rating returned across all of the suitability subclasses.

Assessment of the SMUs suitability for dryland cropping has been conducted in accordance with the methodology described within the *Guidelines for Agricultural Land Evaluation in Queensland* (DSITIA & DNRM 2015) and the *Regional Land Suitability Frameworks for Queensland* – Chapter 10 (DSITIA & DNRM 2013). The Suitability framework for the Inland Fitzroy and Southern Burdekin area focusses on assessing the potential for cultivating twelve specific crops including:

- Barley;
- Chickpea;
- Maize;
- Millet;
- Mungbean;
- Oats;
- Safflower;
- Sorghum;
- Soybean;
- Sunflower;
- Triticale; and
- Wheat.

Numerous parameters outlined in this assessment require calculation of the 'rootzone'. The rootzone is the depth to hard or weathered rock, or the depth to a significant salt bulge within the soil profile. A depth of 0.6 m has been assumed as the rootzone for any profile in which weathered rock, and/or a salt bulge was absent as outlined in the guidelines (DME 1995).

5.2.1 Water Erosion

The land suitability class identified for each SMU based on water erosion was determined using the *Regional Land Suitability Frameworks for Queensland* – Chapter 10, Table E, and is presented in Table 53. Dispersive properties were allocated based on Emerson Class Number and sodicity for each SMU. Erosion of topsoil reduces the productivity of the land through the loss of key nutrients in the soil's upper horizons.

Table 53 Land Suitability Classes for Dryland Cropping based on Water Erosion

Soil Management Unit	Limiting Features	Land Suitability Class
Anderson	Slopes of 5-8% with non-dispersive weakly coherent soil in the surface 200 mm	4
Barry	Slope of 1-3% with non-dispersive weakly coherent soil in the surface 200 mm	3
Charlevue	Slope of 1-3% with dispersive soil in the surface 200 mm	5
Cooinda	Slope of 1-3% with non-dispersive weakly coherent soil in the surface 200 mm	3

Soil Management Unit	Limiting Features	Land Suitability Class
Ellesmere	Slope of 3-5% with non-dispersive weakly coherent soil in the surface 200 mm	4
Geoffrey	Slopes of 3-5% with non-dispersive moderate to strongly coherent soil in the surface 200 mm	3
James	Slopes of 5-8% with non-dispersive moderate to strongly coherent soil in the surface 200 mm	3
Kosh	Slope of 1-3% with non-dispersive moderate to strongly coherent soil in the surface 200 mm	2
Namoi	Slopes of 3-5% with non-dispersive weakly coherent soil in the surface 200 mm	4
Nigel	Slopes of 3-5% with non-dispersive moderate to strongly coherent soil in the surface 200 mm	3
Normanby	1-3% with non-dispersive moderate to strongly coherent soil in the surface 200 mm	2
Wallace	Slopes of 0.5-1% with non-dispersive weakly coherent soil in the surface 200 mm	2

5.2.2 Erosion hazard, Subsoil Erodibility

The land suitability class identified for each Soil Management Unit based on erosion hazard and subsoil erodibility was determined using the *Regional Land Suitability Frameworks for Queensland* – Chapter 10, Table Es, and is presented in Table 54. Subsoil was assessed based on soils ESP, EC, CEC and Ca/Mg ratio. Soils with high ESP and low EC have a tendency to disperse (DME 1995). Low Ca/Mg ratios also indicate dispersive properties of soil. CEC is required to interpreting the ESP value as the lower the CEC value, the less significant the role of the ESP.

Table 54 Land Suitability Classes for Dryland Cropping based on Erosion Hazard and Subsoil Erodibility

Soil Management Unit	Limiting Features	Land Suitability Class
Anderson	Slopes of 5-8% with no subsoil (200-1000 mm) dispersion	3
Barry	Slope of 1-3% with low to moderate dispersive subsoil (200-1000 mm) and clay content greater than 20%	3
Charlevue	Slope of 1-3% with strongly dispersive subsoil (200-1000 mm) on 2 or more tests and clay content greater than 20%	4
Cooinda	Slope of 1-3% with low to moderate dispersive subsoil (200-1000 mm) and clay content greater than 20%	3
Ellesmere	Slope of 3-5% with strongly dispersive subsoil (200-1000 mm) on 2 or more tests and clay content greater than 20%	5
Geoffrey	Slopes of 3-5% with strongly dispersive subsoil (200-1000 mm) on 2 or more tests and clay content greater than 20%	5
James	Slopes of 5-8% with no subsoil (200-1000 mm) dispersion	3
Kosh	Slope of 1-3% with strongly dispersive subsoil (200-1000 mm) on 2 or more tests and clay content greater than 20%	4
Namoi	Slopes of 3-5% with low to moderate dispersive subsoil (200-1000 mm) and clay content greater than 20%	3
Nigel	Slopes of 3-5% with no subsoil (200-1000 mm) dispersion	3
Normanby	1-3% with no subsoil (200-1000 mm) dispersion	1
Wallace	Slopes of 0.5-1% with no subsoil (200-1000 mm) dispersion	1

5.2.3 Soil Water Availability

The land suitability class identified for each Soil Management Unit based on soil water availability was determined using the *Regional Land Suitability Frameworks for Queensland* – Chapter 10, Table M, and is presented in Table 55. PAWC values were estimated with reference to Table 2.3 of the *Technical Guidelines for the Environmental Management of Exploration and Mining in Queensland – Land Suitability Assessment Techniques* (DME 1995). These cut-off levels are not based on a particular cropping species, but on cropping as a general land use. The soils are assessed on the depth to weathered rock, or other root inhibiting factors such as a salt bulge or significant sodicity. PAWC cut-off levels for each of the land suitability classes are as follows:

Class 1: >125 mm

Class 2: 100-125 mm

Class 3: 75-100 mm

Class 4: 50-75 mm

Class 5: <50 mm

These values were used to delegate land suitability classes for different groups of crop species, as outlined in *Regional Land Suitability Frameworks for Queensland* - Chapter 10, Table M.

Table 55 Land Suitability Classes for Dryland Cropping based on Soil Water Availability

Soil Management Unit	PAWC (mm)	Land Suitability Class (Group A)	Land Suitability Class (Group B)	Land Suitability Class (Group C)
Anderson	100-125	3	3	4
Barry	125-150	2	2	3
Charlevue	75-100	3	4	5
Cooinda	75-100	3	4	5
Ellesmere	100-125	3	3	4
Geoffrey	75-100	3	4	5
James	100-125	3	3	4
Kosh	100-125	3	3	4
Namoi	100-125	3	3	4
Nigel	100-125	3	3	4
Normanby	100-125	3	3	4
Wallace	75-100	3	4	5

5.2.4 Narrow Moisture Range

The land suitability class identified for each SMU based on narrow moisture range was determined using the *Regional Land Suitability Frameworks for Queensland* – Chapter 10, Table Pm, and is presented in Table 56. The narrow moisture range of a soil plays a role in determining the soil's capacity for cultivation within the restraints of machinery.

Table 56 Land Suitability Classes for Dryland Cropping based on Narrow Moisture Range

Soil Management Unit	Limiting Features	Land Suitability Class
Anderson	Narrow moisture range for cultivation – imperfectly drained to moderately well drained; hard setting when dry and not 'spewy' when wet.	3
Barry	Narrow moisture range for cultivation – imperfectly drained to moderately well drained; hard setting when dry and not 'spewy' when wet. Hard setting pedal clays.	3
Charlevue	Narrow moisture range for cultivation – imperfectly drained to moderately well drained; hard setting when dry and not 'spewy' when wet. Hard setting pedal clays.	3
Cooinda	Narrow moisture range for cultivation – imperfectly drained to moderately well drained; hard setting when dry and not 'spewy' when wet. Hard setting pedal clays.	3
Ellesmere	Moderate moisture range for cultivation – moderately well drained to rapidly drained; predominantly hard setting when dry and not 'spewy' when wet. Moderately well drained hard setting loamy surfaced soils.	2
Geoffrey	Wide moisture range for cultivation – moderately well drained to rapidly drained; not hard setting when dry and not 'spewy' (i.e. boggy) when wet. Deep sands and thick sandy surfaced texture contrast soils	1
James	Moderate moisture range for cultivation – moderately well drained to rapidly drained; predominantly hard setting when dry and not 'spewy' when wet. Moderately well drained hard setting loamy surfaced soils.	2
Kosh	Narrow moisture range for cultivation – imperfectly drained to moderately well drained; hard setting when dry and not 'spewy' when wet. Hard setting pedal clays.	3
Namoi	Moderate moisture range for cultivation – moderately well drained to rapidly drained; predominantly hard setting when dry and not 'spewy' when wet. Moderately well drained hard setting loamy surfaced soils.	2
Nigel	Narrow moisture range for cultivation – imperfectly drained to moderately well drained; hard setting when dry and 'spewy' when wet. Loamy surfaced (less than 0.4 m).	3
Normanby	Moderate moisture range for cultivation – moderately well drained to rapidly drained; not hard setting when dry and not 'spewy' when wet. Well drained earths.	2
Wallace	Narrow moisture range for cultivation – imperfectly drained to moderately well drained; hard setting, firm or weakly self-mulching when dry and not 'spewy' when wet. Hard setting or weakly self-mulching, pedal clays.	3

5.2.5 Surface Condition

The land suitability class identified for each SMU based on surface condition was determined using the *Regional Land Suitability Frameworks for Queensland* – Chapter 10, Table Ps, and is presented Table 57. The physical condition of soils plays a direct role with seed germination and emergence. Adverse conditions such as hard setting or crusting of surface soils reduces plant establishment through creating a barrier, reducing seed soil contact.

Table 57 Land Suitability Classes for Dryland Cropping based on Surface Condition

Soil Management Unit	Limiting Features	Land Suitability Class

Anderson	Loamy, fine sand, silty or clayey surface soils that are hard setting, massive or crusting.	4
Barry	Clay soils with hard setting, firm pedal or weakly self-mulching surface horizons.	3
Charlevue	Clay soils with hard setting, firm pedal or weakly self-mulching surface horizons.	3
Cooinda	Clay soils with hard setting, firm pedal or weakly self-mulching surface horizons.	3
Ellesmere	Soils with soft, firm or only weakly hard setting, sandy to loamy surface horizons	2
Geoffrey	Soils with soft, firm or only weakly hard setting, sandy to sandy loam surface horizons	2
James	Clay soils with hard setting, firm pedal or weakly self-mulching surface horizons.	3
Kosh	Loamy, fine sand, silty or clayey surface soils that are hard setting, massive or crusting.	4
Namoi	Clay soils with hard setting, firm pedal or weakly self-mulching surface horizons.	3
Nigel	Loamy, fine sand, silty or clayey surface soils that are hard setting, massive or crusting.	4
Normanby	Soils with soft or loose sandy to sandy loam surface horizons	1
Wallace	Coarse self-mulching clays (peds greater than 5–10 mm); poor seed soil contact due to separation of large peds with drying	3

5.2.6 Rockiness

The land suitability class identified for each SMU based on rockiness was determined using the *Regional Land Suitability Frameworks for Queensland* – Chapter 10, Table R, and is presented in Table 58. Rocky outcrops and soils containing coarse fragments hinder cultivation of crops and may damage harvesting machinery.

Table 58 Land Suitability Classes for Dryland Cropping based on Rockiness

Soil Management Unit	Limiting Features	Land Suitability Class (Group A)	Land Suitability Class (Group B)
Anderson	Gravels less than 20 mm and abundance less than 10%	1	1
Barry	Gravels less than 20 mm and abundance less than 10%	1	1
Charlevue	Gravels less than 20 mm and abundance less than 10%	1	1
Cooinda	Gravels less than 20 mm and abundance less than 10%	1	1
Ellesmere	Gravels less than 20 mm and abundance less than 10%	1	1
Geoffrey	Gravels less than 20 mm and abundance less than 10%	1	1
James	Gravels less than 20 mm and abundance 20-50%	2	3
Kosh	Gravels less than 20 mm and abundance less than 10%	1	1
Namoi	Gravels less than 20 mm and abundance less than 10%	1	1
Nigel	Gravels less than 20 mm and abundance less than 10%	1	1

Soil Management Unit	Limiting Features	Land Suitability Class (Group A)	Land Suitability Class (Group B)
Normanby	Gravels less than 20 mm and abundance less than 10%	1	1
Wallace	Gravels less than 20 mm and abundance less than 10%	1	1

5.2.7 Microrelief

The land suitability class identified for each SMU based on microrelief was determined using the *Regional Land Suitability Frameworks for Queensland* – Chapter 10, Table Tm, and is presented in Table 59. Suitability classes for microrelief are based on the degree to which land needs to be levelled for dryland cropping.

Table 59 Land Suitability Classes for Dryland Cropping based on Microrelief

Soil Management Unit	Limiting Features	Land Suitability Class (Group A)
Anderson	No microrelief across the majority (greater than 70%) of the land surface	1
Barry	No microrelief across the majority (greater than 70%) of the land surface	1
Charlevue	No microrelief across the majority (greater than 70%) of the land surface	1
Cooinda	No microrelief across the majority (greater than 70%) of the land surface	1
Ellesmere	No microrelief across the majority (greater than 70%) of the land surface	1
Geoffrey	No microrelief across the majority (greater than 70%) of the land surface	1
James	No microrelief across the majority (greater than 70%) of the land surface	1
Kosh	No microrelief across the majority (greater than 70%) of the land surface	1
Namoi	No microrelief across the majority (greater than 70%) of the land surface	1
Nigel	No microrelief across the majority (greater than 70%) of the land surface	1
Normanby	No microrelief across the majority (greater than 70%) of the land surface	1
Wallace	No microrelief across the majority (greater than 70%) of the land surface	1

5.2.8 Wetness

The land suitability class identified for each Soil Management Unit based on wetness was determined using the *Regional Land Suitability Frameworks for Queensland* – Chapter 10, Table W, and is presented in Table 60. Soil that becomes waterlogged due to poor permeability and drainage may reduce plant growth, oxygen supply to roots and cause plants to become more susceptible to disease.

Table 60 Land Suitability Classed for Dryland Cropping based on Wetness

Soil Management	Limiting Features	Land Suitability Class (Group A)	Land Suitability Class (Group B)	Land Suitability Class (Group C)

Unit				
Anderson	Moderately well drained and moderately permeable	1	1	2
Barry	Moderately well drained and highly permeable	1	1	2
Charlevue	Poorly drained	5	5	5
Cooinda	Imperfectly drained and slowly permeable	4	4	4
Ellesmere	Moderately well drained and slowly permeable	2	2	2
Geoffrey	Imperfectly drained and slowly permeable	4	4	4
James	Moderately well drained and moderately permeable	1	1	2
Kosh	Poorly drained	5	5	5
Namoi	Moderately well drained and slowly permeable	2	2	2
Nigel	Poorly drained	5	5	5
Normanby	Moderately well drained and highly permeable	1	1	2
Wallace	Moderately well drained and moderately permeable	1	1	2

5.2.9 Summary of Land Suitability for Dryland Cropping

Table 61 Summary of Land Suitability Limitations for Dryland Cropping

Limitation		Anderson	Barry	Charlevue	Cooinda	Ellesmere	Geoffrey	James	Kosh	Namoi	Nigel	Normanby	Wallace
Water Erosion		4	3	5	3	4	3	3	2	4	3	2	2
Erosion Hazard, Subsoil Erodibility		3	3	4	3	5	5	3	4	3	3	3	1
Soil Water Availability	A	3	2	3	3	3	3	3	3	3	3	3	3
	B	3	2	4	4	3	4	3	3	3	3	3	4
	C	4	3	5	5	4	5	4	4	4	4	4	5
Narrow Moisture Range		3	3	3	3	2	1	2	3	2	3	2	3
Surface Condition		4	3	3	3	2	2	3	4	3	4	1	3
Rockiness	A	1	1	1	1	1	1	2	1	1	1	1	1
	B	1	1	1	1	1	1	3	1	1	1	1	1
Microrelief		1	1	1	1	1	1	1	1	1	1	1	1
Wetness	A	1	1	5	4	2	4	1	5	2	5	1	1
	B	1	1	5	4	2	4	1	5	2	5	1	1
	C	2	2	5	4	2	4	2	5	2	5	2	2
Overall Suitability Rating		4	3	5	5	5	5	4	5	4	5	4	5

Key: green shading suitable
red shading unsuitable

Land suitability for dryland cropping on the Project is most limited by soil water availability, soil wetness, erosion, and surface condition. Plants require suitable quantities of water to reach optimum production, and therefore maximum rooting depth, with the ability of the soil to take in water (wetness) playing a large part in crop survival. Topsoil and subsoil erosion also limit the ability of the soil to support crops. Soil preparation for sowing in the form of tillage may increase the risk of soil dispersion through slaking caused by the manipulation of soil aggregates by machinery. Surface condition also limits the soil classes, with hard setting soils found across most SMUs. Surface condition directly impacts seedling emergence and establishment by reducing seed-soil contact.

In Central Queensland, Class 1, 2 and 3 lands for dryland cropping are required to have the capacity to store sufficient levels of moisture to sustain a crop cycle from planting to harvesting with minimal rainfall. Class 4 lands are considered marginal for dryland cropping, requiring significant levels of rainfall for crop success. Class 5 lands are unsuitable for dryland cropping due to severe limitations.

Examination of the land suitability limitations for dryland cropping (Table 61) indicates that 156.5 ha of the Project is suitable for cropping with moderate limitations (Class 3), and 409.1 ha of land is marginally suitable for cropping (Class 4). The remaining 5607 ha of land is unsuitable (Class 5) due to land and soil limitations.

Only the Barry SMU is classified as Class 3, presenting soil characteristics suitable for cropping with moderate limitations. Although listed above as Class 3, it is not genuinely expected that this landform would be suitable for dryland cropping on the Project site. This is due to its presence being limited to a narrow corridor along associated with Charlevue Creek.

SMUs Anderson, James, Namoi, and Normanby are listed as Class 4 and therefore marginally suitable for broadacre cropping. The major limitations for these SMUs are associated with soil water availability, erosion, wetness and surface condition.

SMUs Charlevue, Cooinda, Ellesmere, Geoffrey, Kosh, Nigel, and Wallace are classified as Class 5 land which is considered unsuitable for broadacre cropping. This is due to their vulnerability to subsoil erodibility, the soil water holding capacity, and the impact these limitations would have on potential crops.

Figure 8 shows the distribution of land suitability classes for broadacre cropping across the Project.

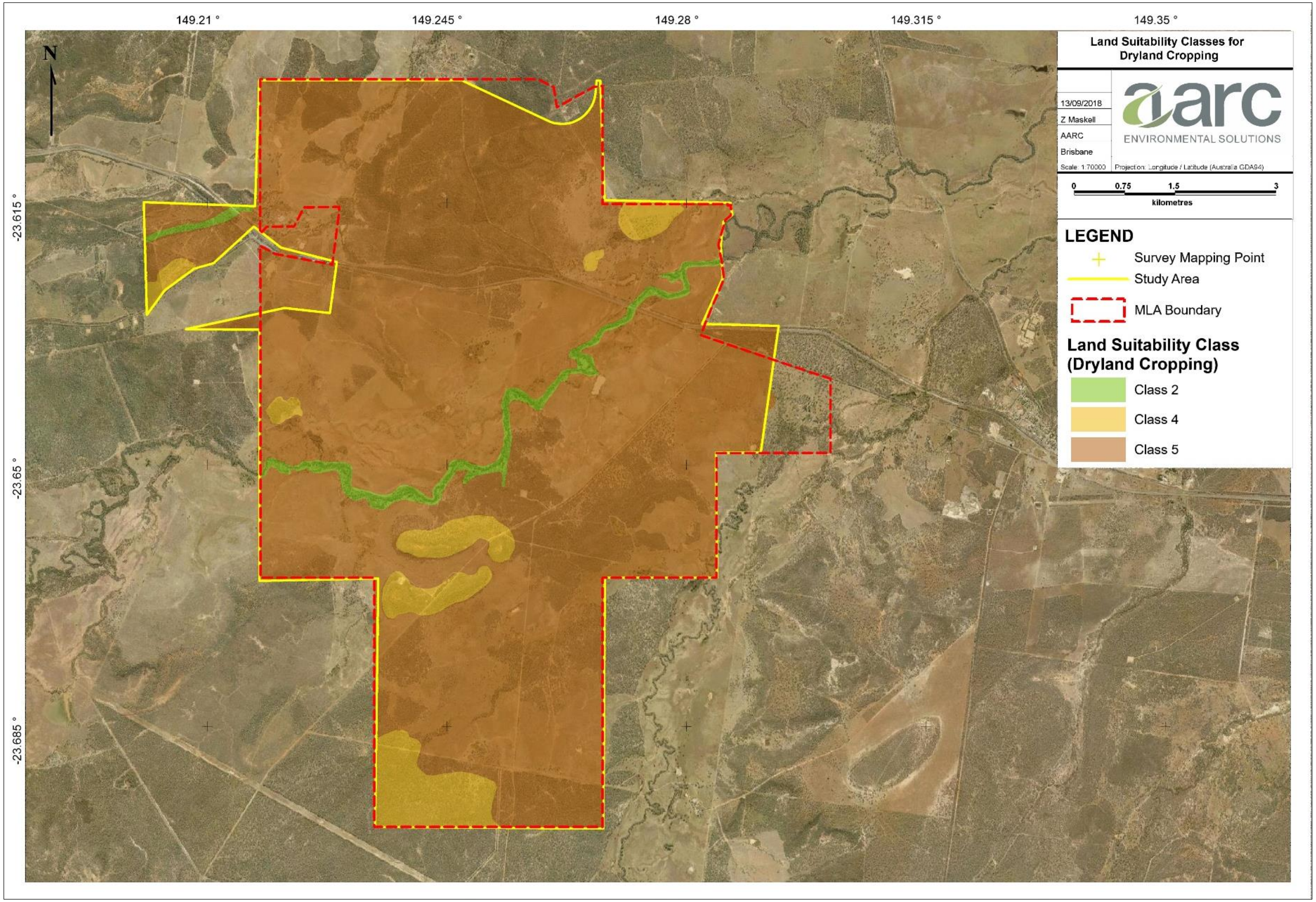


Figure 8 Dryland Cropping Land Suitability Classes

6.0 SOIL HANDLING RECOMMENDATIONS

6.1 TOPSOIL SUITABILITY AND STRIPPING

Useable soil resources are mainly confined to the surface horizons, with the upper part of the surface horizons containing seedstock, micro-organisms, and nutrients necessary for plant growth. Soil microbial activity, organic matter, and other parameters affecting soil fertility, generally decrease with depth. The following section lists a suitable topsoil stripping depth for each SMU and the maximum depth to which suitable subsoil material may be stripped for stockpiling and future rehabilitation. Stripping recommendations were determined based on SMU characteristics and the presence of inherent limitations (such as pH, salinity and sodicity).

Generally, stripping should be timed to occur in conjunction with favourable climatic conditions to reduce compaction and erosion issues. Stripping should generally occur in a single stage, however, where stripping depths exceed 0.30 m it is recommended that two-stage stripping methods are employed to reduce mixing between topsoil and subsoils. Where possible, topsoil will be directly placed in prepared rehabilitation areas and used immediately rather than stockpiled.

Table 62 summarises the maximum recommended depths to which each SMU should be stripped, a detailed discussion of each unit's stripping depth is outlined in the following sections.

Table 62 Maximum Topsoil Stripping Depths for all Soil Management Units

SMU	Topsoil Stripping Depth (m)	Maximum Subsoil Stripping Depth (m)
Anderson	0.0	0.0
Barry	0.2	0.9
Charlevue	0.0	0.0
Cooinda	0.3	0.6*
Ellesmere	0.0	0.0
Geoffrey	0.3	0.5*
James	0.3	0.6
Kosh	0.2	0.5*
Namoi	0.2	0.6*
Nigel	0.0	0.0
Normanby	0.3	0.9*
Wallace	Surface → C Horizon	-

Note: Stripping depths with as asterisk (*) may require nutrient supplements or soil ameliorants for successful use in rehabilitation.

Anderson Soil Management Unit **(Stripping Depth 0.0 m)**

The Anderson SMU is unsuitable for rehabilitation use. This soil is very strongly acid at the surface (pH 4.6) remaining so with depth, where it increases slightly to 4.8. pH values such as these would restrict plant growth and productivity, by reducing the availability of plant nutrients and causing root damage. The addition of lime would neutralise the acidic pH, though this SMU would require vast amounts to accommodate healthy plant growth. The cost of such an exercise would be high, and therefore this SMU is not recommended for use during rehabilitation.

Barry Soil Management Unit **(Stripping Depth 0.9 m)**

The Barry SMU presents no chemical limitations to stripping in the top 0.9 m of the profile. CEC is moderate to low throughout the profile, and exchangeable sodium is below critical values at all depths. The pH ranges from slightly acid to neutral, with Ca/Mg ratios >1.0 in all horizons (further reducing risk of dispersion). Although deficient in nitrate and sulphate (which could be applied as a fertiliser or foliar spray), this soil contains adequate concentrations of most macro and micronutrients. Organic matter is also above 2%. Overall, this SMU is considered a good soil resource for rehabilitation. It is however, associated with Charlevue Creek – a major waterway within the Project. Disturbance of this soil type should be avoided where possible, with the exception of required road crossings where erosion should be closely managed in the disturbed landform.

Charlevue Soil Management Unit **(Stripping Depth 0.0 m)**

The Charlevue SMU has severe chemical limitations that prevent it from becoming an adequate soil resource. pH for this unit is strongly acid in the topsoil (5.4), and though this increases to moderately alkaline with depth (7.9), mixing the horizons to make it usable would be a futile effort, due to the sodicity of the soil. The unit has strongly sodic soil at all depths, ranging from 15.1 to 29.4%. This paired with very low Ca/Mg ratios has resulted in a soil that is prone to dispersion, particularly below 0.2 m where the Emerson Class Number changes from 4, to 2, to 1. The evidence shows that the soil is in fact non-dispersive in the topsoil horizon, though this is where pH is most acidic (and therefore unusable).

The soil could be improved through the use of lime, which would increase the pH and replace some of the sodium with calcium (reducing ESP), but this would be a costly procedure. In addition to this, the unit is low in nutrients, and fertilisers would also need to be added to make it a viable soil resource. It is recommended that this soil should not be utilised in rehabilitation.

Cooinda Soil Management Unit **(Stripping Depth 0.6 m)**

The Cooinda SMU has some limitations in terms of its usability as a soil resource. The pH ranges from moderately acid in the surface soil (5.6 to 5.7) to neutral in the subsoil (6.8). Sodicity also changes from non-sodic (0.9 to 2.1%) in the topsoil, to sodic (10.9%) in the subsoil layer. The actual concentration of sodium in the subsoil layer is quite low (1.1%), though sodicity is presented as high due to the low CEC, giving an Emerson Class number of 3 (dispersive if disturbed) for all layers. Adequate mixing of the A and B horizons from 0.0 to 0.6 m could balance out these inconsistencies in pH and sodicity, creating a soil that is a better growth medium. In addition to this, nutrient levels for this SMU are particularly low. The addition of fertiliser would benefit this soil greatly. Any ameliorated soils should be tested for pH, sodicity, and nutrient content before use.

Ellesmere Soil Management Unit **(Stripping Depth 0.0 m)**

The Ellesmere SMU has severe chemical limitations in terms of pH, which ranges from very strongly acid in the surface soil (4.6) to strongly acid in the lower subsoil (5.5). pH levels such as these will reduce the availability of some plant nutrients, and increase the toxicity of other elements to plants. This could be amended through the addition of liming agents, though the pH is so low that uneconomic quantities would be required to remediate the problem. In addition to this, nutrient levels are so low in this unit that the incorporation of fertilizers is not likely to be economically viable. This SMU should not be utilised as a soil resource in rehabilitation.

Geoffrey Soil Management Unit **(Stripping Depth 0.5 m)**

The Geoffrey SMU is the largest soil unit within the mapping area. Comprised of deep sands overlying sodic, dispersive clays (Emerson Class of 1), this soil is prone to erosion if subsoils are exposed. In addition to this, nutrient levels in the sandier horizons are somewhat limited in terms of their capacity to support plant life.

Topsoil stripping should aim to segregate the A and B horizons of this soil unit, which are easily distinguishable to trained operators. Where possible, stockpiling of the B horizon should be avoided (i.e. directly placed), or closely managed, due to the dispersive nature of the subsoil.

Due to the sandy nature of the A horizons, it is recommended that soil horizons in the natural landscape are restored during rehabilitation. The clay rich subsoils should be placed first on the rehabilitated landform, followed by the sandy A horizon over the top to recreate the A and B horizons. Placement of the subsoil layer is expected to retain soil moisture necessary for successful revegetation.

Furthermore, it is recommended that where possible this SMU is used in flatter areas of the final landform to limit potential erosion issues.

James Soil Management Unit **(Stripping Depth 0.6 m)**

This SMU presents no chemical limitations to stripping in the top 0.6 m of the profile. CEC is very low throughout the profile, and ESP is classified as non-sodic at all depths. The pH is slightly acid, though should not present a problem for plant establishment. Although the Ca/Mg ratio is >1.0 until 0.5 m, as the sodicity is so low, this should not enhance dispersion. As nutrient availability is quite limited, this SMU would benefit from the addition of fertilisers or foliar applications.

Kosh Soil Management Unit **(Stripping Depth 0.5 m)**

The Kosh SMU is one of the larger soil units in the study area, and given its size, the best unit for grazing cattle. It presents a challenge due to the ESP unit, which although non-sodic in the topsoil (0.6%), becomes strongly sodic (19.5%) and erosive in the subsoil horizon. Paired with a reduction in Ca/Mg ratios, the subsoil is likely to become highly dispersive at depth. If utilised in rehabilitation, care will need to be taken to ensure that only the top 0.5 m of soil is stripped for reuse. In addition to this, this SMU could benefit from the addition of fertilisers, particularly those containing NPK. The addition of organic matter (potentially sourced from mulched vegetation removed prior to stripping) would act in increasing the CEC and water holding capacity of the soil.

Left undisturbed, this SMU remains the best area for grazing cattle within the Project. It also presents a significant challenge in stripping, and removing soils. Where possible, it should be left undisturbed.

Namoi Soil Management Unit **(Stripping Depth 0.6 m)**

The Namoi SMU has chemical limitations related to soil pH, which fluctuates from slightly acid (6.1) to strongly acid (5.5) throughout the soil profile. However, it is non-dispersive, and therefore may benefit from mixing with other soil units and/or the addition of lime to reduce pH. Adding lime to this soil would also assist in improving the Ca/Mg ratio of the soil, encouraging increased plant growth. Topsoil could also benefit from the addition of fertiliser.

<u>Nigel Soil Management Unit</u> **(Stripping Depth 0.0 m)**

The Nigel SMU is not recommended to be used in rehabilitation, due to severe limitations related to soil pH. The surface horizon is extremely acidic (4.4), becoming very strongly acidic with depth (4.6). Values such as these are likely to decrease the availability of nutrients to plants, and damage plant roots. Although pH may be amended using liming agents, the size of this unit paired with the cost of such a venture makes the use of lime unsuitable for this unit. The Nigel SMU also has low nutrient levels, and is not considered suitable for use in rehabilitation.

<u>Normanby Soil Management Unit</u> **(Stripping Depth 0.9 m)**

The Normanby SMU has no chemical limitations in terms of stripping and rehabilitation. pH in the surface soil is neutral, and although it becomes slightly acidic at 0.5 m depth, the subsoil is still considered within the suitable range for plant life. Salinity is not an issue in this soil, with EC and chloride values both exceedingly low. Dispersion is also not a likely risk in this SMU, which has non-sodic sandy loams extending to great depths in the profile. Nutrient content in this soil however, is generally low, and the soil may be augmented with fertilisers if used in rehabilitation. In addition to this, the high sand content in this soil means that rehabilitated surfaces should not exceed a 3% slope, to reduce the risk of slumping.

<u>Wallace Soil Management Unit</u> **(Stripping Depth Surface → C Horizon)**

The Wallace SMU is a high-quality soil with excellent potential as a topdressing medium. pH ranges from neutral (6.8) to slightly alkaline (7.4), salinity and sodicity are low, and exchangeable cations are within suitable limits for plant growth. Nutrient content is also quite robust, particularly the unit's NPK concentrations. The main limiting factor for this soil is the shallow depth, which was 0.2 m at the sampled location for this SMU. At this depth, the solum grades abruptly into pale grey parent material (C horizon). Identification of this demarcation is easy due to the stark contrast in colour between the black clay soil and the underlying parent material. As the depth to the C horizon may vary slightly across this unit, the stripping depth of 0.2 m may be an underestimate. Stripping depths are better defined within this SMU as the depth of media that exists above the C horizon, rather than a static depth.

The Wallace SMU would be an excellent resource to use when improving the quality of topsoil within other units, by mixing this material with others that may have limited nutrient/water holding capacity or nutrient content (such as those seen in the Geoffrey SMU).

6.2 TOPSOIL STOCKPILING

Stockpiling of topsoil for extended periods can lead to physiochemical changes in the soil and impact on the viability of the soil seed bank. Management recommendations to reduce the risk of soil degradation and improve the chances of rehabilitation success include the following:

- Where possible, topsoil should be directly placed in prepared rehabilitation areas rather than stockpiled. This will assist in maintaining a viable seedbank and will promote revegetation, thus, reducing potential for erosion;

- Topsoil should also be planted over as soon as possible after being placed in prepared rehabilitation areas. This will assist in preventing erosion of the topsoil, and making the best use of the soil's available nutrients;

- If soil is stored, stockpiles should generally be less than 2 m high and be contoured and positioned to encourage water to drain, and discourage erosion;

- If the stockpiles require grass cover, they will need to be ripped and seeded with a quick establishment pasture, to limit erosion, and maintain a viable seed bank. This should be done if the period of stockpiling is greater than one growing season or six months. Topsoil should ideally be stockpiled for the minimum time, with studies in the Hunter Valley having shown that the majority of deterioration occurs in the first year (Keipert et al. 2005). Establishment of weeds on the stockpiles will also need to be monitored and controlled;

- Where soil has been stockpiled for extended periods, soil testing is recommended. If required, fertilizers, soil ameliorants, and seeding is recommended.

Table 63 shows the estimated volumes of soil per SMU for the whole Project area, given the stripping depths outlined in section 6.1, and areas listed in section 4.0.

Table 63 Estimated Soil Volumes

SMU	Topsoil Stripping Depth (m)	Maximum Subsoil Stripping Depth (m)	SMU Area (m^2)	Potential Topsoil Volume (m^3)	Potential Subsoil Volume (m^3)
Anderson	0.0	0.0	377,800	0	0
Barry	0.2	0.9	1,565,000	313,000	1,095,500
Charlevue	0.0	0.0	2,329,000	0	0
Cooinda	0.3	0.6	349,400	104,820	104,820
Ellesmere	0.0	0.0	145,900	0	0
Geoffrey	0.3	0.5	40,790,000	12,237,000	8,158,000
James	0.3	0.6	1,452,000	435,600	435,600
Kosh	0.2	0.5	9,276,480	1,855,296	2,782,944
Namoi	0.2	0.6	1,758,000	351,600	703,200
Nigel	0.0	0.0	2,864,180	0	0
Normanby	0.3	0.9	484,960	145,488	290,976
Wallace	Minimum 0.2 (Surface → C Horizon)	-	320,400	64,080	-

Key: m^2 metres squared
M^3 metres cubed

6.3 TOPSOIL PLACEMENT

Where possible, placement of topsoil at a thickness of approximately 0.3 m is recommended across the rehabilitated area to create a growth medium of sufficient depth to hold water and support revegetation. If available, subsoils that have been identified as having a high clay content with low erosivity risk can be returned first at a depth of up to 0.5 m, prior to the addition of sandier topsoil. This may assist in providing a more suitable growth medium that holds water for long periods of time.

It is recommended that topsoil is deep ripped, into the underlying spoil surface, to encourage surface water infiltration and minimise soil loss due to erosions. On slopes of spoil dumps, ripping should be undertaken along the contour.

For the Geoffrey SMU, it is recommended that soil horizons in the natural landscape are restored during rehabilitation. The clay rich subsoils should be placed first on the rehabilitated landform, followed by the sandy A horizon over the top to recreate the A and B horizons. Placement of the subsoil layer is expected to retain soil moisture necessary for successful revegetation.

Grass and woody vegetation remaining after land clearing can be incorporated into the rehabilitation design at strategic locations to help limit runoff/erosion (by slowing down overland flow), retain active biological activity, and provide habitat for returning fauna. Additionally, mulched organic material incorporated into the soil (particularly the topsoil) will increase organic carbon levels over time, further stabilising the soil and landscape.

7.0 POTENTIAL IMPACTS AND MANAGEMENT

7.1 LAND SUITABILITY

The development of the Project will disturb land through the construction of infrastructure and operation of the mine. This disturbance will impact the land suitability of the Project throughout the life of the mine and after its closure. Pre-mining land suitability classes were outlined in Section 5.0 and are summarised below in Table 64.

Table 64 Summary of the Size and Suitability Classes for all SMUs

SMU	Land Suitability Class (Grazing)	Land Suitability Class (Cropping)	Total Area (ha)
Anderson	4	4	37.8
Barry	2	3	156.5
Charlevue	4	5	232.9
Cooinda	3	5	34.9
Ellesmere	3	5	14.6
Geoffrey	3	5	4,079
James	4	4	145.2
Kosh	2	5	927.6
Namoi	3	4	177.6
Nigel	4	5	286.4
Normanby	4	4	48.5
Wallace	3	5	32

Key: green shading suitable
red unsuitable

The majority of areas in the final landform will aim to restore a post-mining land use of grazing. The exceptions being water management features such as ponds and drains, which will be returned to a land use of native ecosystems or equivalent. This includes the final pit lake and high walls, that will be restored to achieve a fauna habitat land use. These areas are expected to be unsuitable for grazing and will achieve a reduced land suitability score of 5.

It should be noted that mining activities, including the stripping, stockpiling, handling, and compaction of soil, have the potential to impact its physical, chemical and biological properties. Therefore, the pre-mining land suitability for cattle grazing may be reduced for some rehabilitated landforms. Many of the potential impacts on soil can be mitigated through:

- Good topsoil management practices (See Section 6.0);
- The addition of fertilizers and soil ameliorants; and
- Timely seeding with suitable species.

Where the final landforms represent a relatively flat landscape (e.g. slopes less than 5%) it is envisaged that the post-mining land suitability for cattle grazing will generally reflect that of the pre-mining landscape.

Other areas, such as steeper outer slopes of spoil (e.g. slopes of greater than 10%) may be subject to erosion and as such may be less suited to cattle grazing than the pre-mining landscape. A reduced land suitability score is expected on these landforms.

Landform depressions that perennially hold surface water are expected on the rehabilitated spoil dump. These can act as dams for cattle grazing and can assist in trapping water within the surrounding growth medium. These areas typically do not support pasture species, with wetland flora usually established. As such, a reduction in land suitability for cattle grazing is also expected in these surface depressions.

7.2 EROSION

Disturbance of vegetation and the topsoil layer can lead to the mobilisation of soil through the process of erosion, particularly water erosion through heavy rainfall or overland flow. The risk of erosion at the Project will be increased by the following activities:

- Clearing of vegetation;
- Topsoil stripping and stockpiling;
- Construction of infrastructure; and
- Exposure of slopes.

Management recommendations to reduce the risk and impacts of erosion include:

- Limiting land clearing to the minimum amount of land required for safe operation of the Project;
- Diversion of overland flow/runoff around disturbed areas;
- Progressive rehabilitation of landforms and direct placement of topsoil to help preserve the seed bank and reduce erosion;
- Seeding of topsoil as soon as possible after placement onto rehabilitated areas, to ensure root masses assist in preventing erosion;
- Topsoil stockpiles should be placed away from drainage areas, roads, machinery, transport corridors, and stock grazing areas;
- Topsoil stockpiles should be seeded or covered with a water-shedding lining to prevent unnecessary erosion of soil; and
- The use of sediment control structures such as retention ponds, to minimise the release of water and suspended sediments into the receiving environment.

7.3 EROSION OF REHABILITED LANDFORMS

Erosion of rehabilitated landforms reduces the likelihood of revegetation success, and in extreme cases can compromise the structural integrity of the landform, making it unstable and unsafe. In addition, if not managed correctly, erosion can result in the release of suspended sediments and potential contaminants into the receiving environment.

SMUs within the Project have some dispersive characteristics, and will be potentially subject to erosion, particularly on artificial slopes. The rehabilitated landform design for the Project should consider implementing controls to manage surface runoff on final landform slopes. Such controls include:

- Limiting side slopes of spoil to a maximum slope of 1V:6H (vertical : horizontal) (approximately 16%) or less;
- Construction of contour banks on slopes at a recommended spacing of 80 m for slopes of 1V:6H (MCA 1998). Larger contour drains are generally more stable and longer lasting. It is recommended that drains/berms are a minimum of 5 m wide and a minimum of 500 mm in height. However, construction of larger contours is encouraged. Berms should be constructed of compacted material (IE Aust Erosion and Sediment Control Guidelines(Witheridge et al. 1996));
- Contour banks should convey water to engineered rock-lined spine drains on steep slopes. The size of the rock used should be approximately 300 to 450 mm in diameter. A competent basalt or alternative rock source is recommended. The use of geofabric in construction of rock lined spine drains is also recommended;
- To reduce the need for engineered drains, landform modelling should be centred around gentle concave slopes or terraced profiles. For some materials, designs such as these can significantly reduce runoff velocity and erosion by a magnitude of two or three times, however, the approach can be difficult to implement where space is a limiting factor;
- The incorporation of rock into the topsoil medium can also assist in reducing erodibility, as well as increasing infiltration (Alt et al. 2009); and
- Rehabilitated areas should be ripped to reduce compaction from heavy machinery, encourage infiltration of water and prevent erosion. If engineered waterways are included in the landform, areas should be ripped on a grade (e.g. 0.5%). Otherwise, areas should be ripped on the contour. Ripping depths will vary depending on the type of spoil material, depth of topsoil and equipment used for rehabilitation operations. Typical ripping depths would be 500 to1000 mm.

7.4 SOIL DEGRADATION

Stripping, stockpiling and handling of topsoil can potentially have a negative impact on the chemical and physical attributes of the soil. Specifically, the following impacts may occur as a result of mining activities:

- Exposure of saline or sodic subsoils during soil stripping;
- Loss of soil physical structure due to excavation and handling;
- Loss of the soil seedbank; and
- Impacts on soil fertility due to mixing with subsoils, or resulting from changes in chemistry when subsoils are exposed to oxygen.

Physiochemical changes to the soil may impact on the viability of the soil seed bank and reduce the likelihood of successful rehabilitation if not well managed. Management recommendations to reduce the risk of soil degradation and improve the chances of rehabilitation success include:

- Segregation of saline or sodic soils and clear demarcation of stockpiles to ensure appropriate use of the resource;

- Minimising the handling of topsoil;

- Ensuring that when required, stockpiles are generally less than 2 m high and contoured to encourage water to drain; and

- Carrying out routine testing of soil properties prior to use in rehabilitation. If required, fertilizers, soil ameliorants, and application of a seed mix is recommended to increase the likelihood of rehabilitation success.

8.0 REFERENCES

Alt S, Jenkins A & Lines-Kelly R, New South Wales Department of Primary Industries, (2009) *Saving Soil – A landholder's guide to preventing and repairing soil erosion*, Northern Rivers Catchment Management Authority.

Brooks JD & Smith JW (1969) *The diagenesis of plant lipids during the formation of coal, petroleum and natural gas—II, Coalification and the formation of oil and gas in the Gippsland Basin*, Geochimica et Cosmochimica Acta, 33(10), pp. 1183-1194.

Bureau of Meteorology (BoM) (2018) *Queensland River Basins*, Available from: http://www.bom.gov.au/qld/flood/brochures/qld/map.pdf

Bureau of Rural Science (BRS) (1991) *Digital Atlas of Australian Soils*, Department of Agriculture and Fisheries, Queensland Government, Brisbane. Available from: <http://www.asris.csiro.au/themes/Atlas.html#Atlas_Digital> accessed August 2018.

Connolly EL & Guerinot ML (2002) *Iron stress in plants*, Genome Biology, 3(8), reviews1024,1–reviews1024.4.

Department of Environment and Science (DES) (2018) *Fitzroy Drainage Basin – Facts and Maps*, Department of Environment and Science , Queensland Government, Brisbane. Available from: <https://wetlandinfo.des.qld.gov.au/wetlands/facts-maps/basin-fitzroy/ > accessed August 2018.

Department of Minerals and Energy (DME) (1995) *Technical Guidelines for Environmental Management of Exploration and Mining in Queensland – Land Suitability Assessment Techniques*, Department of Natural Resources, Mines and Energy, Queensland Government. Brisbane.

Department of Primary Industries (DPI), Thwaites RN & Maher JM (eds.) (1993) *Understanding and Managing Soils in the Central Highlands*, Department of Primary Industries Training Series, Department of Agriculture and Fisheries, Queensland Government, Brisbane.

Department of Science, Information Technology and Innovation (DSITI) & Department of Natural Resources and Mines (DNRM) (2015) *Guidelines for Agricultural Land Evaluation in Queensland* (2nd edition), Department of Science, Information Technology, Innovation and Arts & Department of Natural Resources, Mines and Energy, Queensland Government, Brisbane.

Department of Science, Information Technology and Innovation (DSITI) & Department of Natural Resources and Mines (DNRM) (2013), *Regional Land Suitability Frameworks for Queensland*. Queensland Government (Department of Science, Information Technology and Innovation and Department of Natural Resources and Mines), Brisbane Queensland. Chapter 10 – Suitability Framework for the Inland Fitzroy and Southern Burdekin area.

Dickins JM & Malone EJ (1973) *Geology of the Bowen Basin, Queensland. Bureau of Mineral Resources, Geology and Geophysics Bulletin No. 130,* Australian Government Publishing Service, Canberra.

Geoscience Australia (2018) *Province and Sedimentary Basin Geology - Bowen Basin*, Geoscience Australia. Available from: <http://www.ga.gov.au/scientific-topics/energy/province-sedimentary-basin-geology/petroleum/onshore-australia/bowen-basin> accessed August 2018.

Hazelton P & Murphy B (2016) *Interpreting Soil Test Results – What do all the Numbers Mean? Third Edition.* CSIRO Publishing, Melbourne.

Hutton AC (2009) *Geological Setting of Australasian Coal Deposits,* Australasian Coal Mining Practice (pp. 40-84).

Isbell RF (1996) (eds. 2002) *The Australian Soil Classification,* Australian Soil and Land Survey Handbook Series, CSIRO Publishing, Melbourne.

Isbell RF (1996) (eds. 2016) *The Australian Soil Classification,* Australian Soil and Land Survey Handbook Series, CSIRO Publishing, Melbourne.

Kabata-Pendias A & Pendias H (2001) *Trace Elements in Soils and Plants (3rd Edition) CRC Press*, New York.

Keipert NL (2005), *Effect of Different Stockpiling Procedures on Topsoil Characteristics in Open Cut Coal Mine Rehabilitation in the Hunter Valley, New South Wales* ,Coal Mines and Mining, University of New England.

McKenzie NJ, Grundy MJ, Webster R & Ringrose-Voase (2008) *Guidelines for Surveying Soil and Land Resources,* Australian Soil and Land Survey Handbook Series, CSIRO Publishing, Melbourne.

Minerals Council of Australia (MCA) (1998), *Back from the Brink: Reshaping Minerals Tertiary Education*, Minerals Council of Australia, Canberra.

Mutton AJ (2003) *Queensland Coals - Physical and Chemical Properties, Colliery and Company Information*, Department of Natural Resources, Mines and Energy, Queensland Government, Brisbane. Available from: <https://www.dnrm.qld.gov.au/?a=267497> accessed August 2018.

National Committee on Soil and Terrain (NCST) (2009) *Australian Soil and Land Survey Field Handbook*, Third Edition, Australian Soil and Land Survey Handbook Series, CSIRO Publishing, Melbourne.

Rayment GE & Lyons D (2011) *Soil Chemical Methods – Australasia*, Australian Soil and Land Survey Handbook Series, CSIRO Publishing, Melbourne.

Smith KA, Ball T, Conen F, Dobbie KE, Massheder A & Rey A (2018) *Exchange of greenhouse gases between soil and atmosphere: interactions of soil physical factors and biological processes*, European Journal of Soil Science, 69(1), pp. 10-20.

Speck NH, Wright RL, Sweeny FC, Perry RA, Fitzpatrick EA, Nix HA, Gunn RH & Wilson IB (1967), *Lands of the Dawson-Fitzroy Area,* Queensland. Land Research Series No 21, CSIRO, Melbourne.

Witheridge, Grant & Walker, Robert & Institution of Engineers, Australia, Queensland Division (1996), *Soil erosion and sediment control : engineering guidelines for Queensland construction sites,* Institution of Engineers, Queensland Division, Brisbane, Qld

Withnall IW & Cranfield LC (2012) *Queensland Geological framework,* Department of Natural Resources, Mines and Energy, Queensland Government, Brisbane. Available from <https://www.dnrm.qld.gov.au/__data/assets/pdf_file/0007/197647/geology-of-queensland.pdf> accessed August 2018.

Withnall IW (1989) *Precambrian and Palaeozoic geology of the south eastern Georgetown Inlier, north Queensland*, Queensland Department of Mines, Report 2, pp. 102, Department of Natural Resources, Mines and Energy, Queensland Government, Brisbane.

Appendix A Lab Results

A

		DP1				DP2			DP3			DP4	
		DP1: 0-10	DP1: 20-30	DP1: 50-60	DP1: 80-90	DP2: 0-10	DP2: 20-30	DP2: 50-60	DP3: 0-10	DP3: 20-30	DP3: 50-60	DP4: 0-10	DP4: 20-30
Analyte grouping/Analyte	**Unit**												
EA002: pH 1:5 (Soils)													
pH Value	pH Unit	5.8	5.6	6.0	8.1	5.6	5.7	6.8	5.7	5.5	6.1	6.8	7.4
EA010: Conductivity													
Electrical Conductivity @ 25°C	µS/cm	26	6	4	137	15	13	43	11	8	7	90	38
EA055: Moisture Content (Dried @ 105-110°C)													
Moisture Content	%	2.7	0.8	0.8	9.0	4.2	6.0	10.0	2.8	3.2	6.6	5.4	13.8
EA058: Emerson Aggregate Test													
Color (Munsell)		Dark Brown	Brown	Brown	Yellowish Brown	Dark Brown	Brown	Yellowish Brown	Dark Brown	Dark Brown	Yellowish Red	Very Dark Brown	Dark Brown
Texture		Loamy Sand	Loam	Sandy Clay Loam	Sandy Clay Loam	Sandy Clay Loam	Sandy Loam	Sandy Clay	Sandy Clay Loam	Sandy Clay Loam	Sandy Clay Loam	Sandy Clay Loam	Sandy Clay Loam
Emerson Class Number		4	4	4	1	3	3	3	3	3	3	3	4
EA150: Soil Classification - National Committee on Soil and Terrain (2009)													
Silt (2-20 µm)	%	9	----	----	----	20	----	----	11	----	----	39	----
Fine Sand (0.02-0.2 mm)	%	44	----	----	----	25	----	----	32	----	----	18	----
Coarse Sand (0.2-2.0 mm)	%	31	----	----	----	23	----	----	30	----	----	6	----
ED006: Exchangeable Cations on Alkaline Soils													
Exchangeable Calcium	meq/100g	0.7	0.2	0.1	0.9	1.9	1.5	1.9	1.0	0.8	0.7	18.7	27.3
Exchangeable Magnesium	meq/100g	0.7	0.2	0.2	5.9	2.0	2.6	6.7	0.6	0.8	2.1	18.3	16.1
Exchangeable Potassium	meq/100g	0.3	0.2	<0.1	<0.2	0.4	0.2	0.1	0.2	<0.1	<0.1	1.8	0.3
Exchangeable Sodium	meq/100g	<0.1	<0.1	<0.1	2.0	<0.1	<0.1	1.1	<0.1	<0.1	0.1	0.1	0.3
Cation Exchange Capacity	meq/100g	1.7	0.8	0.4	8.8	4.4	4.6	9.8	2.0	1.9	3.0	39.0	44.0
Exchangeable Sodium Percent	%	1.0	1.8	8.2	22.1	0.9	2.1	10.9	0.6	1.8	4.1	0.3	0.6
Calcium/Magnesium Ratio		1.0	1.0	0.5	<0.2	1.0	0.6	0.3	1.7	1.0	0.3	1.0	1.7
Magnesium/Potassium Ratio		1.9	1.4	----	----	5.0	17.0	52.0	2.8	----	----	9.9	52.8
ED021: Bicarbonate Extractable Potassium (Colwell)													

Bicarbonate Extractable K (Colwell)	mg/kg	<200	----	----	----	<200	----	----	<200	----	----	**652**	----
ED040S : Soluble Sulfate by ICPAES													
Sulfate as SO4 2-	mg/kg	<10	----	----	----	<10	----	----	<10	----	----	**10**	----
Sulfur as S	mg/kg	<10	----	----	----	<10	----	----	<10	----	----	<10	----
Silica	mg/kg	**48**	----	----	----	**68**	----	----	**44**	----	----	**165**	----
ED045G: Chloride by Discrete Analyser													
Chloride	mg/kg	**20**	<10	<10	**110**	<10	**10**	**40**	<10	<10	<10	**30**	**10**
ED091 : Calcium Chloride Extractable Boron													
Boron	mg/kg	**0.2**	----	----	----	**0.4**	----	----	**0.2**	----	----	**0.5**	----
ED092: DTPA Extractable Metals													
Copper	mg/kg	<1.00	----	----	----	<1.00	----	----	<1.00	----	----	**1.61**	----
Iron	mg/kg	**166**	----	----	----	**76.9**	----	----	**86.3**	----	----	**63.4**	----
Manganese	mg/kg	**16.0**	----	----	----	**61.6**	----	----	**43.7**	----	----	**53.4**	----
Zinc	mg/kg	**2.16**	----	----	----	**1.82**	----	----	**2.09**	----	----	**1.02**	----
EK057G: Nitrite as N by Discrete Analyser													
Nitrite as N (Sol.)	mg/kg	<0.1	----	----	----	**0.2**	----	----	<0.1	----	----	**0.8**	----
EK058G: Nitrate as N by Discrete Analyser													
Nitrate as N (Sol.)	mg/kg	**3.0**	----	----	----	**1.2**	----	----	**1.7**	----	----	**6.6**	----
EK059G: Nitrite plus Nitrate as N (NOx) by Discrete Analyser													
Nitrite + Nitrate as N (Sol.)	mg/kg	**3.0**	----	----	----	**1.4**	----	----	**1.7**	----	----	**7.4**	----
EK080: Bicarbonate Extractable Phosphorus (Colwell)													
Bicarbonate Ext. P (Colwell)	mg/kg	**8**	**6**	**8**	**6**	**15**	**6**	**6**	**7**	**6**	**7**	**169**	**47**
EP004: Organic Matter													
Organic Matter	%	**1.8**	**2.2**	**0.8**	**0.6**	**1.0**	**1.0**	**1.0**	**0.8**	**0.6**	**0.9**	**4.1**	**1.7**
Total Organic Carbon	%	**1.0**	**1.2**	<0.5	<0.5	**0.6**	**0.6**	**0.6**	<0.5	<0.5	<0.5	**2.4**	**1.0**

		DP6			DP7			DP14				DP17		
		DP6: 0-10	DP6: 20-30	DP6: 50-60	DP7: 0-10	DP7: 20-30	DP7: 50-60	DP14: 0-10	DP14: 20-30	DP14: 50-60	DP14: 80-90	DP17: 0-10	DP17: 20-30	DP17: 50-60
Analyte grouping/Analyte	**Unit**													
EA002: pH 1:5 (Soils)														
pH Value	pH Unit	5.4	6.4	7.9	5.5	6.0	7.8	6.5	6.8	6.9	7.2	6.2	6.1	6.4
EA010: Conductivity														
Electrical Conductivity @ 25°C	µS/cm	280	431	458	6	10	193	63	12	10	12	13	6	15
EA055: Moisture Content (Dried @ 105-110°C)														
Moisture Content	%	9.1	11.8	10.7	2.0	1.2	9.2	2.3	5.1	4.3	7.2	1.5	7.0	10.2
EA058: Emerson Aggregate Test														
Color (Munsell)		Yellowish Brown	Dark Yellowish Brown	Olive Brown	Brown	Brown	Dark Yellowish Brown	Dark Brown	Dark Brown	Dark Brown	Dark Brown	Dark Brown	Dark Reddish Brown	Dark Red
Texture		Sandy Clay Loam	Clay Loam	Sandy Clay	Sandy Clay Loam	Sandy Clay Loam	Sandy Clay	Sandy Clay	Sandy Clay	Sandy Clay	Sandy Clay	Gravelly Sand	Sandy Clay	Sandy Clay
Emerson Class Number		4	2	1	4	3	2	3	4	3	3	8	3	4
EA150: Soil Classification - National Committee on Soil and Terrain (2009)														
Silt (2-20 µm)	%	5	----	----	17	----	----	24	----	----	----	9	----	----
Fine Sand (0.02-0.2 mm)	%	48	----	----	32	----	----	37	----	----	----	35	----	----
Coarse Sand (0.2-2.0 mm)	%	23	----	----	28	----	----	20	----	----	----	24	----	----
ED006: Exchangeable Cations on Alkaline Soils														
Exchangeable Calcium	meq/100g	1.7	3.2	2.7	0.3	<0.1	0.8	6.4	6.1	5.5	10.0	2.0	3.1	2.4
Exchangeable Magnesium	meq/100g	3.1	6.4	6.5	0.4	0.7	6.8	5.2	4.9	4.6	7.5	1.8	2.4	3.2
Exchangeable Potassium	meq/100g	0.1	<0.1	<0.2	0.1	<0.1	<0.2	0.9	0.2	0.2	0.3	0.4	0.3	<0.1
Exchangeable Sodium	meq/100g	1.2	1.7	3.8	<0.1	0.2	2.9	<0.1	<0.1	<0.1	0.2	<0.1	<0.1	<0.1
Cation Exchange Capacity	meq/100g	6.3	15.1	13.1	1.3	1.2	10.4	12.5	11.3	10.4	18.0	4.3	5.9	5.8
Exchangeable Sodium Percent	%	19.8	0.5	29.4	4.3	21.0	27.5	0.3	0.5	0.7	1.0	0.4	0.7	1.4
Calcium/Magnesium Ratio		0.5	11.4	0.4	0.8	<0.1	<0.2	1.2	1.2	1.2	1.3	1.1	1.3	0.8
Magnesium/Potassium Ratio		27.9	----	----	3.4	----	----	5.7	20.4	25.6	24.8	5.0	8.2	----
ED021: Bicarbonate Extractable Potassium (Colwell)														

Bicarbonate Extractable K (Colwell)	mg/kg	<200	----	----	<200	----	----	**596**	----	----	----	<200	----	----
ED040S : Soluble Sulfate by ICPAES														
Sulfate as SO4 2-	mg/kg	**20**	----	----	<10	----	----	<10	----	----	----	<10	----	----
Sulfur as S	mg/kg	<10	----	----	<10	----	----	<10	----	----	----	<10	----	----
Silica	mg/kg	**299**	----	----	**248**	----	----	**77**	----	----	----	**118**	----	----
ED045G: Chloride by Discrete Analyser														
Chloride	mg/kg	**420**	**680**	**630**	<10	**10**	**200**	**20**	<10	<10	<10	<10	<10	<10
ED091 : Calcium Chloride Extractable Boron														
Boron	mg/kg	**0.8**	----	----	<0.2	----	----	**0.4**	----	----	----	**0.3**	----	----
ED092: DTPA Extractable Metals														
Copper	mg/kg	<1.00	----	----	<1.00	----	----	<1.00	----	----	----	<1.00	----	----
Iron	mg/kg	**29.7**	----	----	**21.7**	----	----	**53.4**	----	----	----	**21.4**	----	----
Manganese	mg/kg	**5.45**	----	----	**9.15**	----	----	**37.2**	----	----	----	**18.7**	----	----
Zinc	mg/kg	<1.00	----	----	**2.23**	----	----	**2.88**	----	----	----	<1.00	----	----
EK057G: Nitrite as N by Discrete Analyser														
Nitrite as N (Sol.)	mg/kg	<0.1	----	----	<0.1	----	----	**0.4**	----	----	----	**0.1**	----	----
EK058G: Nitrate as N by Discrete Analyser														
Nitrate as N (Sol.)	mg/kg	**0.4**	----	----	**0.7**	----	----	**1.7**	----	----	----	**1.1**	----	----
EK059G: Nitrite plus Nitrate as N (NOx) by Discrete Analyser														
Nitrite + Nitrate as N (Sol.)	mg/kg	**0.4**	----	----	**0.7**	----	----	**2.1**	----	----	----	**1.2**	----	----
EK080: Bicarbonate Extractable Phosphorus (Colwell)														
Bicarbonate Ext. P (Colwell)	mg/kg	**12**	<5	**11**	**15**	**5**	**6**	**64**	**12**	**19**	**27**	**14**	**7**	**8**
EP004: Organic Matter														
Organic Matter	%	**1.0**	**1.3**	**1.1**	<0.5	**0.5**	<0.5	**3.3**	**3.0**	**2.9**	**2.8**	**2.8**	**2.2**	**2.6**
Total Organic Carbon	%	**0.6**	**0.7**	**0.6**	<0.5	<0.5	<0.5	**1.9**	**1.7**	**1.7**	**1.6**	**1.6**	**1.3**	**1.5**

		DP26			DP34			DP40				DP50		
		DP26: 0-10	DP26: 20-30	DP26: 50-60	DP34: 0-10	DP34: 20-30	DP34: 50-60	DP40: 0-10	DP40: 20-30	DP40: 50-60	DP40: 80-90	DP50: 0-10	DP50: 20-30	DP50: 50-60
Analyte grouping/Analyte	**Unit**													
EA002: pH 1:5 (Soils)														
pH Value	pH Unit	**4.6**	**4.7**	**4.8**	**6.3**	**7.7**	**8.5**	**4.6**	**4.6**	**5.1**	**5.5**	**6.7**	**6.6**	**6.1**
EA010: Conductivity														
Electrical Conductivity @ 25°C	µS/cm	**64**	**28**	**20**	**36**	**83**	**415**	**20**	**11**	**17**	**26**	**36**	**6**	**3**
EA055: Moisture Content (Dried @ 105-110°C)														
Moisture Content	%	**1.0**	**4.3**	**8.2**	**2.8**	**7.1**	**9.0**	**1.4**	**3.4**	**11.8**	**10.0**	**6.1**	**1.7**	**1.5**
EA058: Emerson Aggregate Test														
Color (Munsell)		**Very Dark Greyish Brown**	**Brown**	**Yellowish Red**	**Very Dark Greyish Brown**	**Dark Yellowish Brown**	**Dark Yellowish Brown**	**Very Dark Greyish Brown**	**Brown**	**Dark Red**	**Red**	**Dark Reddish Brown**	**Yellowish Red**	**Yellowish Red**
Texture		**Sandy Loam**	**Sandy Clay Loam**	**Sandy Clay**	**Sandy Clay Loam**	**Sandy Clay**	**Sandy Clay**	**Sandy Loam**	**Sandy Clay Loam**	**Sandy Clay**	**Sandy Clay**	**Sandy Loam**	**Loamy Sand**	**Sandy Loam**
Emerson Class Number		**3**	**4**	**4**	**4**	**2**	**2**	**3**	**3**	**4**	**4**	**4**	**4**	**4**
EA150: Soil Classification - National Committee on Soil and Terrain (2009)														
Silt (2-20 µm)	%	**7**	**----**	**----**	**16**	**----**	**----**	**9**	**----**	**----**	**----**	**3**	**----**	**----**
Fine Sand (0.02-0.2 mm)	%	**27**	**----**	**----**	**28**	**----**	**----**	**40**	**----**	**----**	**----**	**25**	**----**	**----**
Coarse Sand (0.2-2.0 mm)	%	**36**	**----**	**----**	**34**	**----**	**----**	**30**	**----**	**----**	**----**	**63**	**----**	**----**
ED006: Exchangeable Cations on Alkaline Soils														
Exchangeable Calcium	meq/ 100g	**0.7**	**0.4**	**0.2**	**4.4**	**4.4**	**4.1**	**0.4**	<0.1	<0.1	<0.1	**1.3**	**1.4**	**0.9**
Exchangeable Magnesium	meq/ 100g	**0.2**	**0.2**	**1.0**	**1.7**	**6.9**	**9.7**	**0.2**	**0.2**	**1.7**	**3.4**	**0.6**	**0.4**	**0.5**
Exchangeable Potassium	meq/ 100g	**0.4**	**0.2**	<0.1	**0.6**	**0.2**	<0.2	**0.2**	**0.1**	**0.1**	**0.1**	**0.4**	**0.3**	<0.1
Exchangeable Sodium	meq/ 100g	<0.1	<0.1	<0.1	<0.1	**1.8**	**3.4**	<0.1	<0.1	**0.2**	**0.6**	<0.1	<0.1	<0.1
Cation Exchange Capacity	meq/ 100g	**2.7**	**2.8**	**4.2**	**6.8**	**13.3**	**17.4**	**2.3**	**2.2**	**5.7**	**6.9**	**2.4**	**2.1**	**1.6**
Exchangeable Sodium Percent	%	**3.7**	**2.6**	**4.5**	**0.6**	**13.2**	**19.5**	<0.1	**6.4**	**10.5**	**13.8**	<0.1	<0.1	<0.1
Calcium/Magnesium Ratio		**3.5**	**2.0**	**0.2**	**2.6**	**0.6**	**0.4**	**2.0**	<0.1	<0.1	<0.1	**2.2**	**3.5**	**1.8**
Magnesium/Potassium Ratio		**0.5**	**1.4**	**----**	**2.7**	**33.5**	**----**	**0.9**	**1.7**	**12.6**	**27.5**	**1.4**	**1.4**	**----**
ED021: Bicarbonate Extractable Potassium (Colwell)														

Bicarbonate Extractable K (Colwell)	mg/kg	<200	----	----	<200	----	----	**532**	----	----	----	**275**	----	----
ED040S : Soluble Sulfate by ICPAES														
Sulfate as SO4 2-	mg/kg	**20**	----	----	<10	----	----	<10	----	----	----	<10	----	----
Sulfur as S	mg/kg	<10	----	----	<10	----	----	<10	----	----	----	<10	----	----
Silica	mg/kg	**50**	----	----	**413**	----	----	**77**	----	----	----	**66**	----	----
ED045G: Chloride by Discrete Analyser														
Chloride	mg/kg	**30**	**10**	**10**	<10	**60**	**490**	<10	<10	<10	<10	<10	<10	<10
ED091 : Calcium Chloride Extractable Boron														
Boron	mg/kg	**0.6**	----	----	**0.4**	----	----	**0.4**	----	----	----	<0.2	----	----
ED092: DTPA Extractable Metals														
Copper	mg/kg	<1.00	----	----	<1.00	----	----	<1.00	----	----	----	<1.00	----	----
Iron	mg/kg	**296**	----	----	**32.4**	----	----	**327**	----	----	----	**29.1**	----	----
Manganese	mg/kg	**5.46**	----	----	**17.5**	----	----	**3.13**	----	----	----	**13.0**	----	----
Zinc	mg/kg	<1.00	----	----	**1.20**	----	----	<1.00	----	----	----	<1.00	----	----
EK057G: Nitrite as N by Discrete Analyser														
Nitrite as N (Sol.)	mg/kg	**0.2**	----	----	**0.5**	----	----	**0.2**	----	----	----	<0.1	----	----
EK058G: Nitrate as N by Discrete Analyser														
Nitrate as N (Sol.)	mg/kg	**10.2**	----	----	**2.5**	----	----	**1.6**	----	----	----	**10.3**	----	----
EK059G: Nitrite plus Nitrate as N (NOx) by Discrete Analyser														
Nitrite + Nitrate as N (Sol.)	mg/kg	**10.4**	----	----	**3.0**	----	----	**1.8**	----	----	----	**10.3**	----	----
EK080: Bicarbonate Extractable Phosphorus (Colwell)														
Bicarbonate Ext. P (Colwell)	mg/kg	**11**	**65**	**6**	**13**	**7**	**5**	**6**	<5	**7**	**5**	**6**	<5	<5
EP004: Organic Matter														
Organic Matter	%	**3.3**	**2.3**	**2.2**	**4.0**	**1.7**	**0.8**	**5.0**	**1.5**	**1.2**	**0.9**	**1.1**	**0.7**	**0.6**
Total Organic Carbon	%	**1.9**	**1.3**	**1.2**	**2.3**	**1.0**	<0.5	**2.9**	**0.9**	**0.7**	<0.5			

		DP52		
		DP52: 0-10	DP52: 20-30	DP52: 50-60
Analyte grouping/Analyte	**Unit**			
EA002: pH 1:5 (Soils)				
pH Value	pH Unit	**4.4**	**4.6**	**4.6**
EA010: Conductivity				
Electrical Conductivity @ 25°C	µS/cm	**38**	**10**	**10**
EA055: Moisture Content (Dried @ 105-110°C)				
Moisture Content	%	**7.3**	**2.3**	**2.3**
EA058: Emerson Aggregate Test				
Color (Munsell)		**Very Dark Brown**	**Dark Brown**	**Strong Brown**
Texture		**Sandy Loam**	**Sandy Loam**	**Sandy Loam**
Emerson Class Number		**4**	**4**	**4**
EA150: Soil Classification - National Committee on Soil and Terrain (2009)				
Silt (2-20 µm)	%	**7**	----	----
Fine Sand (0.02-0.2 mm)	%	**34**	----	----
Coarse Sand (0.2-2.0 mm)	%	**42**	----	----
ED006: Exchangeable Cations on Alkaline Soils				
Exchangeable Calcium	meq/ 100g	**0.8**	<0.1	<0.1
Exchangeable Magnesium	meq/ 100g	**0.4**	<0.1	<0.1
Exchangeable Potassium	meq/ 100g	**0.2**	**0.1**	<0.1
Exchangeable Sodium	meq/ 100g	<0.1	<0.1	<0.1
Cation Exchange Capacity	meq/ 100g	**2.8**	**1.7**	**1.6**
Exchangeable Sodium Percent	%	**1.3**	<0.1	<0.1
Calcium/Magnesium Ratio		**2.0**	----	----
Magnesium/Potassium Ratio		**1.6**	<0.1	----
ED021: Bicarbonate Extractable Potassium (Colwell)				
Bicarbonate Extractable K (Colwell)	mg/kg	<200	----	----
ED040S : Soluble Sulfate by ICPAES				

Sulfate as SO4 2-	mg/kg	<10	----	----
Sulfur as S	mg/kg	<10	----	----
Silica	mg/kg	**61**	----	----
ED045G: Chloride by Discrete Analyser				
Chloride	mg/kg	**10**	<10	<10
ED091 : Calcium Chloride Extractable Boron				
Boron	mg/kg	**0.2**	----	----
ED092: DTPA Extractable Metals				
Copper	mg/kg	<1.00	----	----
Iron	mg/kg	**331**	----	----
Manganese	mg/kg	**3.21**	----	----
Zinc	mg/kg	<1.00	----	----
EK057G: Nitrite as N by Discrete Analyser				
Nitrite as N (Sol.)	mg/kg	<0.1	----	----
EK058G: Nitrate as N by Discrete Analyser				
Nitrate as N (Sol.)	mg/kg	**11.2**	----	----
EK059G: Nitrite plus Nitrate as N (NOx) by Discrete Analyser				
Nitrite + Nitrate as N (Sol.)	mg/kg	**11.2**	----	----
EK080: Bicarbonate Extractable Phosphorus (Colwell)				
Bicarbonate Ext. P (Colwell)	mg/kg	**7**	**6**	**6**
EP004: Organic Matter				
Organic Matter	%	**4.6**	**1.6**	**1.2**
Total Organic Carbon	%	**2.7**	**0.9**	**0.7**

Appendix B Soil Profile Data

Project Name: Dingo Soils

[Site Description]

Date:	20/06/2018		**Site:**	DP1	
Location:	Atkinson		**Coordinates:**	E 0731029	N 7377997
Landform Pattern:	Plain		**Micro Relief:**	-	
Landform Element:	Plain		**Rock Outcrops:**	-	
Morphological Type:	Flat		**S C Fragments:**	-	
Site Disturbance:	3		**Substrate:**	Sandstone/mudstone	
Erosion:	Stable		**Surface Condition:**	Firm	
Landform	Elevation:	160	**Permeability:**	1	
	Slope (%):	2	**Drainage:**	2	
	Relief:		**Run-off:**	2	

[Geoffrey]

[Soil Description]

Horizon	Depth (cm)	Boundary	Colour	Mottles	Texture	Coarse Fragments	Structure	Segregations	Consistency	Field pH	
A1	0-10	D	10YR6/3 (D) 10YR4/3 (W)	-	FLS	-	V	-	D2	5	6
A2E	10-60	A	10YR7/2 (D) 10YR5/3 (W)	-	FLS	-	G	-	D1	30	6
B2	60-90		10YR5/2	FO3	FSMC	-	M4LE	-	D5	60	6.5
										90	7.5

Vegetation: E. tesselaris, C. clarksoniana, E. crebra, A. rhodoxylon

Notes: Springwood/Luxoc? B2 grey matrix with orange mottles. Elevation? Refer to topo map.

Project Name: Dingo Soils

[Site Description]

Date:	21/06/2018		**Site:**	DP2	
Location:	Atkinson		**Coordinates:**	E 0729295	N 7378337
Landform Pattern:	Plain		**Micro Relief:**	-	
Landform Element:	Plain		**Rock Outcrops:**	-	
Morphological Type:	Flat		**S C Fragments:**	12SMS	
Site Disturbance:	3		**Substrate:**	Q. alluvium/colluvium	
Erosion:	Stable		**Surface Condition:**	H	
Landform	Elevation:	139	**Permeability:**	2	
	Slope (%):	2	**Drainage:**	3	
	Relief:		**Run-off:**	3	

[Cooinda]

[Soil Description]

Horizon	Depth (cm)	Boundary	Colour	Mottles	Texture	Coarse Fragments	Structure	Segregations	Consistency	Field pH	
A1	0-10	C	10YR3/6	-	SCL	12SM	S3PL	-	D2	5	6
A2	10-25	D	7.5YR3/4	-	SLC	12SM	M3PO	-	D2	15	5.5
B21	25-45	S	10YR4/4	-	SLC	12SM	M3PO	-	D3	35	6
B22	45-60		10YR4/6	-	MHC	12SM	M4LE	-	D4	55	7

Vegetation: E. populnea, F. dissosperma

Notes:

Project Name: Dingo Soils

[Site Description]

Date:	21/06/2018		**Site:**	DP3
Location:	Atkinson		**Coordinates:**	E 0728011 / N 7378628
Landform Pattern:	Rise		**Micro Relief:**	-
Landform Element:	Hill Crest		**Rock Outcrops:**	-
Morphological Type:	Crest		**S C Fragments:**	-
Site Disturbance:	1		**Substrate:**	Laterite or Q. alluvium
Erosion:	S		**Surface Condition:**	H
Landform	Elevation:	139	**Permeability:**	2
	Slope (%):	4	**Drainage:**	4
	Relief:		**Run-off:**	4

[Namoi]

[Soil Description]

Horizon	Depth (cm)	Boundary	Colour	Mottles	Texture	Coarse Fragments	Structure	Segregations	Consistency	Field pH	
A1j	0-17	C	7.5YR5/4 (D) 7.5YR3/4 (W)	-	SCL	-	MLE	-	D3	5	5
A3j	17-40	D	7.5YR5/6 (D) 5YR4/4 (W)	-	SCL+	-	WAB	-	D3	25	5.5
B1	40-55	D	5YR4/6	-	LC	-	WAB	-	D4	45	6
B2	55-70		5YR5/8	2FR1	LMC	12SM	MPO	-	D4	60	6.5

Vegetation: E. crebra (D), A. rhodoxylon, H. contortus

Notes: B2 – brown orange matrix

Project Name: Dingo Soils

[Site Description]

Date:	21/06/2018		**Site:**	DP4
Location:	Atkinson		**Coordinates:**	E 0730098 N 7380449
Landform Pattern:	Rise		**Micro Relief:**	**Small cracks (shrink swell)**
Landform Element:	Hill slope		**Rock Outcrops:**	**-**
Morphological Type:	Upper slope		**S C Fragments:**	**-**
Site Disturbance:	4		**Substrate:**	**Q. alluvium**
Erosion:	Stable		**Surface Condition:**	**M**
Landform	Elevation:	135	**Permeability:**	**3**
	Slope (%):	1	**Drainage:**	**4**
	Relief:		**Run-off:**	**2**

[Wallace]

[Soil Description]

Horizon	Depth (cm)	Boundary	Colour	Mottles	Texture	Coarse Fragments	Structure	Segregations	Consistency	Field pH	
A	0-5	D	7.5YR2.5/2	-	MHC	-	W4LE	-	D5	3	6.5
B2	5-24	C	7.5YR2.5/2	-	HC	11SMS	M5SB	-	D5	15	6.5
C	24-50		7.5YR4/1	-	-			-	D6	35	6.5

Vegetation: Cleared, one grass species (A. latifolia)

Notes: Substrate not likely rock, but tertiary sediments. Slickensides in B2. Shrink swell clay forms small cracks across surface.

Project Name: Dingo Soils

[Site Description]

Date:	21/06/2018	**Site:**	DP5	
Location:	Atkinson	**Coordinates:**	E 0728662	N 7379700
Landform Pattern:	Plain	**Micro Relief:**	-	
Landform Element:	Plain	**Rock Outcrops:**	-	
Morphological Type:	Flat	**S C Fragments:**	-	
Site Disturbance:	2	**Substrate:**	Sandstone or mudstone	
Erosion:	Stable	**Surface Condition:**	S	
Landform	Elevation:	**Permeability:**	2	
	Slope (%):	**Drainage:**	2	
	Relief:	**Run-off:**	1	

[Geoffrey]

[Soil Description]

Horizon	Depth (cm)	Boundary	Colour	Mottles	Texture	Coarse Fragments	Structure	Segregations	Consistency	Field pH	
A1	0-12	D		-	S	-	V	-	D1	5	5.5
A2j	12-30	D		-	S	-	V	-	D1	15	5.5
A3e	30-54	A		-	S	-	G	-	D1	40	6
B2	54-65			21FYD	SMC	-	M3LE	-	T5	60	7

Vegetation: C. clarksoniana, M. leucadendra, C. cunninghamiana

Notes:

Project Name: Dingo Soils

[Site Description]

Date:	21/06/2018		**Site:**	DP6	
Location:	Atkinson		**Coordinates:**	E 0730331	N 7381303
Landform Pattern:	Rise		**Micro Relief:**	-	
Landform Element:	Hill slope		**Rock Outcrops:**	-	
Morphological Type:	Mid slope		**S C Fragments:**	21SMS	
Site Disturbance:	2		**Substrate:**	Sedimentary rock	
Erosion:	Stable		**Surface Condition:**	H	
Landform	Elevation:	153	**Permeability:**	2	
	Slope (%):		**Drainage:**	2	
	Relief:		**Run-off:**	4	

[Charlevue]

[Soil Description]

Horizon	Depth (cm)	Boundary	Colour	Mottles	Texture	Coarse Fragments	Structure	Segregations	Consistency	Field pH	
A1	0-11	C	10YR5/3 (D) 10YR3/3 (W)	-	LMC	-	W2PO	-	D4	5	5.8
A3	11-27	S	10YR4/4	-	MC	-	M2SB	-	D5	15	6
B2	27-60		10YR5/6	-	MHC	-	M3LE	-	T6	40	7

Vegetation: F. dissosperma, E. populnea

Notes:

Project Name: Dingo Soils

[Site Description]

Date:	21/06/2018		**Site:**	DP7	
Location:	Atkinson		**Coordinates:**	E 0732069	N 7388338
Landform Pattern:	Plain		**Micro Relief:**	-	
Landform Element:	Plain		**Rock Outcrops:**	-	
Morphological Type:	Flat		**S C Fragments:**	-	
Site Disturbance:	2		**Substrate:**	Sandstone or mudstone	
Erosion:	S		**Surface Condition:**	H	
Landform	Elevation:	155	**Permeability:**	2	
	Slope (%):		**Drainage:**	2	
	Relief:		**Run-off:**	3	

[Geoffrey]

[Soil Description]

Horizon	Depth (cm)	Boundary	Colour	Mottles	Texture	Coarse Fragments	Structure	Segregations	Consistency	Field pH	
A1	0-20	D	10YR4/6	-	SCL	-	W2LE	-	D2	10	5.5
A2e	20-34	A	7.5YR7/3 (D) 7.5YR5/4 (W)	-	FSCL	-	G	-	D1	25	5.5
B2	34-65		10YR4/6	-	SMC	-	M3LE	-	T5	50	7

Vegetation: C. cunninghamiana, E. populnea

Notes:

Project Name: Dingo Soils

[Site Description]

Date:	22/06/2018		**Site:**	DP8	
Location:	Atkinson		**Coordinates:**	E 0730656	N 7378873
Landform Pattern:	Rise		**Micro Relief:**	-	
Landform Element:	Hill slope		**Rock Outcrops:**	-	
Morphological Type:	Upper slope		**S C Fragments:**	-	
Site Disturbance:	4		**Substrate:**	Sandstone or mudstone	
Erosion:	Stable		**Surface Condition:**	H	
Landform	Elevation:	141	**Permeability:**	2	
	Slope (%):	6	**Drainage:**	3	
	Relief:		**Run-off:**	3	

[Geoffrey]

[Soil Description]

Horizon	Depth (cm)	Boundary	Colour	Mottles	Texture	Coarse Fragments	Structure	Segregations	Consistency	Field pH	
Aj	0-32	S	7.5YR5/6 (D) 7.5YR4/3 (W)	-	SL	12SMS	G	-	D1	15	5.5
B	32-60		7.5YR4/6	M31FO	MC	-	W3LE	-	D6	50	6.5

Vegetation: Cleared

Notes:

Project Name: Dingo Soils

[Site Description]

Date:	22/06/2018		**Site:**	**DP9**	
Location:	Atkinson		**Coordinates:**	**E 0731431**	**N 7381263**
Landform Pattern:	Rise		**Micro Relief:**	**-**	
Landform Element:	Hill slope		**Rock Outcrops:**	**- (outcrop up slope DO20)**	
Morphological Type:	Lower slope		**S C Fragments:**	**-**	
Site Disturbance:	2		**Substrate:**	**Quartzite sandstone**	
Erosion:	Stable		**Surface Condition:**	**S**	
Landform	Elevation:	117	**Permeability:**	**3**	
	Slope (%):	5	**Drainage:**	**3**	
	Relief:		**Run-off:**	**3**	

[Geoffrey – shallow phase]

[Soil Description]

Horizon	Depth (cm)	Boundary	Colour	Mottles	Texture	Coarse Fragments	Structure	Segregations	Consistency	Field pH	
A1	0-11	D	7.5YR3/2	-	SL	-	V	-	D1	5	5.5
A2	11-19	C	10YR3/3	-	SL	-	W2AB	-	D2	15	5.5
B2	19-45	C	10YR5/2	M3DOC	SLC	-	W2LE	-	D3	30	5.5
B3	45-55		10YR5/3	M3DOC	SLC	32SM	V	-	D4	50	5.5

Vegetation: A. rhodoxylon and E. crebra

Notes: Soil increases down slope. Quartzite and redder soils up hill. Looks like shallow phase Geoffrey?

Project Name: Dingo Soils

[Site Description]

Date:	22/06/2018		**Site:**	DP10	
Location:	Atkinson		**Coordinates:**	E 0732219	N 7382129
Landform Pattern:	Plain		**Micro Relief:**	-	
Landform Element:	Plain		**Rock Outcrops:**	-	
Morphological Type:	Flat		**S C Fragments:**	14UMVS	
Site Disturbance:	2		**Substrate:**	Quartzite? Q. alluvium?	
Erosion:	S		**Surface Condition:**	H	
Landform	Elevation:	117	**Permeability:**	2	
	Slope (%):	1	**Drainage:**	2	
	Relief:		**Run-off:**	1	

[Charlevue]

[Soil Description]

Horizon	Depth (cm)	Boundary	Colour	Mottles	Texture	Coarse Fragments	Structure	Segregations	Consistency	Field pH	
A1e	0-16	S	7.5YR6/2 (D) 7.5YR4/3 (W)	-	SCL	-	M2LE	-	D2	10	5.5
B21	16-28	C	7.5YR3/4	-	MC	-	M2LE	-	D4	20	6
B22	28-60		10YR4/6	-	MHC	-	W3LE	-	T5	40	6.5
										50	7

Vegetation: E. populnea, F. dissosperma, C. spinarum

Notes: Texture contrast soil. Clay variant, may not be Geoffrey.

Project Name: Dingo Soils

[Site Description]

Date:	22/06/2018		**Site:**	DP11
Location:	Atkinson		**Coordinates:**	E 0733663 / N 7382923
Landform Pattern:	Plain		**Micro Relief:**	-
Landform Element:	Plain		**Rock Outcrops:**	-
Morphological Type:	Flat		**S C Fragments:**	-
Site Disturbance:	2		**Substrate:**	Q. alluvium
Erosion:	Stable		**Surface Condition:**	H
Landform	Elevation:	108	**Permeability:**	2
	Slope (%):	1	**Drainage:**	2
	Relief:		**Run-off:**	2

[Charlevue]

[Soil Description]

Horizon	Depth (cm)	Boundary	Colour	Mottles	Texture	Coarse Fragments	Structure	Segregations	Consistency	Field pH	
A1e	0-12	C	7.5YR3/3 (W) 7.5YR5/3 (D)	-	LC	-	W3LE	-	D5	5	5.5
A2e	12-34	A	7.5YR4/4 (W) 7.5YR6/4 (D)	-	LC	-	V	-	D5	30	5.5
B2	34-70		5YR4/4	-		-	M3LE	-	D5	50	6.5

Vegetation: E. populnea, C. spinarum

Notes:

Project Name: Dingo Soils

[Site Description]

Date:	22/06/2018	**Site:**	DP12
Location:	Atkinson	**Coordinates:**	E 0733811 N 7383903
Landform Pattern:	Rise	**Micro Relief:**	-
Landform Element:	Hill crest	**Rock Outcrops:**	-
Morphological Type:	crest	**S C Fragments:**	-
Site Disturbance:	2	**Substrate:**	Sandstone or mudstone
Erosion:	Stable	**Surface Condition:**	H
Landform	Elevation: 137	**Permeability:**	2
	Slope (%): 3	**Drainage:**	3
	Relief:	**Run-off:**	3

[Geoffrey]

[Soil Description]

Horizon	Depth (cm)	Boundary	Colour	Mottles	Texture	Coarse Fragments	Structure	Segregations	Consistency	Field pH	
A1	0-8	C	10YR4/3	-	SL	-	M3PL	-	D2	5	5
A2e	8-58	A	10YR6/3 (D) 10YR4/3 (W)	-	SL	-	G	-	D1	30	6
A3e	58-63	A	10YR7/2 (D) 10YR5/3 (W)	-	SL	-	V	-	D2	60	6.5
B2	63-70		10YR5/4	M41FOD	MC	12UMS	M3LE	-	D5	66	6.5

Vegetation: E. crebra, C. clarksoniana

Notes: This unit will have low moisture holding capacity, unless water trapped by clay layer.

Project Name: Dingo Soils

[Site Description]

Date:	22/06/18		**Site:**	DP13
Location:	Atkinson		**Coordinates:**	E 0731176 N 7382463
Landform Pattern:	Plain		**Micro Relief:**	-
Landform Element:	Plain		**Rock Outcrops:**	-
Morphological Type:	Flat		**S C Fragments:**	-
Site Disturbance:	2		**Substrate:**	Sandstone or mudstone
Erosion:	Stable		**Surface Condition:**	H
Landform	Elevation:	155	**Permeability:**	1
	Slope (%):	2	**Drainage:**	2
	Relief:		**Run-off:**	2

[Geoffrey]

[Soil Description]

Horizon	Depth (cm)	Boundary	Colour	Mottles	Texture	Coarse Fragments	Structure	Segregations	Consistency	Field pH	
A1	0-12	C	10YR6/3	-	SCL	-	W3PL	-	D2	5	6
A2e	12-38	C	10YR7/4 (D) 10YR5/4 (W)	-	SL	-	V	-	D1	20	5.8
A3e	38-51	A	10YR8/2 (D) 10YR6/4 (W)	-	SL	-	G	-	D1	45	5.5
B2	51-68		10YR5/4	M42DRD	MC	-	M3LE	-	T5	60	6.5

Vegetation: C. clarksoniana, E. crebra, A. rhodoxylon

Notes: Same unit as DP12

Project Name: Dingo Soils

[Site Description]

Date:	22/06/2018		**Site:**	DP14	
Location:	Matt		**Coordinates:**	E 0729800	N 7382699
Landform Pattern:	Alluvial Plain		**Micro Relief:**	-	
Landform Element:	Plain		**Rock Outcrops:**	-	
Morphological Type:	Flat		**S C Fragments:**	-	
Site Disturbance:	2		**Substrate:**	Q. alluvium	
Erosion:	Stable		**Surface Condition:**	H	
Landform	Elevation:	141	**Permeability:**	3	
	Slope (%):	2	**Drainage:**	4	
	Relief:		**Run-off:**	3	

[Barry]

[Soil Description]

Horizon	Depth (cm)	Boundary	Colour	Mottles	Texture	Coarse Fragments	Structure	Segregations	Consistency	Field pH	
A	0-15	D	7.5YR4/3	-	LMC	-	M3PL	-	D4	5	6.5
B21	15-31	D	7.5YR3/3	-	LMC	-	M3SB	-	D4	20	6.5
B22	31-52	D	7.5YR4/4	-	CL	-	M3PO	-	D5	40	6.5
B23	52-85	C	7.5YR4/4	-	LC	-	M3PL	-	D5	70	6.5
B24	85-105		7.5YR3/3	-	LMC	-	M3PO	-	D4	95	6.5

Vegetation: E. populnea, L. hookeri, E. tereticornis

Notes: Alluvial unit

Project Name: Dingo Soils

[Site Description]

Date:	23/06/2018		**Site:**	DP15	
Location:	Atkinson		**Coordinates:**	E 0729898	N 7377652
Landform Pattern:	Rise		**Micro Relief:**	-	
Landform Element:	Hill crest		**Rock Outcrops:**	-	
Morphological Type:	Crest		**S C Fragments:**	-	
Site Disturbance:	2		**Substrate:**	Sandstone or mudstone	
Erosion:	Stable		**Surface Condition:**	S	
Landform	Elevation:	140	**Permeability:**	2	
	Slope (%):	4	**Drainage:**	2	
	Relief:		**Run-off:**	3	

[Geoffrey]

[Soil Description]

Horizon	Depth (cm)	Boundary	Colour	Mottles	Texture	Coarse Fragments	Structure	Segregations	Consistency	Field pH	
A1e	0-10	D	10YR6/3 (D) 10YR4/3 (W)	-	FSL	-	V	-	D2	5	6
A2e	10-40	C	10YR6/4 (D) 10YR5/4 (W)	-	FSL	11UM-S	V	-	D2	20	5.5
A3e	40-50	A	10YR7/3 (D) 10YR5/4 (W)	-	FSL	32UM-S	G	-	D1	45	6
B2	50-55		10YR5/6	M42DRD	MC	-	M2SB	-	D5	55	6.5

Vegetation: E. crebra, E. tesselaris, C. clarksoniana, A. excelsa

Notes: Looks same as DP13 (bleached A horizon), Lots of erosion approximately 100m south. Texture contrast soils are prone to erosion and sensitive to stripping.

Project Name: Dingo Soils

[Site Description]

Date:	23/06/2018		**Site:**	DP16.1	
Location:	Matt		**Coordinates:**	E 0729618	N 7381631
Landform Pattern:	Rise		**Micro Relief:**	-	
Landform Element:	Hill crest		**Rock Outcrops:**	-	
Morphological Type:	Crest		**S C Fragments:**	41UM-S	
Site Disturbance:	2		**Substrate:**	Iron-rich sedimentary	
Erosion:	Stable		**Surface Condition:**	H	
Landform	Elevation:	145	**Permeability:**	3	
	Slope (%):	6	**Drainage:**	5	
	Relief:		**Run-off:**	4	

[James]

[Soil Description]

Horizon	Depth (cm)	Boundary	Colour	Mottles	Texture	Coarse Fragments	Structure	Segregations	Consistency	Field pH	
A1	0-10	D	5YR3/4	-	SCL	11UM-S	W3PL	-	D4	5	6
B21	10-28	D	2.5YR3/6	-	CL	31UM-S	G	-	D3	20	6
B22	28-58		2.5YR3/6	-	CL	51SM-S	M3PO	-	D4	45	6

Vegetation: A. rhodoxylon, C. clarksoniana

Notes: Very red soil on hill. Started as topography increased. Uniform textures throughout.

Project Name: Dingo Soils

[Site Description]

Date:	23/06/2018		**Site:**	DP16.2	
Location:	Matt		**Coordinates:**	E 0729199	N 7381193
Landform Pattern:	Alluvial plain		**Micro Relief:**	-	
Landform Element:	Plain		**Rock Outcrops:**	-	
Morphological Type:	Flat		**S C Fragments:**	Small 1-5mm rounded fm nodules in places	
Site Disturbance:	4		**Substrate:**	Iron-rich sedimentary	
Erosion:	S (eroded stream ~100m away)		**Surface Condition:**	H	
Landform	Elevation:	132	**Permeability:**	3	
	Slope (%):	2	**Drainage:**	3	
	Relief:		**Run-off:**	3	

[Kosh]

[Soil Description]

Horizon	Depth (cm)	Boundary	Colour	Mottles	Texture	Coarse Fragments	Structure	Segregations	Consistency	Field pH	
A	0-9	D	7.5YR4/3	-	CL	-	M2SB	-	D2	5	6.5
B21	9-42	D	5YR3/2	-	MC	14AM	M3LE	-	D5	30	8
B22	42-76		5YR4/4	-	MC	-	M3LE	-	D4	60	8

Vegetation: Cleared, C. spinarum, V. nilotica, E. populnea

Notes: This alluvial plain appears to have formed from reddish hills in the surrounding area (vegetated). Clayey, but different from black vertosol in DP4.

Project Name: Dingo Soils

[Site Description]

Date:	23/06/2018		**Site:**	DP17	
Location:	Matt		**Coordinates:**	E 0729348	N 7381855
Landform Pattern:	Rise		**Micro Relief:**	-	
Landform Element:	Hill slope		**Rock Outcrops:**	-	
Morphological Type:	Mid slope		**S C Fragments:**	21RM-S	
Site Disturbance:	2		**Substrate:**	Q. alluvium/colluvium	
Erosion:	Stable		**Surface Condition:**	H	
Landform	Elevation:	139	**Permeability:**	3	
	Slope (%):	4	**Drainage:**	4	
	Relief:		**Run-off:**	3	

[James]

[Soil Description]

Horizon	Depth (cm)	Boundary	Colour	Mottles	Texture	Coarse Fragments	Structure	Segregations	Consistency	Field pH	
A1	0-9	D	5YR3/4	-	CL	-	M2PL	-	D2	5	6
B21	9-28	D	5YR3/4	-	LMC	-	W2AB	-	D3	20	6
B22	28-48	D	2.5YR3/6	-	LC	-	M2SB	-	D3	40	6
B23	48-85		2.5YR3/6	-	LMC	-	M3LE	-	D4	60	6.5
										70	6.5

Vegetation: A. rhodoxylon, E. crebra

Notes: Mid-slope on non-alluvial side of red hill

Project Name: Dingo Soils

[Site Description]

Date:	23/06/2018		**Site:**	**DP18**	
Location:	Matt		**Coordinates:**	**E 0728774**	**N 7381822**
Landform Pattern:	Rise		**Micro Relief:**	**-**	
Landform Element:	Hill slope		**Rock Outcrops:**	**-**	
Morphological Type:	Lower slope		**S C Fragments:**	**-**	
Site Disturbance:	2		**Substrate:**	**Sandstone or mudstone**	
Erosion:	A3		**Surface Condition:**	**H**	
Landform	Elevation:	136	**Permeability:**	**1**	
	Slope (%):	2	**Drainage:**	**3**	
	Relief:		**Run-off:**	**3**	

[Geoffrey - Creek Cutting]

[Soil Description]

Horizon	Depth (cm)	Boundary	Colour	Mottles	Texture	Coarse Fragments	Structure	Segregations	Consistency	Field pH	
Ae	0-45	C	10YR4/3	-	LC	-	V	-	D5	20	5.5
B	45→		10YR6/6	M41DYD	HC	-	S3AB	2NN1	D5	70	7

Vegetation: E. crebra

Notes: Creek cutting site (no samples taken)

Project Name: Dingo Soils

[Site Description]

Date:	23/06/2018		**Site:**	DP19	
Location:	Matt		**Coordinates:**	E 0728412	N 7382010
Landform Pattern:	Rise		**Micro Relief:**	-	
Landform Element:	Foot slope		**Rock Outcrops:**	-	
Morphological Type:	Lower slope		**S C Fragments:**	-	
Site Disturbance:	4		**Substrate:**	Q. alluvium/colluvium	
Erosion:	Stable		**Surface Condition:**	H	
Landform	Elevation:	145	**Permeability:**	2	
	Slope (%):	2	**Drainage:**	3	
	Relief:		**Run-off:**	3	

[Geoffrey]

[Soil Description]

Horizon	Depth (cm)	Boundary	Colour	Mottles	Texture	Coarse Fragments	Structure	Segregations	Consistency	Field pH	
A1	0-10	C	5YR4/2	-	SCL	22UM-S	W2PO	-	D3	5	6.5
A2e	10-22	D	5YR7/1 (D) 5YR4/2 (W)	-	SCL	22UM-S	V	-	D3	15	6.5
A3e	22-48	D	5YR8/1 (D) 5YR6/2 (W)	-	LSC	22RM-S	G	2NN2	D1	30	6.5
B1	48-65	C	5YR6/2	M3FOD	SLMC	12AM-S	W2SB	3NN2	D4	55	6.5
B2	65-85		5YR6/2	M3FOD	MC	-	W2LE		D4	75	6

Vegetation: E. crebra, E. tesselaris, E. populnea, C. brewsteri

Notes: Beige flats/rises (Geoffrey)

Project Name: Dingo Soils

[Site Description]

Date:	23/06/.2018		**Site:**	DP20
Location:	Matt		**Coordinates:**	E 0730151	N 7382804
Landform Pattern:	Rise		**Micro Relief:**	-
Landform Element:	Drainage depression		**Rock Outcrops:**	-
Morphological Type:	Depression		**S C Fragments:**	32UM-S
Site Disturbance:	2		**Substrate:**	Sandstone or mudstone
Erosion:	A3		**Surface Condition:**	H
Landform	Elevation:	153	**Permeability:**	1
	Slope (%):		**Drainage:**	2
	Relief:		**Run-off:**	4

[Geoffrey - Creek Cutting]

[Soil Description]

Horizon	Depth (cm)	Boundary	Colour	Mottles	Texture	Coarse Fragments	Structure	Segregations	Consistency	Field pH	
A1e	0-20	C	10YR4/3	-	SL	-	V	-	D4	10	5
B2	20→		10YR6/6	M41DYD	MHC	-	M3LE	2NN1	D5	50	6.5

Vegetation: A. rhodoxylon, E. crebra

Notes: Creek cutting, same as DP18/19 (Geoffrey)

Project Name: Dingo Soils

[Site Description]

Date:	23/06/2018		**Site:**	DP21
Location:	Matt		**Coordinates:**	E 0731807 N 7384730
Landform Pattern:	Plain		**Micro Relief:**	-
Landform Element:	Plain		**Rock Outcrops:**	-
Morphological Type:	Flat		**S C Fragments:**	-
Site Disturbance:	3		**Substrate:**	Q. alluvium/colluvium
Erosion:	Stable		**Surface Condition:**	H
Landform	Elevation:	143	**Permeability:**	2
	Slope (%):	2	**Drainage:**	3
	Relief:		**Run-off:**	2

[Kosh]

[Soil Description]

Horizon	Depth (cm)	Boundary	Colour	Mottles	Texture	Coarse Fragments	Structure	Segregations	Consistency	Field pH	
A1	0-8	C	7.5YR4/3	-	SL	-	W2LE	-	D2	5	6
B1	8-28	C	5YR4/3	-	LMC	-	W3LE	-	D4	20	6
B2	28-70		5YR4/4	-	MC	-	V	-	D5	50	6.5

Vegetation: V. nilotica, C. spinarum, E. tesselaris, E. tereticornis (shrubs)

Notes: Different unit – more blocky structure in top soils than powdery unit (Geoffrey).

Project Name: Dingo Soils

[Site Description]

Date:	23/06/2018		**Site:**	DP22
Location:	Matt		**Coordinates:**	E N
Landform Pattern:	Plain		**Micro Relief:**	-
Landform Element:	Plain		**Rock Outcrops:**	-
Morphological Type:	Flat		**S C Fragments:**	-
Site Disturbance:	4		**Substrate:**	Q. alluvium
Erosion:	Stable		**Surface Condition:**	H
Landform	Elevation:	149	**Permeability:**	2
	Slope (%):	1	**Drainage:**	2
	Relief:		**Run-off:**	2

[Kosh]

[Soil Description]

Horizon	Depth (cm)	Boundary	Colour	Mottles	Texture	Coarse Fragments	Structure	Segregations	Consistency	Field pH	
A1	0-10	C	5YR4/3	-	LMC	-	M2AB	-	D4	5	6
A2e	10-22	A	5YR6/2 (D) 5YR4/2 (W)	-	LC	-	V	-	D4	15	6
B2	22-85		7.5YR3/4	-	MHC	-	M4LE	-	T5	40	6
										70	7.5

Vegetation: Cleared with V. nilotica, C. lasiantha

Notes: Different unit to other texture contrast soils. Clay is dark brown not grey, and bleached horizons are very shallow. B2 is soapy.

Project Name: Dingo Soils

[Site Description]

Date:	24/06/2018		**Site:**	DP23	
Location:	Matt		**Coordinates:**	E 0730391	N 7384342
Landform Pattern:	Plain		**Micro Relief:**	-	
Landform Element:	Plain		**Rock Outcrops:**	-	
Morphological Type:	Flat		**S C Fragments:**	-	
Site Disturbance:	4		**Substrate:**	Q. alluvium	
Erosion:	Stable		**Surface Condition:**	H	
Landform	Elevation:	113	**Permeability:**	2	
	Slope (%):	1	**Drainage:**	2	
	Relief:		**Run-off:**	2	

[Kosh]

[Soil Description]

Horizon	Depth (cm)	Boundary	Colour	Mottles	Texture	Coarse Fragments	Structure	Segregations	Consistency	Field pH	
A1	0-10	C	5YR3/3	-	MC	-	W2SB	-	D5	5	6
B21	10-24	D	5YR3/2	-	MHC	-	M3AB	-	D4	15	6
B22	24-44	D	5YR3/3	-	MHC	-	M2LE	-	T4	30	6
B23	44-73		7.5YR3/4	-	MHC	-	M3LE	-	T4	50	6.5
										70	7.5

Vegetation: Cleared with V. nilotica

Notes: Same as DP22. Soapy B23.

Project Name: Dingo Soils

[Site Description]

Date:	24/06/18		**Site:**	DP24	
Location:	Matt		**Coordinates:**	E 0729605	N 7383991
Landform Pattern:	Plain or alluvial plain		**Micro Relief:**	-	
Landform Element:	Plain		**Rock Outcrops:**	-	
Morphological Type:	Flat		**S C Fragments:**	-	
Site Disturbance:	4		**Substrate:**	Q. alluvium	
Erosion:	Stable		**Surface Condition:**	H	
Landform	Elevation:	117	**Permeability:**	3	
	Slope (%):	1	**Drainage:**	4	
	Relief:		**Run-off:**	2	

[BOUNDARY]

[Soil Description]

Horizon	Depth (cm)	Boundary	Colour	Mottles	Texture	Coarse Fragments	Structure	Segregations	Consistency	Field pH	
A1	0-10	C	10YR3/4	-	L	-	G	-	D2	5	6.5
A2e	10-23	A	10YR6/3 (D) 10YR4/3 (W)	-	SL	-	M3PL	-	D2	15	6.5
B1	23-54	D	7.5YR4/6	-	SL	-	V	-	D1	35	6.5
B2	54-85		7.5YR5/6	-	SCL	-	W2SB	2MN2	D4	60	6.5
										80	6.5

Vegetation: Cleared. Small E. populnea and C. brewsteri

Notes: Alluvial unit. Closer to river. Sandier soil than DP22/23 – no clay horizon. Potential boundary unit?

Project Name: Dingo Soils

[Site Description]

Date:	24/06/2018		**Site:**	DP25
Location:	Matt		**Coordinates:**	E 0727595 N 7383271
Landform Pattern:	Plain		**Micro Relief:**	-
Landform Element:	Plain		**Rock Outcrops:**	-
Morphological Type:	Flat		**S C Fragments:**	-
Site Disturbance:	4		**Substrate:**	Q. alluvium
Erosion:	Stable		**Surface Condition:**	H
Landform	Elevation:	115	**Permeability:**	2
	Slope (%):	1	**Drainage:**	2
	Relief:		**Run-off:**	2

[Kosh]

[Soil Description]

Horizon	Depth (cm)	Boundary	Colour	Mottles	Texture	Coarse Fragments	Structure	Segregations	Consistency	Field pH	
A1j	0-9	C	5YR6/3 (D) 7.5YR3/4 (W)	-	SCL	-	V	-	D2	5	6
A2e	9-23	D	7.5YR7/4 (D) 7.5YR4/4 (W)	-	SLC	-	V	-	D3	15	6
B1	23-33	C	7.5YR4/4	-	MC	-	M4LE	-	D5	30	6
B2	33-65		5YR3/4	-	MHC	-	W3LE	-	D5	40	7
										60	8

Vegetation: Cleared with V. nilotica, C. lasiantha. More alluvial units seem to have E. populnea (DP24)

Notes: Same as DP22 and DP23 – likely sodic. Soapy B2.

Project Name: Dingo Soils

[Site Description]

Date:	24/06/2018		**Site:**	DP26
Location:	Matt		**Coordinates:**	E 0726714 N 7383558
Landform Pattern:	Rise		**Micro Relief:**	-
Landform Element:	Hill slope		**Rock Outcrops:**	-
Morphological Type:	Upper slope		**S C Fragments:**	-
Site Disturbance:	2		**Substrate:**	Coarse grained sed – iron-rich
Erosion:	Stable		**Surface Condition:**	H
Landform	Elevation:	124	**Permeability:**	2
	Slope (%):	6	**Drainage:**	4
	Relief:		**Run-off:**	4

[Anderson]

[Soil Description]

Horizon	Depth (cm)	Boundary	Colour	Mottles	Texture	Coarse Fragments	Structure	Segregations	Consistency	Field pH	
A1	0-10	D	10YR3/2	-	SL	-	V	-	D2	5	4.5
A2e	10-32	C	10YR6/3 (D) 5YR4/4 (W)	-	SL	33SM	V	-	D2	15	5.0
B21	32-50	D	10YR5/3	M3FR1	MC	-	M2PO	-	D5	35	5.5
B22	50-75		10YR6/2	M4DR2	MC	-	S2AB	-	D4	60	5.5
										70	5.5

Vegetation: E. crebra, A. rhodoxylon

Notes: Almost at crest of hill. Not many hills on this property.

Project Name: Dingo Soils

[Site Description]

Date:	24/06/2018		**Site:**	DP27
Location:	Matt		**Coordinates:**	E 0725835 N 7384918
Landform Pattern:	Rise		**Micro Relief:**	-
Landform Element:	Hill slope		**Rock Outcrops:**	-
Morphological Type:	Lower slope		**S C Fragments:**	-
Site Disturbance:	2		**Substrate:**	Q. alluvium
Erosion:	Stable		**Surface Condition:**	H
Landform	Elevation:	130	**Permeability:**	2
	Slope (%):	3	**Drainage:**	2
	Relief:		**Run-off:**	3

[Kosh]

[Soil Description]

Horizon	Depth (cm)	Boundary	Colour	Mottles	Texture	Coarse Fragments	Structure	Segregations	Consistency	Field pH	
A1	0-9	D	7.5YR4/3	-	CL	-	W1SB	-	D4	5	6
B1	9-25	S	7.5YR4/3	-	MC	-	W2SB	-	D4	15	6
B21j	25-38	C	10YR7/4 (D) 7.5YR4/4 (W)	-	MHC	-	W2LE	-	D3	30	6
B22	38-60		10YR4/6	-	MHC	-	M2LE	-	T5	45	6.5
										60	7.5

Vegetation: E. crebra, E. populnea, C. brewsteri

Notes: Another one like DP22/23 (Kosh). Soapy B22 suggests sodic subsoil.

Project Name: Dingo Soils

[Site Description]

Date:	24/06/2018		**Site:**	DP28	
Location:	Matt		**Coordinates:**	E 0726342	N 7383254
Landform Pattern:	Plain		**Micro Relief:**	-	
Landform Element:	Plain		**Rock Outcrops:**	-	
Morphological Type:	Flat		**S C Fragments:**	-	
Site Disturbance:	4		**Substrate:**	Q. alluvium	
Erosion:	Stable		**Surface Condition:**	H	
Landform	Elevation:	122	**Permeability:**	2	
	Slope (%):	2	**Drainage:**	2	
	Relief:		**Run-off:**	2	

[BOUNDARY]

[Soil Description]

Horizon	Depth (cm)	Boundary	Colour	Mottles	Texture	Coarse Fragments	Structure	Segregations	Consistency	Field pH	
A1	0-8	D	7.5YR4/3	-	SL	-	W2AB	-	D2	5	7.5
A2j	8-28	D	7.5YR6/4 (D) 7.5YR4/4 (W)	-	SL	-	V	-	D2	20	6.5
A3j	28-44	A	5YR6/4 (D) 5YR4/6 (W)	-	SL	-	V	-	D3	35	6
B2	44-75		5YR4/4	-	MC	-	M2LE	-	T5	50	5.5
										65	6

Vegetation: Cleared, A. salicina, E. populnea shrubs

Notes: Appears to be different unit. Deep surface soils. Red clay subsoil. Neutral surface with acidic subsurface. Could be Kosh/Anderson?

Project Name: Dingo Soils

[Site Description]

Date:	24/06/2018		**Site:**	DP29	
Location:	Matt		**Coordinates:**	E 0727377	N 7382782
Landform Pattern:	Alluvial plain		**Micro Relief:**	-	
Landform Element:	Levee		**Rock Outcrops:**	-	
Morphological Type:	Depression/flat		**S C Fragments:**	-	
Site Disturbance:	2		**Substrate:**	Q. alluvium	
Erosion:	Stable		**Surface Condition:**	H	
Landform	Elevation:	124	**Permeability:**	3	
	Slope (%):	3	**Drainage:**	4	
	Relief:		**Run-off:**	4	

[Barry]

[Soil Description]

Horizon	Depth (cm)	Boundary	Colour	Mottles	Texture	Coarse Fragments	Structure	Segregations	Consistency	Field pH	
A1	0-15	D	7.5YR3/3	-	MC	-	M3PO	-	D2	8	6
B21	15-33	D	7.5YR4/4	-	MHC	-	M3PO	-	D3	25	6
B22	33-80		7.5YR3/2	-	MC	-	M4PO	-	D3	40	6
										60	6
										80	6

Vegetation: E. tesselaris, E. populnea, L. hookeri, C. spinarum, C. brewsteri

Notes: Alluvial unit

Project Name: Dingo Soils

[Site Description]

Date:	24/06/18		**Site:**	DP30	
Location:	Matt		**Coordinates:**	E 0728190	N 7383971
Landform Pattern:	Rise		**Micro Relief:**	-	
Landform Element:	Hill slope		**Rock Outcrops:**	-	
Morphological Type:	Mid slope		**S C Fragments:**	-	
Site Disturbance:	2-4 (on fence)		**Substrate:**	Sandstone or mudstone	
Erosion:	Stable		**Surface Condition:**	L	
Landform	Elevation:	141	**Permeability:**	1	
	Slope (%):	4	**Drainage:**	1	
	Relief:		**Run-off:**	3	

[Geoffrey]

[Soil Description]

Horizon	Depth (cm)	Boundary	Colour	Mottles	Texture	Coarse Fragments	Structure	Segregations	Consistency	Field pH	
A1	0-8	D	7.5YR4/2	-	SL	-	V	-	D2	5	6
A2j	8-30	D	7.5YR6/3 (D) 7.5YR4/3 (W)	-	S	-	G	-	D1	20	6
A3e	30-72	A	7.5YR7/2 (D) 10YR6/3 (W)	-	S	-	G	-	D1	50	6
B2	72-95		10YR6/4	M4DR/OS	MC	-	M2AB	-	T5	80	6
										90	6

Vegetation: A. excelsa, M. leucadendra, P. pubecens, C. clarksoniana

Notes: Same as DP18/19 (Geoffrey) from Atkinson. Pale bleached sands over grey clay with orange mottles.

Project Name: Dingo Soils

[Site Description]

Date:	24/06/2018		**Site:**	DP31	
Location:	Matt		**Coordinates:**	E 0729088	N 3783173
Landform Pattern:	Plain		**Micro Relief:**	-	
Landform Element:	Plain		**Rock Outcrops:**	-	
Morphological Type:	Flat		**S C Fragments:**	-	
Site Disturbance:	4		**Substrate:**	Q. alluvium	
Erosion:	Stable		**Surface Condition:**	H	
Landform	Elevation:	147	**Permeability:**	2	
	Slope (%):	1	**Drainage:**	4	
	Relief:		**Run-off:**	1	

[Kosh]

[Soil Description]

Horizon	Depth (cm)	Boundary	Colour	Mottles	Texture	Coarse Fragments	Structure	Segregations	Consistency	Field pH	
A1	0-8	D	7.5YR4/4	-	CL	-	V	-	D2	5	6.5
A2e	8-25	C	7.5YR6/4 (D) 7.5YR4/4 (W)	-	CL	-	V	-	D2	20	7
B1j	25-38	D	5YR4/6 (D) 5YR4/4 (W)	-	MC	-	W3AB	-	D4	30	6.5
B2	38-80		5YR4/6	-	MC	-	M2LE	-	D5	45	6
										80	6.5

Vegetation: Cleared, C. brewsteri, E. populnea, A. harpophylla, A. salicina

Notes: No alkaline subsoil here. Too close to creek?

Project Name: Dingo Soils

[Site Description]

Date:	24/06/2018		**Site:**	DP32
Location:	Matt		**Coordinates:**	E 0729720 N 7385206
Landform Pattern:	Rise		**Micro Relief:**	-
Landform Element:	Hill slope		**Rock Outcrops:**	-
Morphological Type:	Simple slope		**S C Fragments:**	-
Site Disturbance:	2		**Substrate:**	Sandstone
Erosion:	Stable		**Surface Condition:**	S
Landform	Elevation:		**Permeability:**	1
	Slope (%):		**Drainage:**	2
	Relief:		**Run-off:**	3

[Geoffrey]

[Soil Description]

Horizon	Depth (cm)	Boundary	Colour	Mottles	Texture	Coarse Fragments	Structure	Segregations	Consistency	Field pH	
A1	0-10	C	5YR4/2	-	LS	-	G	-	D1	5	5.5
A2e	10-60	C	5YR7/2 (D) 5YR 5/2 (W)	-	S	-	G	-	D1	35	6
A3j	60-70	A	5YR8/2 (D) 5YR7/3 (W)	-	LS	-	G	-	D1	65	6.5
B2	70-90		5YR7/2	M42DOC	MC	-	M3LE	-	D5	80	7.5

Vegetation: M. leucadendra, C. clarksoniana, C. cunninghamiana, E. tereticornis

Notes: Geoffrey

Project Name: Dingo Soils

[Site Description]

Date:	25/06/2018		**Site:**	DP33	
Location:	Matt		**Coordinates:**	E 0727686	N 7385306
Landform Pattern:	Rise		**Micro Relief:**	-	
Landform Element:	Hill crest		**Rock Outcrops:**	-	
Morphological Type:	Crest		**S C Fragments:**	-	
Site Disturbance:	4		**Substrate:**	Sandstone	
Erosion:	Stable		**Surface Condition:**	F	
Landform	Elevation:	131	**Permeability:**	1	
	Slope (%):	2	**Drainage:**	2	
	Relief:		**Run-off:**	3	

[Geoffrey]

[Soil Description]

Horizon	Depth (cm)	Boundary	Colour	Mottles	Texture	Coarse Fragments	Structure	Segregations	Consistency	Field pH	
A1	0-10	C	5YR3/3	-	LS	-	V	-	D2	5	6
A2	10-70	D	5YR4/6	-	S	-	G	-	D1	40	6
A3j	70-83	A	7.5YR6/6 (D) 7.5YR5/6 (W)	-	S	-	G	-	D2	75	6
B2	83-100		7.5YR5/3	M42PRS	MHC	-	M5LE	-	T5	90	5.5

Vegetation: Cleared. A. harpophylla saplings, nearby veg C. clarksoniana, C. cunninghamiana, M. leucadendra

Notes: Sand appears less obviously bleached at crest vs. mid-lower slopes. Water available for less time. Mottling very prominent, though only red – no orange. Less variable water table.

Project Name: Dingo Soils

[Site Description]

Date:	25/06/2018		**Site:**	DP34
Location:	Matt		**Coordinates:**	E 0728311 N 7385163
Landform Pattern:	Rise		**Micro Relief:**	-
Landform Element:	Foot slope		**Rock Outcrops:**	-
Morphological Type:	Lower slope		**S C Fragments:**	-
Site Disturbance:	4		**Substrate:**	Q. alluvium
Erosion:	Stable		**Surface Condition:**	H
Landform	Elevation:	117	**Permeability:**	2
	Slope (%):	2	**Drainage:**	2
	Relief:		**Run-off:**	3

[Kosh]

[Soil Description]

Horizon	Depth (cm)	Boundary	Colour	Mottles	Texture	Coarse Fragments	Structure	Segregations	Consistency	Field pH	
A1	0-12	D	10YR3/3	-	SCL	-	W3SB	-	D2	5	6
A2e	12-24	C	10YR7/3 (D) 10YR6/3 (W)	-	SCL	-	V	-	D3	17	6
B2	24-80		10YR5/6	-	MHC	-	M2LE	-	T5	30	6
										50	7.5
										70	8

Vegetation: Cleared with V. nilotica, C. spinarum

Notes: Kosh

Project Name: Dingo Soils

[Site Description]

Date:	25/06/2018		**Site:**	DP35
Location:	Matt		**Coordinates:**	E 0730393 / N 7384004
Landform Pattern:	Plain		**Micro Relief:**	-
Landform Element:	Plain		**Rock Outcrops:**	-
Morphological Type:	Flat		**S C Fragments:**	-
Site Disturbance:	2		**Substrate:**	Q. alluvium
Erosion:	Stable		**Surface Condition:**	H
Landform	Elevation:	97	**Permeability:**	2
	Slope (%):	3	**Drainage:**	4
	Relief:		**Run-off:**	3

[Kosh]

[Soil Description]

Horizon	Depth (cm)	Boundary	Colour	Mottles	Texture	Coarse Fragments	Structure	Segregations	Consistency	Field pH	
A1	0-8	D	7.5YR4/3	-	LC	-	V	-	D4	5	6
A2j	8-32	C	7.5YR5/4 (D) 7.5YR3/4 (W)	-	MC	-	W3AB	-	D3	20	6
B2	32-85		7.5YR3/4	-	MHC	-	M3LE	-	T4	40	6
										60	6.5
										80	7.5

Vegetation: E. teritecornis, A. hemiglauca, A. salicina, L. hookeri

Notes: Kosh

Project Name: Dingo Soils

[Site Description]

Date:	25/06/2018		**Site:**	DP36	
Location:	Matt		**Coordinates:**	E 0730325	N 7383633
Landform Pattern:	Alluvial plain		**Micro Relief:**	-	
Landform Element:	Levee		**Rock Outcrops:**	-	
Morphological Type:	Flat		**S C Fragments:**	-	
Site Disturbance:	2		**Substrate:**	Q. alluvium	
Erosion:	AN		**Surface Condition:**	H	
Landform	Elevation:	99	**Permeability:**	4	
	Slope (%):	2	**Drainage:**	4	
	Relief:		**Run-off:**	3	

[Barry]

[Soil Description]

Horizon	Depth (cm)	Boundary	Colour	Mottles	Texture	Coarse Fragments	Structure	Segregations	Consistency	Field pH	
A1	0-18	D	5YR3/4	-	CL	-	W3PL	-	D4	10	6.5
A3	18-70	D	5YR4/4	-	SCL	-	V	-	D3	40	6.5
B2	70-95		5YR3/3	-	SLMC	-	W1LE	-	D4	80	6.5
										95	6.5

Vegetation: E. tesselaris, E. populnea, E. tereticornis

Notes: DP35 is not ALP but PLA, not LEV but PLA.

Project Name: Dingo Soils

[Site Description]

Date:	25/06/2018		**Site:**	DP37
Location:	Beath		**Coordinates:**	E · N
Landform Pattern:	Rise		**Micro Relief:**	-
Landform Element:	Hill Crest		**Rock Outcrops:**	-
Morphological Type:	Crest		**S C Fragments:**	2MN2-S
Site Disturbance:	3		**Substrate:**	Coarse iron sandstone
Erosion:	Stable		**Surface Condition:**	H
Landform	Elevation:		**Permeability:**	3
	Slope (%):		**Drainage:**	3
	Relief:		**Run-off:**	3

[Anderson]

[Soil Description]

Horizon	Depth (cm)	Boundary	Colour	Mottles	Texture	Coarse Fragments	Structure	Segregations	Consistency	Field pH	
A1	0-20	D	5YR4/4	-	CL	-	V	-	D3	10	4.5
A2	20-40	D	5YR4/4	-	LMC	12RM	W2PL	-	D3	30	4.5
B2	40-82	D	5YR4/6	-	LMC	32AM	W1LE	1MN1	D5	60	5.5
B3	82-97		5YR4/6	-	LC	11UM	V	-	D4	90	5.8

Vegetation: E. australe, C. clarksoniana, E. crebra, A. rhodoxylon

Notes: Red soil

Project Name: Dingo Soils

[Site Description]

Date:	25/06/2018		**Site:**	DP38	
Location:	Beath		**Coordinates:**	E 0724862	N 7386456
Landform Pattern:	Rise		**Micro Relief:**	-	
Landform Element:	Hill slope		**Rock Outcrops:**	-	
Morphological Type:	Mid-slope		**S C Fragments:**	-	
Site Disturbance:	3		**Substrate:**	Sandstone	
Erosion:	Stable		**Surface Condition:**	S	
Landform	Elevation:	150	**Permeability:**	2	
	Slope (%):		**Drainage:**	3	
	Relief:		**Run-off:**	3	

[Geoffrey]

[Soil Description]

Horizon	Depth (cm)	Boundary	Colour	Mottles	Texture	Coarse Fragments	Structure	Segregations	Consistency	Field pH	
A1	0-15	C	10YR3/3	-	SLC	-	V	-	D2	5	5.5
A2j	15-55	D	10YR6/3 (D) 10YR5/3 (W)	-	SLC	-	G	-	D1	30	4.5
B1j	55-72	D	10YR7/4 (D) 10YR5/4 (W)	-	SLC	-	V	-	D2	60	4.5
B2	72-90		10YR6/4	M31FO/YD	SLC	-	W2SB	-	D4	90	5

Vegetation: M. leucadendra, Acacia sp.

Notes: This sand is much deeper than other Geoffrey units.

Project Name: Dingo Soils

[Site Description]

Date:	25/06/2018		**Site:**	DP39
Location:	Bradbury		**Coordinates:**	E 0729901 / N 7386161
Landform Pattern:	Rise		**Micro Relief:**	-
Landform Element:	Hill slope		**Rock Outcrops:**	-
Morphological Type:	Mid-slope		**S C Fragments:**	-
Site Disturbance:	2		**Substrate:**	Sandstone
Erosion:	Stable		**Surface Condition:**	S
Landform	Elevation:	141	**Permeability:**	1
	Slope (%):	3	**Drainage:**	2
	Relief:		**Run-off:**	2

[Geoffrey]

[Soil Description]

Horizon	Depth (cm)	Boundary	Colour	Mottles	Texture	Coarse Fragments	Structure	Segregations	Consistency	Field pH	
A1j	0-8	C	10YR6/3 (D) 10YR4/4 (W)	-	LS	-	G	-	D2	5	4.8
A2e	8-36	A	10YR7/4 (D) 10YR4/6 (W)	-	LS	-	G	-	D2	20	4.8
B2	36-72		10YR6/4	M42DOD	MHC	-	M5LE	-	D6	40	6
										55	6
										70	7

Vegetation: C. clarksoniana, A. excelsa, P. pubecens, E. crebra

Notes:

Project Name: Dingo Soils

[Site Description]

Date:	25/06/2018		**Site:**	DP40
Location:	Bradbury		**Coordinates:**	E 0729623 N 7386575
Landform Pattern:	Rise		**Micro Relief:**	-
Landform Element:	Hill crest		**Rock Outcrops:**	-
Morphological Type:	Crest		**S C Fragments:**	-
Site Disturbance:	-		**Substrate:**	Fine sandstone
Erosion:	Stable		**Surface Condition:**	H
Landform	Elevation:	142	**Permeability:**	2
	Slope (%):	3	**Drainage:**	4
	Relief:		**Run-off:**	2

[Ellesmere]

[Soil Description]

Horizon	Depth (cm)	Boundary	Colour	Mottles	Texture	Coarse Fragments	Structure	Segregations	Consistency	Field pH	
A1	0-10	D	7.5YR3/4	-	FSL	-	M3PL	-	D2	5	5
A2	10-20	D	7.5YR3/4	-	SCL	-	G	-	D2	15	4.5
B1	20-40	D	7.5YR4/4	-	LC	-	G	-	D2	30	4.5
B2	40-65	C	5YR4/6		MC	-	M2PO	-	D4	50	5.5
B3	65-87		7.5YR6/3		MC	-	M2PO	-	T5	70	5.5

Vegetation: A. sherleyi

Notes: Similar looking to Geoffrey but with different veg and less sandy. Also highly acidic.

Project Name: Dingo Soils

[Site Description]

Date:	26/06/2018		**Site:**	DP41
Location:	Alan		**Coordinates:**	E 0727396	N 7386922
Landform Pattern:	Plain		**Micro Relief:**	-
Landform Element:	Plain		**Rock Outcrops:**	-
Morphological Type:	Flat		**S C Fragments:**	-
Site Disturbance:	4		**Substrate:**	Sandstone
Erosion:	Stable		**Surface Condition:**	H
Landform	Elevation:	97	**Permeability:**	2
	Slope (%):	1	**Drainage:**	2
	Relief:		**Run-off:**	2

[Kosh – pale varient]

[Soil Description]

Horizon	Depth (cm)	Boundary	Colour	Mottles	Texture	Coarse Fragments	Structure	Segregations	Consistency	Field pH	
A1	0-10	D	5YR4/3	-	L	-	W2SB	-	D3	5	6
A2j	10-30	S	7.5YR7/4	-	L	-	V	-	D4	20	5.5
B21j	30-42	C	7.5YR7/4	-	SMC	-	M2LE	-	D5	35	6
B22	42-82			-	MC	-	M3LE	-	D5	50	7
										80	9

Vegetation: Cleared with C. spinarum and V. nilotica

Notes: Kosh. Not sandy enough for Geoffrey, in correct location for Kosh and has alkaline subsoil.

Project Name: Dingo Soils

[Site Description]

Date:	26/06/2018		**Site:**	DP42	
Location:	Alan		**Coordinates:**	E 0728049	N 7387508
Landform Pattern:	Rise		**Micro Relief:**	-	
Landform Element:	Hill slope		**Rock Outcrops:**	-	
Morphological Type:	Upper slope		**S C Fragments:**	-	
Site Disturbance:	4		**Substrate:**	Sandstone	
Erosion:	Stable		**Surface Condition:**	S	
Landform	Elevation:	98	**Permeability:**	2	
	Slope (%):	5	**Drainage:**	4	
	Relief:		**Run-off:**	3	

[Geoffrey]

[Soil Description]

Horizon	Depth (cm)	Boundary	Colour	Mottles	Texture	Coarse Fragments	Structure	Segregations	Consistency	Field pH	
A1	0-13	D	10YR4/3	-	LS	-	V	-	D1	8	5
A2e	13-44	D	10YR7/4 (D) 10YR5/4 (W)	-	S	-	G	-	D1	30	5
A3e	44-66	C	10YR7/4 (D) 10YR5/4 (W)	-	LS	-	V	-	D2	55	5
B1j	66-97	A	10YR6/4 (D) 10YR5/6 (W)	M22FR/OD	CS	-	W2SB	-	D2	75	6
B2	97-110		10YR6/6	M42DR/OC	SLMC	-	M2LE	-	D4	90	6

Vegetation: Cleared with E. australe and C. clarksoniana shrubs

Notes: Geoffrey.

Project Name: Dingo Soils

[Site Description]

Date:	26/06/2018		**Site:**	DP43
Location:	Alan		**Coordinates:**	E 0727017 / N 7387656
Landform Pattern:	Rise		**Micro Relief:**	-
Landform Element:	Hill crest		**Rock Outcrops:**	-
Morphological Type:	Crest		**S C Fragments:**	-
Site Disturbance:	2		**Substrate:**	Sandstone
Erosion:	Active sheet		**Surface Condition:**	H
Landform	Elevation:	138	**Permeability:**	3
	Slope (%):	3	**Drainage:**	3
	Relief:		**Run-off:**	2

[Nigel]

[Soil Description]

Horizon	Depth (cm)	Boundary	Colour	Mottles	Texture	Coarse Fragments	Structure	Segregations	Consistency	Field pH	
A	0-20	D	10YR3/3	-	S	-	V	-	D1	5	4.8
A2	20-63	D	2.5YR3/6	-	S	-	G	-	D1	30	5.5
B1	63-68	C	2.5YR4/6	-	LS	-	G	-	D2	50	5.5
C	68→				C (laterite pebbles)					60	5.5

Vegetation: A. sherleyi and cleared

Notes: Same as laterite unit from Joan Bradbury's property (Nigel)

Project Name: Dingo Soils

[Site Description]

Date:	26/06/2018		**Site:**	DP44
Location:	Alan		**Coordinates:**	E 0726526 / N 7387223
Landform Pattern:	Rise		**Micro Relief:**	-
Landform Element:	Plain		**Rock Outcrops:**	-
Morphological Type:	Flat		**S C Fragments:**	-
Site Disturbance:	4		**Substrate:**	Sandstone or mudstone
Erosion:	Stable		**Surface Condition:**	S
Landform	Elevation:	146	**Permeability:**	1
	Slope (%):	1	**Drainage:**	4
	Relief:		**Run-off:**	2

[Geoffrey]

[Soil Description]

Horizon	Depth (cm)	Boundary	Colour	Mottles	Texture	Coarse Fragments	Structure	Segregations	Consistency	Field pH	
A1	0-12	D	7.5YR3/4	-	LS	-	V	-	D2	8	6
A2e	12-35	C	10YR6/4 (D) 10YR4/6 (W)	-	S	-	G	-	D2	20	6
A3j	35-67	C	10YR7/4 (D) 10YR5/8 (W)	-	LS	-	W1LE	-	D2	50	6
B2	67-75		10YR5/6	Faint orange	SLMC	-	V	-	D5	70	6

Vegetation: Open clearing, pastures, near E. tesselaris, E. crebra, C. clarksoniana

Notes: Did not reach clay layer but still Geoffrey.

Project Name: Dingo Soils

[Site Description]

Date:	26/06/2018		**Site:**	DP45
Location:	Alan		**Coordinates:**	E 0727775 N 7385854
Landform Pattern:	Rise		**Micro Relief:**	-
Landform Element:	Hill slope		**Rock Outcrops:**	-
Morphological Type:	Upper slope		**S C Fragments:**	-
Site Disturbance:	3		**Substrate:**	Sandstone or mudstone
Erosion:	Stable		**Surface Condition:**	S
Landform	Elevation:	128	**Permeability:**	1
	Slope (%):	3	**Drainage:**	2
	Relief:		**Run-off:**	2

[Geoffrey]

[Soil Description]

Horizon	Depth (cm)	Boundary	Colour	Mottles	Texture	Coarse Fragments	Structure	Segregations	Consistency	Field pH	
A1	0-12	D	7.5YR3/3	-	SL	-	V	-	D1	8	4.8
A2j	12-55	D	7.5YR7/3 (D) 7.5YR464 (W)	-	SL	-	G	-	D1	30	5
A3e	55-61	A	10YR7/4 (D) 10YR6/3 (W)	-	S	-	G	-	D1	55	6
B2	61-73		10YR6/2	42PRC	MC	-	M3LE	-	D5	70	6

Vegetation: E. crebra, C. clarksoniana, Acacia spp.

Notes: Did not sample this site.

Project Name: Dingo Soils

[Site Description]

Date:	26/06/2018		**Site:**	DP46	
Location:	Alan		**Coordinates:**	E 0727034	N 7386292
Landform Pattern:	Drainage depression		**Micro Relief:**	-	
Landform Element:	Levee		**Rock Outcrops:**	-	
Morphological Type:	Depression		**S C Fragments:**	-	
Site Disturbance:	3		**Substrate:**	Q. alluvium	
Erosion:	AW		**Surface Condition:**	H	
Landform	Elevation:	115	**Permeability:**	1	
	Slope (%):	1	**Drainage:**	2	
	Relief:		**Run-off:**	3	

[Geoffrey]

[Soil Description]

Horizon	Depth (cm)	Boundary	Colour	Mottles	Texture	Coarse Fragments	Structure	Segregations	Consistency	Field pH	
A1	0-15	A	10YR4/4	-	LC	-	V	-	D5	10	5.8
A2	15-50	C	10YR4/6 (W) 10YR7/4 (D)	-	MC	-	S3PO	-	D5	40	6
B2	50-70		7.5YR5/6		MC	-	S3AB	2MN2	D5	60	6.5
										100	7

Vegetation: E. teritecornis, Acacia spp.

Notes: Second alluvial unit. Looks like alluvial variant of Geoffrey. Topsoil not as sandy or deep.

Project Name: Dingo Soils

[Site Description]

Date:	27/06/2018		**Site:**	DP47	
Location:	Kevin		**Coordinates:**	E 0732691	N 7384997
Landform Pattern:	Plain		**Micro Relief:**	-	
Landform Element:	Plain		**Rock Outcrops:**	-	
Morphological Type:	Flat		**S C Fragments:**	-	
Site Disturbance:	4		**Substrate:**	Q. alluvium	
Erosion:	Stable		**Surface Condition:**	H	
Landform	Elevation:	90	**Permeability:**	2	
	Slope (%):	2	**Drainage:**	2	
	Relief:		**Run-off:**	2	

[Kosh]

[Soil Description]

Horizon	Depth (cm)	Boundary	Colour	Mottles	Texture	Coarse Fragments	Structure	Segregations	Consistency	Field pH	
A1	0-10	C	10YR3/3	-	CL	-	W3PL	-	D2	5	6.5
A2e	10-21	D	10YR6/3 (D) 7.5YR4/3 (W)	-	CL	-	V	-	D4	15	7
B21j	21-33	C	7.5YR6/4 (D) 7.5YR4/4 (W)	-	MHC	-	W2AB	-	D5	25	7
B22	33-70		7.5YR3/3	-	MHC	-	M3SB	-	D5	40	7
										70	8.5

Vegetation: Cleared with C. lasiantha, V. nilotica, C. spinarum

Notes: Likely Kosh

Project Name: Dingo Soils

[Site Description]

Date:	27/06/2018		**Site:**	DP48
Location:	Kevin		**Coordinates:**	E 0732221 N 7386415
Landform Pattern:	Rise		**Micro Relief:**	-
Landform Element:	Hill slope		**Rock Outcrops:**	-
Morphological Type:	Upper slope		**S C Fragments:**	-
Site Disturbance:	4		**Substrate:**	Iron-rich sandstone
Erosion:	Stable		**Surface Condition:**	S
Landform	Elevation:	95	**Permeability:**	4
	Slope (%):	3	**Drainage:**	5
	Relief:		**Run-off:**	2

[Normanby]

[Soil Description]

Horizon	Depth (cm)	Boundary	Colour	Mottles	Texture	Coarse Fragments	Structure	Segregations	Consistency	Field pH	
A1	0-7	C	2.5YR4/4	-	LS	-	G	-	D1	5	6.5
A2	7-23	D	2.5YR3/3	-	LS	-	V	-	T2	15	6.5
B1	23-75	D	10R4/6	-	LS	-	V	-	T3	35	6.5
B2	75-90		10R4/6	-	SLMC	-	W1LE	-	T3	80	7

Vegetation: E. crebra, A. oleifolius, cleared

Notes: Red earth occupies upper slope in this area

Project Name: Dingo Soils

[Site Description]

Date:	27/06/2018		**Site:**	DP49
Location:	Bradbury		**Coordinates:**	E 0730993 N 7387688
Landform Pattern:	Rise		**Micro Relief:**	-
Landform Element:	Hill slope		**Rock Outcrops:**	-
Morphological Type:	Simple slope		**S C Fragments:**	-
Site Disturbance:	3		**Substrate:**	Sandstone
Erosion:	Stable		**Surface Condition:**	F
Landform	Elevation:	107	**Permeability:**	1
	Slope (%):	4	**Drainage:**	2
	Relief:		**Run-off:**	3

[Geoffrey]

[Soil Description]

Horizon	Depth (cm)	Boundary	Colour	Mottles	Texture	Coarse Fragments	Structure	Segregations	Consistency	Field pH	
A1	0-10	C	7.5YR4/3	-	LS	-	V	-	D2	5	5.5
A2e	10-36	D	10YR4/3 (W) 10YR6/3 (D)	-	LS	-	V	-	D1	25	6
A3e	36-54	A	10YR8/2 (D) 10YR6/4 (W)	-	LS	-	G	-	D1	45	6
B2	54-80		10YR6/3	32DY	MHC	-	M3LE	-	T4	60	7
										80	7

Vegetation: C. cunninghamiana, E. teritecornis

Notes: Geoffrey

Project Name: Dingo Soils

[Site Description]

Date:	26/06/2018		**Site:**	DP50	
Location:	Bradbury		**Coordinates:**	E 0731220	N 7385733
Landform Pattern:	Plain		**Micro Relief:**	-	
Landform Element:	Plain		**Rock Outcrops:**	-	
Morphological Type:	Flat		**S C Fragments:**	-	
Site Disturbance:	4		**Substrate:**	Iron-rich sandstone	
Erosion:	Stable		**Surface Condition:**	S	
Landform	Elevation:	119	**Permeability:**	3	
	Slope (%):	2	**Drainage:**	4	
	Relief:		**Run-off:**	2	

[Normanby]

[Soil Description]

Horizon	Depth (cm)	Boundary	Colour	Mottles	Texture	Coarse Fragments	Structure	Segregations	Consistency	Field pH	
A1	0-8	D	5YR4/3	-	SL	-	V/G	-	D1	5	6
A2	8-23	D	2.5YR4/3	-	SL	-	G	-	D2	15	6
B21	23-54	D	2.5YR4/6	-	SL	-	G	-	D2	35	6
B22	54-73		2.5YR3/6	-	SL	-	W1LE	-	D2	60	6

Vegetation: Cleared with E. crebra

Notes:

Project Name: Dingo Soils

[Site Description]

Date:	27/06/2017		**Site:**	DP51
Location:	Bradbury		**Coordinates:**	E 0729334 N 7387801
Landform Pattern:	Rise		**Micro Relief:**	-
Landform Element:	Hill slope		**Rock Outcrops:**	-
Morphological Type:	Simple slope		**S C Fragments:**	-
Site Disturbance:	2		**Substrate:**	Iron rich sandstone
Erosion:	Stable		**Surface Condition:**	S
Landform	Elevation:	150	**Permeability:**	3
	Slope (%):	3	**Drainage:**	4
	Relief:		**Run-off:**	2

[Nigel]

[Soil Description]

Horizon	Depth (cm)	Boundary	Colour	Mottles	Texture	Coarse Fragments	Structure	Segregations	Consistency	Field pH	
A1	0-11	C	10YR4/4	-	LS	-	V	-	D1	5	5
A2j	11-30	D	5YR3/3 (W) 7.5YR5/6 (D)	-	LS	-	G	-	D2	20	5
A3j	30-45	D	10YR5/8	-	SCL	-	G	-	D2	35	5.5
B2	45-76	C	10YR5/6	-	SLC	-	V	-	D3	60	5.5
C	76-86									80	6

Vegetation: M. leucadendra, C. clarksoniana, E. tesselaris, Acacia sp.

Notes:

Project Name: Dingo Soils

[Site Description]

Date:	27/06/2018		**Site:**	DP52	
Location:	Bradbury		**Coordinates:**	E 0729292	N 7388122
Landform Pattern:	Rise		**Micro Relief:**	-	
Landform Element:	Hill slope		**Rock Outcrops:**	-	
Morphological Type:	Crest		**S C Fragments:**	-	
Site Disturbance:	1		**Substrate:**	Laterite	
Erosion:	Stable		**Surface Condition:**	S	
Landform	Elevation:	148	**Permeability:**	3	
	Slope (%):	5	**Drainage:**	3	
	Relief:		**Run-off:**	3	

[Nigel]

[Soil Description]

Horizon	Depth (cm)	Boundary	Colour	Mottles	Texture	Coarse Fragments	Structure	Segregations	Consistency	Field pH	
A1	0-22	D	7.5YR3/4	-	LS	-	V	-	D2	10	5.5
A2j	22-40	C	5YR4/6 (W) 7.5YR5/8 (D)	-	CS	-	V	-	D1	30	5
B2	40-60	D	7.5YR4/4	-	CS	-	W2PO	-	D1	50	5.5
B3	60-75		10YR4/6	-	CS	-	V	1MN2	D2	70	6

Vegetation: A. rhodoxylon, E. crebra

Notes: Unit is rosewood laterite

Project Name: Dingo Soils

[Site Description]

Date:	27/06/2018		**Site:**	DP53
Location:	Bradbury		**Coordinates:**	E 0728508 N 7388239
Landform Pattern:	Rise		**Micro Relief:**	-
Landform Element:	Hill slope		**Rock Outcrops:**	-
Morphological Type:	Upper slope		**S C Fragments:**	-
Site Disturbance:	2		**Substrate:**	Sandstone or mudstone
Erosion:	Stable		**Surface Condition:**	H
Landform	Elevation:	120	**Permeability:**	1
	Slope (%):	4	**Drainage:**	2
	Relief:		**Run-off:**	4

[Geoffrey]

[Soil Description]

Horizon	Depth (cm)	Boundary	Colour	Mottles	Texture	Coarse Fragments	Structure	Segregations	Consistency	Field pH	
A1	0-10	D	7.5YR3/3	-	FSL	-	V	-	D1	5	6
A2j	10-24	D	10YR3/3 (D) 10YR6/2 (W)	-	CS	-	G	-	D1	18	6
A3e	24-42	A	10YR7/2 (D) 7.5YR5/3 (W)	-	LS	-	G	-	D1	35	5.5
B2	42-58		10YR5/2		MC	-	M3LE	-	D5	50	6

Vegetation: E. populnea, C. spinarum

Notes:

Project Name: Dingo Soils

[Site Description]

Date:	28/06/2018		**Site:**	DP54	
Location:	Bradbury		**Coordinates:**	E 0731040	N 7386289
Landform Pattern:	Plain		**Micro Relief:**	-	
Landform Element:	Plain		**Rock Outcrops:**	-	
Morphological Type:	Flat		**S C Fragments:**	-	
Site Disturbance:	4		**Substrate:**	Sandstone or mudstone	
Erosion:	Stable		**Surface Condition:**	L	
Landform	Elevation:	112	**Permeability:**	1	
	Slope (%):	1	**Drainage:**	2	
	Relief:		**Run-off:**	2	

[Geoffrey]

[Soil Description]

Horizon	Depth (cm)	Boundary	Colour	Mottles	Texture	Coarse Fragments	Structure	Segregations	Consistency	Field pH	
A1	0-9	C	10YR4/4	-	LS	-	V	-	D1	5	6
A2e	9-29	C	7.5YR7/3 (D) 7.5YR5/3 (W)	-	LS	-	G	-	D2	20	6
A3e	29-38	A	10YR7/3 (D) 7.5YR6/4 (W)	-	LS	-	G	-	D2	35	6
B2	38-45		7.5YR5/3	M42FOD	MHC	-	M2LE	-	D5	45	6.5

Vegetation: Cleared

Notes:

Project Name: Dingo Soils

[Site Description]

Date:	28/06/2018		**Site:**	DP55	
Location:	Atkinson		**Coordinates:**	E 0733270	N 7383687
Landform Pattern:	Ruse		**Micro Relief:**	M and T (biotic)	
Landform Element:	Hill slope		**Rock Outcrops:**	-	
Morphological Type:	Upper slope		**S C Fragments:**	-	
Site Disturbance:	4		**Substrate:**	Mudstone or sandstone	
Erosion:	Stable		**Surface Condition:**	H	
Landform	Elevation:	105	**Permeability:**	1	
	Slope (%):	3	**Drainage:**	2	
	Relief:		**Run-off:**	2	

[Geoffrey]

[Soil Description]

Horizon	Depth (cm)	Boundary	Colour	Mottles	Texture	Coarse Fragments	Structure	Segregations	Consistency	Field pH	
A1	0-10	C	10YR4/3	-	LS	-	V	-	D2	5	6
A2j	10-20	C	10YR6/3 (D) 10YR4/6 (W)	-	LS	-	V	-	D3	15	6
A31j	20-46	S	10YR6/4 (D) 10YR6/4 (W)	-	LS	-	G	-	D2	35	6
A32j	46-52	A	10YR8/3 (D) 7.5YR6/4 (W)	-	LS	-	G	-	D1	48	6
B2	52-62		10YR5/6	-	MHC	-	M2LE	-	T5	60	6.5

Vegetation: Cleared with gum shrubs (C. clarksoniana)

Notes: Lots of uneven ground

Project Name: Dingo Soils

[Site Description]

Date:	28/06/2018		**Site:**	DP56	
Location:	Atkinson		**Coordinates:**	E 0731652	N 7383912
Landform Pattern:	Rise		**Micro Relief:**	-	
Landform Element:	Hill crest		**Rock Outcrops:**	-	
Morphological Type:	Crest		**S C Fragments:**	-	
Site Disturbance:	4		**Substrate:**	Sandstone or mudstone	
Erosion:	Stable		**Surface Condition:**	S	
Landform	Elevation:	103	**Permeability:**	1	
	Slope (%):	2	**Drainage:**	2	
	Relief:		**Run-off:**	3	

[Geoffrey]

[Soil Description]

Horizon	Depth (cm)	Boundary	Colour	Mottles	Texture	Coarse Fragments	Structure	Segregations	Consistency	Field pH	
A1	0-10	C	10YR4/3	-	LS	-	V	-	D1	5	6
A2	10-19	C	10YR5/3	-	LS	-	M2PL	-	D2	15	6
A31e	19-47	D	10YR8/4 (D) 7.5YR6/4 (W)	-	LS	-	V	-	D1	35	6
A32e	47-53	A	10YR8/4 (D) 7.5YR5/4 (W)	-	LS	-	V	-	D2	45	6
B2	53-76		10YR6/6	M31FRD	MHC	-	M3LE	-	T5	55	7

Vegetation: Cleared.

Notes:

Project Name: Dingo Soils

[Site Description]

Date:	28/06/2018		**Site:**	DP57
Location:	Matt		**Coordinates:**	E 0726879 / N 7381963
Landform Pattern:	Rise		**Micro Relief:**	-
Landform Element:	Hill slope		**Rock Outcrops:**	-
Morphological Type:	Mid slope		**S C Fragments:**	-
Site Disturbance:	4		**Substrate:**	Sandstone or mudstone
Erosion:	Stable		**Surface Condition:**	F
Landform	Elevation:	112	**Permeability:**	1
	Slope (%):	3	**Drainage:**	2
	Relief:		**Run-off:**	3

[Geoffrey]

[Soil Description]

Horizon	Depth (cm)	Boundary	Colour	Mottles	Texture	Coarse Fragments	Structure	Segregations	Consistency	Field pH	
A1	0-9	C	7.5YR4/3	-	SCL	-	V	-	D2	5	6
A2	9-23	D	7.5YR6/4	-	SCL	-	V	-	D3	30	6
A31	23-70	C	7.5YR6/6	-	SLC	-	V	-	D3	55	6
A32e	70-80	A	7.5YR5/6	-	SLC	-	G	-	D2	75	6
B2	80-100		7.5YR5/6	M42PRC	MC	-	M2LE	-	T5	100	6.5

Vegetation: Cleared with C. brewsteri

Notes: Higher in landscape = less bleaching and redder soil. (Geoffrey)

Project Name: Dingo Soils

[Site Description]

Date:	28/06/2018		**Site:**	DP58
Location:	Matt		**Coordinates:**	E 0728775 N 7384245
Landform Pattern:	Rise		**Micro Relief:**	-
Landform Element:	Hill slope		**Rock Outcrops:**	-
Morphological Type:	Mid slope		**S C Fragments:**	-
Site Disturbance:	4		**Substrate:**	Sandstone or mudstone
Erosion:	Stable		**Surface Condition:**	S
Landform	Elevation:	131	**Permeability:**	1
	Slope (%):	5	**Drainage:**	2
	Relief:		**Run-off:**	3

[Geoffrey]

[Soil Description]

Horizon	Depth (cm)	Boundary	Colour	Mottles	Texture	Coarse Fragments	Structure	Segregations	Consistency	Field pH	
A1	0-15	C	7.5YR4/4	-	LS	-	V	-	D1	10	6
A2e	15-55	C	7.5YR7/3 (D) 7.5YR6/3 (W)	-	LS	-	V	-	D1	35	6
A3e	55-62	A	7.5YR7/3 (D) 7.5YR5/4 (W)	-	LS	-	V	-	D1	58	6.5
B2	62-66		7.5YR6/3	-	MC	-	W2LE	-	D5	64	7

Vegetation: Cleared, M. leucadendra, C. cunninghamiana, C. clarksoniana

Notes:

Project Name: Dingo Soils

[Site Description]

Date:	28/06/2018		**Site:**	DP59
Location:	Matt		**Coordinates:**	E 0726749 / N 738337
Landform Pattern:	Rise		**Micro Relief:**	-
Landform Element:	Hill slope		**Rock Outcrops:**	-
Morphological Type:	Lower slope		**S C Fragments:**	-
Site Disturbance:	4		**Substrate:**	Fine sandstone
Erosion:	Stable		**Surface Condition:**	F
Landform	Elevation:	144	**Permeability:**	2
	Slope (%):	4	**Drainage:**	3
	Relief:		**Run-off:**	3

[Kosh]

[Soil Description]

Horizon	Depth (cm)	Boundary	Colour	Mottles	Texture	Coarse Fragments	Structure	Segregations	Consistency	Field pH	
A1	0-5	C	7.5YR2.5/3	-	CL	-	W1LE	-	D2	5	6.5
B21	5-24	C	7.5YR3/2	-	CL	-	W2PO	-	D3	15	7
B22j	24-40	C	10YR4/3 (D) 10YR3/3 (W)	-	LC	-	W2AB	-	D3	30	7.5
B23	40-68		10YR3/4	-	MC	-	M3LE	-	D5	45	8
										60	8.5

Vegetation: Cleared with C. lasiantha, C. spinarum

Notes: B23 soapy. (Kosh)

Appendix C Soil Observation Data

Site Name	Date	Latitude	Longitude	Elevation	Soil Unit	Vegetation Notes
DO1	20/06/2018	-23.69	149.24	136.51	Namoi	E. crebra, E. tereticornis
DO2	21/06/2018	-23.69	149.24	136.01	Geoffrey	E. crebra, Acacia spp, C. clarksoniana
DO3	21/06/2018	-23.69	149.25	136.75	Geoffrey	E. populnea
DO4	21/06/2018	-23.67	149.25	129.08	*boundary*	W: A. rhodoxylon E: E. crebra, E. populnea
DO5	21/06/2018	-23.67	149.26	130.10	Wallace	Cleared
DO6	21/06/2018	-23.67	149.26	125.32	Charlevue	E. crebra, E. populnea
DO7	21/06/2018	-23.67	149.26	127.57	*boundary*	Cleared
DO8	21/06/2018	-23.67	149.26	139.19	*boundary*	N: Cleared S: E. crebra, E. populnea, E. tereticornis
DO9	21/06/2018	-23.68	149.25	143.03	Geoffrey	E. crebra, silver wattle, E. exerta
DO10	21/06/2018	-23.68	149.24	172.43	*boundary*	E: E. crebra, A. rhodoxylon
DO11	21/06/2018	-23.68	149.24	168.21	Geoffrey	Cleared
DO12	21/06/2018	-23.68	149.25	163.36	Geoffrey	Cleared
DO13	21/06/2018	-23.68	149.25	157.39	*boundary*	Cleared
DO14	21/06/2018	-23.68	149.26	126.09	Geoffrey	E. crebra. Silver wattle
DO15	21/06/2018	-23.67	149.26	120.15	*boundary*	
DO16	21/06/2018	-23.67	149.26	120.78	*boundary*	Cleared
DO17	21/06/2018	-23.67	149.26		*boundary*	A. rhodoxylon, E. populnea
DO18	21/06/2018	-23.67	149.26	123.08	Wallace	E. populnea, F. dissosperma
DO19	21/06/2018	-23.67	149.26	122.75	*boundary*	Silver leaf iron bark
DO20	21/06/2018	-23.66	149.27	132.22	Unsure	A. rhodoxylon, E. crebra
DO21	21/06/2018	-23.66	149.27	126.74	*boundary*	A. rhodoxylon, E. crebra
DO22	21/06/2018	-23.66	149.27	118.17	Geoffrey	A. rhodoxylon, E. crebra
DO23	22/06/2018	-23.66	149.27	116.85	*boundary*	A. rhodoxylon, E. populnea
DO24	22/06/2018	-23.66	149.27	123.34	Charlevue	E. populnea, A. rhodoxylon, F. dissosperma
DO25	22/06/2018	-23.65	149.28	115.16	Charlevue	E. populnea, A. rhodoxylon, F. dissosperma
DO26	22/06/2018	-23.66	149.28	110.70	*boundary*	E: E. crebra, E. tereticornis W: E. populnea, F. dissosperma
DO27	22/06/2018	-23.65	149.29	107.36	Charlevue	E. populnea, C. spinarum
DO28	22/06/2018	-23.65	149.29	121.09	*boundary*	N: E. crebra S: E. populnea
DO29	22/06/2018	-23.64	149.29	151.43	Geoffrey	E. crebra
DO30	22/06/2018	-23.63	149.29	148.82	Geoffrey	W: E. populnea, C. cunninghamiana E: E. crebra
DO31	22/06/2018	-23.69	149.25	141.68	*boundary*	N: C. cunninghamiana, silver wattle S: C. clarksoniana, E. crebra, E. tesselaris
DO32	22/06/2018	-23.69	149.25	137.70	*boundary*	W: E. populnea, F. dissosperma E: C. cunninghamiana, silver wattle
DO33	22/06/2018	-23.68	149.26	123.72	Geoffrey	E. crebra, E. tesselaris. C. cunninghamiana
DO34	22/06/2018	-23.66	149.25	142.72	Kosh	E. crebra, C. clarksoniana, A. rhodoxylon
DO35	22/06/2018	-23.66	149.25	134.31	Kosh	Cleared with C. spinarum, C. lasiantha, V. nilotica
DO36	22/06/2018	-23.66	149.25	133.08	*boundary*	NW: Cleared with C. spinarum SE: A. rhodoxylon, E. crebra

Site Name	Date	Latitude	Longitude	Elevation	Soil Unit	Vegetation Notes
DO37	22/06/2018	-23.66	149.25	130.55	Kosh	Cleared, C. spinarum, C. lasiantha
DO38	22/06/2018	-23.66	149.23	119.76	Kosh	Cleared, V. nilotica
DO39	22/06/2018	-23.67	149.24	131.19	James	C. clarksoniana, E. crebra Charlevue, A. rhodoxylon
DO40	23/06/2018	-23.66	149.25	136.54	James	E. crebra, A. rhodoxylon
DO41	23/06/2018	-23.66	149.25	130.72	*boundary*	N: A. rhodoxylon S: E. crebra, A. rhodoxylon, E. populnea
DO42	23/06/2018	-23.66	149.25	131.46	James	C. clarksoniana, E. crebra, A. rhodoxylon
DO43	23/06/2018	-23.66	149.24	137.23	*boundary*	W: E. crebra, C. clarksoniana, A. rhodoxylon E: E. crebra, C. clarksoniana
DO44	23/06/2018	-23.66	149.24	133.07	*boundary*	NE: E. crebra, SW: Cleared
DO45	23/06/2018	-23.65	149.24	134.12	Barry	L. hookeri, E. tereticornis, C. cunninghamiana
DO46	23/06/2018	-23.65	149.26	160.48	Geoffrey	E. crebra, A. rhodoxylon, C. brewsteri
DO47	23/06/2018	-23.65	149.26	156.06	Unsure	F. dissosperma, E. populnea
DO48	23/06/2018	-23.65	149.25	146.98	*boundary*	SW: E. crebra, A. rhodoxylon NE: L. hookeri, C. clarksoniana, E. tereticornis
DO49	23/06/2018	-23.66	149.25		*boundary*	SW: E. crebra N: A. rhodoxylon
DO50	23/06/2018	-23.66	149.25	157.90	*boundary*	S: E. crebra N: A. rhodoxylon
DO51	23/06/2018	-23.66	149.26	157.27	Geoffrey	A. rhodoxylon
DO52	23/06/2018	-23.65	149.27	159.55	Geoffrey	E. populnea, E. crebra, A. rhodoxylon
DO53	23/06/2018	-23.64	149.27	154.17	Geoffrey	
DO54	24/06/2018	-23.63	149.21	146.89	Unsure	A. salicina, E. crebra, A. rhodoxylon
DO55	24/06/2018	-23.64	149.22		Anderson	E. crebra, A. rhodoxylon, E. australe
DO56	24/06/2018	-23.64	149.22	125.28	*boundary*	SE: Cleared NW: Cleared with E. crebra, A. rhodoxylon
DO57	24/06/2018	-23.65	149.23	135.23	*boundary*	S: E. populnea, L. hookeri, C. clarksoniana N: DP22 (Kosh)
DO58	24/06/2018	-23.64	149.23	153.93	Geoffrey	M. leucadendra, C. cunninghamiana, silver wattle
DO59	24/06/2018	-23.64	149.23	155.62	Geoffrey	Cleared, silver acacia shrubs
DO60	24/06/2018	-23.63	149.26	101.34	*boundary*	W: C. cunninghamiana, M leucadendra, C. clarksoniana E: Cleared
DO61	24/06/2018	-23.63	149.25	107.73	Geoffrey	Cleared with M. leucadendra
DO62	24/06/2018	-23.63	149.25	117.22	Geoffrey	Cleared with M. leucadendra, C. cunninghamiana
DO63	24/06/2018	-23.63	149.24	121.62	Geoffrey	Cleared
DO64	24/06/2018	-23.63	149.23	120.99	Geoffrey	C. cunninghamiana, M. leucadendra, C. clarksoniana
DO65	24/06/2018	-23.63	149.23	119.36	Geoffrey	Cleared, E. populnea shrubs
DO66	24/06/2018	-23.63	149.24	112.17	*boundary*	Cleared
DO67	24/06/2018	-23.63	149.24	115.92	Kosh	
DO68	24/06/2018	-23.63	149.24	114.36	*boundary*	S: Geoffrey N: Kosh
DO69	24/06/2018	-23.63	149.24	115.14	*boundary*	S: V. nilotica N: gum shrubs
DO70	24/06/2018	-23.63	149.24	114.56	Geoffrey	M. leucadendra, C. clarksoniana
DO71	24/06/2018	-23.63	149.25	101.65	Geoffrey	C. clarksoniana

Site Name	Date	Latitude	Longitude	Elevation	Soil Unit	Vegetation Notes
DO72	24/06/2018	-23.64	149.25	99.67	*boundary*	N: C. clarksoniana, E. populnea S: V. nilotica, C. lasiantha
DO73	24/06/2018	-23.65	149.24	103.09	Kosh	V. nilotica, A. salicina
DO74	24/06/2018	-23.64	149.23	103.96	*boundary*	N: M. leucadendra, silver wattle S: V. nilotica
DO75	25/06/2018	-23.62	149.20	161.90	Anderson	E. austral, C. clarksoniana, E. crebra
DO76	25/06/2018	-23.62	149.21		*boundary*	NE: A. excelsa, M. leucadendra SW: E. australe
DO77	25/06/2018	-23.62	149.21	150.49	Geoffrey	
DO78	25/06/2018	-23.62	149.21	142.42	Geoffrey	M. leucadendra, C. clarksoniana, silver wattle
DO79	25/06/2018	-23.62	149.20	142.41	Barry	E. populnea, A. excelsa
DO80	25/06/2018	-23.62	149.20		Geoffrey	M. leucadendra
DO81	25/06/2018	-23.62	149.26	130.63	Geoffrey	M. leucadendra, C. cunninghamiana, E. australe, E. tesselaris, E. populnea, C. clarksoniana
DO82	25/06/2018	-23.61	149.25	145.47	Geoffrey	A. excelsa, E. crebra, C. clarksoniana, E. australe
DO83	25/06/2018	-23.60	149.25		Nigel	A. rhodoxylon
DO84	25/06/2018	-23.60	149.25	141.34	*boundary*	NW: E. populnea, A. excelsa, C. clarksoniana, E. australe SE: A. rhodoxylon
DO85	25/06/2018	-23.62	149.25	137.74	*boundary*	SE: C. clarksoniana, E. crebra, E. australe, A. excelsa NW: A. sherleyi
DO86	25/06/2018	-23.62	149.22	97.63	Geoffrey	E. tesselaris, E. tereticornis
DO87	25/06/2018	-23.62	149.23	97.59	*boundary*	
DO88	26/06/2018	-23.61	149.23	95.61	Geoffrey	P. pubecens, A. excelsa, E. crebra, E. tesselaris
DO89	26/06/2018	-23.60	149.24	103.38	Geoffrey	A. excelsa, C. clarksoniana, P. pubecens
DO90	26/06/2018	-23.60	149.24		Geoffrey	A. excelsa, C. clarksoniana, P. pubecens
DO91	26/06/2018	-23.60	149.24	97.07	Geoffrey	E. populnea, A. harpophylla, E. tereticornis
DO92	26/06/2018	-23.60	149.23	99.37	Geoffrey	E. populnea, C. lasiantha, C. brewsteri, C. clarksoniana
DO93	26/06/2018	-23.60	149.23	112.69	Geoffrey	Cleared with C. clarksoniana
DO94	26/06/2018	-23.60	149.23	112.07	Geoffrey	E. crebra, C. clarksoniana, A. excelsa, C. cunninghamiana, M. leucadendra
DO95	26/06/2018	-23.61	149.23	125.99	*boundary*	W: Lancewood Ellesmere E: E. crebra, C. clarksoniana, A. excelsa, C. cunninghamiana, M/ leucadendra
DO100	26/06/2018	-23.60	149.22	133.16	*boundary*	NE: Cleared SW: A. sherleyi
DO101	26/06/2018	-23.60	149.22	135.95	Nigel	Lancewood
DO102	26/06/2018	-23.60	149.22		*boundary*	SW: A. excelsa, C. clarksoniana, M. leucadendra, E. crebra NE: A. sherleyi
DO103	26/06/2018	-23.60	149.22	136.65	Geoffrey	
DO104	26/06/2018	-23.60	149.22	139.50	*boundary*	Cleared
DO105	26/06/2018	-23.61	149.22	144.54	*boundary*	
DO106	26/06/2018	-23.61	149.22	144.11	*boundary*	
DO107	26/06/2018	-23.61	149.22	138.97	Nigel	
DO108	26/06/2018	-23.62	149.22	132.74	*boundary*	

Site Name	Date	Latitude	Longitude	Elevation	Soil Unit	Vegetation Notes
DO109	26/06/2018	-23.62	149.22	122.39	Geoffrey	
DO110	26/06/2018	-23.61	149.21	133.53	*boundary*	
DO111	26/06/2018	-23.62	149.23	118.64	Geoffrey	
DO112	26/06/2018	-23.62	149.23	126.91	Geoffrey	
DO113	26/06/2018	-23.62	149.24	131.25	Geoffrey	
DO114	26/06/2018	-23.62	149.24	133.52	Geoffrey	A. excelsa, E. australe, C. clarksoniana, C. cunninghamiana, M. leucadendra
DO115	26/06/2018	-23.62	149.22	114.31	Geoffrey	Cleared with E. populnea and C. spinarum
DO116	26/06/2018	-23.62	149.22		Geoffrey	E. teritecornis
DO117	26/06/2018	-23.62	149.22	110.71	*boundary*	W: Cleared E: E. populnea, E. tereticornis, E. tesselaris
DO118	26/06/2018	-23.61	149.23	109.29	*boundary*	NW: Cleared with gum shrubs SE: Cleared with C. spinarum and C. lasiantha
DO119	26/06/2018	-23.61	149.22	127.46	*boundary*	S: Cleared N: A. rhodoxylon, A. sherleyi, E. crebra
DO200	26/06/2018	-23.61	149.23	113.78	Geoffrey	
DO201	26/06/2018	-23.62	149.22	114.21	Kosh	C. spinarum, E. populnea (shrubs)
DO202	27/06/2018	-23.63	149.28	88.31	*boundary*	E: M. leucadendra, E. crebra W: Cleared with C. spinarum, C. lasiantha and V. nilotica
DO203	27/06/2018	-23.63	149.28	88.35	Barry	E: M. leucadendra, E. crebra, A. hemiglauca W: Cleared with C. spinarum, C. lasiantha and V. nilotica
DO204	27/06/2018	-23.62	149.28		Kosh	L. hookeri, E. tereticornis, A. hemiglauca
DO205	27/06/2018	-23.62	149.28	89.52	*boundary*	Cleared with C. lasiantha
DO206	27/06/2018	-23.62	149.28	90.15	*boundary*	E: Cleared with C. lasiantha W: E populnea S: L. hookeri
DO207	27/06/2018	-23.62	149.28	87.91	*boundary*	NW: C. brewsteri, A. salicina SE: V. nilotica
DO208	27/06/2018	-23.62	149.28	88.71	Normanby	V. nilotica, C. lasiantha
DO209	27/06/2018	-23.62	149.28	96.42	Unsure	
DO210	27/06/2018	-23.62	149.27	98.61	*boundary*	W: E. populnea, A. hemiglauca, E. crebra E: Cleared
DO211	27/06/2018	-23.62	149.27	100.35	*boundary*	
DO212	27/06/2018	-23.62	149.27	99.42	*boundary*	
DO213	27/06/2018	-23.61	149.27	104.48	Geoffrey	M. leucadendra, E. tereticornis, A. excelsa, C. cunninghamiana
DO214	27/06/2018	-23.60	149.26	118.34	*boundary*	S: M. leucadendra, C. cunninghamiana N: A. rhodoxylon
DO215	27/06/2018	-23.60	149.26	118.67	*boundary*	
DO216	27/06/2018	-23.63	149.27	112.48	Geoffrey	N: A. excelsa, P. pubecens, C. clarksoniana, E. crebra S: A. rhodoxylon
DO217	27/06/2018	-23.62	149.26	113.31	Geoffrey	
DO218	27/06/2018	-23.62	149.27	114.90	Geoffrey	E. crebra. C. clarksoniana
DO219	27/06/2018	-23.62	149.27	113.93	*boundary*	SE: C. clarksoniana NW: E. crebra

Site Name	Date	Latitude	Longitude	Elevation	Soil Unit	Vegetation Notes
DO220	27/06/2018	-23.62	149.27	119.20	*boundary*	
DO221	27/06/2018	-23.62	149.27	115.32	Geoffrey	
DO222	27/06/2018	-23.62	149.27	118.86	*boundary*	
DO223	27/06/2018	-23.62	149.26	118.08	*boundary*	W: M. leucadendra, E. tereticornis E: Cleared with E. crebra
DO224	27/06/2018	-23.61	149.25	134.53	*boundary*	N: M. leucadendra, E. tereticornis, A. excelsa, C. cunninghamiana S: A. sherleyi
DO225	27/06/2018	-23.61	149.25	147.83	*boundary*	S: M. leucadendra, E. tereticornis, A. excelsa, C. cunninghamiana N: A. rhodoxylon
DO226	27/06/2018	-23.61	149.26	115.50	Geoffrey	E. tereticornis
DO227	27/06/2018	-23.63	149.26	97.94	Geoffrey	A. rhodoxylon, E. populnea, A. hemiglauca
DO228	27/06/2018	-23.63	149.27	97.28	Geoffrey	
DO229	27/06/2018	-23.63	149.29	107.20	Geoffrey	
DO230	27/06/2018	-23.64	149.29	96.27	Geoffrey	
DO231	27/06/2018	-23.66	149.23	104.96	Kosh	V. nilotica, C. lasiantha, C. spinarum
DO232	28/06/2018	-23.66	149.23	107.90	Geoffrey	
DO233	28/06/2018	-23.67	149.26	109.30	*boundary*	
DO234	28/06/2018	-23.67	149.25	117.29	Unsure	A. rhodoxylon
DO235	28/06/2018	-23.67	149.26	113.80	*boundary*	
DO236	28/06/2018	-23.66	149.26	136.84	*boundary*	N: C. clarksoniana, C. cunninghamiana, M. leucadendra S: A. rhodoxylon
DO237	28/06/2018	-23.64	149.24	128.20	*boundary*	N: Low lying grasses S: longer grasses on rise
DO238	28/06/2018	-23.64	149.22	147.20	Geoffrey	C. brewsteri, E. populnea
DO239	28/06/2018	-23.64	149.22	147.21	Geoffrey	E. populnea, silver wattle, C. clarksoniana
DO240	28/06/2018	-23.64	149.22	142.71	Geoffrey	C. brewsteri, silver wattle
DO241	28/06/2018	-23.64	149.23	148.84	Geoffrey	C. brewsteri, silver wattle
DO243	28/06/2018	-23.65	149.26	150.16	*boundary*	A. rhodoxylon
DO244	28/06/2018	-23.66	149.26	143.69	Charlevue	A. rhodoxylon
DO245	28/06/2018	-23.64	149.23	138.43	Geoffrey	C. brewsteri, silver wattle
DO246	28/06/2018	-23.69	149.26	140.80	Geoffrey	Cleared
DO247	28/06/2018	-23.69	149.26	142.68	Geoffrey	Cleared
DO248	28/06/2018	-23.67	149.26	132.57	Wallace	Cleared
DO249	28/06/2018	-23.64	149.29	124.77	Geoffrey	Cleared
DO250	28/06/2018	-23.64	149.27	119.88	Kosh	Cleared with V. nilotica, C. lasiantha, C. spinarum
DO251	28/06/2018	-23.62	149.28	113.38	Geoffrey	Cleared
DO252	28/06/2018	-23.64	149.28	126.57	Geoffrey	Cleared
DO253	28/06/2018	-23.67	149.24	136.26	James	E. crebra, A. rhodoxylon
DO254	28/06/2018	-23.66	149.23	133.32	Geoffrey	Cleared
DO255	28/06/2018	-23.66	149.24	128.72	Kosh	Cleared with V. nilotica, C. lasiantha, C. spinarum
DO256	28/06/2018	-23.67	149.24	136.77	Geoffrey	Cleared
DO257	28/06/2018	-23.65	149.26	134.96	Geoffrey	
DO258	28/06/2018	-23.68	149.26	134.77	Geoffrey	
DO260	28/06/2018	-23.61	149.26	128.32	Geoffrey	

Site Name	Date	Latitude	Longitude	Elevation	Soil Unit	Vegetation Notes
DO261	28/06/2018	-23.61	149.23	126.20	Geoffrey	
DO262	28/06/2018	-23.62	149.21	143.30	Geoffrey	
DO263	28/06/2018	-23.62	149.21	140.69	Geoffrey	
DO264	28/06/2018	-23.64	149.27	107.58	*boundary*	SE: Cleared NW: Cleared with V. nilotica and C. lasiantha
DO265	28/06/2018	-23.64	149.28		Geoffrey	Cleared with E. populnea
Heavy clay intergrade	28/06/2018	-23.67	149.25	113.92	*boundary*	

Appendix J Terrestrial Ecology Assessment

aarc
ENVIRONMENTAL SOLUTIONS

GEMINI PROJECT
TERRESTRIAL ECOLOGY ASSESSMENT

PREPARED FOR

MAGNETIC SOUTH PTY LTD

DECEMBER 2020

BRISBANE OFFICE
Suite 5, 1 Swann Road
Taringa, QLD 4068
P +61 7 3217 8772

CAIRNS OFFICE
PO Box 4887
Cairns, QLD 4879
P +61 7 4057 9402

E info@aarc.net.au
AARC.NET.AU

ACN. 620 818 920
ABN. 71 620 818 920

AARC Environmental Solutions Pty Ltd

Document History and Status

Issue	Rev.	Issued To	Qty	Date	Reviewed	Approved
Draft	0.1	SG	1	09/2019	SG	SG
Final	0.2	Magnetic South	1	09/2019	PI	PI
Final	0.3	GB	1	09/2019	GB	GB
Final	0.4	GB	1	12/2020	GB	GB

Author: Lucia Lopez
Project Manager: Gareth Bramston
Name of Client: Magnetic South Pty Ltd
Name of Project: Gemini Project
Title of Document: Ecology Terrestrial Assessment
Document Version: Final

Opinions and judgments expressed herein, which are based on our understanding and interpretation of current regulatory standards, should not be construed as legal opinions. Information obtained from interviews and contained in the documentation has been assumed to be correct and complete. AARC Environmental Solutions Pty Ltd does not accept any liability for misrepresentation of information or for items not visible, accessible, nor able to be inspected at the sites at the time of the site visits.

GEMINI PROJECT
TERRESTRIAL ECOLOGY
ASSESSMENT

INDEX

1.0 INTRODUCTION ... 1

1.1 SCOPE OF STUDY ... 1

1.2 PROJECT OVERVIEW ... 1

1.3 REGIONAL SETTING ... 2

1.3.1 Current Land Use ... 3

1.3.2 Local Waterways and Topography ... 3

1.3.3 Geology ... 4

1.3.4 Regional Climate ... 8

2.0 RELEVANT LEGISLATION AND POLICY ... 9

2.1 ENVIRONMENT PROTECTION AND BIODIVERSITY CONSERVATION ACT 1999 ... 9

2.2 NATURE CONSERVATION ACT 1992 ... 9

2.2.1.1 Nature Conservation (Wildlife) Regulation 2006 ... 10

2.2.1.2 Nature Conservation (Wildlife Management) Regulation 2006 ... 10

2.3 BIOSECURITY ACT 2014 ... 10

2.4 VEGETATION MANAGEMENT ACT 1999 ... 10

2.5 BIODIVERSITY STATUS ... 11

2.6 QUEENSLAND ENVIRONMENTAL OFFSETS FRAMEWORK ... 12

3.0 DESKTOP ASSESSMENT ... 14

3.1 VEGETATION ... 15

3.1.1 Regulated Vegetation ... 15

3.1.2 Threatened Ecological Communities ... 15

3.1.3 Regional Ecosystems ... 15

3.2 SPECIES OF CONSERVATION SIGNIFICANCE ... 19

3.2.1 Flora ... 19

3.2.1.1 State and Commonwealth Listed Flora Species ... 19

3.2.1.2 Back on Track Flora Species Prioritisation ... 20

3.3 FAUNA ... 21

3.3.1 State and Commonwealth Listed Fauna Species ... 21

3.3.1.1 Listed Migratory and Marine Species ... 22

3.3.1.2 Back on Track Fauna Species Prioritisation ... 23

3.4 ENVIRONMENTALLY SENSITIVE AREAS ... 24

3.5 WETLANDS ... 25

3.5.1 Groundwater Dependent Ecosystem ... 25

4.0 METHODOLOGY ... 31

4.1 FIELD SURVEY GUIDELINES ... 31

4.2 SURVEY SEASONALITY ... 31

4.3 SURVEY SITE SELECTION ... 32

4.4 FLORA ... 32

4.4.1 Vegetation Mapping and Community Description ... 33

4.4.2 Targeted Searches for Species of Conservation Significance ... 34

4.5 FAUNA ... 36

4.5.1 Fauna Trapping Sites and Survey Locations ... 36

4.5.2 Fauna Survey Sites ... 36

4.5.3 Detection Techniques ... 39

4.5.4 Fauna Survey Effort ... 42

5.0 FLORA RESULTS AND DISCUSSION ... 44

5.1 FLORA SURVEY RESULTS ... 44

5.1.1 VC 1: Narrow-leaved ironbark and Clarkson's bloodwood woodland with a sparse shrub layer on sand plains ... 47

5.1.2 VC 2: Lancewood (*Acacia shirleyi)* and/or Rosewood (*Acacia rhodoxylon)* woodland on lateritic duricrust ... 49

5.1.3 VC 3: Blue gum (*Eucalyptus tereticornis)* or River gum (*Eucalyptus camaldulensis)* with *Bauhinia* spp. and *Casuarina cunninghamiana* fringing woodland on drainage features ... 51

5.1.4 VC 4: Poplar box *(Eucalyptus populnea)* woodland on alluvial plains ... 53

5.1.5 VC 5: Mixed polygon: Ironbark, Bloodwood and Blue gum woodland along ephemeral creeks 55

5.1.6 VC 6: Mixed polygon: Blue gum, Poplar box and Ironbark woodland along ephemeral creeks 56

5.1.7 Non-remnant and Regrowth Vegetation ... 56

5.2 WEEDS OF MANAGEMENT CONCERN ... 57

5.3 FLORA OF CONSERVATION SIGNIFICANCE ... 58

5.3.1 Threatened Ecological Communities not identified in the study area ... 58

5.3.2 Flora Species of Conservation Significance Identified in the Study Area ... 60

5.3.3 Flora Species of Conservation Significance Not Identified in the Study Area ... 62

5.4 WETLANDS ... 63

5.4.1 Groundwater Dependent Ecosystems ... 64

6.0 FAUNA RESULTS AND DISCUSSION ... 65

6.1 FAUNA SURVEY RESULTS ... 65

6.1.1 Amphibians ... 65

6.1.2 Reptiles ... 66

6.1.3 Birds ... 68

6.1.4 Mammals 71
6.2 PEST SPECIES 75
6.3 FAUNA SPECIES OF CONSERVATION SIGNIFICANCE 76
6.3.1 Fauna Species of Conservation Significance Identified in the Study Area 76
6.3.2 Fauna Species of Conservation Significance Not Identified in the Study Area 77
7.0 POTENTIAL IMPACTS 83
7.1 TERRESTRIAL FLORA 83
7.1.1 Vegetation Communities 83
7.1.2 Flora Species of Conservation Significance and Habitat 83
7.1.3 Weed Species 83
7.1.4 Wetlands 83
7.1.5 Groundwater Dependant Ecosystems 84
7.2 TERRESTRIAL FAUNA 84
7.2.1 Fauna Species of Conservation Significance and Habitat 84
7.2.2 Pest Species 86
8.0 MITIGATION AND MANAGEMENT STRATEGIES 88
8.1.1 Terrestrial Flora 88
8.1.1.1 Vegetation Communities 88
8.1.1.2 Flora Species of Conservation Significance 88
8.1.1.3 Weed Species 88
8.1.1.4 Wetlands / GDEs 89
8.1.2 Terrestrial Fauna 89
8.1.2.1 Fauna Species of Conservation Significance 89
8.1.2.2 Pest Species 90
9.0 PROJECT ENVIRONMENTAL OFFSETS 91
9.1 ASSESSMENT OF PRESCRIBED MATTERS IDENTIFIED IN THE STUDY AREA 91
9.1.1 Regulated Vegetation 91
9.1.2 Conservation Significant Species, Protected Wildlife Habitat and Essential Habitat 92
9.1.3 HES Wetland 98
9.2 OFFSETS REQUIREMENTS 99
10.0 REFERENCES 102

LIST OF FIGURES

Figure 1	Project and Study Area Location	5
Figure 2	Waterways and topography associated with the Study Area	6
Figure 3	Regional Setting	7
Figure 4	Mean temperature and rainfall data for the region (Source: SILO)	8
Figure 5	Regulated Vegetation (VM Act) classed as Endangered or Of Concern	17
Figure 6	Regional Ecosystems Vegetation Management Map for the study area	18
Figure 7	Wetland Habitats	27
Figure 8	Potential Terrestrial GDEs (BoM)	28
Figure 9	Potential Aquatic GDEs (BoM)	29
Figure 10	Potential Terrestrial GDEs (DES)	30
Figure 11	Gemini Project flora survey sites	35
Figure 12	Gemini Project Fauna sites	38
Figure 13	Vegetation Communities within the study area	46
Figure 14	Species of Conservation Significance observed within the study area	78
Figure 15	Conceptual Project Layout	87
Figure 16	Vegetation Communities and Disturbance	93
Figure 17	Regulated Vegetation Offsets Requirements	94
Figure 18	Essential Habitat (VM Act)	95

LIST OF TABLES

Table 1	VM Class listing criteria for regional ecosystems	11
Table 2	Biodiversity Status additional listing criteria for regional ecosystems	11
Table 3	Regional Ecosystems mapped within the study area	16
Table 4	Criteria adopted for the likelihood of occurrence determination	19
Table 5	Flora Species of Conservation Significance with the potential to occur within the study area	20
Table 6	Back on Track Priority Flora Species for the Fitzroy NRM Region	20
Table 7	EVNT Fauna species with the potential to occur within the study area	21
Table 8	Listed migratory species with the potential to occur within the study area	22
Table 9	Back on Track Fauna Species from the Fitzroy NRM Region	23
Table 10	Survey effort	43
Table 11	Vegetation Community Overview	44
Table 12	Vegetation Community 1 Profile	47
Table 13	Vegetation Community 2 Profile	50

Table 14 Vegetation Community 3 Profile 51
Table 15 Vegetation Community 4 Profile 53
Table 16 Weed species of management concern identified in the study area 58
Table 17 Flora Species of Conservation Significance not identified in the study area 62
Table 18 Introduced species identified in the study area 76
Table 19 Fauna Species of Conservation Significance not identified in the study area 79
Table 20 Summary of regulated vegetation within the proposed disturbance 92
Table 21 MSES Impact Assessment of the Project on the southern Squatter pigeon 96
Table 22 MSES Impact Assessment of the Project on the Greater glider 97
Table 23 MSES Impact Assessment of the Project on the Short-beaked echidna 97
Table 24 MSES Wetland Significant Residual Impact Assessment 98
Table 25 Summary of Assessment of Prescribed Matters 99
Table 26 MSES Offset Requirements 100

LIST OF PHOTO PLATES

Photo Plate 1 Ironbark and Bloodwood woodland on sand plains 48
Photo Plate 2 VC 1 regrowth patch with *Acacia spp.* 49
Photo Plate 3 Lancewood woodland within the study area 50
Photo Plate 4 Blue gum (*Eucalyptus tereticornis) or River Gum (E. camaldulensis)* woodland along the Charlevue Creek 52
Photo Plate 5 Poplar box *(Eucalyptus populnea)* woodland on alluvial plains 54
Photo Plate 6 VC 5 – RE 11.5.2/11.3.25 55
Photo Plate 7 Non-remnant *Acacia* spp regrowth 57
Photo Plate 8 *Cryptostegia grandiflora* identified in the study area 58
Photo Plate 9 *Cerbera dumicola* at the study area 62
Photo Plate 10 *Melaleuca spp.* dominated HES wetland 64
Photo Plate 11 Common green tree frog (*Litoria caerulea*) observed at DF02 66
Photo Plate 12 *Box-patterned gecko (Lucasium steindachneri)* observed at DF09 67
Photo Plate 13 Freckled monitor (*Varanus tristis orientalis*) observed at DF10 67
Photo Plate 14 Pale-headed snake (*Hoplocephalus bitorquatus*) observed at DF01 68
Photo Plate 15 Brown falcon (*Falco berigora*) observed in the study area 69
Photo Plate 16 Squatter Pigeon (*Geophaps scripta scripta*) observed at the study area 70
Photo Plate 17 Rufous bettong (*Aepyprymnus rufescens*) observed in the study area 73
Photo Plate 18 Short-beaked Echidna (*Tachyglossus aculeatus*) observed in the study area 74
Photo Plate 19 Greater glider (*Petauroides volans*) observed in the study area 75
Photo Plate 20 Feral cat (*Felis catus*) recorded on the camera trap at DF05 76

LIST OF APPENDICES

Appendix A Database Searches .... A
Appendix B Likelihood of Occurrence for Threatened Ecological Communities (TEC) .... B
Appendix C Likelihood of Occurrence for Flora Species of Conservation Significance C
Appendix D Likelihood of Occurrence for Fauna Species of Conservation Significance .... D
Appendix E Fauna Survey Sites .... E
Appendix F Herbarium Identifications .... F
Appendix G Bat Call Analysis .... G
Appendix H Flora Species List .... H
Appendix I Fauna Species List I
Appendix J Weed Species and Management Plans .... J
Appendix K Pest Species and Management Plans .... K

LIST OF ABBREVIATIONS

AARC	AARC Environmental Solutions Pty Ltd
ALA	Atlas of Living Australia
BCA	Biodiversity and Conservation Values report
BOM	Bureau of Meteorology
BoT	Back on Track
BVG	Broad Vegetation Group
C	Least Concern
CE	Critically Endangered
cm	Centimetre
DES	Department of Environment and Science
E	Endangered
EA	Environmental Authority
EPBC Act	Environment Protection and Biodiversity Conservation Act 1999
EPC	Exploration Permit Coal
ESA	Environmental Sensitive Area
ERE	Endangered Regional Ecosystem
EVNT	Endangered, Vulnerable or Near Threatened species
GDE	Groundwater Dependent Ecosystem(s)
GDE Atlas	National Atlas of Groundwater Dependent Ecosystems
GIS	Geographical Information System
GPS	Geographical Positioning System
ha	hectares
HES	High Ecological Significance
LC	Least Concern
mbgl	metre(s) below ground level

mAHD	metre(s) Australian height datum
Ma	Marine
Mi	Migratory
MLES	Matters of Local Environmental Significance
mm	millimetres
MNES	Matters of National Environmental Significance
MSES	Matters of State Environmental Significance
NC Act	Nature Conservation Act 1992
NCWR	Nature Conservation (Wildlife) Regulation 2006
NP	National Park
NRM	Natural Resource Management
NT	Near Threatened
PMAV	Property Maps of Assessible Vegetation
RAD	Recovery Actions Database
ROM	Run of mine
RE	Regional Ecosystem
REDD	Regional Ecosystem Description Database
SILO	Scientific Information for Land Owners
SL	Special Least Concern
SPRAT	Species Profile and Threats Database
TEC	Threatened Ecological Community
V	Vulnerable
VM Act	Vegetation Management Act 1999
VMR	Vegetation Management Regulation 2000
WoNS	Weeds of National Significance

1.0 INTRODUCTION

AARC Environmental Solutions Pty Ltd (AARC) was commissioned by Magnetic South Pty Ltd (Magnetic South) to prepare a terrestrial ecology assessment for the Gemini Project, located approximately 110 km east of Emerald and 125 km west of Rockhampton in the Bowen Basin of Central Queensland (Figure 1). The Project is a proposed metallurgical open-cut coal mine and associated infrastructure, producing Pulverised Coal Injection (PCI) coal Coking Coal products for export for steel production.

In the absence of a defined MLA at the time of the commencement of the ecological studies, an assessment of the terrestrial ecological values was conducted within the broader Exploration Permit Coal (EPC) 881 (herein referred to as the study area). This assessment forms part of the supporting studies required for the Project's approval process.

1.1 SCOPE OF STUDY

To assess the ecological values of terrestrial ecosystems within the study area, the following scope of works was undertaken:

- Database searches to identify species of conservation significance known from the region (provided in Appendix A). These species were targeted during the field survey component of the study;
- Field surveys employing standard methodologies such as the *Terrestrial Vertebrate Fauna Survey Guidelines of Queensland* (Eyre et al. 2018) and *Queensland Herbarium Methodology for Survey and Mapping of Regional Ecosystems and Vegetation Communities in Queensland Version 4.0* (Neldner et al. 2017) to develop an inventory of terrestrial flora and fauna species inhabiting the study area, particularly species of conservation significance[1]; and
- Preparation of an assessment report describing the terrestrial ecological values identified on site, potential impacts of the Project, management strategies to minimise the impacts associated with the proposed mining activities and offset requirements.

1.2 PROJECT OVERVIEW

The main activities associated with the Project include:

- Exploration activities continuing in order to support mine planning;
- Development of a Mine Infrastructure Area (MIA) including mine offices, bathhouse, crib rooms, warehouse/stores, workshop, fuel storage, refuelling facilities, explosives magazine and sewage, effluent and liquid waste storage;
- Construction and operation of a Coal Handling Preparation Plant (CHPP) and coal handling facilities adjacent to the MIA (including Run-of-Mine (ROM) coal and, product stockpiles and rejects bin/overflow [coarse and fine rejects]);

[1] 'Species of conservation significance' or 'threatened species' when referred to within this document are references to species listed as Near Threatened, Vulnerable or Endangered under the Queensland *Nature Conservation Wildlife Regulation 2006* or Vulnerable, Endangered, Critically Endangered or Migratory under the *Environmental Protection and Biodiversity Conservation Act 1999*.

- Construction and operation of a surface conveyor from the product stockpiles to a Train Load Out (TLO) facility and rail loop connecting to the Blackwater-Gladstone Branch Rail to transport product coal to coal terminals at Gladstone for export;

- Construction of access roads from the Capricorn Highway to the MIA, and to the TLO facility;

- Installation of a raw water supply pipeline to connect to the Blackwater Pipeline network;

- Construction of a 66 kilovolt (kV) transmission line and switching/substation to connect to the existing regional network;

- Other associated minor infrastructure, plant, equipment and activities;

- Development of mine areas (open cut pits) and out-of-pit waste rock emplacements;

- Drilling and blasting of competent waste material;

- Mine operations using conventional surface mining equipment (excavators, front end loaders, rear dump trucks, dozers);

- Mining up to 1.9 Million tonnes per annum (Mtpa) ROM Coal – average 1.8 Mtpa for a construction/production period of approximately 20 years;

- Progressive placement of waste rock in:

    - Emplacements, adjacent to and near the open cut voids;

    - Mine voids, behind the advancing open cut mining operations;

- Progressive rehabilitation of waste rock emplacement areas and mined voids;

- Progressive establishment of soil stockpiles, laydown area and borrow pits (for road base and civil works). Material will be sourced from local quarries where required;

- Disposal of CHPP rejects (coarse and fine rejects) in out of pit spoil dumps, and in-pit behind the mining void;

- Progressive development of internal roads and haul roads including a causeway over Charlevue Creek to enable coal haulage and pit access; and

- Development of water storage dams and sediment dams, and the installation of pumps, pipelines, and other water management equipment and structures including temporary levees, diversions and drains.

Existing local and regional infrastructure, facilities and services would be used to support Project activities. These include the SunWater water distribution network, the Blackwater railway system (Aurizon rail network), Ergon's electricity network, the Capricorn Highway, and Gladstone export coal terminals.

1.3 REGIONAL SETTING

The study area is located within the Brigalow Belt bioregion. This bioregion occupies over a fifth of Queensland; from Townsville in the north to near the border of New South Wales in the south. The Brigalow (*Acacia harpophylla*) woodland characterises the Brigalow Belt bioregion but other vegetation such as semi-evergreen vine thickets, dry Eucalypt woodlands and native Bluegrass (*Dichanthium* sp) grasslands are also present. Due to the size of Brigalow Belt bioregion, it covers a broad climatic gradient as well as a diversity of soils and topography; the Brigalow Belt hosts a high diversity flora and fauna (Young et al. 1999; McFarland et al. 1999 cited in DES 2018c).

As a result of agricultural and development activities, most of the relatively undisturbed areas surrounding the study area are confined to the rugged parts of the landscape with lower developmental value (DES 2018c), parks and reserve areas. At a local level, the study area is positioned in relatively flat terrain, dissected by Charlevue Creek, which has a lower elevation than the surrounding land. The Stanley Creek and the Springton Creek, as well as small tributaries associated with the main waterways, also traverse the study area.

Several protected areas and state forest surround the study area (Figure 3). State Forests in Queensland have been traditionally used as a source of supplies such as timber; however, the presence of large areas of remnant vegetation now act as ecological corridors that connect isolated habitats. The Project is situated south of Taunton National Park (Scientific), (Taunton Nation Park), a scientific reserve under the *Land Act 1994 (Queensland)*, established to protect a population of Bridled nail-tail wallabies. Taunton National Park connects to the Walton State Forest via Wallaby Late Nature Refuge, which contains suitable remnant and regrowth remnant areas used by the bridle nail-tail wallaby for feeding and shelter. Walton State Forest connects to the sandstone ridges and plateau located at the west and south of the Project on which is located Arthur's Bluff State Forest, Blackdown Tableland National Park and Dawson Range State Forest. Dawson Range Forest is connected via remnant vegetation, to Duaringa State Forest, which, like Walton State Forest, is not located in the sandstone plateau. State mapped ecological corridors connect all the protected areas mentioned above.

Importantly, none of the described protected areas and state forests are directly connected to the study area, which is comprised of predominately pastureland and fragmented remnant vegetation. This fragmentation is the result of farming activities, including historical vegetation clearing to facilitate grazing and selective logging (e.g. Rosewood (*Acacia rhodoxylon*).

1.3.1 Current Land Use

The land within the study area is currently used for low intensity cattle grazing, small scale selective logging and resource exploration activities. The Capricorn Highway and a number of publicly gazetted roads including Normanby Street, Charlevue Road, Cooinda Road, Red Hill Road, and Ellesmere Road traverse the study area. The Aurizon rail network, which runs parallel to the Capricorn Highway, forms the northern boundary of the Project.

1.3.2 Local Waterways and Topography

The study area lies within the Fitzroy River Basin, which encompasses an area of 142,545 square kilometres (km^2) and contains the Comet, Connors, Dawson, Don, Nogoa and Mackenzie Rivers, which make up its six sub-catchment areas (BoM 2018; DES 2018a). The study area lies within the Mackenzie River sub-catchment, which covers a total area of 12,985 km^2, and is situated in the centre of the Fitzroy River catchment.

The major water body associated with the study area is Charlevue Creek, which traverses the study area in a north-easterly direction. This creek begins within the boundaries of Blackdown Tableland National Park, flowing north-east before joining with Springton Creek and the Fitzroy River, eventually emptying into the Pacific Ocean approximately 46 km north of Gladstone. Stanley Creek and Springton Creek cross the study area in the north-west and south-east, respectively. These two creeks also eventually converge with the Mackenzie River. First and second order streams associated with

Charlevue Creek and Springton Creek also occur in the study area. Figure 2 shows the extent and location of the waterways within the study area.

Springton Creek and Charlevue Creek are defined watercourses under the *Water Act 2000 (Queensland).* Springton Creek and Charlevue Creek within the study area are 5th order streams. Stanley Creek is considered a 2nd order stream.

The topography of the land varies from flat to undulating, with elevation within the study area ranging between 120 metres (m) and 150 m. The landscape is influenced by Charlevue Creek, which has a lower elevation than the adjacent terrain. The topography of the study area is representative of the surrounding region.

1.3.3 Geology

The geology of the region is dominated by its position within the Bowen Basin, one of Queensland's largest depositional regions, which formed through a period of rifting and subsidence lasting from the Early Permian - Mid-Triassic. The area is dominated by clastic sedimentary rocks of marine and lacustrine origin, including sandstones, conglomerates, mudstones, siltstones and coal (Geoscience Australia 2018).

The coastal and inland depositional environments which created these deposits allowed for the formation of extensive coal seams throughout the Bowen Basin, with the anoxic deposition of organic matter subsequently compacted and de-volatised through compression and increased temperatures (Brooks & Smith 1969).

Generally, coal seams found in the east-central part of the basin contain higher quality coking coal deposits, with rank falling below coking range farther south and west (Hutton 2009). The high-quality coal measures are of Permian age, buried less than 60 m from the surface (Mutton 2003).

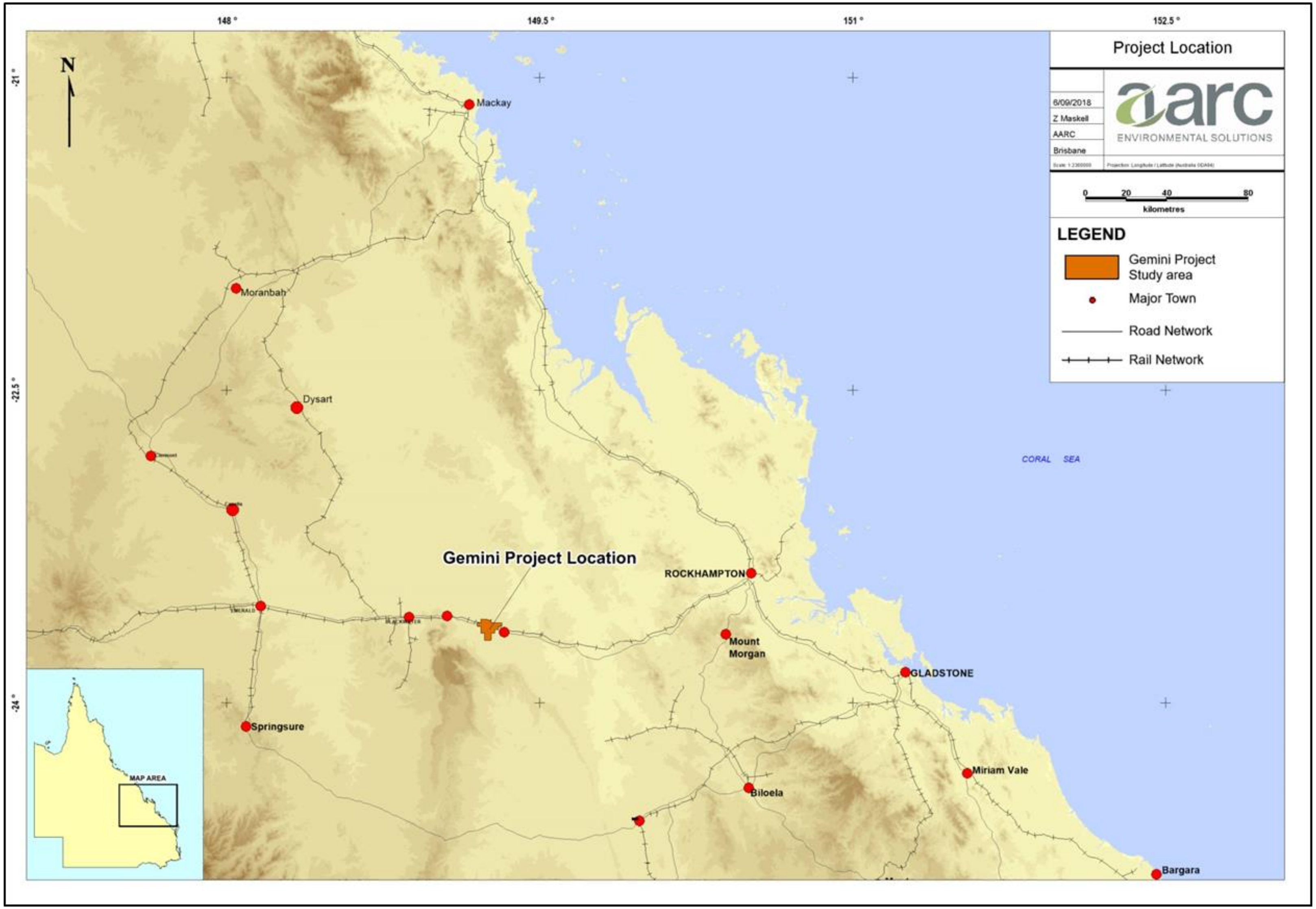


Figure 1 Project and Study Area Location

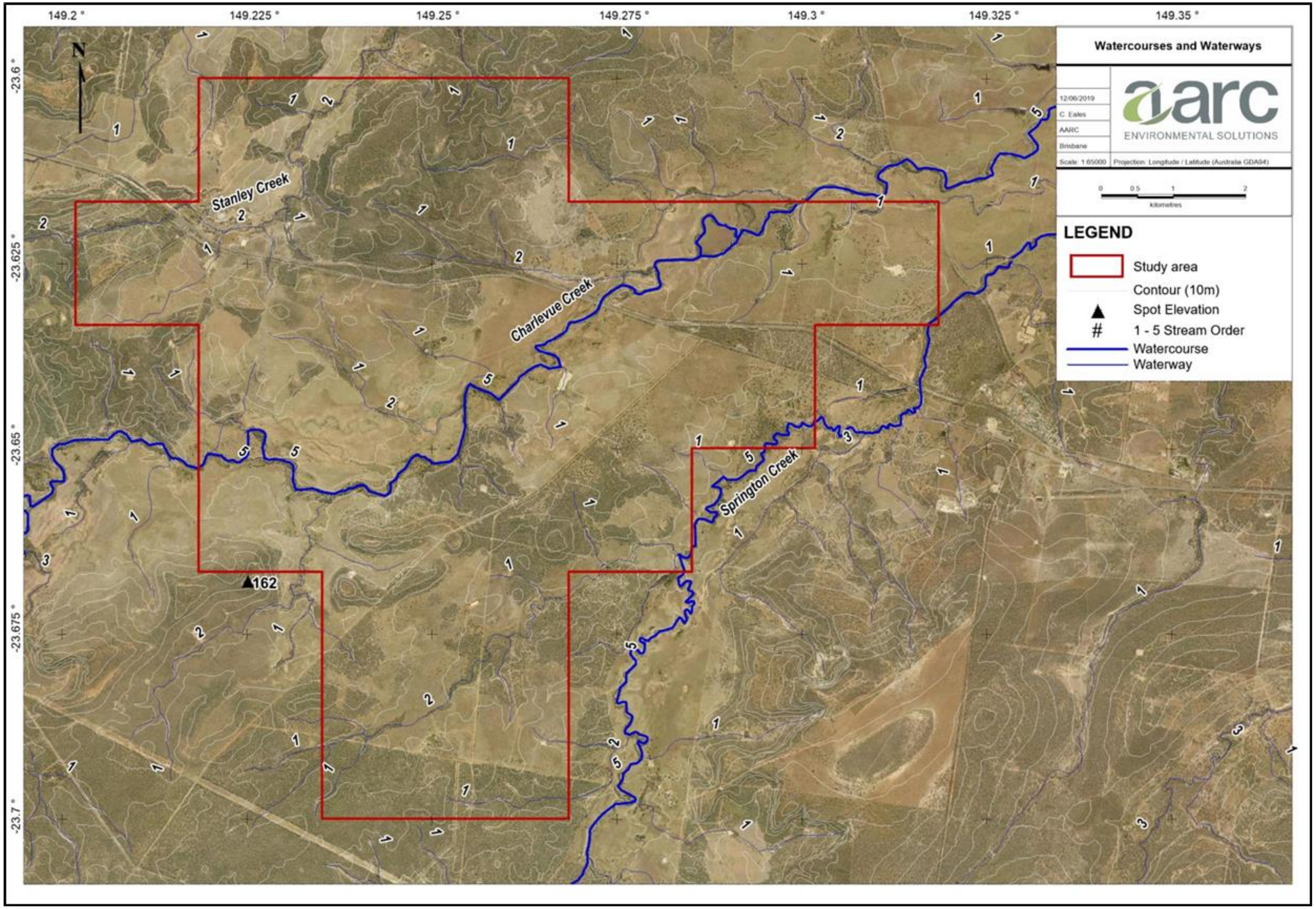


Figure 2 Waterways and topography associated with the Study Area

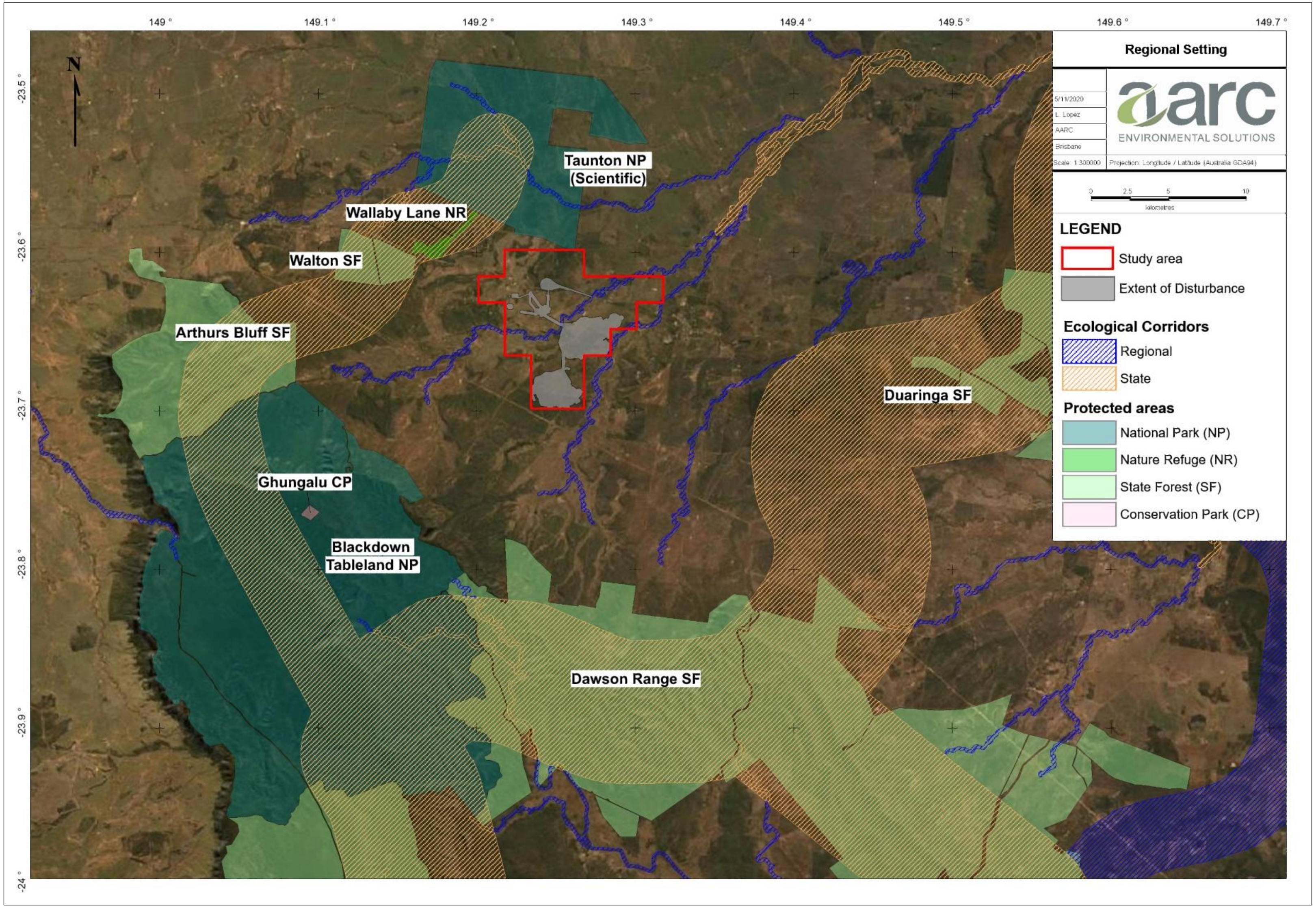


Figure 3 Regional Setting

1.3.4 Regional Climate

The regional climate is classified as semi-arid, characterised with warm, dry summers and warm winters. Climate data for the study area has been sourced from Scientific Information for Land Owners (SILO) climate database (Queensland Government), which operates by interpolating data from the Commonwealth Bureau of Meteorology (BoM) into a single point data drill.

Figure 4 shows the predicted average temperature and rainfall for the area from January 1999 to July 2019. The data indicates the annual mean rainfall for the region is highest between December and March with the maximum average occurring in December (111.5 millimetres (mm)).

The hottest months typically occur between October and March while the coldest months occur between May and September. The highest mean maximum temperature usually occurs in December (34.2 degrees Celsius (°C)) and the lowest mean minimum temperature in July (8.5°C). The mean annual maximum temperature for the region is predicted to be 29.8°C, and the mean annual minimum temperature is predicted to be 16°C.

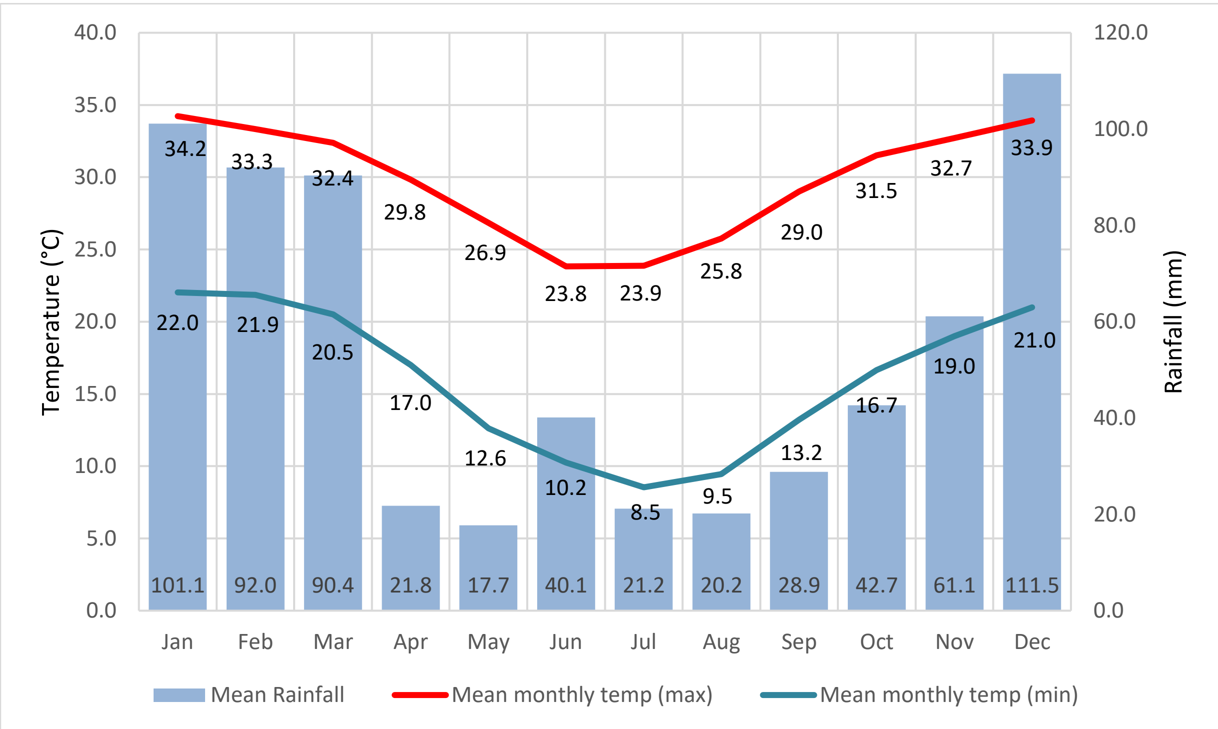


Figure 4 Mean temperature and rainfall data for the region (Source: SILO)

2.0 RELEVANT LEGISLATION AND POLICY

Commonwealth and State legislation and policies relevant to the assessment of terrestrial ecological values in the study area are discussed below.

2.1 ENVIRONMENT PROTECTION AND BIODIVERSITY CONSERVATION ACT 1999

Under the Commonwealth *Environmental Protection and Biodiversity Conservation Act 1999* (EPBC Act), an action requires approval from the Federal Environment Minister if the action has, will have, or is likely to have a significant impact on a Matter of National Environmental Significance (MNES).

An EPBC Referral (2010/5775) was lodged in 2010 for the Gemini Project previously known as the Dingo West Project by Dingo West Pty Ltd, which was declared 'Not a Controlled Action if undertaken in a Particular Manner' in July 2011.

The Particular Manner Decision conditions (EPBC 2010/5775) are as follows:

1. *To prevent downstream impacts to the Fitzroy River Turtle (Rheodytes leukops) the person taking the action must appropriately bund or locate pits in a manner that prevents surface water from entering the pit during a 1:1000 year flood event (as indicated in flood modelling at Attachment A).*

2. *To prevent downstream impacts to the Fitzroy River Turtle (Rheodytes leukops) the person taking the action must appropriately bund or locate dams in a manner that prevents surface water from entering or damaging the dams during a during a 1:1000 year flood event (as indicated in flood modelling at Attachment A).*

The Gemini Project complies with the Particular Manner Decision (EPBC 2010/5775). Furthermore, the level of impact to MNES have been assessed to be no greater than those described in the EPBC Referral (20105775).

The potential impact of the Project on the Fitzroy River Turtle is addressed in the Aquatic Ecology Assessment (AARC 2020).

2.2 NATURE CONSERVATION ACT 1992

The most relevant components of the Queensland *Nature Conservation Act 1992* (NC Act) to the Project, are the sections which pertain to Wildlife and Habitat Conservation. The classes of wildlife to which the NC Act applies includes protected wildlife. According to the NC Act current at the time of the assessment in 2019, protected wildlife was defined as Extinct wildlife; Endangered wildlife; Vulnerable wildlife; Near Threatened wildlife; and Least Concern wildlife.

'Threatening processes' are also relevant to wildlife and habitat conservation. The NC Act defines 'threatening processes' as any process that is capable of:

a) threatening the survival of any protected area, area of major interest, protected wildlife, community of native wildlife or native wildlife habitat; or

b) affecting the capacity of any protected area, area of major interest, protected wildlife, community of native wildlife or native wildlife habitat to sustain natural processes.

The NC Act is relevant to the Project for any protected flora or fauna species (as detailed in the NCWR) found in the study area.

2.2.1.1 Nature Conservation (Wildlife) Regulation 2006

Species listed under the above threatened species classes are published in the associated Nature Conservation (Wildlife) Regulation 2006 (NCWR). This report has considered the recent amendments made to listed threatened species in 2019.

2.2.1.2 Nature Conservation (Wildlife Management) Regulation 2006

The *Nature Conservation (Wildlife Management) Regulation 2006* provides for the management of wildlife, other than wildlife in a protected area.

This regulation also pertains to the clearing, growing, harvesting and trading of protected plants in Queensland. As per Section 282 of the Regulation, a protected plant clearing permit for protected plants (other than in a protected area) may be required for any vegetation clearing of an area containing EVNT species (DES 2019a).

2.3 BIOSECURITY ACT 2014

The Queensland *Biosecurity Act 2014* (Biosecurity Act) provides comprehensive biosecurity measures to safeguard our economy, agricultural and tourism industries, environment and way of life, from pests (e.g. wild dogs and weeds), diseases (e.g. foot-and-mouth disease), and contaminants (e.g. lead on grazing land).

Biosecurity matters are separated into three broad categories:

- A '**prohibited matter'** is a biosecurity matter that is not found in Queensland but would have a significant adverse impact on our health, way of life, and the economy or the environment if it entered the State. Prohibited matters must be reported to Biosecurity Queensland within 24 hours and all reasonable steps taken to minimise the risks of the prohibited matter and not make the situation worse.

- A '**restricted matter'** is a biosecurity matter found in Qld and has a significant impact on human health, social amenity, the economy or the environment. Restricted matters are further broken down into seven categories, with each category placing restrictions on the dealings with the biosecurity matter or actions required to be taken to minimise the spread and adverse impact of the biosecurity matter.

- An '**other matter'** is a biosecurity matter that is not a prohibited or restricted matter. Everyone is obligated to take all reasonable and practical steps to minimise the risks associated with other biosecurity matters under their control.

The Biosecurity Act is relevant to the Project in regard to the control and management of invasive plant and animal species.

2.4 VEGETATION MANAGEMENT ACT 1999

The *Vegetation Management Act 1999 (Qld)* (VM Act) is a part of a planning framework for the management of native vegetation across Qld. The *Vegetation Management Regulation 2012* (VMR) prescribes the status (otherwise known as the Vegetation Management Class (VM Class)) of each of the Regional Ecosystems (RE) identified within Qld.

The specific criteria used to assess the VM Class of RE are defined in Table 1. 'Remnant Vegetation' for an area of Queensland for which there is no RE map or remnant vegetation map, is any vegetation where the predominant canopy:

- covers more than 50% of the undisturbed predominant canopy;
- averages more than 70% of the vegetation's undisturbed height; and
- is composed of species characteristic of the vegetation's undisturbed dominant canopy.

Table 1 VM Class listing criteria for regional ecosystems

VM Class	Criteria
Endangered	• remnant vegetation is less than 10 % of its pre-clearing extent across the bioregion; or • 10–30% of its pre-clearing extent remains and the remnant vegetation is less than 10,000 ha.
Of Concern	• remnant vegetation is 10–30% of its pre-clearing extent across the bioregion; or • more than 30% of its pre-clearing extent remains and the remnant extent is less than 10,000 ha.
Least Concern	• remnant vegetation is over 30% of its pre-clearing extent across the bioregion, and the remnant area is greater than 10,000 ha.

2.5 BIODIVERSITY STATUS

The Department of Environment and Science (DES) Biodiversity Status is a classification assigned to REs and is used for a range of planning and management applications. These applications include the Biodiversity Planning Assessments and the determination of environmentally sensitive areas that are used for regulation of the mining industry through provisions in the *Environmental Protection Act 1994* (EP Act).

The biodiversity status is based on an assessment of the condition of remnant vegetation in addition to the criteria used to determine the class under the VM Act; including other threatening processes, such as reduction in biodiversity; weed invasion; grazing pressures; inappropriate fire management; fragmentation; and infrastructure development.

Table 2 Biodiversity Status additional listing criteria for regional ecosystems

Biodiversity Status	Criteria in addition to VM Class listing
Endangered	• less than 10% of its pre-clearing extent remains unaffected by severe degradation and/or biodiversity loss; or • 10–30% of its pre-clearing extent remains unaffected by severe degradation and/or biodiversity loss and the remnant vegetation is less than 10,000ha; or • it is a rare RE subject to a threatening process.
Of Concern	• 10–30% of its pre-clearing extent remains unaffected by moderate degradation and/or biodiversity loss.

Biodiversity Status	Criteria in addition to VM Class listing
No Concern at Present	• the degradation criteria listed above for 'endangered' or 'of concern' RE are not met.

2.6 QUEENSLAND ENVIRONMENTAL OFFSETS FRAMEWORK

The Queensland environmental offsets framework consists of the *Environmental Offsets Act 2014*, *Environmental Offsets Regulation 2014*, and the *Queensland Environmental Offsets Policy (*Version 1.6) (DES 2018b). The offsets framework requires environmental offsets to be delivered where an activity is likely to result in a significant residual impact on a prescribed environmental matter. The *Significant Residual Impact Guideline* (DES 2014a) is used to determine whether the residual impacts are significant.

Prescribed Environmental Matters include:

- Matters of National Environmental Significance (MNES);
- Matters of State Environmental Significance (MSES) (outlined below); and
- Matters of Local Environmental Significance (MLES).

MSES are defined in Schedule 2 of the *Environmental Offsets Regulation 2014*, and comprise:

- Regulated vegetation including:
  i. REs that are listed as 'Endangered' or 'Of Concern' (under the *Vegetation Management Act 1999* (VM Act));
  ii. REs that intersect areas shown as wetlands on the 'vegetation management wetlands map' (as certified under the VM Act);
  iii. REs located within the defined distance from the defining banks of a relevant watercourse or relevant drainage feature identified on the 'regulated vegetation management watercourse and drainage feature map' (as certified under the VM Act);
  iv. iv. REs mapped as essential habitat on the 'essential habitat map' (as certified under the VM Act) for flora and fauna listed as 'endangered' or 'vulnerable' (under the Nature Conservation Act 1992 (NC Act)); or
  v. A prescribed regional ecosystem is a matter of State environmental significance, for a prescribed activity mentioned in schedule 1, item 7(e)[2], if the ecosystem is an area of essential habitat on the essential habitat map for an animal that is near threatened wildlife or a plant that is near threatened wildlife;
- Remnant REs that contain an area of land required for ecosystem functioning (i.e. a connectivity area);
- Mapped wetlands and watercourses including:
  i. A wetland in a 'wetland protection area'; or of 'high ecological significance' as shown on the 'map of referable wetlands' (as defined under the *Environmental Protection Regulation 2019* (EP Regulation)); or

[2] Prescribed activity mentioned in schedule 1, item 7(e): development for which an environmental offset may be required under the State code 16 (Native vegetation clearing).

   ii. A wetland or watercourse in 'high ecological value waters' (as defined under the *Environmental Protection (Water and Wetland Biodiversity) Policy 2019*);

- Designated precincts in a strategic environmental area under the *Regional Planning Interests Regulation 2014*;
- Protected wildlife habitat, which includes;
   i. High risk areas on the 'flora survey trigger map' that contain 'endangered' or 'vulnerable' plants (under the NC Act;
   ii. Areas (not on the 'flora survey trigger map') that contain 'endangered' or 'vulnerable' plants (under the NC Act);
   iii. Koala habitat area (as defined in the NC Act);
   iv. Habitat for 'endangered', 'vulnerable' and 'special least concern' animals (under the NC Act);
- Protected areas (under the NC Act) and highly protected zones of State marine parks (under the Marine Parks Act 2004);
- Fish habitat areas and waterways providing for fish passage (under the Fisheries Act 1994);
- Waterways providing for fish passage;
- Marine plants (under the Fisheries Act 1994); and
- Legally secured offset areas.

3.0 DESKTOP ASSESSMENT

Several desktop assessments were conducted to collate information on terrestrial ecological values identified in the region. These searches include previous surveys, community records and other sources. A review of databases facilitates the formulation of specific field survey techniques to target certain flora and fauna species known from the region.

All database searches were based on either the Lot/Plan, study area, or the central coordinate point (-23.6380 149.2514), depending on the database search undertaken. Database search results can be found in Appendix A. The following database searches were undertaken:

1. Environmental Reports Online (search based on EPC boundary);
    a. Biodiversity Planning Assessments;
    b. Matters of State Environmental Significance, including the regulated vegetation map;
    c. Regional Ecosystems;
2. Environmentally Sensitive Area (ESA) Mapping (search based on EPC boundary);
3. Regional Ecosystems Report (search based on EPC boundary);
4. Protected Plants Flora Survey Trigger Map (search based on central coordinate point);
5. EPBC Act Protected Matters Search Tool (PMST) (two searches based on central coordinate point with 10 km and 50 km buffers);
6. Wildlife Online Species List Request (two searches based on central coordinate point with 10 km and 50 km buffers);
    a. Rare and Threatened Species (two searches based on central coordinate point with 10 km and 50 km buffers);
    b. Introduced Species (search based on central coordinate point with 50 km buffer); and
7. Department of Environment and Science (DES) interactive Wetland*Maps* database and Map of Referable Wetlands;
8. Bureau of Meteorology (BoM) and Department of Natural Resources Mines and Energy (DNRME) mapping of Groundwater Dependent Ecosystems (GDEs); and
9. ‘Back on Track’ Species Prioritisation Framework Recovery Actions Database (RAD) for Queensland for the Fitzroy Natural Resource Management Region.

Additional resources that provide species records and related information such as the Atlas of Living Australia (ALA) were consulted where appropriate, such as to support determinations of the likelihood of individual species occurring (Appendix A).

The following sections address items of nature conservation relevant to the study area, that have been identified within the desktop assessment.

3.1 VEGETATION

3.1.1 Regulated Vegetation

The Regulated Vegetation Management Map was consulted, and the following regulated vegetation categories have been identified within the Project:

- Category B: Remnant vegetation.
- Category C: High-value regrowth vegetation.
- Category R: Regrowth within 50 m of a watercourse or drainage feature located in Great Barrier Reef catchment areas.
- Category X: Non-remnant vegetation.

Figure 5 outlines the Endangered or Of Concern Regulated Vegetation identified as likely to occur within the study area.

3.1.2 Threatened Ecological Communities

The EPBC Act PMST identified three TECs that could potentially occur within 10 km of the study area (1 to 3), and two additional TECs potentially occurring within 50 km of the study area (4 and 5).

1. Brigalow (*Acacia harpophylla* dominant and co-dominant);
2. Coolabah – Black Box Woodlands of the Darling Riverine Plains and the Brigalow Belt South Bioregions;
3. Weeping Myall Woodlands;
4. Natural Grasslands of the Qld Central Highlands and the northern Fitzroy Basin; and
5. Semi-evergreen vine thickets of the Brigalow Belt (North and South) and Nandewar Bioregions.

On the 4th July 2019, the Commonwealth government amended the list of threatened species and communities protected by the EPBC Act. Amongst numerous amendments, one was considered relevant to the study area, being the listing of a new TEC:

6. Poplar Box Grassy Woodland on Alluvial Plains.

The *Conservation Advice (including listing advice) for the Poplar Box Grassy Woodland on Alluvial Plains* (TSSC n.d.) outlines five REs in Queensland that correspond fully or partly with the Poplar box TEC. Of these, RE 11.3.2 (*Eucalyptus populnea* woodland on alluvial plains) is mapped (desktop) as occurring within the study area. Consequently, the Poplar Box TEC has been added to the list of TECs potentially occurring within 50 km of the study area.

Each TEC, PMST type of presence and desktop assessment of likelihood of occurrence is outlined in Appendix B.

3.1.3 Regional Ecosystems

Current DES mapping identifies six remnant REs occurring within the study area (Table 3, Figure 6).

Table 3 Regional Ecosystems mapped within the study area

Regional Ecosystem	Description	VM Act Status	DES Biodiversity Status	EPBC Act
11.3.1	*Acacia harpophylla* and/or *Casuarina cristata* open forest on alluvial plains	Endangered	Endangered	Brigalow (*Acacia harpophylla* dominant and co-dominant)
11.3.2	*Eucalyptus populnea* woodland on alluvial plains	Of concern	Of concern	Poplar Box grassy woodland on alluvial plains Weeping Myall (*Acacia pendula)* Woodland
11.3.25	*Eucalyptus tereticornis* or *E. camaldulensis* woodland fringing drainage lines	Least concern	Of concern	
11.5.2	*Eucalyptus crebra, Corymbia spp.,* with *E. moluccana* woodland on lower slopes of Cainozoic sand plains and/or remnant surfaces	Least concern	No concern at present	
11.5.9b	*Eucalyptus crebra* and other *Eucalyptus spp.* and *Corymbia spp.* woodland on Cainozoic sand plains and/or remnant surfaces	Least concern	No concern at present	
11.7.2	*Acacia spp.* woodland on Cainozoic lateritic duricrust. Scarp retreat zone	Least concern	No concern at present	

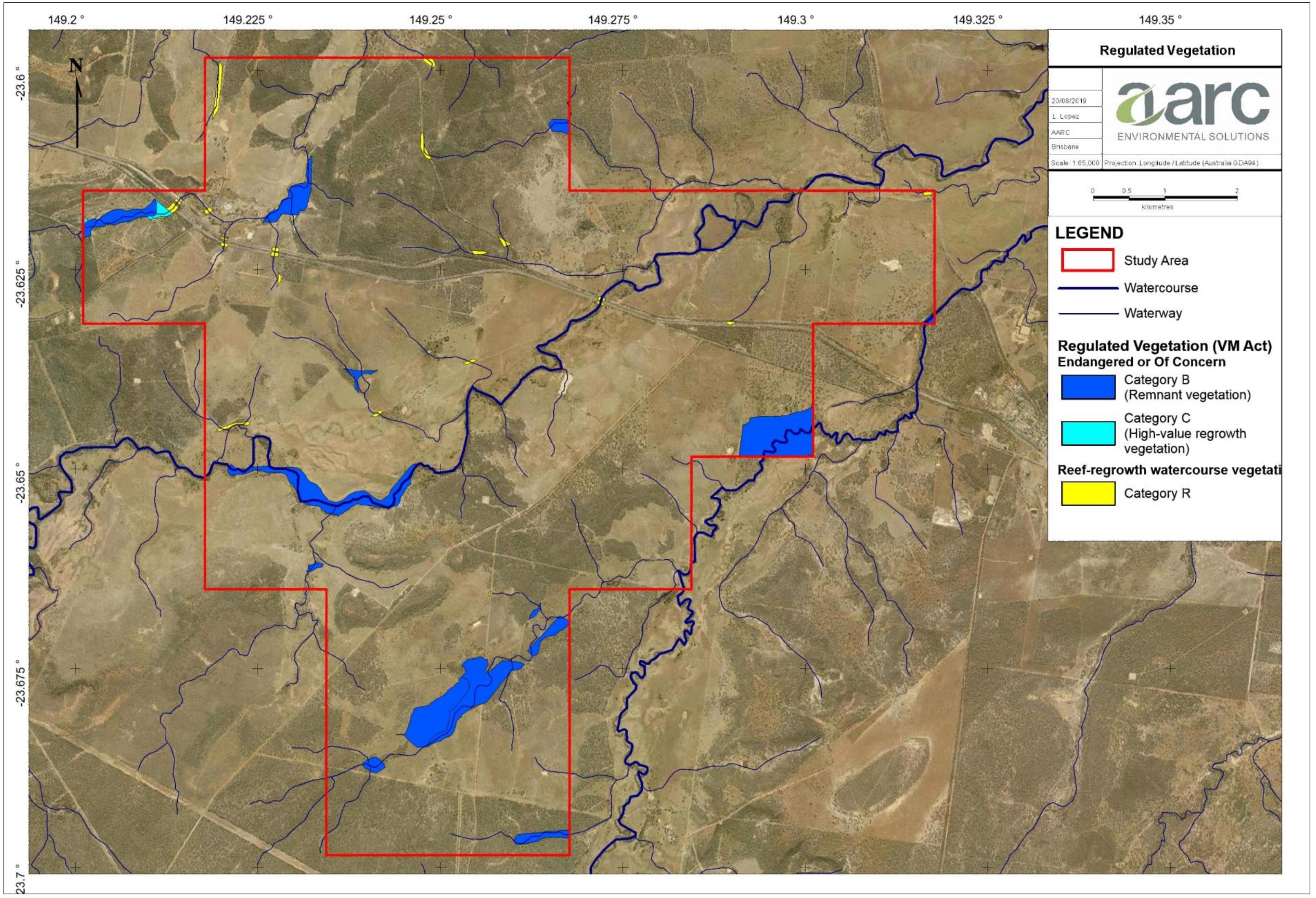


Figure 5 Regulated Vegetation (VM Act) classed as Endangered or Of Concern

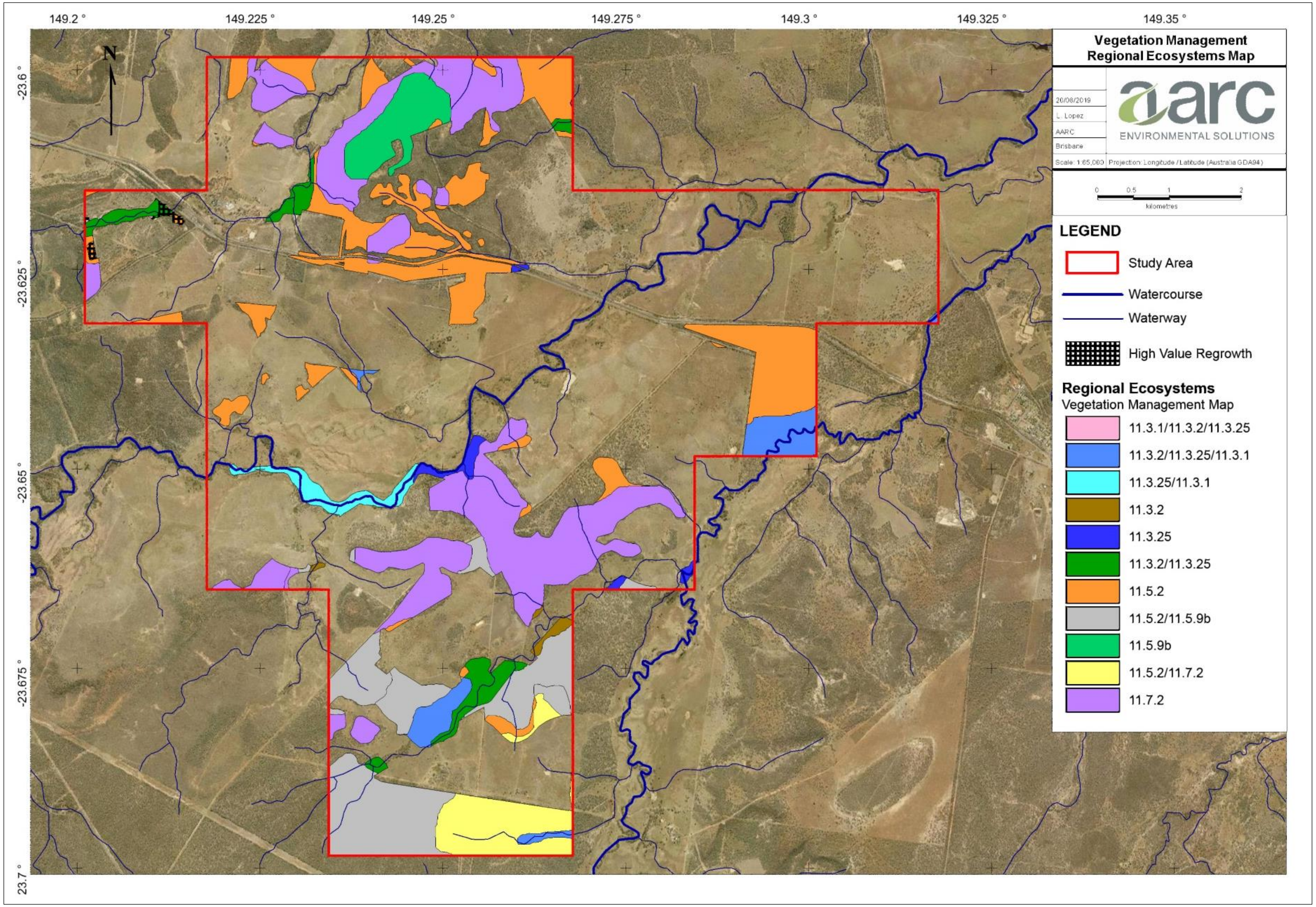


Figure 6 Regional Ecosystems Vegetation Management Map for the study area

3.2 SPECIES OF CONSERVATION SIGNIFICANCE

Species of conservation significance identified from the desktop assessment were assigned a likelihood of occurrence based on the criteria specified in Table 4. The assessment was based on the knowledge of ecologists, habitat suitability, previous surveys conducted near the study area and scientific literature.

Desktop assessments to determine the likelihood of each species identified during the database searches, with the potential to occur within the study area, were undertaken before conducting the field surveys.

Targeted searches were undertaken in the field for species identified as either being likely to occur or having the potential to occur, within the study area, based on the desktop sources. The methodology was applied again after surveys to determine the likelihood of occurrence once additional site-based information became available.

Table 4 Criteria adopted for the likelihood of occurrence determination

Likelihood of Occurrence	Criteria

Unlikely	• Species or species habitat may occur, is likely to occur or is known to occur from the broader search area (based on database searches); **but**
	  o preferred habitat has not been identified within the study area, **and** there are no confirmed species records within 10 km of the study area; **or**
	  o preferred habitat occurs within the study area, **but** there are no confirmed species records within 50 km of the study area.

Potential	• Species or species habitat may occur, is likely to occur or is known to occur from the broader search area (based on database searches); **and** o preferred habitat occurs within the study area, **but** there are no confirmed species records within 10 km of the study area; **however**, there are confirmed species records within 50 km of the study area; **or** • Species indicated as likely during the desktop assessment, but field surveys revealed no evidence of occurrence in the study area.
Likely	• Preferred habitat occurs within the study area, **and** confirmed species records within 10 km of the study area; **however**, species not yet confirmed as occurring within the study area.
Known	• Confirmed species records within the study area (generally as a result of subsequent field survey).

3.2.1 Flora

3.2.1.1 State and Commonwealth Listed Flora Species

The PMST and the Wildlife Online Database identified 33 Endangered, Vulnerable or Near Threatened (EVNT) flora species with the potential to occur within the 50 km buffer zone (Appendix A).

Each flora species, its protection status, habitat requirements, and assessment of the likelihood of occurrence is provided in Appendix C.

Out of the 33 species identified by the desktop assessment, six were considered to have the potential to occur within the study area and were targeted during the field survey. These six species and their conservation status under Commonwealth and State legislation are listed in Table 5.

Table 5 Flora Species of Conservation Significance with the potential to occur within the study area

Scientific Name	NC Act status	EPBC status	Potential Presence in Buffer Area	
			10 km	50 km
Bertya opponens	LC	V	-	-
Bertya pedicellata	NT	-	-	x
Cerbera dumicola	NT	-	x	x
Solanum adenophorum	NT	-	-	x
Solanum dissectum	E	E	-	x
Solanum elachophyllum	E	-	x	x

EPBC – *Environment Protection and Biodiversity Conservation Act 1999*
NC Act – *Nature Conservation Act 1992*
NT – Near Threatened
E – Endangered

3.2.1.2 Back on Track Flora Species Prioritisation

A RAD database search identified 35 Back on Track flora species ranked as either 'high' or 'critical' from the Fitzroy NRM Region. Of these 35 species, 30 are listed as EVNT under the NC Act and 16 are listed as EVNT under the EPBC Act. A list of these species and their relevant state and Commonwealth listings is presented in Table 6.

Table 6 Back on Track Priority Flora Species for the Fitzroy NRM Region

Species Name	Common Name	Fitzroy NRM Region	State BoT Rank	NC Act Status	EPBC Act Status
Apatophyllum olsenii		High	High	E	V
Atalaya collina		High	Medium	E	E
Bowenia serrulata	Byfield fern	Critical	Critical	LC	-
Cadellia pentastylis	Ooline	Critical	Critical	E	-
Capparis humistrata		High	Medium	E	-
Comesperma oblongatum		High	High	V	V
Commersonia pearnii		Critical	High	E	-
Cupaniopsis shirleyana	Wedge-leaf tuckeroo	High	High	V	V
Cycas megacarpa		Critical	Critical	E	E
Cycas ophiolitica	Marlborough blue	Critical	Critical	E	E
Eleocharis blakeana		High	Medium	LC	-
Eriocaulon carsonii		High	High	E	E
Eucalyptus pachycalyx subsp. waajensis		High	High	E	-
Eucalyptus raveretiana	Black ironbox	High	High	LC	-
Grevillea venusta	Grevillea	High	High	V	-
Hakea trineura		High	High	V	V
Homoranthus decumbens		High	High	V	E
Lissanthe brevistyla		High	High	V	-

Species Name	Common Name	Fitzroy NRM Region	State BoT Rank	NC Act Status	EPBC Act Status
Logania diffusa		High	High	V	V
Macrozamia platyrhachis		Critical	Critical	E	E
Macrozamia serpentina		Critical	Critical	E	-
Marsdenia brevifolia		High	High	V	V
Melaleuca groveana		High	Medium	NT	-
Melaleuca irbyana		High	Medium	E	-
Myriophyllum artesium		High	High	E	-
Olde-andia gibsonii		Critical	Critical	E	-
Olearia macdonnellensis		High	High	-	V
Phaius australis		Critical	Critical	E	E
Pisonia grandis		High	High	LC	-
Plectranthus graniticola		High	High	V	-
Rhaponticum australe		High	High	V	V
Rhodamnia angustifolia		High	Medium	E	-
Solanum adenophorum		High	High	E	-
Solanum dissectum		High	Medium	E	E
Trioncinia retroflexa		Critical	High	E	-

EPBC – *Environment Protection and Biodiversity Conservation Act 1999*
NC Act – *Nature Conservation Act 1992*
E – Endangered
V – Vulnerable
NT – Near Threatened
LC – Least Concern

3.3 FAUNA

3.3.1 State and Commonwealth Listed Fauna Species

Database searches identified 29 EVNT fauna species with the potential to occur within the 50 km of the study area (Appendix A).

A detailed assessment to determine the likelihood of EVNT species to occur in the study area was completed prior to conducting the field survey, for the purpose of determining targeted species and to guide field survey methodology. The detailed assessment was based on the knowledge of ecologists, habitat suitability and scientific literature. This assessment is provided in Appendix D.

The detailed assessment of the likelihood of occurrence considered that 16 of the 29 species identified by the desktop assessment had the potential to occur within the study area and were targeted during the field survey. These 16 species and their conservation status under Commonwealth and State legislation are listed in Table 7.

Table 7 EVNT Fauna species with the potential to occur within the study area

Scientific Name	Common Name	NC Act status	EPBC status
Amphibians			
Adelotus brevis	Tusked frog	V	-

Scientific Name	Common Name	NC Act status	EPBC status
Reptiles			
Delma torquata	Collared delma	V	V
Strophurus taenicauda	Golden-tailed gecko	NT	-
Birds			
Calyptorhynchus lathami erebus	Glossy black-cockatoo (northern)	V	-
Erythrotriorchis radiatus	Red goshawk	E	V
Geophaps scripta scripta	Squatter pigeon (southern subspecies)	V	V
Grantiella picta	Painted honeyeater	V	V
Lathamus discolor	Swift parrot	E	C
Ninox strenua	Powerful owl	V	-
Pedionomus torquatus	Plains-wanderer	V	C
Poephila cincta cincta	Black-throated finch (white-rumped subspecies)	E	E
Turnix melanogaster	Black-breasted button quail	V	V
Mammals			
Chalinolobus dwyeri	Large-eared pied bat	V	V
Onychogalea fraenata	Bridled nailtail wallaby	E	E
Petauroides volans	Greater glider	V	V
Phascolarctos cinereus	Koala	V	V

EPBC – *Environment Protection and Biodiversity Conservation Act 1999*
NC Act – *Nature Conservation Act 1992*
NT – Near Threatened
V – Vulnerable
C – Critically Endangered
E – Endangered

3.3.1.1 Listed Migratory and Marine Species

The EBPC PMST indicated 21 marine and/or migratory species known from 50 km of the study area (Appendix A).

The assessment of likelihood of occurrence (Appendix D) considered that nine of the 21 species had the potential to occur within the study area.

Table 8 Listed migratory species with the potential to occur within the study area

Scientific Name	Common Name	NC Act status	EPBC status
Ardea alba	Great egret	-	Ma
Ardea ibis	Cattle egret	-	Ma
Calidris acuminata	Sharp-tailed sandpiper	SL	Ma, Mi

Scientific Name	Common Name	NC Act status	EPBC status
Chrysococcyx osculans	Black-eared cuckoo	-	Ma
Hirundapus caudacutus	White-throated needletail	-	Ma, Mi
Merops ornatus	Rainbow bee-eater	-	Ma
Monarcha melanopsis	Black-faced Monarch	SL	Ma, Mi
Motacilla flava	Yellow wagtail	SL	Ma, Mi
Myiagra cyanoleuca	Satin flycatcher	SL	Ma, Mi

EPBC – *Environment Protection and Biodiversity Conservation Act 1999*
NC Act – *Nature Conservation Act 1992*
Ma – Marine
Mi – Migratory
SL – Special Least Concern

3.3.1.2 Back on Track Fauna Species Prioritisation

A RAD database search identified 35 Back on Track fauna species ranked as either 'high' or 'critical' from the Fitzroy NRM Region. A list of these species and their relevant State and Commonwealth listings is presented in Table 9.

Table 9 Back on Track Fauna Species from the Fitzroy NRM Region

Species Name	Common Name	Fitzroy NRM Region	State BoT Rank	NC Act Status	EPBC Act Status
Amphibians					
Taudactylus pleione	Kroombit tinkerfrog	High	High	E	CE
Reptiles					
Phyllurus caudiannulatus	Ringed thin-tailed gecko	High	Medium	V	-
Phyllurus championae		Critical	Critical	LC	-
Elseya albagula	Southern snapping turtle	High	High	E	CE
Rheodytes leukops	Fitzroy River turtle	High	High	V	V
Caretta caretta	Loggerhead turtle	Critical	Critical	E	E
Strophurus taenicauda	Golden-tailed gecko	High	Medium	NT	-
Acanthophis antarcticus	Common death adder	High	Medium	V	-
Denisonia maculata	Ornamental snake	High	Medium	V	V
Hoplocephalus stephensii	Stephens' banded snake	High	High	LC	-
Delma inornata		High	High	LC	-
Delma torquata	Collared delma	High	High	V	V
Anomalopus brevicollis		High	High	LC	-
Egernia rugosa	Yakka skink	High	Medium	V	V
Lerista allanae	Allan's lerista	High	High	E	E
Varanus semiremex	Rusty monitor	High	High	LC	-
Birds					
Erythrotriorchis radiatus	Red goshawk	High	High	E	V
Esacus magnirostris	Beach stone-curlew	High	High	V	-
Stagonopleura guttata	Diamond firetail	High	High	LC	-

Species Name	Common Name	Fitzroy NRM Region	State BoT Rank	NC Act Status	EPBC Act Status
Sternula albifrons	Little tern	High	High	SL	-
Epthianura crocea macgregori	Yellow chat (Dawson)	High	High	E	CE
Grantiella picta	Painted honeyeater	High	High	V	V
Turnix melanogaster	Black-breasted button quail	Critical	Critical	V	V
Mammals					
Dasyurus maculatus maculatus	Spotted-tailed quoll (southern subspecies)	High	High	V	E
Dugong dugon	Dugong	Critical	Critical	V	-
Taphozous australis	Coastal sheathtail bat	High	High	NT	-
Onychogalea fraenata	Bridled nailtail wallaby	Critical	Critical	E	E
Petrogale penicillata	Brush-tailed rock-wallaby	High	High	V	V
Macroderma gigas	Ghost bat	Critical	Critical	E	V
Xeromys myoides	Water mouse	Critical	High	V	V
Petaurus australis australis	Yellow-bellied glider (southern subspecies)	High	High	LC	-
Bettongia tropica	Northern bettong	Critical	Critical	E	E
Pteropus poliocephalus	Grey-headed flying-fox	Critical	Critical	LC	V
Kerivoula papuensis	Golden-tipped bat	High	Medium	LC	-
Nyctophilus corbeni	Eastern long-eared bat	High	Medium	V	V
Arachnids					
Selenocosmia crassipes		Critical	Critical	LC	-
Selenotypus plumipes		Critical	Critical	LC	-
Gastropods					
Adclarkia dawsonensis	Boggomoss snail	Critical	Critical	E	CE
Billordia nicoletteae		High	High	-	-
Perioinsolita pokryszkoae		High	High	-	-
Sphaerospira mossmani		High	High	-	-
Dimidarion slatyeri		Critical	High	-	-

EPBC – *Environment Protection and Biodiversity Conservation Act 1999*
NC Act – *Nature Conservation Act 1992*
CE – Critically Endangered
E – Endangered
V – Vulnerable
NT – Near Threatened
LC – Least Concern

3.4 ENVIRONMENTALLY SENSITIVE AREAS

ESA mapping presents Category A, B, and C areas of conservation significance, including those under international agreements (e.g. Ramsar sites), fish habitat areas, declared catchment areas, Wild River nominated waterways and areas listed under the Directory of Important Wetlands. ESA mapping indicates that several ESAs occur within the study area (Appendix A).

A small section of (around 2.5 ha) of Taunton NP, falls within the study area, on the north west corner of the study area. This NP is identified as Category A ESA. Category B ESA, Endangered Regional Ecosystems is mapped as potentially occupying several parcels of land within the study area. These areas of Category B ESA represent the Endangered RE 11.3.1 (*Acacia harpophylla* and/or *Casuarina cristata* open forest on alluvial plains) as a mixed polygon, as mapped by the QLD Government in Figure 6.

3.5 WETLANDS

A review of the DES interactive Wetland*Maps* database and the Map of Referable Wetlands indicated three types of waterbodies are present within the study area. Riverine wetlands have been identified in association with the Charlevue Creek. Several small riverine, palustrine and lacustrine wetlands also mapped as potentially present within the study area (Figure 7). No wetlands of national or international importance have been recorded within the study area or surrounds. One High Ecological Significance (HES) wetland occurs approximately 4 km east of the study area (Figure 7).

The Aquatic Conservation Assessments defines the study area as having a sub-catchment conservation significance of medium, indicating that these wetlands have varied combinations of high and medium values amongst the assessment criteria.

3.5.1 Groundwater Dependent Ecosystem

Groundwater Dependent Ecosystems (GDEs) are ecosystems that are reliant on groundwater for their survival; they can be solely reliant on groundwater such as ecosystems relying on aquifers, or may intermittently depend on groundwater, which would be the case of riparian vegetation, particularly on ephemeral river systems (IESC 2019). GDEs are grouped according to the 'Groundwater dependant ecosystem typology framework' which separates GDEs based on their type of groundwater reliance (DSITI 2015). The three GDE types include:

- surface expression GDEs: a GDE which uses groundwater after it has been discharged to the surface. This includes all groundwater-fed surface water bodies, such as rivers, wetlands, lakes and springs. This definition refers only to the aquatic (inundated) component of a system, and therefore excludes any vegetation which may fringe a surface water body (BoM 2019);

- terrestrial GDEs: a GDE that accesses subsurface groundwater to meet all or some of its water requirements (BoM 2019); and

- subterranean GDEs: wetland systems that occur below the surface of the ground and can include aquifer ecosystems and cave ecosystems.

The BoM has developed an interactive tool for assistance in the identification of GDEs, the National Atlas of GDEs (GDE Atlas). This GDE Atlas 'National assessment' mapping was produced by conducting a national-scale assessment which involved a nationally consistent methodology using remote sensing and GIS rules-based analysis (BoM 2019). GDE Atlas is a tool used for planning, management and development and incorporates a national dataset of GDEs throughout Australia. The GDE Atlas supplies information to support the identification of GDEs but does not provide a definitive map of GDEs.

The BoM mapped both terrestrial and surface expression (aquatic) GDEs as having the potential to occur within the study area. Figure 8 shows the potential terrestrial GDEs occurring within the study area whilst Figure 9 shows the potential aquatic GDEs occurring within the study area. Within the study area high potential terrestrial GDEs were mapped in association with Charlevue Creek and Springton Creek. Moderate potential GDEs were associated with some of the smaller waterways.

The GDE classification includes (BoM 2019):

- High potential for groundwater interaction: GDE Atlas terminology used to classify ecosystems as likely to be interacting with groundwater. It indicates that groundwater is likely to be present, and the ecosystem is likely to be using it. This categorisation means that the majority of data analysed indicated a high potential for groundwater interaction, or that the most reliable (and most heavily weighted) datasets indicated high potential.

- Moderate potential for groundwater interaction: GDE Atlas terminology used to classify ecosystems that may interact with groundwater. It indicates that groundwater is possibly present, and the ecosystem may use it. Where data is conflicting (some data suggests that groundwater interaction is occurring, while other data suggests it is not), and is weighted equally (both datasets are considered equally good indicators of groundwater interaction), this will be the resulting categorisation.

- Low potential for groundwater interaction: GDE Atlas terminology used to classify ecosystems as unlikely to be interacting with groundwater. It indicates that groundwater is unlikely to be present, or if it is present, the ecosystem is unlikely to use it. This categorisation means that all datasets suggest groundwater interaction is unlikely, or that the most reliable (and most heavily weighted) datasets suggest that groundwater interaction is unlikely.

The Department of Environment and Science (DES) also has developed a map that shows the location and extent of known and potential GDEs throughout Queensland. The information to produce this map has been sourced from expert knowledge, literature and existing datasets. No surface expression GDEs or Subterranean GDEs were mapped by DES as occurring or having the potential to occur within the study area. Within the study area there are several 'derived GDE - low-confidence' potential terrestrial GDE areas along Charlevue Creek, Springton Creek and Stanley Creek. Figure 10). 'Derived GDE – low confidence' are GDE's that have not been field sampled, but according to expert knowledge, there is a low confidence in the mapping rule set and therefore in the prediction that the mapped ecosystem has some degree of groundwater dependence (Queensland Government, 2012). When comparing to Government RE mapping these potential GDEs are in association with RE 11.3.2, 11.3.25 and 11.3.1.

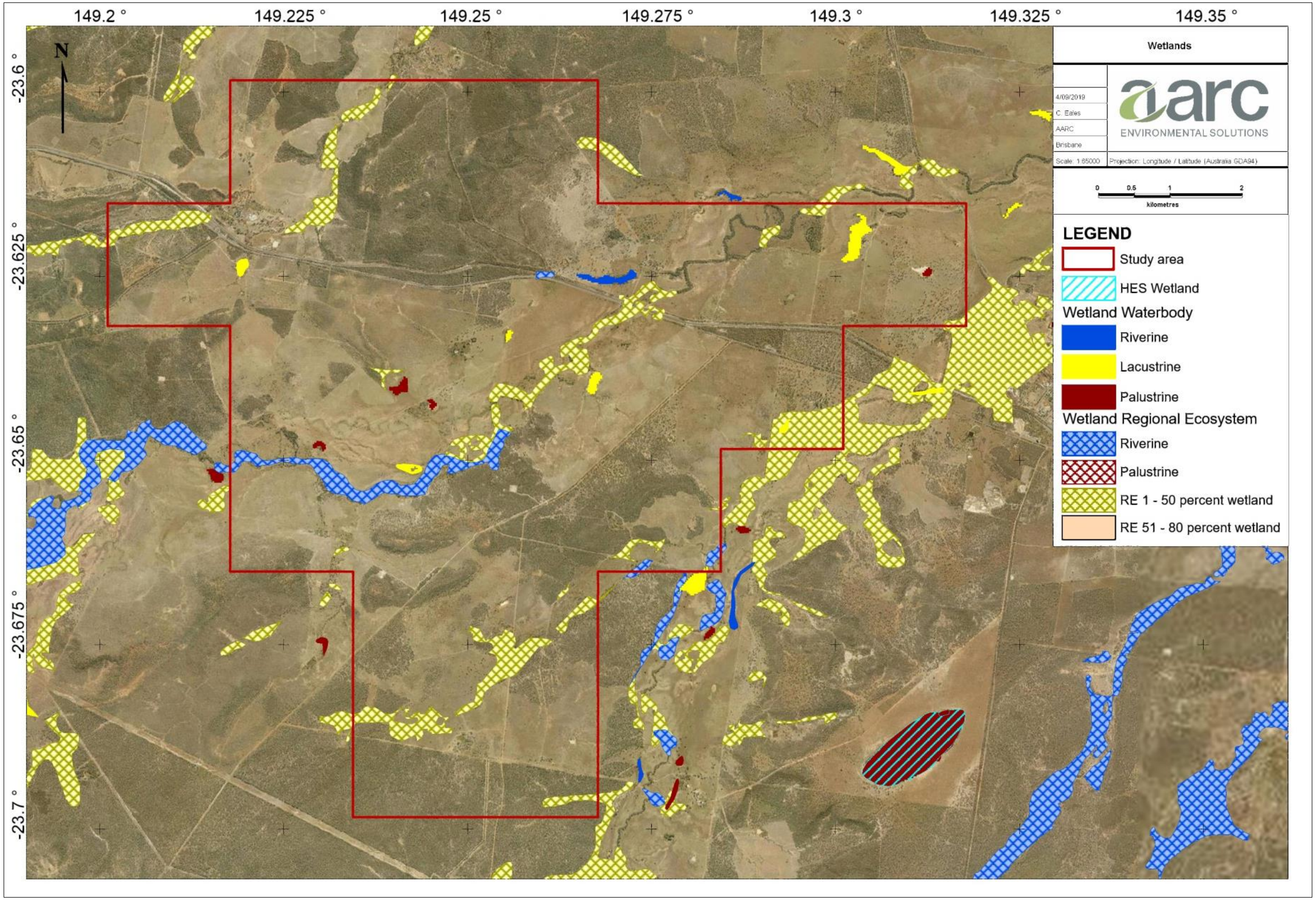


Figure 7 Wetland Habitats

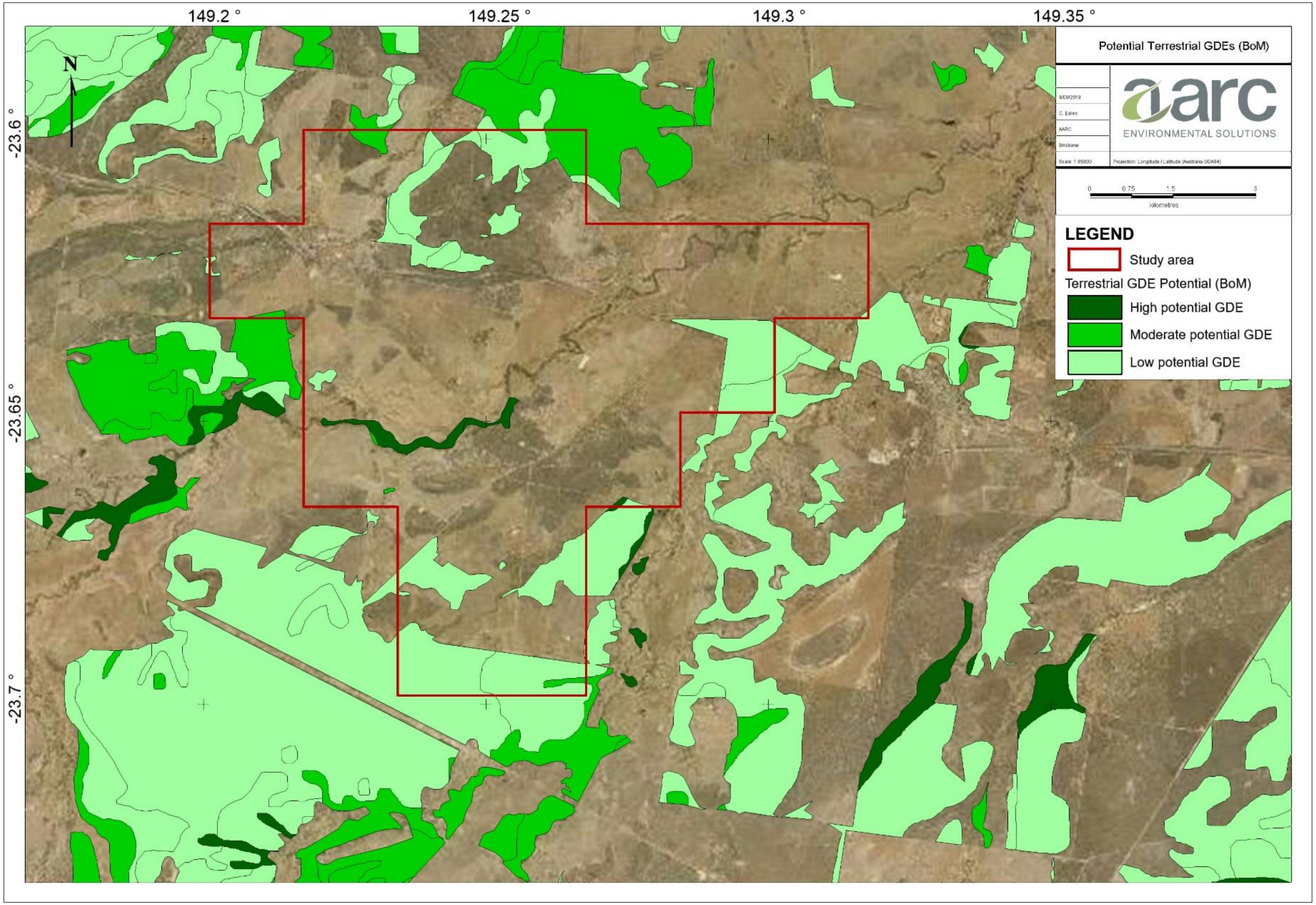


Figure 8 Potential Terrestrial GDEs (BoM)

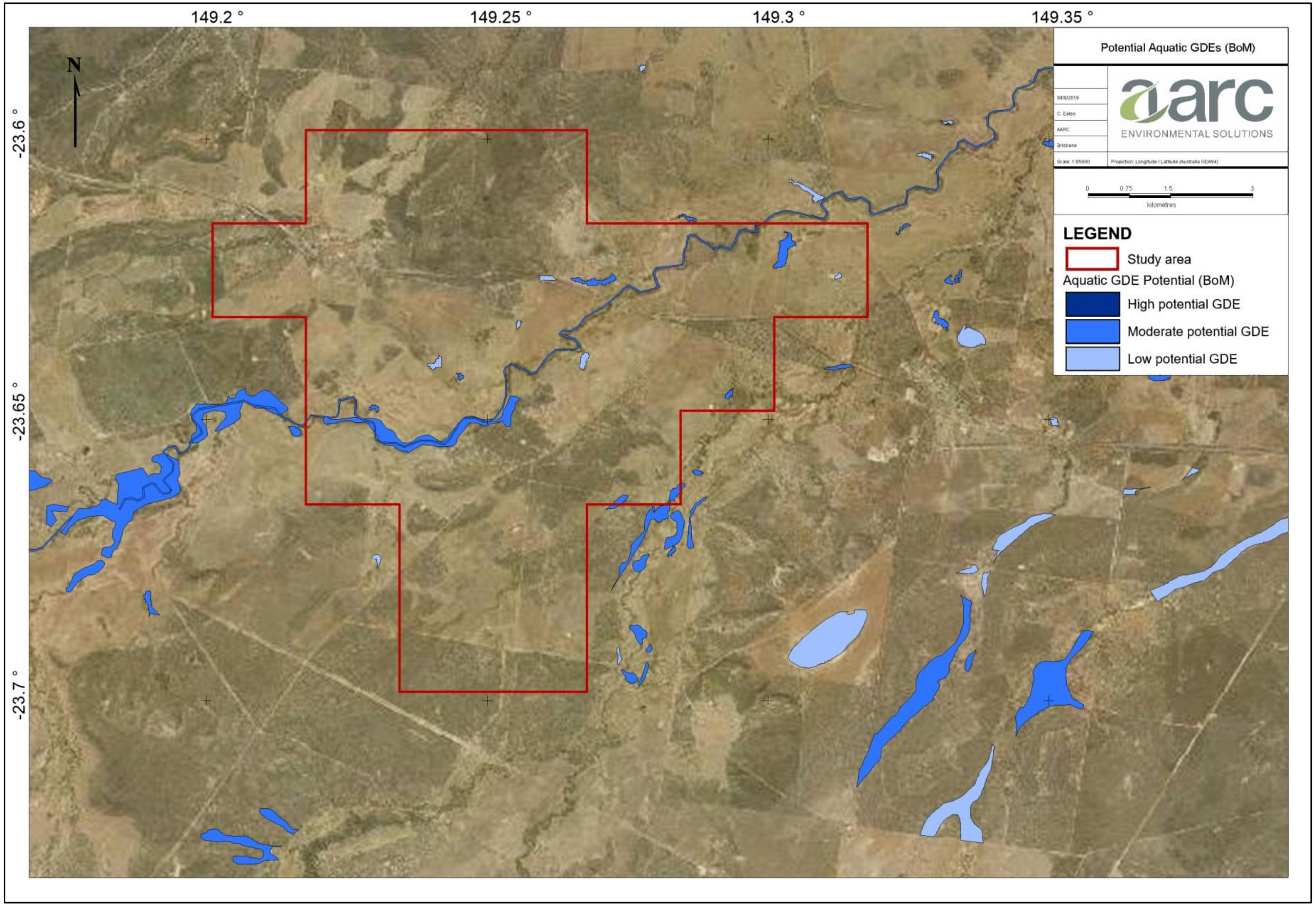


Figure 9 Potential Aquatic GDEs (BoM)

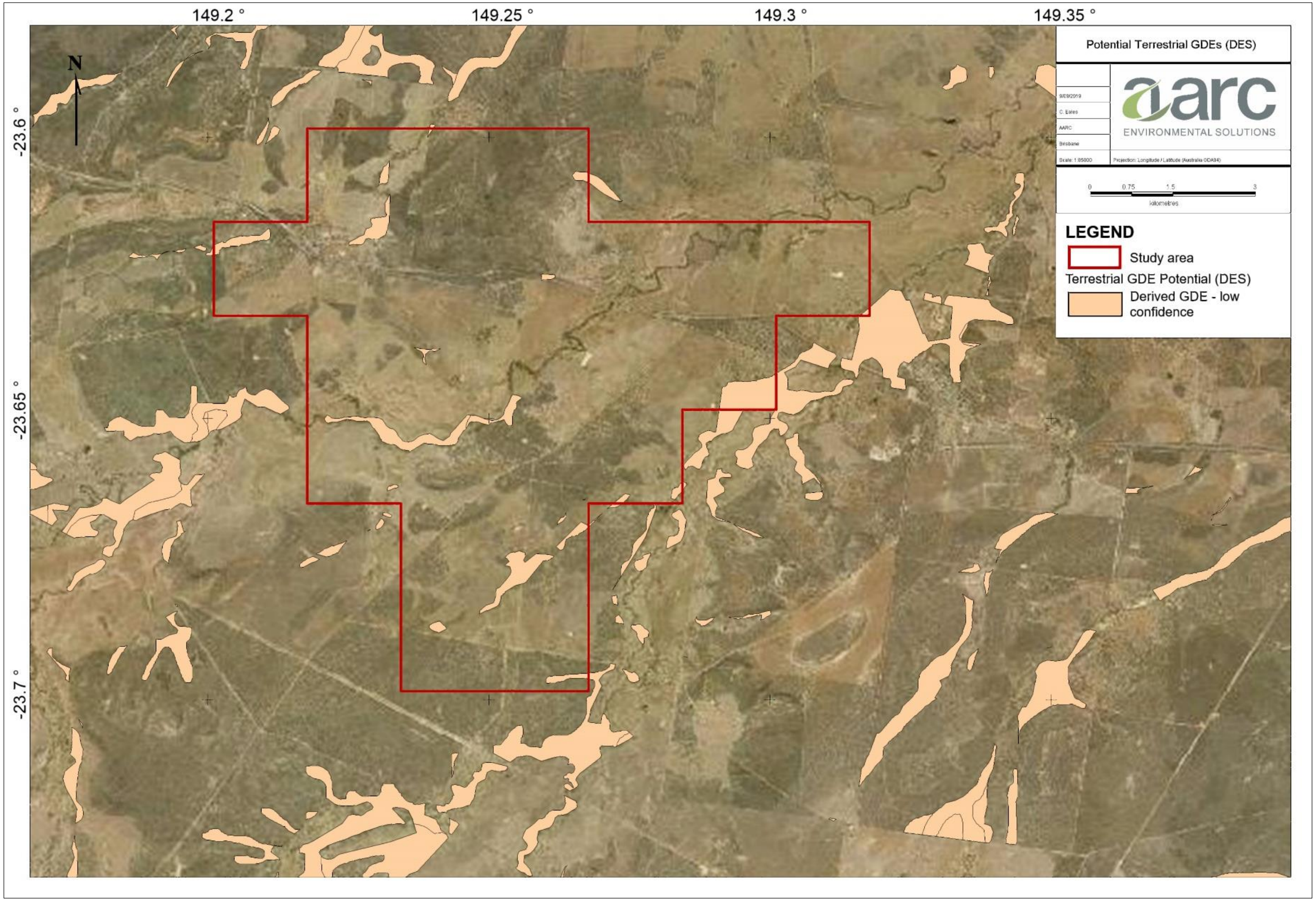


Figure 10 Potential Terrestrial GDEs (DES)

4.0 METHODOLOGY

4.1 FIELD SURVEY GUIDELINES

Field surveys have been undertaken since 2017, covering a range of seasonal and climatic conditions. Over the study period, several updates to existing survey guideline material occurred, as well as the introduction of entirely new material.

At the time of reporting the material that has guided methodology is as follows:

- *Site examination for threatened and endangered plant species* (Goff, Dawson & Rochow 1982);
- *Management of endangered plants* (Cropper 1993);
- *Survey guidelines for Australia's threatened bats* (DoEE 2010a);
- *Survey guidelines for Australia's threatened birds* (DoEE 2010b);
- *Survey guidelines for Australia's threatened mammals* (DoEE 2011a);
- *Survey guidelines for Australia's threatened reptiles* (DoEE 2011b);
- *Survey Standards: Greater Glider, Petauroides volans* (MacHunter, Brown, Loyn & Lumsden 2011);
- *Terrestrial Vertebrate Fauna Survey Guidelines for Queensland (V3.0)* (Eyre et al*.* 2018);
- *Methodology for surveying and mapping regional ecosystems and vegetation communities in Queensland (V5.0)* (Neldner et al*.* 2019); and

4.2 SURVEY SEASONALITY

Survey timing was selected following the *Terrestrial Vertebrate Fauna Survey Guidelines for Queensland V3.0* (Eyre et al*.* 2018). These guidelines recommend that fauna surveys within the Brigalow Belt bioregion should be conducted during spring to early summer (i.e. September to mid-November) and during autumn (i.e. March to mid-May).

The autumn survey should be undertaken after summer as the temperatures decrease but before the onset of cold winter nights. Autumn coincides with another active period, including dispersal and migration of many species (Eyre et al*.* 2018). The first and third ecological survey for the study area was undertaken during autumn, from the 4th - 12th May 2017 and from the 16th - 23rd February 2018.

The spring season timing provides ideal survey conditions as temperatures begin to rise, and a peak on vertebrate activity is observed with the commencement of the breeding period for many species (Eyre et al*.* 2018). The second survey was undertaken during spring, from the 18th - 30th September 2017.

A fourth survey targeting Microchiroptera bat species and vegetation mapping took place from the 22nd - 29th March 2018, meeting the requirements for the *Survey Guidelines for Australia's Threatened Bats* (DoEE 2010a).

The final surveys to finalise the vegetation mapping took place on the 1st, 2nd and 19th August 2019.

Autumn 2017 Survey

Mild conditions were recorded in the study area during the May 2017 ecology survey according to data obtained with SILO and personal observations. Throughout the survey period, a total of 20.2 mm of rainfall was recorded within the region, however, within the study area, the rain was only registered on the evening of the 9th and during the day on the 10th. Maximum daily temperatures were slightly lower than average for the study area's locality reaching only 28.5°C and dropping to 11°C at night.

Spring 2017 Survey

No rainfall was registered during the spring survey period. There was some fluctuation on the temperature throughout the fieldwork, with the highest temperature recorded in the region of 38.5°C and a minimum temperature of 13°C.

Autumn 2018 Surveys

Hot and wet conditions were recorded in the study area (SILO) during the autumn 2018 Ecology survey. Throughout the survey period, 61.5 mm of rainfall was recorded within the region, with most of the rainfall in the study area registered on the 20th of February. Maximum daily temperatures reached 35.5°C, dropping to 19.5°C at night.

During the second autumn 2018 survey (consistent on targeted micro-bat and vegetation mapping survey) the conditions were mild, with 6.1 mm of rainfall registered in the region. Maximum temperatures reached 34.5°C on the 28th of March, and minimum temperatures reached 18°C.

Winter Surveys 2019

No rainfall was registered during the spring survey period. Field observations recorded overcast the 1st of August and sunny and warm the 2nd and the 19th of August. The temperatures recorded during the day in the region reached 29°C as maximum and 20°C as the minimum.

4.3 SURVEY SITE SELECTION

Site selection aimed to ensure adequate representation of vegetation and habitat types within the study area. Where possible, sites were aligned with the proposed disturbance footprint; however, preference was given to representative vegetation/habitat of higher condition.

Access limitations influenced site selection to a minor extent. Regular repeat safe access is essential to all fauna trapping sites and forms a requirement of the animal ethics permits under which surveys are completed. However, multiple surveys were conducted by AARC ecologists over a period of three years to ensure that a comprehensive and representative survey effort was completed for the site.In fact, all habitat types identified in the study area were surveyed at least three times across both seasons meeting Queensland guidelines requirements (Section 4.5).

4.4 FLORA

The flora survey regime was designed to meet the following objectives:

1. Obtain a detailed floristic summary of the study area through the compilation of a flora species list;

2. Define distinct vegetation communities and compile detailed descriptions of the floristic assemblages in each community;

3. Detect and identify EVNT flora species and threatened ecological communities; and

4. Produce a comprehensive site vegetation map at a 1:10,000 scale.

Plants species were identified using several taxonomic keys, field guides and online reference material. For any plant species that could not be identified in the field, a sample was collected and sent to the Queensland Herbarium.

4.4.1 Vegetation Mapping and Community Description

Methods used to produce a vegetation map and define communities were in accordance with those described in *Methodology for surveying and mapping regional ecosystems and vegetation communities in Queensland* (V5.0) (Neldner et al*.* 2019). Version 1.0 of this document was first released by the Qld Herbarium in 1999, with further additions and refinement to the methodology documented in subsequent versions (2004, 2005, 2017, 2019). Field mapping and community description were undertaken in accordance with the version of this guideline that was current at the time of each flora survey.

All RE's are described in this consolidated report in accordance with the Qld RE Description Database (REDD) (DES 2019c). The use of the terms 'remnant' and 'non-remnant vegetation' are as per the definitions of the VM Act. Neldner et al*.* (2019) describes four levels of floristic sampling, two of which were utilised in the study area assessment and defined below.

Secondary Transects: were used for classification and detailed descriptions of regional ecosystems and vegetation communities. Each site consisted of a 50 m long transect specifically marked using a Global Positioning System (GPS) at the start and end points, each accompanied by a photograph taken with a viewpoint of the transect. Foliage projection cover was measured along the transect and calculated as a percentage. Percentage composition of each ground cover species was recorded in five 1 m x 1 m quadrats located at 10 m intervals along the transect line. Within the 50 m x 10 m plot, each species present was recorded including relative abundance within each stratum, the height of each stratum, and stem density (for woody stems only). Species representative of the community but located outside of the plot were also recorded. Where a plant could not be positively identified to species level, a voucher specimen was collected for identification by the Qld Herbarium. According to Neldner et al*.* 2019, a minimum of three secondary sites within a regional ecosystem is desirable for a detailed description of the floristic composition and structural variation.

Quaternary Sites: are rapid vegetation assessments primarily used to verify regional ecosystem/vegetation community mapping. Each site consisted of a rapid assessment of the vegetation within an approximately 20 m by 20 m plot. Data collected included marking the GPS location, taking photographs, recording the dominant species in the characteristic stratum as well as stratum height. Soil and landform data were recorded to confirm land zone, as many REs can only be differentiated by the land zone they occur on, due to their floristic assemblage descriptions being virtually identical. Quaternary sites were recorded across the study area, mostly on foot.

Flora was sampled in autumn, spring and winter season to best account for both annual and perennial species assemblages. Flora survey sites, in particular secondary sites, were selected to be representative of the RE within the study area, allowing for several secondary sites within each vegetation community. Sampling was undertaken at a minimum density of 25 observations per 100 ha to complete mapping at the 1:10,000 scale (Neldner et al. 2019). Survey density was higher in areas with remnant vegetation or where vegetation types were changing, to accurately reflect the vegetation boundaries in the vegetation map. Subsequently, the flora sites were projected on a Geographical Information System (GIS) and used in conjunction with satellite images, aerial photographs, topographical and geological maps to produce a ground verified vegetation map.

A total of 28 secondary transects and over 1000 quaternary sites were sampled across the study area. The locations of all the flora secondary transects and quaternary sites are shown in Figure 11.

4.4.2 Targeted Searches for Species of Conservation Significance

A literature review was undertaken to gain an understanding of each species of conservation significance, their preferred habitat and ecology. Several resources were consulted to pre-determine habitat to be targeted during the field surveys, including, but not limited to:

- Commonwealth Listing Advice;
- Commonwealth Approved Conservation Advice;
- Species Profile and Threats Database (SPRAT); and
- WetlandInfo: Plants, Animals, Soils, Water and More Search Tool.

The predominant survey technique utilised for targeted species across the cumulative survey effort was the ‘timed meander’ technique (Cropper 1993; Goff 1982). This technique involved traversing suitable habitat in a random manner so as to maximise the coverage of habitat and the encounter rate of different species. For any EVNT plants observed the location recorded using a GPS. If there was any uncertainty in the identification of a species, a representative voucher specimen was collected for identification by the Queensland Herbarium following the Herbarium procedures (DSITI 2016).

While conducting the quaternary sites across remnant and non-remnant areas, if habitat met the required conditions for targeted species, these habitats were searched, and species were recorded opportunistically (e.g. rocky areas for *Cerbera dumicola*).

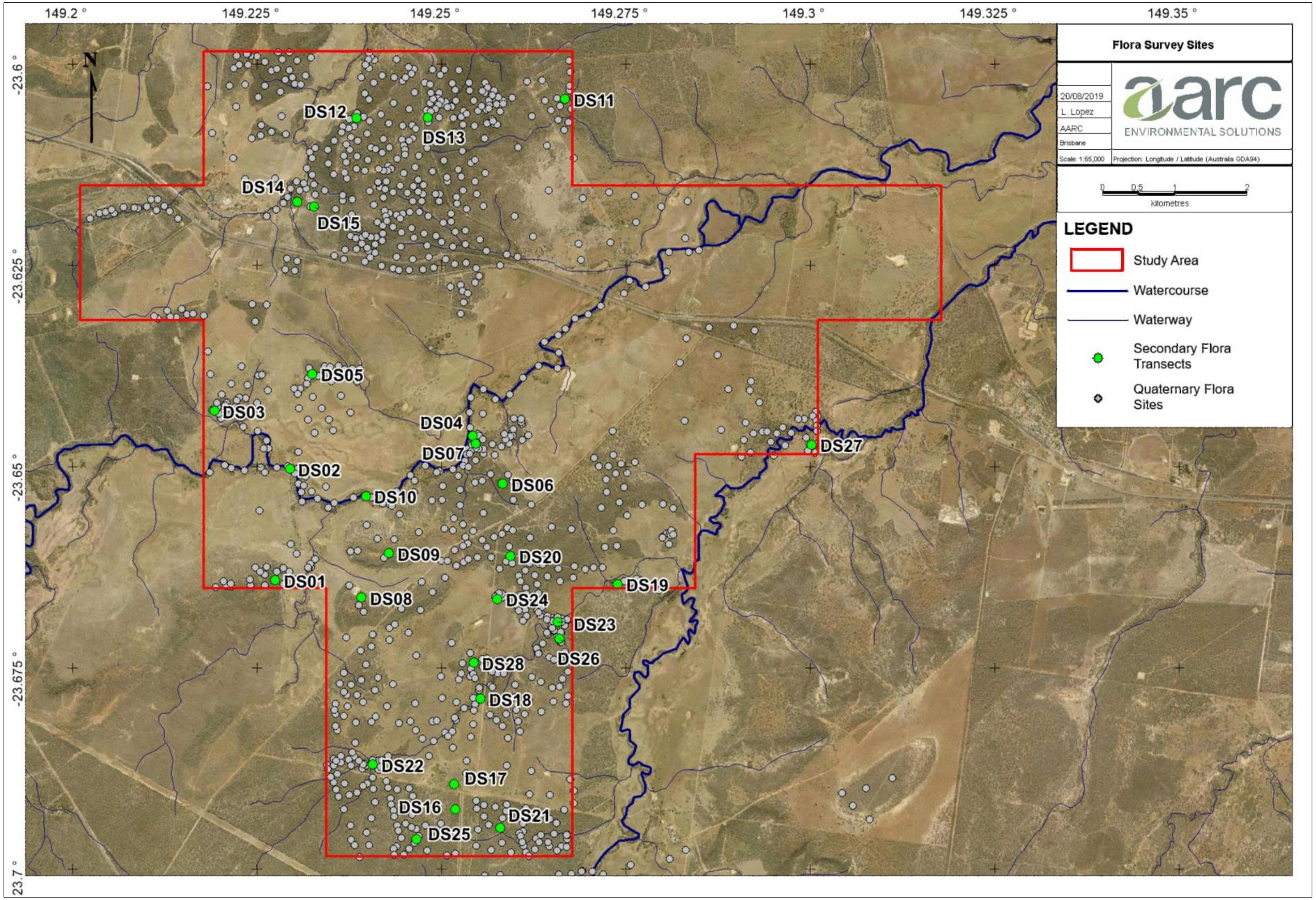


Figure 11 Gemini Project flora survey sites

4.5 FAUNA

4.5.1 Fauna Trapping Sites and Survey Locations

Site scoping was conducted prior to each survey by undertaking a desktop assessment to determine habitat types of the intended study area in accordance with survey objectives. Examination of satellite imagery, topographical features, broad vegetation group (BVG) guided the location of baseline fauna trapping efforts ensuring adequate distribution and representation of fauna habitat types. The preferred habitat of targeted species was identified in the same manner to locate targeted trapping and survey effort in suitable locations.

Vehicle-based reconnaissance was carried out, where possible, to assist in locating suitable survey sites, maximising the representative fauna habitat survey coverage. This preliminary assessment also aided in targeting habitats potentially occupied by species of conservation significance. Vegetation communities optimal for installing fauna sites were then surveyed on foot to allow further ecological familiarisation and comprehensive survey coverage.

The fauna survey methodology employed for the study area was based on the *Survey Guidelines for Australia's Threatened Bats* (DoEE 2010a) and the *Terrestrial Vertebrate Fauna Survey Guidelines for Queensland V2.0* (Eyre et al. 2014) which was the current version at the time of all surveys. The scope of the fauna field surveys was to develop an inventory of terrestrial fauna species inhabiting the study area, particularly species of conservation significance', as such field surveys were designed using the stratified sampling methods as detailed within the *Terrestrial Vertebrate Fauna Survey Guidelines of Queensland* (Eyre et al. 2018). The survey was conducted in compliance with AARC's scientific purposes permit and animal ethics approval. All fauna trapping efforts were conducted over four consecutive nights (unless otherwise stated).

Sampling of vertebrate fauna was conducted primarily along transects established in each of the major fauna habitat types and at changes in vegetation community groups. During all surveys, observations of species outside the specific fauna study locations but within the survey area were noted as incidental observations.

Many fauna species, notably frogs and reptiles, do not have widely accepted common names. Scientific names for species often change with taxonomic revisions. For the purpose of this report, all nomenclature used will follow that used in the ALA database (ALA 2019).

4.5.2 Fauna Survey Sites

Fauna sampling was conducted amongst representative areas of the main habitat types on the study area site to maximise the potential for sampling all wildlife present, with the exception of the cleared agricultural areas as the habitat values present were limited. Four major habitat types were targeted throughout the field surveys these included:

- Habitat type 1: Woodlands dominated *Eucalyptus crebra* (Narrow-leaved red ironbark) frequently with *Corymbia spp.* or *Callitris spp.* on flat to undulating plains.
- Habitat type 2: Low woodlands to tall shrublands dominated by *Acacia* spp. on residuals. Species include *A. shirleyi* (Lancewood) and *A. rhodoxylon* (Rosewood).
- Habitat type 3: Open forests and woodlands dominated by *Eucalyptus tereticornis* (Blue gum) fringing drainage lines.

- Habitat type 4: Woodlands dominated by *Eucalyptus populnea* (Poplar box) on alluvium, sand plains and foot slopes of hills and ranges

A total of 15 full fauna survey sites, 8 harp trap sites and 3 mist nets were established across the study area during the ecology survey period. All fauna survey locations are illustrated in Figure 7 and Figure 8 and described in Table 7. The detection techniques employed at each site is defined in Appendix E, and for descriptions of each technique refer to Section 4.5.2. Total survey effort undertaken during each survey is detailed in Table 10, and total survey effort accumulated across all surveys is summarised in Table 10.

Descriptions and photos of the survey sites are provided in Appendix E whereas all fauna survey locations indicating the habitat type where they were located and targeted micro-bat trapping sites are shown in Figure 12.

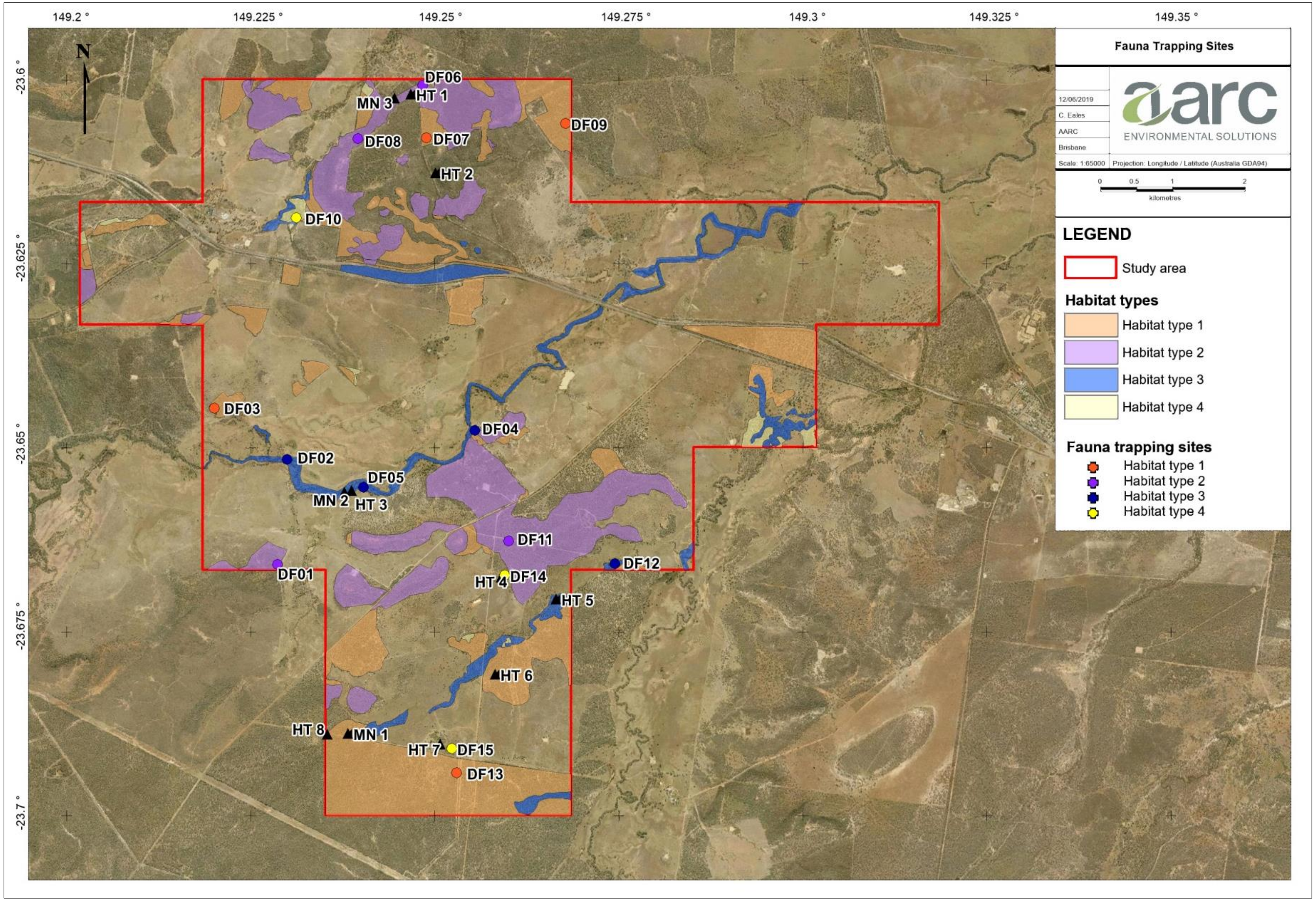


Figure 12 Gemini Project Fauna sites

4.5.3 Detection Techniques

A description of the techniques employed to survey the fauna occurring on the study area site (unless otherwise stated in the site description in Appendix E) is provided below:

Elliott trapping

Elliott traps are aluminium boxes with doors triggered by a floor treadle that are used to target small ground-dwelling mammals inhabiting the study area site. Traps were baited with a mixture of oats, peanut butter, and vanilla essence (referred to here-in as 'mammal bait'). At each site, two parallel lines each with 10 Elliott traps were placed at 10 m intervals. Alternatively, where fauna sites were established in linear riparian habitats, traps were positioned at 10 m intervals along a single central transect. Traps were strategically positioned under shrubs or beside logs to reduce exposure of trapped animals to the sun, wind and rain and maximise trap success.

Automated Camera Trapping

Automated camera trapping is a less invasive method of surveying medium and large-sized nocturnal terrestrial species. Cameras are usually attached to a tree in a position that offers an unobstructed view over a track or clearing. A bait tube constructed with PVC and filled with bait (on this occasion chicken necks), is pegged to the ground and positioned in clear view of the camera. Motion-sensing technology in the camera detect movement and trigger a photographic response. This is a highly effective survey method and is now widely used instead of cage trapping (Eyre et al*.* 2018). Automated cameras were deployed for four nights at all fauna survey locations during the survey period.

Pitfall Trapping

To target small ground-dwelling taxa (e.g. reptiles, mammals, and amphibians), a pitfall trap line was established at all fauna sites. Each line consisted of a 30 centimetre (cm) tall drift fence running along the ground and crossing the middle of four 20 litre buckets buried flush with the soil surface. Each pitfall trapping line was constructed in a T-shape design with 45 m of drift fence and buckets placed at approximately 7.5 m intervals. The bottom edge of each drift fence was buried to guide target animals towards the buckets. A small amount of soil, vegetation litter, a damp sponge and a small plastic pipe were placed in the bottom of each bucket to provide shelter and moisture for captured wildlife.

Funnel Trapping

Funnel traps are elongated box-shaped traps made of wire and fine mesh. Six funnel traps were positioned at each fauna site in order to catch medium and large-sized terrestrial reptiles, snakes and some species of medium-sized skinks, dragons and geckos. Funnel traps were also set with a damp sponge and covered with hessian bags to provide shelter and moisture for captured wildlife. Where pitfall trapping lines were established at a fauna site, funnel traps were placed at the end of each drift fence. In the absence of a pitfall line, funnel traps were placed in suitable habitat along fallen timber or rocky outcrops throughout the fauna site (100 by 100 m plot).

Microbat Surveying

Micro-bats (Microchiropterans) form an extremely diverse group of wildlife and the identification of individual species requires the use of specialised survey methods due to the superficial similarity of many species, their small size, and largely inaudible calls.

The QLD Government *Terrestrial Vertebrate Fauna Survey Guidelines for Queensland v3.0* recommended method for bat survey is the use of a bat recorder (i.e. ANABAT). These are automated devices that record the echolocation calls of microbat species. The majority of microbat species in Australia can be identified from a species specific 'call signature'. However, there is a small selection of species that cannot be reliably identified to species level by call signature. The *Nyctophilus* genus has several species in Australia and cannot be identified further than the genus level. Corben's long-eared bat (*Nyctophilus corbeni*) is listed as Vulnerable under both the EPBC Act and the NC Act. The distribution of *Nyctophilus corbeni* overlies much of central Queensland, including the study area.

A Long-eared bat (*Nyctophilus* sp.) was detected via echolocation records on the study area during surveys but could not be identified to species level. Ecologists completed a targeted micro-bat survey in order to correctly identify the *Nyctophilus* species to adequately satisfy the *Survey Guidelines for Australia's Threatened Bats* (DoEE 2010a). This targeted micro-bat survey utilised Harp Traps and Mist Nets in addition to ANABAT recorder.

The use of the following methodology was conducted in accordance with the *Survey Guidelines for Australia's Threatened Bats* and the *Terrestrial Vertebrate Fauna Survey Guidelines for Queensland (Eyre et. al 2018).* These fauna survey methods were only adopted for the specialised Micro-bat 2018 autumn survey conducted by AARC ecologists.

ANABAT Recorders

In order to navigate and hunt at night micro-bats use high frequency echolocation calls, most of which are above the frequency range audible to humans (i.e. ultrasound). These echolocation calls provide an opportunity to unobtrusively survey and identify micro-bats through the use of a specialised ultrasonic recorders. During the survey event, bat call detection devices (i.e. Songmeter or ANABAT recorder) were strategically positioned to detect micro-bat calls at all fauna trapping sites. A bat call detector was left at each site for a minimum of 3 nights. This specialised micro-bat survey was utilised during all terrestrial surveys. A bat call detector was left at each site for 3 nights, and bat call analysis performed by Greg Ford of Balance Environmental (Appendix G).

Mist Net

Mist nets are more versatile than harp traps and can be used in a wider variety of habitat types and locations to capture bats, including open areas. The mist net consisted of fine monofilament net approximately 12 m wide by 5 m tall with a mesh size of 19 mm and was held in tension using rope rigging between two trees. The height of the net is divided into 'benches' or 'shelves', each with a loose pocket of netting that helps entangle the captured bats.

A single Mist Net was deployed at three locations over the second autumn survey. They were generally set several hours after sunset, these nets remained raised for a minimum of 1 hour at each survey site. The position of each Mist Net was marked using a handheld GPS. Photographs of each of these sites were taken with a digital camera and site data (such as vegetation type, weather conditions and habitat condition) was recorded.

Harp Trap

Harp trapping is employed for resolving the presence of species whose calls cannot be separated or identified using bat detectors, such as the *Nyctophilus* genus, and for collecting abundance and demographic information such as sex, age or breeding condition, which cannot be determined from call echolocation. Harp traps consisted of two or three banks of vertically strung nylon lines held in a rigid aluminium frame above a large calico holding bag and mounted on adjustable legs. Harp traps are most suited to restricted flyways in well vegetated areas, such as along creeks and tracks, preferably placed where fringing vegetation abuts the trap edges on both sides and above. Bats flying along a flyway are typically unable to detect the lines and get caught between the banks of nylon line and slide down into the large, plastic-lined cloth holding bag, where the bats are unable to climb out.

A single two bank harp trap was deployed at eight sites. Traps were deployed for four nights per site. They were set up shortly before dusk each night and packed up either at dawn or in the early morning. Traps were checked several hours after dusk and again before dawn each night. The position of each trap was marked with a handheld GPS. Photographs of each trap site were taken with a digital camera and site data (such as vegetation type, weather conditions and habitat condition) was recorded.

Bird Surveying

Dedicated searches for birds was conducted visually and aurally during early mornings during peak avian activity. A dedicated search for diurnal birds was conducted visually and aurally at each fauna site. A minimum of one hour of bird surveying per fauna site was conducted in the early morning or late afternoon when bird activity was highest. In addition, opportunistic diurnal searches were also conducted on foot in areas considered likely to have high avian diversity (e.g. vegetated watercourses or dams), or likely to contain cryptic or threatened bird species.

Spotlighting

Spotlighting was carried out in the early evenings (before midnight) during all surveys to maximise encounter rate of nocturnal wildlife such as night birds and arboreal mammals primarily active at night. Two spotlighting techniques were employed:

1. Foot traverses: Dedicated spotlighting events were undertaken on foot at each fauna site. Searches were undertaken over two events where possible, one within the first hour following nightfall, and one after the first hour. Two ecologists randomly traversed the area with spotlights and binoculars, and wherever possible, bark crevices and tree hollows were examined. A slow walking speed (approximately 1 km per hour) was maintained across the length of the survey area to fully facilitate intensive listening and thorough visual searching.

2. Vehicle searches: During any driving on the study area after dark, spotlighting was conducted by the passenger/s from the slow-moving vehicle, to maximise study area coverage that cannot be achieved with foot traverses alone. Spotlights were used to scan trackside vegetation for arboreal and ground-dwelling wildlife.

Call Playback

Several nocturnal bird species are highly cryptic; occurring in naturally low population densities, are wide-ranging, and call infrequently. Detection rates are typically low without solicitation in the form of playback of pre-recorded calls to elicit a response (Kavanagh and Peake 1993; Debus 1995). Detectability of smaller nocturnal bird species such as the Southern Boobook *Ninox novaeseelandiae* and Australian owlet nightjar (*Aegotheles cristatus*), and the arboreal marsupial Yellow-bellied glider (*Petaurus australis*) also increase with playback of large owl calls. Smaller, cryptic arboreal species such as Squirrel glider (*P. norfolcensis*) and Sugar glider (*P. breviceps*) can also respond to owl call playback.

Call playback is undertaken prior to spotlighting foot traverses to minimise the chance of spooking species capable of leaving the area undetected. A series of species call would be selected depending on the surrounding habitat suitability, and each would be played for three minutes, followed by a two-minute listening period, with the cycle repeated three times for each species. Calls were played using a megaphone and loud enough so that the softest call could be heard 100-200 m away. Following the completion of all playback cycles, the area would then be spotlighted as described above.

Habitat Searching

To further enhance the likelihood of detecting small cryptic species, dedicated diurnal searches were conducted at each fauna site. This was spread over several events, two per site, during the survey period. Additional habitat searches were carried out during trap checks and while doing the flora surveys. Searches were typically undertaken during the late morning, allowing for reptile activity to increase with rising temperatures, but before the maximum heat of the day. Searching techniques involve the careful rolling of rocks and logs, rustling through leaf litter, and peeling back of exfoliating bark from standing trees. For targeted reptile species, dedicated searches were conducted opportunistically when preferred habitat was encountered (e.g. Gilgai formations or dense ground debris).

Evidence of wildlife was also searched for during these surveys' identification of tracks, scats and other signs of occupation (e.g. tree trunk scratches). For scats not identifiable in the field, they were collected and sent to a scat analysis expert (Barbara Triggs) for identification of the species responsible for the scat and/or where possible, the identification of prey species material present in predator scats.

Incidental Recordings

Throughout each survey period, ecologists were traversing the study area on foot and by a vehicle every day for numerous hours whilst conducting routine survey activities (e.g. driving between sites, checking traps, vegetation surveys etc.). The ecologists remained alert and would record numerous wildlife species as observed or heard during the survey period. As with the habitat searches, this included signs or evidence of wildlife and included constant vigilance for raptor nests. Ecologists visited all areas of the study area throughout the surveys.

4.5.4 Fauna Survey Effort

Survey effort undertaken during each survey event is detailed in Table 10 for each fauna sampling technique.

As per Eyre et al*.* 2014 recommendations, each habitat type located within the study area had a minimum of three fauna sites across the identified survey seasons. The Project is located within the Brigalow Belt, which the fauna survey guideline recommends surveying during Spring and Autumn (Eyre et al. 2014).

While conducting the flora surveys across remnant and non-remnant areas, if habitat conditions met the required conditions for targeted species, these habitats were searched, and species were recorded opportunistically.

Table 10 Survey effort

Sampling Technique	Survey Effort				
	Autumn Survey 2017	Spring Survey 2017	Autumn Survey 2018	Micro-bat Survey 2018	Total Survey effort
Elliott Trapping	4 sites x 20 traps x 4 nights = 320 trap nights	6 sites x 20 traps x 4 nights = 480 trap nights	5 sites x 20 traps x 4 nights = 400 trap nights	-	1,200 TTN
Automated Camera Trapping	4 sites x 1 camera x 4 nights = 16 trap nights	6 sites x 1 camera x 4 nights = 24 trap nights	5 sites x 1 camera x 4 nights = 20 trap nights	-	60 TTN
Pitfall Trapping	4 sites x 4 pitfalls x 4 nights = 64 trap nights	6 sites x 4 pitfalls x 4 nights = 96 trap nights	5 sites x 4 pitfalls x 4 nights = 80 trap nights	-	240 TTN
Funnel Trapping	4 sites x 6 funnels x 4 nights = 96 trap nights	6 sites x 6 funnels x 4 nights = 144 trap nights	5 sites x 6 funnels x 4 nights = 120 trap nights	-	360 TTN
ANABAT	(3 sites x 1 bat detector x 3 nights) + (1 site x 1 bat detector x 2 nights) = 11 active nights	(3 sites x 1 bat detector x 3 nights) + (1 site x 1 bat detector x 2 nights) + (1 site x 1 bat detector x 4 nights) = 15 active nights	4 sites x 1 bat detector x 3 nights = 12 active nights	-	38 TTN
Harp Trapping	-	-	2 sites x 1 harp x 4 nights = 8 trap nights	8 sites x 1 harp x 7 nights = 56 trap nights	64 TTN
Mist Netting	-	-	-	3 sites x 1 mist net = 3 trap nights	3 TTN
Call Playback (CPB) (30 minutes per session 2 sessions)	4 sites x 5 CPB x 2 nights = 40 CPB	6 sites x 4 CPB x 2 nights = 48 CPB	(4 sites x 4 CPB x 2 nights) + (1 site x 3 CPB x 1 night) + (1 site x 4 CPB x 1 night) = 39 CPB	-	127 CPB
Bird Surveying (60 minutes per session 2 sessions)	8 person hours at fauna sites 15 person hours of opportunistic bird surveying	12 person hours at fauna sites 20 person hours of opportunistic bird surveying	10 person hours at fauna sites 15 person hours of opportunistic bird surveying	-	80 TPH
Spotlighting (30 minutes per session 2 sessions)	4 person hours at fauna sites 4 person hours of opportunistic spot lighting	6 person hours at fauna sites 5 person hours of opportunistic spot lighting	5 person hours at fauna sites 5 person hours of opportunistic spot lighting	-	29 TPH
Habitat Searching (60 minutes per session 2 sessions)	8 person hours at fauna sites 12 person hours of opportunistic habitat searching	12 person hours at fauna sites 15 person hours of opportunistic habitat searching	10 person hours at fauna sites 10 person hours of opportunistic habitat searching	-	67 TPH

TTN: Total trap nights
TPH: Total person hours

5.0 FLORA RESULTS AND DISCUSSION

5.1 FLORA SURVEY RESULTS

A total of 207 flora species were identified in the study area. One flora species listed as Near Threatened under the NC Act but not listed under the EPBC Act, was observed on the Central East of the study area; *Cerbera dumicola*. A total of 33 introduced species were recorded on the study area, of which five are listed as weed species under the Queensland Biosecurity Act and/or classified by the Australian Government as a Weed of National Significance (WoNS). All four are listed as Restrictive Invasive plants for Queensland, and only three of them are also classified as WoNS; Parthenium weed (*Parthenium hysterophorus*) and Velvety tree pear (*Opuntia tomentosa)*. A full flora list for the study area is provided in Appendix H. Weed species fact sheets for these species are attached in Appendix J.

Six vegetation communities classed as Remnant Vegetation as defined by the VM Act were identified in the study area during the field surveys. The vegetation communities have been mapped when possible as homogeneous polygons with the exception of some "mixed polygons" which consisted of two or more vegetation communities that were mapped together due to the impracticability in clearly delineating each RE.

Associations within the communities reflect different vegetation structures and compositions, which occur in different geophysical locations. Table 11 outlines the RE characteristic of each vegetation community, where applicable, as well as a short description of the vegetation present. A description is provided in Sections 5.1.1 to 5.1.7, whilst Figure 13 shows the distribution of vegetation communities in the study area.

Approximately 5,331 ha in the study area (73.7 % of the total) is not associated with remnant or high value regrowth vegetation. These cleared areas consist mostly of pasture species such as Buffel grass and Sabi grass and patches of regrowth of predominately *Acacia acradenia*. Moreover, remnant areas present different degrees of disturbance such as fire, dieback and selective logging (e.g. Rosewood (*Acacia rhodoxylon)*). The study area presents a high level of fragmentation, providing limited to no connectivity value between the protected areas and state forests surrounding the study area (Section 1.3).

Analysis of the vegetation communities recorded within the study area confirms that none meet the condition thresholds to constitute a TEC, listed as threatened at the national level (see Section 5.3.1).

Table 11 Vegetation Community Overview

Vegetation Community	Regional Ecosystem	Community Description
VC 1	11.5.2	Narrow-leaved ironbark and Clarkson's bloodwood woodland with a sparse shrub layer on sand plains.
VC 2	11.7.2	Lancewood (*Acacia shirleyi*) and/or Rosewood (*Acacia rhodoxylon)* woodland on lateritic duricrust.
VC 3	11.3.25	Blue gum (*Eucalyptus tereticornis) or E. camaldulensis* with *Bauhinia* spp. and *Casuarina cunninghamiana* fringing woodland on drainage features.
VC 4	11.3.2	Poplar box (*Eucalyptus populnea)* woodland on alluvial plains.
VC 5	11.5.2/11.3.25	Mixed polygon where the dominant vegetation community was VC 1 (*Eucalyptus crebra* and *Corymbia clarksoniana*

Vegetation Community	Regional Ecosystem	Community Description
		woodland) but along ephemeral creeks and with an important presence of Blue gums.
VC 6	11.3.25/11.3.2/11.5.2	Mixed polygon as a result of combination of VC 3 with elements of VC 4 and some elements of VC 1 due to edge effect.
Non-Remnant	NA	Non-remnant vegetation

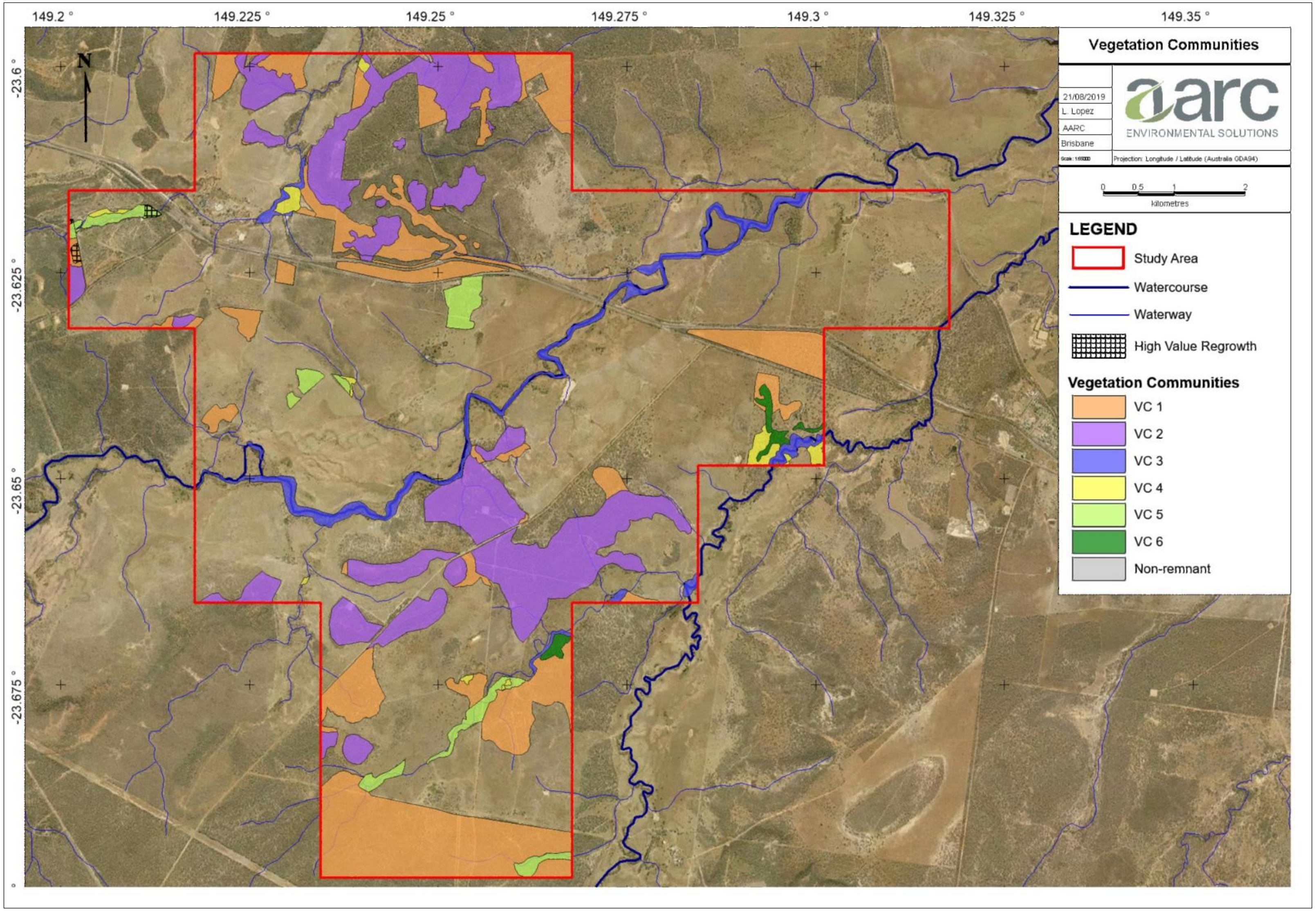


Figure 13 Vegetation Communities within the study area

5.1.1 VC 1: Narrow-leaved ironbark and Clarkson's bloodwood woodland with a sparse shrub layer on sand plains

VC 1 consists of Narrow-leaved ironbark (*Eucalyptus crebra)* and Clarkson's bloodwood (*Corymbia clarksoniana)* woodland with a sparse shrub layer on sand plains and is consistent with RE 11.5.2. *Allocasuarina luehmannii* is dominant in some sandy patches throughout the study area.

VC 1 is the most abundant vegetation community, covering a total of 872.23 ha (12.02%) of the study area. Table 12 provides a summary of community structure and corresponding conservation status.

Table 12 Vegetation Community 1 Profile

Associated Regional Ecosystem	11.5.2: *Eucalyptus crebra*, *Corymbia* spp., with *E. moluccana* woodland on lower slopes of Cainozoic sand plains and/or remnant surfaces
Extent within Project	872.23 ha
Remnant Status	Remnant and 2.71 ha mapped as High Value Regrowth
EPBC Act	Not listed
VM Act Status	Least Concern
Biodiversity Status	No concern at present
Tree Layer	*Eucalyptus crebra* and *Corymbia clarksonia* (12 - 14 m) and occasionally *Allocasuarina luehmannii* dominant on the tree layer. *Alphitonia excelsa* and *Petalostigma pubescens* are dominant in a smaller tree layer.
Shrub Layer	The 0.5 m to 2 m tall shrub layer is usually dominated by *Erythroxylum australe, Petalostigma pubescens, Psydrax johnsonii* and *Carissa spinarum.*
Ground Layer	The ground layer is typically dominated by *Cleistochloa sp. (*Duaringa K.B.Adison 42*)*, *Eragrostis lacunaria, Aristida calycina, Aristida caput-medusae*, and sometimes exotics such as *Melinis repens* and *Urochloa mosambicensis.*
Structure Category	Sparse
Biosecurity Act and/or WoNS Weed Species	*Opuntia tomentosa*
Crown Cover (%)	Average of 60% canopy cover
Ground Cover (%)	On average, bare ground comprised 29% of the total area, whilst organic litter formed 60%

Photo Plate 1 Ironbark and Bloodwood woodland on sand plains

Conservation Value

No species of conservation significance were recorded in this vegetation community.

The following exotic species were recorded in VC 1 during the ecology surveys: Velvety tree pear (*Opuntia tomentosa),* Red natal grass (*Melinis repens*), Paddy's lucerne (*Sida rhombifolia*) and Green panic (*Megathyrsus maximum*). Velvety Tree Pear is classified as a WoNS.

Vegetation Condition and Habitat Value

RE 11.5.2 is listed as Least Concern under the VM Act and the DES's Biodiversity Status. The extent of this community in reserve areas is low (DES 2019c).

VC 1 presents patches of regrowth vegetation thorough the study area. Areas that have been subjected to past disturbance such as fire, dieback and selective logging now hold coloniser species. Patches of *Acacia cretata* and *Acacia rhodoxylon* young trees of about 1.5-2m dominate the shrub layer across the study area (Photo Plate 2).

Photo Plate 2 VC 1 regrowth patch with *Acacia spp.*

5.1.2 VC 2: Lancewood (*Acacia shirleyi)* and/or Rosewood (*Acacia rhodoxylon)* woodland on lateritic duricrust

VC 2 consists of *Acacia* monospecific woodland on lateritic soil, mainly Lancewood (*Acacia shirleyi*) and Rosewood (*Acacia rhodoxylon).* It occurs around rocky areas in the North of the study area but also on flat lateritic areas in the centre and south, covering approximately 734.23 ha (10.12%) of the study area. This community occurs on lateralised mesa slopes, breakaways, scree slopes and remnant colluvium. A summary of VC 2 is presented below in Table 13.

Table 13 Vegetation Community 2 Profile

Associated Regional Ecosystem	11.7.2*: Acacia spp.* woodland on Cainozoic lateritic duricrust. Scarp retreat zone.
Extent within the study area	734.23 ha
Remnant Status	Remnant
EPBC Act	Not listed
VM Act Status	Least Concern
Biodiversity Status	Of Concern
Tree Layer	*Eucalyptus crebra* as occasional emergent tree with *Acacia shirleyi* or *Acacia rhodoxylum* monospecific dominant in the tree layer.
Shrub Layer	Very sparse shrub layer with dominance of *Acacia rhodoxylum, Erythroxylum australe, Alstonia constricta, Psydrax forsteri* and *Carissa spinarum.*
Ground Layer	The ground layer is typically dominated by *Entolasia stricta* (D)*, Calyptochloa gracilima* (D)*, Aristida caput-medusae* (D) *and Paspalidium caespitosum* (D)*.*
Structure Category	Sparse
Biosecurity Act and/or WoNS Weed Species	None
Crown Cover (%)	Average of 70% canopy cover
Ground Cover (%)	On average, bare ground comprised 15.5% of the total area, whilst organic litter comprised 65%

D – Dominant

Photo Plate 3 Lancewood woodland within the study area

<u>Conservation Value</u>

Cerbera dumicola, listed as NT under the NC Act was recorded in two locations within the study area, both of them associated with VC 2. Section 5.3 below discusses this listed species in further detail.

The following exotic species were recorded in VC 2 during the ecology surveys: Sabi grass (*Urochloa mosambicensis*), *Sida cordifolia,* Red natal (*Melinis repens), Malvastrum americanum* and Shrubby stylo *(Stylosanthes scabra)*.

<u>Vegetation Condition and Habitat Value</u>

RE 11.7.2 is listed as Least Concern under the VM Act and the DES's Biodiversity Status. The extent of this community in reserve areas is low (DES 2019c).

VC 2 presents different degrees of disturbance thorough the study area. As per VC 1, areas that have been subjected to past fire, dieback and selective logging. Rosewood has been targeted for logging due to its high value as fence post. Lancewood, on the other hand, has been left relatively undisturbed due to its value stabilising the soil in an area highly susceptible to erosion. *Acacia rhodoxylon* young and thin trees of about 1.5-2m can be found in patches across the study area.

5.1.3 VC 3: Blue gum (*Eucalyptus tereticornis)* or River gum (*Eucalyptus camaldulensis)* with *Bauhinia* spp. and *Casuarina cunninghamiana* fringing woodland on drainage features

This community is located along Charlevue Creek and other ephemeral creeks within the study area. It covers approximately 143.74 ha, close to 2% of the study area, and occurs on alluvial plains. Table 14 provides a detailed description of VC 3. Occasional small patches of *Corymbia tessellaris* or *Eucalyptus populnea* were present on adjacent alluvial floodplains.

Table 14 Vegetation Community 3 Profile

Associated Regional Ecosystem	11.3.25: *Eucalyptus tereticornis* or *E. camaldulensis* woodland fringing drainage lines.
Extent within Project	143.74 ha
EPBC Act	Not listed
VM Act Status	Least Concern
Biodiversity Status	Of Concern
Tree Layer	*Eucalyptus tereticornis* or *E. camaldulensis* dominant species with occasional *Eucalyptus crebra, Eucalyptus populnea, Corymbia tessellaris and Corymbia clarksoniana.* In a lower tree layer, the dominant species are *Bauhinia carronii* and *Cassia brewsterii* and occasionally *Melaleuca nervosa* would be the dominant species.
Shrub Layer	The 0.5 m to 2 m tall shrub layer is generally dominated by *Carissa spinarum, Terminalia oblongata, Melaleuca nervosa* and *Alphitonia constricta.*
Ground Layer	The ground layer is typically dominated by *Dichantium sericeum* (D), *Megathyrsus maximus* (D), *Cenchrus ciliaris* (D), *Urochloa mosambicensis* (D) and *Bothriochloa ewartiana* (D).

Structure Category	Mid-dense
Biosecurity Act and/or WoNS Weed Species	*Cryptostegia grandiflora*, *Parthenium hysteropus* and *Opuntia tomentosa*
Crown Cover (%)	Average of 58% canopy cover
Ground Cover (%)	On average, bare ground comprised 8.5% of the total area, whilst organic litter formed 53%

D – Dominant

Photo Plate 4 Blue gum (*Eucalyptus tereticornis) or River Gum (E. camaldulensis)* woodland along the Charlevue Creek

Conservation Value

No species of conservation significance were recorded within VC 3.

The weed species Rubber vine (*Cryptostegia grandiflora*), Parthenium weed (*Parthenium hysteropus*) and Velvety tree pear (*Opuntia tomentosa)* were recorded in this community, along the Charlevue Creek.

Introduced species Buffel grass *(Cenchrus ciliaris),* Green panic *(Megathyrsus maximus*), Sabi grass *(Urochloa mosambicensis) Sida cordifolia, Malvastrum americanum* and *Bidens pilosa* were recorded in VC 3. Buffel grass and Green panic were occasionally recorded as the dominant species in the ground layer.

Vegetation Condition and Habitat Value

RE 11.3.25 is listed as Least Concern under the VM Act and Of Concern under DES's Biodiversity Status. The extent of this RE in reserves is low (DES 2019c).

Often associated with regional ecosystems 11.3.2 and 11.3.4, elements of which such as *Corymbia tessellaris* and *Eucalyptus populnea* may occur on adjacent alluvial plains. In highly cleared areas, in particular north of the Capricorn Highway, a narrow fringe of riparian vegetation is often the only surviving woody vegetation and it is not mapped as remnant in the Government vegetation map. This RE is impacted by grazing pressure and edge effects, where the dominant ground layer is dominated by the exotic pasture species that grow in the grazing area.

The presence of large, remnant, hollow-bearing trees such as *Eucalyptus tereticornis and E. camaldulensis* provide important denning and breeding habitat for a variety of arboreal mammals and birds.

5.1.4 VC 4: Poplar box *(Eucalyptus populnea)* woodland on alluvial plains

This community is located in small patches within the study area. It covers approximately 36.52 ha (0.5%) of the study area on alluvial soils. Table 15 provides a summary of conservation status and vegetative structure for VC 4.

Table 15 Vegetation Community 4 Profile

Associated Regional Ecosystem	11.3.2: *Eucalyptus populnea* woodland on alluvial plains.
Extent within Project	36.52 ha
EPBC Act	Analysis of this vegetation (Section 5.3.1) confirms that VC4 does not meet the condition thresholds to constitute a TEC.
VM Act Status	Of Concern
Biodiversity Status	Of Concern
Tree Layer	Tree layer dominated by *Eucalyptus populnea* (in some occasions *E. melanophloia*) (12-14m), with occasional *Corymbia dallachiana, C. clarksoniana* and *C. tessellaris.*
Shrub Layer	Very spare shrub layer dominated by *Atalaya hemiglauca, Archidendropsis basaltica, Flindersia dissosperma, Carissa spinarum* (dominant in the lower shub layer) and occasionally *Alphitonia excelsa.*
Ground Layer	The ground layer is typically dominated by *Bothriochloa ewartiana, Aristida calycina, Aristida perniciosa* (D), *Eragrostis sororia, Eragrostis lacunaria, Cynodon dactylon, Urochloa mosambicensis* (D), *Heteropogon contortus* (D) and *Themeda triandra,*
Structure Category	Sparse
Biosecurity Act and/or WoNS Weed Species	*Harrisia martini* and *Vachellia farnesiana*
Crown Cover (%)	Average of 53% canopy cover
Ground Cover (%)	On average, bare ground comprised 12.5% of the total area, whilst organic litter comprised 34%

D – Dominant

Photo Plate 5 Poplar box *(Eucalyptus populnea)* woodland on alluvial plains

<u>Conservation Value</u>

No species of conservation significance were recorded within VC 4.

The exotic species Sabi grass (*Urochloa mosambicensis*), *Sida cordifolia*, Shrubby stylo (*Stylosanthes scabra*), Red natal (*Melinis repens*), *Malvastrum americanum*, *Bidens pilosa,* Mimosa bush (*Vachellia farnesiana*) and Harrisia cactus (*Harrisia martinii*) were recorded in VC 4.

VC4 is most consistent with RE 11.3.2, which is an associated RE of the Poplar box grassland on alluvial plains and Weeping myall woodland TEC. None of these TECs were identified within the study area. A summary of the survey effort to determine the presence of both TECs is detailed in Section 5.3.1.

<u>Vegetation Condition and Habitat Value</u>

RE 11.3.2 is classified as Of Concern under the VM Act and Of Concern at present under DES's Biodiversity Status. The extent of this RE in reserves is low.

VC 4 was only present in small patches within the study area, some of them too small to map. This community presented evidence of edge effect with exotic pasture species such as *Urochloa mosambicensis* occasionally dominating the ground layer. Regrowth of VC 4 was recorded in the south of the study area and along Cooinda road, in the middle of the study area. Recruitment of Poplar box was observed across the study area, with sections within VC 4 of very young and thin trunks.

5.1.5 VC 5: Mixed polygon: Ironbark, Bloodwood and Blue gum woodland along ephemeral creeks

VC 5 is limited to small patches within the study area and consist on a combination of VC 1 with elements of VC 3 (Blue gums, 20% of the vegetation community) due to the presence of ephemeral drainage features in the vicinity of VC 1. *Melaleuca nervosa* is occasionally present as dominant species on the tree and shrub layers. It covers approximately 96.71 ha (1.33%) of the study area.

VC 5 is illustrated in Photo Plate 6.

Conservation Value

No species of conservation significance were recorded within VC 5. The same exotic pasture species recorded in VC 1 where observed in the ground layer of this community throughout the study area.

Vegetation Condition and Habitat Value

This community was only present in three patches within the study area, where it was not possible to separate the vegetation into two defined communities. There is evidence of edge effect, where exotic pasture species are present in the groundcover. Regrowth of VC 5 was similar to the regrowth of VC 1, with the same pioneer *Acacia* spp. as described before. Both RE's, 11.5.2 and 11.3.25 are classified as Least Concern under the VM Act but while RE 11.5.2 is classified as Least Concern under the DES's Biodiversity Status, RE 11.3.25 is classified as Of Concern. The extent of these REs in reserves is low (DES 2019c).

Photo Plate 6 VC 5 – RE 11.5.2/11.3.25

5.1.6 VC 6: Mixed polygon: Blue gum, Poplar box and Ironbark woodland along ephemeral creeks

VC 6 is located in small patches within the study area and consist on a combination of VC 3 (Blue gums) along several small ephemeral drainage channels, with elements of VC 4 (Poplar box), present in the alluvial plains between the channels and VC 1 (Ironbark) due to edge effect. VC 6 covers a total of 21.83 ha (0.3%) of the study area.

Conservation Value

No species of conservation significance occurred within VC 6.

Habitat Value

VC 6 was only present in two patches within the study area, where it was not possible to separate the vegetation into three defined communities. As per VC 5, there is evidence of edge effect, with exotic pasture species present in the groundcover and occasionally dominant. The RE classification for the three REs present is as follows: 11.3.25 is listed as Least Concern under the VM Act and Of Concern under DES's Biodiversity Status; 11.3.2 is listed as Of Concern under the VM Act and the DES's Biodiversity Status; and 11.5.2 is listed as Least Concern under the VM Act and the DES's Biodiversity Status. The extent of these RE in reserves is low (DES 2019c).

5.1.7 Non-remnant and Regrowth Vegetation

Non-remnant regrowth vegetation is present in areas that have been disturbed by human activities, such as logging and preparation for grazing through the entire study area. There are numerous patches of regrowth vegetation, including areas that are mapped as remnant in the Vegetation Management Regional Ecosystem Map but have been assessed as non-remnant as a result of the field surveys.

This vegetation is not classed as remnant vegetation, therefore is not defined by an RE.

There is one large patch of vegetation north of the study area mapped as remnant which vegetation consists of *Acacia* spp regrowth. According to local knowledge (farmers) around six years ago, there was a fire that affected the north part of the EPC, the area north of the Capricorn Highway. As a result of that fire, there is regrowth across all the vegetation communities, especially VC 1 and VC 4. A large patch of woodland originally mapped as 11.5.9b is now categorised as non-remnant vegetation. This particular area presents only an extremely sparse tree layer (*Eucalyptus crebra* and *Corymbia clarksoniana*) and a dense shrub layer of pioneer *Acacia* spp., mainly *Acacia cretata.*

Photo Plate 7 Non-remnant *Acacia* spp regrowth

The areas of the study area not mapped in Figure 13 are mainly pasture land with more or less evidence of regrowth or dead vegetation. This regrowth corresponds with early stages of V4, V1 or V2. Regrowth of *Acacia cretata* is especially abundant within several vegetation communities, such V1, but also in the pasture area. Evidence of burning and ring barking has been recorded thorough these pasture areas.

The ground layer of the non-remnant vegetation is dominated by exotic pasture grasses such as Buffel grass (*Cenchrus ciliaris*), Indian bluegrass (*Bothriochloa pertusa*), Sabi grass (*Urochlora mosambicensis*) and Red natal grass (*Melinis repens).*

5.2 WEEDS OF MANAGEMENT CONCERN

A total of 33 introduced species were identified onsite. The exotic pasture grasses dominate the ground layer of the study area, particularly in cleared areas. A range of other exotic grasses and forbs are also present across the study area in low to moderate abundance. A complete list of the flora species, indicating their native or introduced status can be found in Appendix H.

Three of these introduced species are classed as WoNS; Parthenium weed (*Parthenium hysterophorus*), Rubber vine (*Cryptostegia grandiflora)* and Velvety tree pear (*Opuntia tomentosa*). Introduced plant species are classified by the Commonwealth Government as WoNS if they present a serious threat to industry, water supply, human health/safety, plant communities and/or cultural values.

The above mentioned three species, together with Harrisia cactus *(Harrisia martini)* are similarly classed as Restricted Invasive Species under the Biosecurity Act (DAF 2018).

Vachellia farnesiana, also found in the study area, is not a prohibited or restricted invasive plant under the Biosecurity Act. However, by law, everyone has a general biosecurity obligation (GBO) to take reasonable and practical steps to minimise the risks associated with invasive plants and animals under their control (DAF 2016).

Weed species of management concern found in the study area are listed in Table 16. All species present are known to occur commonly throughout the broader region.

Table 16 Weed species of management concern identified in the study area

Scientific name	Common name	WoNS Status	*Biosecurity Act 2014* Category 3
Harrisia martinii	Harrisia cactus	-	x
Cryptostegia grandiflora	Rubber vine	Yes	x
Opuntia tomentosa	Velvety tree pear	Yes	x
Parthenium hysterophorus	Parthenium	Yes	x
Bryophyllum sp	Mother of millions	-	x
*Vachellia farnesiana**	Mimosa bush	-	-

Note: * Considered a noxious weed of management concern.
Category 3: A person must not distribute the invasive plant either by sale or gift, release it into the environment.

Photo Plate 8 *Cryptostegia grandiflora* identified in the study area

5.3 FLORA OF CONSERVATION SIGNIFICANCE

5.3.1 Threatened Ecological Communities not identified in the study area

Brigalow (*Acacia harpophylla dominant and co-dominant)*

The Brigalow (*Acacia harpophylla* dominant and co-dominant) TEC comprises patches of vegetation in which *Acacia harpophylla* is one of the most abundant tree species. The tree layer may be dominated by *Acacia harpophylla* or have a co-dominant presence with other species such as Belah (*Casuarina cristata*) and other species of Acacia or Eucalyptus. Within Queensland, the Brigalow TEC is consistent with 16 RE described by the Queensland Herbarium, including RE 11.3.1, originally mapped within the study area.

A patch must meet the following condition thresholds to be considered the Brigalow TEC:

- The patch is 0.5 ha or more in size; and
- Exotic perennial plants comprise less than 50% of the total vegetation cover of the patch, as assessed over a minimum sample area of 0.5 ha (100 m by 50 m), that is representative of the patch.

Despite being mapped as present along the Charlevue and Springton Creeks in association with RE 11.3.1, Brigalow (*Acacia harpophylla)* was only recorded within the study area as a few individual stands. Two trees were recorded along the Charlevue Creek and a small patch with six trees was recorded on the bank of Springton Creek, close to the eastern boundary of the study area.

The sparse Brigalow individuals do not form a clear vegetation community, not reaching dominance in the canopy nor the minimum size of 0.5 ha specified as condition thresholds to qualify as Brigalow TEC.

Weeping myall *(Acacia pendula)* Woodland

Weeping myall woodlands often occur as monotypic stands generally 4 – 12 m high in which Weeping myall trees are the sole or dominant overstorey species. Other canopy species such as Western rosewood (*Alectryon oleifolius* subsp. elongatus), Poplar box (*Eucalyptus populnea*), or Black box (*Eucalyptus largiflorens*) may occur in association with this community.

Within Queensland, this community is known to occur in association with two REs including RE 11.3.2 (*Eucalyptus populnea* woodland on alluvial plains) and 11.3.28 (*Eucalyptus coolabah* +/- *Casuarina cristata* open woodland on alluvial plains). Of the extent of these REs throughout Queensland, it is estimated that only 5% supports the Weeping myall woodlands community. Most patches of the TEC are less than 1 or 2 ha in area.

This TEC has been previously described as potentially occurring on the study area based on the mapping of Poplar box woodlands on alluvial plains (11.3.2), has been ground-truthed as non-remnant based on the negligible canopy cover. However, due to the cycles of senescence that affect the dominant species Weeping myall, the criteria used to assess a vegetation community includes canopy cover as sparse as 5% and dominated by living, dead or defoliated Weeping myall trees (DEWHA 2009). As a result, additional survey effort was employed in this area, to identify any dead and/or defoliated trees. This area was dominated by *Acacia cretata* regrowth, confirming the absence of Weeping myall woodland TEC on the study area.

Poplar box Grassy Woodland on Alluvial Plains

Assessments of the RE 11.3.2 present within the study area (VC 4) have concluded that the TEC Poplar box Grassy Woodland is not present within the study area.

To be listed as TEC, the Poplar box in alluvial plains is to meet certain thresholds, such as size and vegetation condition. The following thresholds have been sourced from the *Draft Conservation Advice (including listing advice) for the Poplar Box Grassy Woodland on Alluvial Plains* (TSSC n. d.):

Class A Highest Quality

- **Category A1:** Patch equal or larger than 1 ha: The patch has little or no perennial weeds and a diverse native understorey. 90% or more of the perennial vegetation cover is native species **and** with 30 or more native plant species in the ground layer per ha.

- **Category A2:** Patch equal or larger than 5 ha. A large patch with low perennial weeds and diverse native understorey. 70% or more of the perennial vegetation cover is ground layer is native **and** with 30 or more native plant species in the ground layer per ha.

- **Category A3:** Patch equal or larger than 5 ha. A large patch with high quality habitat features. 10 trees per ha that either are large (30 cm or more in diameter at breast height) and/or have developed hollows **and** smaller trees, saplings or seedlings suggesting of periodic recruitment **and** with 20 or more native plant species in the ground layer per ha.

Class B Moderate Quality

- A large patch with moderate quality native understorey. 50% of perennial vegetation cover in ground layer is native **and** 20 or more native plant species per ha in the ground layer **or** 10 trees per ha that either are large (30 cm or more in diameter at breast height) and/or have developed hollows

VC 4 does not meet the threshold to constitute a TEC due to the size of the patches and poor condition of the community with a high presence of exotic pastures, occasionally dominant. Some trees recorded from the largest patch of VC 4 within the study area were larger than 30cm in diameter at breast height, however, some sections of the same patch presented younger and smaller specimens, not meeting the average of 10 or more per ha.

5.3.2 Flora Species of Conservation Significance Identified in the Study Area

Targeted searches across the study area detected the presence of one flora species of conservation significance in several of the seasonal surveys, *Cerbera dumicola* (Photo Plate 9). This species is listed as NT under the NC Act.

Cerbera dumicola is a shrub or small tree growing to 4 m high (DES 2018b). The species occurs across a range of habitats in central and southern Queensland. This species is associated with a range of vegetation communities such as sandstone hills in open *Eucalyptus umbra* subsp. *carnea*; woodlands of *Acacia shirleyi* with *Corymbia dolichocarpa*; acidic soils in mine rehabilitation area; woodland of *A. catenulata* and *A. shirleyi* with *E. thozetiana* on a slope of sand/clay soil; semi-deciduous notophyll-microphyll vine forest of *Brachychiton australis*, *Gyrocarpus americanus*, *Flindersia australis*, *Pleiogynium timorense*, *Drypetes deplanchei* and *Sterculia quadrifida* on rhyolite hillslopes; open-woodland of *E. melanophloia* with occasional *Acacia shirleyi*, *E. populnea* and *E. brownii*; semi-evergreen vine thicket with *Corymbia citriodora* and *Corymbia aureola emergents*; woodland of *A. rhodoxylon* on brown, sandy loam; and in *Corymbia tessellaris* - *Acacia aneura* open woodland (DES 2018b).

Cerbera dumicola has been severely impacted by land clearing with extensive fragmentation of its original habitat. While it can be very common at some of its known localities, many of the remnant populations comprise few individuals. It is likely to be more widespread than is currently known as these eucalypt dominated woodlands are poorly surveyed in southern Queensland. Threatening processes include:

- Land clearing for agriculture, which has undoubtedly been the main reason in the past for reductions in the area of occupancy, number of populations, number of individuals. Many populations are in areas mapped as 'non-remnant vegetation', hence are still able to be cleared; and

- Land clearing for mining. Several populations have been recorded from mining leases in the central highlands coalfields and are presumed lost (DES 2018b).

Cerbera dumicola has been identified during the vegetation surveys in two very localised rocky areas associated with vegetation community VC 2 and VC 1 (on an ecotone with VC 2) (Figure 14). This species was not identified elsewhere in the study area, within similar habitat types, during targeted searches.

The species is regionally abundant, having been recorded outside of the study area on multiple occasions (AVH 2019).

It is not expected that the proposed Project will impact on the known *Cerbera dumicola* individuals due to their location. The species has been recorded at the boundary of the study area and adjacent to areas of existing disturbance. Suitable habitat is extensive throughout the local area including immediately east of the study area.

Photo Plate 9 ***Cerbera dumicola*** **at the study area**

5.3.3 Flora Species of Conservation Significance Not Identified in the Study Area

Table 17 below discusses EVNT species that are known from the broader region and have been identified from desktop searches but were not observed on site during surveys.

The assessment of the potential for presence and impact on each species is based on the knowledge of ecologists, information obtained from field surveys on the study area, previous surveys conducted on or near the study area and scientific literature. This assessment revealed that of the four species previously assessed with potential to occur within the study area, three were considered unlikely to occur within the study area.

Table 17 Flora Species of Conservation Significance not identified in the study area

Scientific Name Common Name	Status		Likelihood of Occurrence Post Survey
	NC Act	EPBC Act	
Bertya opponens	C	V	Potential The study area contained suitable habitat. However, there are no records of the species within 50 km of the study area and the species was not identified during the field survey. It is therefore considered unlikely the Project will impact on this species.
Bertya pedicellata	NT	-	Potential The study area contained suitable habitat. However, the species was not identified during the field survey, it is considered unlikely the Project will impact on this species.
Solanum adenophorum	V	-	Unlikely The study area did not contain suitable habitat for this species in the form of cracking clay soils and Brigalow woodland. The species was not detected during the field survey, indicating potential for Project impact to be low.
Solanum dissectum	E	E	Unlikely The study area did not contain suitable habitat for this species in the form of cracking clay soils and Brigalow woodland. The species was not detected during the field survey, indicating potential for Project impact to be low.
Solanum elachophyllum	E	-	Unlikely The study area did not contain suitable habitat for this species in the form of cracking clay soils. Further, the species was not detected during the field survey, indicating potential for Project impact to be low.

EPBC – *Environment Protection and Biodiversity Conservation Act 1999*
NC Act – *Nature Conservation Act 1992*
CE – Critically Endangered
NT – Near Threatened
V – Vulnerable
E – Endangered
C – Least Concern

5.4 WETLANDS

Field surveys concluded that all the potential lacustrine and palustrine wetlands within the study area (Figure 7) are either not present or have been identified as artificial (farm) dams. The only wetlands confirmed within the study area in accordance with the DES interactive Wetland*Maps* database are riverine wetlands and have been mapped as VC 3, VC 5 and VC 6.

Field surveys concluded that all the potential lacustrine and palustrine wetlands identified within the study area from desktop searches (Figure 7) are either not present or have been identified as artificial (farm) dams. The only natural wetlands within the study area are riverine wetlands associated with riparian and vegetation along Charlevue Creek and have been mapped as VC 3, VC 5 and VC 6 (Figure 13).

Outside the study area, there is a large palustrine wetland (approximately 82 ha) located about 4 km to the east of the boundary. This wetland, identified as high ecological significance (HES) under the *Environmental Protection (Water and Wetland Biodiversity) Policy* 2019, is not connected to the study area through any waterbodies or watercourses. Current government mapping and field inspections of the mapped wetlands identified the vegetation as non-remnant. Field assessment identified the presence of flora species known to inhabit wetland environments (Photo Plate 10). No water was observed during the site inspection. Assessment of potential impact to this wetland as an MSES have been addressed in Section 9.1.3.

Photo Plate 10 ***Melaleuca spp.*** **dominated HES wetland**

5.4.1 Groundwater Dependent Ecosystems

The above-mentioned wetlands have the potential to be partially dependent on groundwater (BoM 2019). Within the study area high potential terrestrial GDEs and moderate potential aquatic GDEs were identified by database searches in association with Charlevue Creek and Springton Creek. Moderate potential terrestrial GDEs were also mapped in association with some of the smaller waterways.

The HES wetland located 4 km to the east of the study area was also identified as potentially groundwater dependant during the database searches.

Field surveys were undertaken in June 2020 by 3D Environmental (2020) to verify the potential presence of the GDEs within the study area. A comprehensive GDE study has been included in the EA application supporting information document.

The GDE study identified two areas within the study area containing terrestrial GDEs, both dependent on alluvial perched groundwater systems that recharge from surface flow. One of these GDEs is located within Charlevue Creek while the other one is situated within a tributary of the Springton Creek. This study also determined that the HES does not constitute a GDE and therefore, is not discussed further.

Based on the location of the aquifer, salinity data and stable isotope comparisons between water sampled from the trees and groundwater, it is concluded that both perched aquifers are hydraulically disconnected from the regional groundwater table. Furthermore, the results indicate that the trees sampled are not utilising groundwater from the regional Tertiary, alluvial or Permial coal seam aquifers to any significant degree (3D Environmental 2020). Assessment of the potential impact on the identified potential GDEs within the study area, based on the impact assessment included in the GDE study, has been included in Section 7.1.5 of this report.

6.0 FAUNA RESULTS AND DISCUSSION

6.1 FAUNA SURVEY RESULTS

A total of 145 vertebrate species were positively identified in the study area during the surveys, comprising eight amphibians, 83 birds, 33 mammals and 21 reptiles. Six of these species are introduced. One migratory and marine species and one marine species were recorded during the survey. Two threatened fauna species were observed on site. A complete list of the fauna species recorded in the study area is included in Appendix I.

While conducting the aquatic ecology assessment (AARC 2019), a number of vertebrate fauna species were recorded in the study area. These are detailed in the aquatic ecology assessment. One species recorded by the aquatic ecology survey was not recorded by the terrestrial ecology survey, namely the Keelback snake (*Tropidonophis mairii*), which was identified along Charlevue Creek.

Habitat within the study area is highly fragmented, with large areas of pastureland or poor condition regrowth vegetation. These open areas provide hunting habitat for large birds of prey and provide foraging habitat for ground-dwelling mammals. As indicated in section 5.1, there is limited to no connectivity value between the protected areas and state forests surrounding the Project (section 1.3). Further, the main habitats identified within these protected areas and state forests are not present within the study area, specifically;

- Habitat in sandstone escarpments and plateau (from 300 to 850 m above sea level);
- Remnant and regrowth Brigalow woodland; and
- Unfragmented remnant vegetation.

6.1.1 Amphibians

<u>Habitat Values</u>

The species recorded within the study area are well adapted to the habitats identified, with permanent water sources and areas subject to seasonal inundation. These species employ periods of dormancy to contend with drier, less favourable conditions. Habitat variation and suitability increase in response to increased rainfall during the wet season (November - March) providing viable breeding opportunities.

The amphibian species identified are all common species, and impacts from the Project are likely to be localised with minimal effects to broader populations.

<u>Observed Species</u>

A total of eight amphibian species were recorded during the surveys, comprising seven native species and the introduced Cane toad (*Rhinella marina*). The Cane toad is listed as an invasive biosecurity matter under the revised version of the Biosecurity Act and are a major pest species that compete for food with native species.

The native species recorded on site were Ornate burrowing frog (*Platypectrum ornatum*), Common green tree frog (*Litoria caerulea*) Photo Plate 11, Naked tree frog (*Litoria rubella*), Broad-palmed frog (*Litoria latopalmata*), Bumpy rocket frog (*Litoria inermis*), Salmon-striped frog (*Limnodynastes salmini*) and Spotted grass frog (*Limnodynastes tasmaniensis*).

Photo Plate 11 Common green tree frog (*Litoria caerulea*) observed at DF02

Amphibians of Conservation Significance

No amphibian species of conservation significance were observed in the study area during field surveys. However, the Tusked frog (*Adelotus brevis*) has been identified as potentially occurring within the study area due to the proximity of its known range and the presence of suitable habitat (such as dams).

6.1.2 Reptiles

Habitat Values

The study area provided a variety of habitat types such as vegetated drainage features, woodlands to open forests and rocky areas to promote reptile diversity. This included several microhabitats such as tree hollows, fallen timber, dense leaf litter, soil cracks and rock crevices which provide shelter from extreme climates, protection from aerial predators and as habitat for hunting and foraging for food.

Observed Species

A total of 21 reptile species were recorded within the study area during the field surveys, all of which are listed in Appendix I.

The suite of reptiles occurring on the study area included seven species of skink and one species of legless lizard. These species include the Eastern striped skink (*Ctenotus robustus*), Elegant snake-eyed skink (*Cryptoblepharus pulcher*), Shaded litter rainbow-skink (*Carlia munda*), South-eastern morethia skink (*Morethia boulengeri)*, Fire-tailed skink (*Morethia taeniopleura*), the Orange-flanked Rainbow skink (*Carlia rubigo*) and Burton's legless lizard (*Lialis burtonis).*

Five gecko species were identified on the study area, including the Eastern stone gecko (*Diplodactylus vittatus*), Dubious dtella *(Gehyra dubia),* Bynoe's Gecko *(Heteronotia binoei),* Box-patterned gecko *(Lucasium steindachneri)* (Photo Plate 12) and the Prickly knob-tailed gecko (*Nephrurus asper*).

Photo Plate 12 *Box-patterned gecko (Lucasium steindachneri)* observed at DF09

Field surveys also detected the presence of three dragon species, Bearded dragon (*Pogona barbata*), Tommy roundhead (*Diporophora australis*) and Freckled monitor (*Varanus tristis orientalis*).

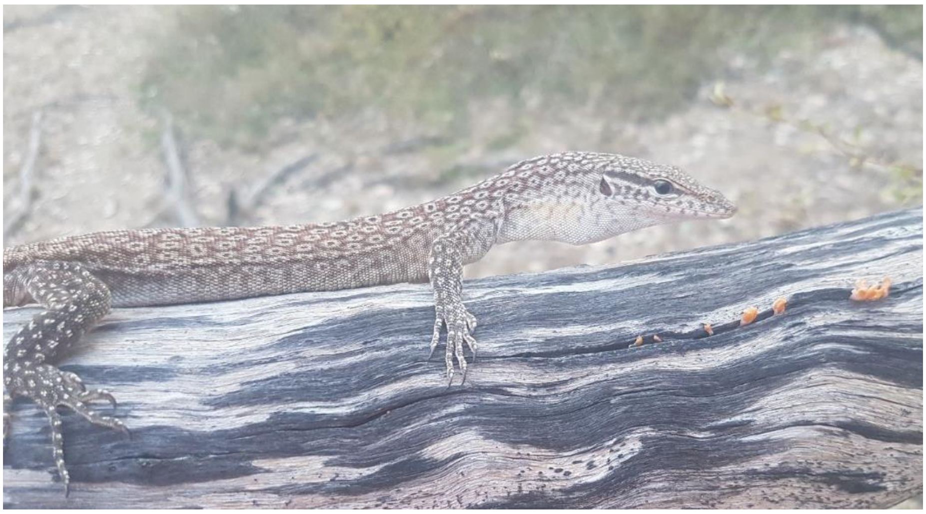


Photo Plate 13 Freckled monitor (*Varanus tristis orientalis*) observed at DF10

Six snake species namely the Black headed python (*Aspidites melanocephalus*), Eastern brown snake (*Pseudonaja textilis*), Pale-headed snake (*Hoplocephalus bitorquatus*) (Photo Plate 14), Carpentaria snake (*Cryptophis boschmai*), Yellow-faced whip snake (*Demansia psammophis)* and Orange-naped snake (*Furina ornata*) were recorded within the study area.

Photo Plate 14 Pale-headed snake (*Hoplocephalus bitorquatus*) observed at DF01

Reptile Species of Conservation Significance

No reptiles of conservation significance were observed on the study area during the survey period. Database searches identified seven reptile species of conservation significance within the region. The habitat requirements and likelihood of each conservation significance species occurring on the study area are described in Appendix D.

6.1.3 Birds

Habitat Values

Avian assemblages are generally determined by factors such as food sources (e.g. fruit, nectar, seeds, and insects), as well as a mosaic of habitat structures such as grasses, thick understorey, mid-storey and canopy vegetation (i.e. vertical habitat complexity). Generally, the more food sources available and the more complex the structure of the vegetation, the more diverse the avifauna will be.

Food sources across the study area comprised seeds, fruit, nectar, insects and vertebrate prey items (or carrion). The diversity of forage resources available in the surveyed habitats suggests that the Project can support a variety of native avian species.

Observed Species

A total of 83 bird species were observed in the study area. Most species observed were common species representative of the dry woodland habitat dominating the study area; however, two species of conservation significance were identified in the study area during the survey period. These species are discussed in more detail in Section 6.3. A full list of bird species observed in the study area is presented in Appendix I.

A variety of granivorous birds were found to be present including the Sulphur-crested cockatoo (*Cacatua galerita*), Crested pigeon (*Ocyphaps lophotes lophotes*), Peaceful dove (*Geopelia striata placida*), southern squatter pigeon (*Geophaps scripta scripta*), Bar-shouldered dove (*Geopelia humeralis*), and Double-barred finch (*Taeniopygia bichenovii*).

The study area was found to support a number of honeyeaters including the White-throated honeyeater (*Melithreptus albogularis*), Brown honeyeater (*Lichmera indistincta ocularis*), Blue-faced honeyeater (*Entomyzon cyanotis*) and Noisy friarbird (*Philemon corniculatus*).

The suite of insectivorous birds recorded on site included the Grey fantail (*Rhipidura albiscapa*), Magpie-lark (*Grallina cyanoleuca*), Black-faced cuckoo-shrike (*Coracina novaehollandiae*), Grey-crowned babbler (*Pomatostomus temporalis*) and Striated pardalote (*Pardalotus striatus*).

A large diversity of omnivorous and carnivorous species was detected on the study area, including the Apostlebird (*Struthidea cinerea*), Pheasant coucal (*Centropus phasianinus*), Grey butcherbird (*Cracticus torquatus*), Australian magpie (*Cracticus tibicen*), Australian raven (*Corvus coronoides*), Laughing kookaburra (*Dacelo novaeguineae*) and Emu (*Dromaius novaehollandiae*).

Several nocturnal bird species including the Tawny Frogmouth (*Podargus strigoides*), Barn owl (*Tyto alba*) and Southern boobook (*Ninox boobook*) were observed during field surveys. Five raptor species, including Whistling kite (*Haliastur sphenurus*) and Brown falcon (*Falco berigora*) (Photo Plate 15) were also recorded on the study area.

Photo Plate 15 Brown falcon (*Falco berigora*) observed in the study area

Aquatic bird species such as the Brolga (*Grus rubicunda*) were also recorded during field surveys.

<u>Birds of Conservation Significance</u>

Threatened Species

The southern subspecies of the Squatter pigeon (*Geophaps scripta scripta*) was recorded in several locations (Figure 14) on the study area at the time of the surveys (Photo Plate 16).

The southern Squatter pigeon occurs along the inland slopes of the Great Dividing Range with a distribution from the Burdekin-Lynd divide in central Queensland, west to Charleville and Longreach, east to the coastline between Proserpine and Gladstone, and south to scattered sites throughout south-eastern Queensland (Cooper et al*.* 2004).

Suitable habitat for the southern Squatter Pigeon exists in open grassy woodland throughout the study area. Within this suitable habitat, fifteen birds were observed during the ecological survey period, the majority of them observed during the spring survey in September 2017. The species is regionally abundant, having been observed outside of the study area on multiple occasions, with AARC ecologists observing the species numerous times on local roads and elsewhere while traversing the local area. No breeding activity was observed in the study area.

It is unlikely that the proposed Project will have a significant impact on the local population of the southern Squatter Pigeon; either the local population or the population in its entirety due to:

- the abundance of more suitable habitat outside of the study area in connected woodland; and
- the local abundance of the southern Squatter pigeon.

A *Significant Residual Impact Assessment* (DEHP 2014a) for the southern Squatter pigeon can be found in Section 9.1.2 of this report.

Photo Plate 16 Squatter Pigeon (*Geophaps scripta scripta*) observed at the study area

Marine and Migratory Species

The EPBC Act lists bird species that are classified as migratory and/or marine. Two migratory and/or marine birds were identified on the study area (Figure 14), comprising of the Rufous fantail (*Rhipidura rufifrons*) which is a migratory and marine species and the Rainbow bee-eater (*Merops ornatus*) which is a marine species.

The Rufous fantail (listed as Special Least Concern under the NC Act) is found in northern and eastern coastal Australia, being more common in the north. It is also found in New Guinea, the Solomon Islands, Sulawesi and Guam. The Rufous fantail is found in rainforest, dense wet forests, swamp woodlands and mangroves, preferring deep shade, and is often seen close to the ground. During migration, it may be found in more open habitats or urban areas. The Rufous fantail is a common and secure species (Blakers et al*.* 1984).

The Rainbow bee-eater inhabits all of mainland Queensland, as well as Indonesia, New Guinea and the Solomon Islands. This species is widespread and breeds throughout most of its range, with the exception of southern birds, which move north to breed.

While these species do inhabit the site, the surrounding region provides suitable habitat that can be utilised and impacts from the study area are unlikely to significantly impact the habitat or distribution of this species in the region. Due to the ephemeral nature of the waterways identified onsite, it is unlikely that the Project provides year-round habitat for these species.

6.1.4 Mammals

Habitat Values

Mammal morphology varies widely from small rodents to larger kangaroos to bats. The ecology of each of these groups is equally variable, and they are assessed separately in the following sections.

Small Mammals

Habitats suitable for small mammals include areas that provide a plentiful food source and suitable shelter sites. The highest density of small mammal species is usually associated with reliable rainfall which is reflected in a reliable source of food and dense ground vegetation, particularly shrubs and grasses.

The diversity of small mammals is often limited by the lack of a predictable food supply and open ground vegetation. Consequently, small mammal populations can fluctuate dramatically in response to rainfall which increases seed production and insect abundance. During less favourable periods, small mammal populations can be very low.

The study area provides a variety of habitat types suitable for small ground-dwelling mammals, including vegetated woodlands, open forests and watercourses, found in vegetation communities VC 1, VC 2 and VC 3. The majority of the study area is comprised of non-remnant vegetation which is mostly utilized as grazing pasture. This community reduces the availability of shelter.

Medium and Large Mammals

Factors affecting the occurrence of medium and large sized mammals are varied. Important factors can include land-clearing, feral animal predation and grazing pressures. Regardless of the clearing that has occurred on the Project, larger macropods have been much less affected than some other mammals. Larger macropods are considered generalists, likely to thrive and flourish in response to areas of grasslands and open vegetation, as they are less vulnerable to small predators such as foxes and cats. They are also highly opportunistic breeders, especially in the presence of permanent water sources such as the dams found onsite.

Most of the study area habitats include pastural land and large areas of low open woodlands. These habitats are likely to support most medium mammals occurring in the region. In particular, the riparian habitats along waterways and watercourses are likely to provide important corridor values for this mammal group.

Larger mammals such as kangaroos have been much less affected by predation than other mammals and by land clearing activities. In fact, many species have flourished in response to increased areas of grassland and open vegetation caused by land clearing activities.

Arboreal Mammals

The majority of arboreal mammals that occur in Australia utilise tree hollows for nesting and shelter (Menkhorst and Knight 2011). A shortage of nest hollows is likely to limit arboreal mammal populations where the density of hollow bearing trees is less than two to eight trees per ha (Smith and Lindenmayer 1988).

Hollow-bearing trees on the study area generally occur along creek-lines or in adjoining vegetation communities. Away from the waterway corridors, hollow-bearing trees are few and are separated by vast open areas that would be difficult for arboreal mammals to cross without venturing onto the ground. Due to the previously cleared and disturbed nature of the study area, arboreal mammal habitat is largely restricted to the waterway corridors of the study area.

Bats

The density and diversity of Australian bat species is determined primarily by the availability of suitable nesting and roosting sites. Roosting sites can include locations such as thick foliage, loose exfoliating bark, rock caves or cavities, tree hollows or even fabricated structures such as old buildings and culverts (Churchill 2008).

Consequently, areas with a large number of hollow-bearing trees that occur within remnant vegetation are of high value to many bat species. As bats have a small body size, these hollows can be much smaller in size than required by some arboreal mammals. Possible roosting sites observed on the study area included tree hollows and exfoliating bark, particularly in VC 1, VC 2 and VC 3.

Potential roosting habitat including rocky areas and drainage areas on the study area were surveyed with an ANABAT echolocation call recorder. Riparian zones with large hollow bearing trees located adjacent to the study area were also surveyed.

Observed Species

In total, 33 mammal species were recorded in the study area, comprising 28 native species and five introduced species, all listed in Appendix I. All introduced species recorded are discussed in Section 6.2.

The suite of native mammal species recorded as having a presence on the study area included the Red-necked wallaby (*Macropus rufogriseus*), Short-beaked echidna (*Tachyglossus aculeatus*), Common brushtail possum (*Trichosurus vulpecula*), Water rat (*Hydromys chrysogaster*), Swamp wallaby (*Wallabia bicolor*), Greater glider (*Petauroides volans volans*), Rufous bettong (*Aepyprymnus rufescens*) (Photo Plate 17), Wallaroo (*Macropus robustus*), Eastern grey kangaroo (*Macropus giganteus*), Black-striped wallaby (*Notamacropus dorsalis*) and Delicate mouse (*Pseudomys delicatulus*).

Photo Plate 17 Rufous bettong (*Aepyprymnus rufescens*) observed in the study area

A total of 17 bat species were positively identified on the study area, none of which are listed under the EPBC Act. Those bat species positively identified on the study area included the Gould's wattled bat (*Chalinolobus gouldii*), Little pied bat (*Chalinolobus picatus*), Hoary wattled bat (*Chalinolobus nigrogriseus*), Northern free-tailed bat (*Chaerephon jobensis*), Eastern bentwing bat (*Miniopterus schreibersii oceanensis*), Inland forest bat (*Vespadelus baverstocki*), Rides free-tailed bat (*Ozimops ridei*), Inland free-tailed bat (*Ozimops petersi*), Northern free-tailed bat (*Ozimops lumsdenae*), Western broad-nosed bat (*Scotorepens balstoni*), Little broad-nosed bat (*Scotorepens greyii*), White-striped Free-tailed bat (*Austronomus australis*), Troughton's Sheath-tailed bat (*Taphozous troughtoni*), Lesser long-eared bat (*Nyctophilus geoffroyi*) and Yellow-bellied sheathtail bat (*Saccolaimus flaviventris*).

A Long-eared bat (Nyctophilus sp.) was also detected through the use of ANABAT recorders on the study area; but could not be identified to species level. The Nyctophilus genus has several species in Australia and cannot be identified further then the genus level through ANABATs and a positive identification requires active trapping. The region is known to form part of the distribution of the Vulnerable *Nyctophilus corbeni* (EPBC Act, NC Act). In response to this, ecologists conducted a targeted micro-bat survey in line with the *Survey Guidelines for Australia's Threatened Bats* (DoEE 2010a). The targeted micro-bat survey utilised Harp Traps and Mist Nets. The targeted micro-bat survey did not identify the Vulnerable species *Nyctophilus corbeni* within the study area but trapped the Lesser long-eared bat (*Nyctophilus geoffroyi*). It is highly likely that the *Nyctophilus* sp. call registered in the ANABAT belonged to the Least Concern *Nyctophilus geoffroyi.*

Several other species of bats not listed as threatened, could not be reliably identified from call analysis due to either poor data quality and/or similarities in call characteristics between species known to occur in the region. Unconfirmed species records include species that could not be distinguished between a group of two to three species. The bat call analysis results are detailed in Appendix G.

<u>Mammals of Conservation Significance</u>

The Short-beaked echidna (*Tachyglossus aculeatus*) (Photo Plate 18) was recorded in the study area across several sites (Figure 14). This species is not an EVNT species but is listed under the NC Act as Special Least Concern and is not listed under the EPBC Act.

The Short-beaked echidna is found in a variety of habitat types including open forests, grasslands and heavily vegetated woodlands. It's distribution spans across Australia, including Tasmania and is considered a habitat generalist. This species presence relies on the abundance of ants which are its only food source (Van Dyck et al*.* 2013). Due to the generality and wide distribution of this species, it is not expected that mining activity will have an impact of this species.

A *Significant Residual Impact Assessment* (DEHP 2014a) for the Short-beaked echidna can be found in Section 9.1.2 of this report.

Photo Plate 18 Short-beaked Echidna (*Tachyglossus aculeatus*) observed in the study area

The Greater glider (*Petauroides volans*) (Photo Plate 19), was detected during the field survey of the study area (Figure 14). The Greater glider is listed under the EPBC Act 1999 as a "Vulnerable" species (DoEE, 2018).

The Greater glider is restricted to eastern Australia, occurring from the Windsor Tableland in north Queensland through to central Victoria, with an elevational range from sea level to 1200 m above sea level. The broad extent of occurrence is unlikely to have changed appreciably since European settlement; however, the area of occupancy has decreased substantially, mostly due to land clearing (TSSC 2016a).

The Greater glider is an arboreal, nocturnal marsupial, restricted mainly to eucalypt forests and woodlands. It is primarily folivorous, with a diet mostly comprising eucalypt leaves, and occasionally flowers. Preferred habitat consists of taller, montane, moist eucalypt forests with relatively old trees and abundant hollows. It also favours forests with a diversity of eucalypt species, due to seasonal variation in its preferred tree species (TSSC 2016a).

Critical microhabitat is an abundance of large hollows of large, old trees for daily denning shelters and breeding purposes. The species is absent from cleared areas and has little ability to disperse between fragments across cleared areas, with habitat connectivity critical to species survival (TSSC 2016a).

Major threats include habitat loss from clearing, high intensity fires, and logging and woodland thinning practices (TSSC 2016a).

Some of the study area has been subject to vegetation clearing to allow cattle grazing. Consequently, only small areas of suitable habitat remain on the site. Generally, habitat of the Great glider is confined to the Eucalypt riparian woodlands such as along the Charlevue Creek. This woodland suits the Greater glider's preferred habitat of tall open woodland with a sparse shrub layer. Vegetation community mapping identified this suitable habitat as VC 3.

Habitat values of the study area are limited by the large areas of non-remnant vegetation and the impacts of grazing. Considering the extent and connection to surrounding good quality habitat and the minimal disturbance caused by the Project to Charlevue Creek, impacts on a local population of Greater glider is unlikely to be significant.

A *Significant Residual Impact Assessment* (DEHP 2014a) for the Greater glider can be found in Section 9.1.2 of this report.

Photo Plate 19 Greater glider (*Petauroides volans*) observed in the study area

6.2 PEST SPECIES

Field surveys positively identified six introduced and/or pest fauna species as having a presence within the study area. Introduced species were recorded through detection of scats, tracks or other traces (e.g. skulls), sensor camera detection and/or direct observation. The suite of introduced species includes the Cane toad (*Rhinella marina*), Wild dog/Dingo (*Canis familiaris/Canis lupus dingo*), Feral cat (*Felis catus*), Rabbit (*Oryctolagus cuniculus*), House mouse (*Mus musculus*) and Feral pig (*Sus scrofa*).

All the non-native fauna species reported from the study area, with the exception of the Cane toad and the House mouse are listed as restricted species under the Biosecurity Act 2014 (DAF 2019) as shown in Table 18.

Table 18 Introduced species identified in the study area

Scientific name	Common name	*Biosecurity Act 2014*			
		Category 3	Category 4	Category 5	Category 6
Canis familiaris or Canis lupus dingo	Wild dog/Dingo	x	x	x	x
Oryctolagus cuniculus	Rabbit	x	x	x	x
Felis catus	Feral cat	x	x	-	x
Sus scrofa	Feral pig	x	x	-	x

Category 3: the invasive animal must not be distributed either by sale or gift or released into the environment.
Category 4: the invasive animal must not be moved.
Category 5: the invasive animal must not be kept.
Category 6: the invasive animal must not be fed.

Photo Plate 20 Feral cat (*Felis catus*) recorded on the camera trap at DF05

The Cane toad and the House mouse are not a prohibited or restricted invasive animal under the Biosecurity Act 2014; however, everyone has a general biosecurity obligation (GBO) to take reasonable and practical steps to minimise the risks associated with invasive plants and animals under their control (DAF 2016b). Cane Toads are recognised as an invasive species, as they present a serious threat to native wildlife. The Cane Toad consumes a wide variety of native animals including frogs, small reptiles, mammals and birds and causes the death of native predators that consume their toxins.

6.3 FAUNA SPECIES OF CONSERVATION SIGNIFICANCE

6.3.1 Fauna Species of Conservation Significance Identified in the Study Area

Field surveys across the study area detected the presence of four fauna species of conservation significance:

- The southern Squatter pigeon (*Geophaps scripta scripta*) and Greater glider (*Petauroides volans*), both species are listed as Vulnerable under the EPBC Act and the NC Act;

- The Short-beaked echidna (*Tachyglossus aculeatus*) This species is not an EVNT species but is listed under the NC Act as Special Least Concern; and

- The Rufous fantail (*Rhipidura rufifrons*) listed as migratory and marine species, was identified in the study area.

A description of the four species is included in Sections 6.1.3 and 6.1.4, respectively.

6.3.2 Fauna Species of Conservation Significance Not Identified in the Study Area

Table 19 discusses EVNT and Migratory species that are known from the broader region and have been identified from desktop searches already identified as likely or potential to occur within the study area but were not observed on site during surveys.

The assessment of potential for presence and impact on each species is based on the knowledge of ecologists, information obtained from field surveys on the study area, previous surveys conducted on or near the study area and scientific literature. This assessment indicated that only 11 of the 19 species were considered as possible to occur on within the study area.

The distribution of the marine and migratory species identified from desktop searches is widespread in eastern Australia (Simpson and Day, 2010). The study area is not at the limit of these species' range, nor are these species considered to be declining within the region. Therefore, it is unlikely that the Project will have a significant impact on the regional populations of these species.

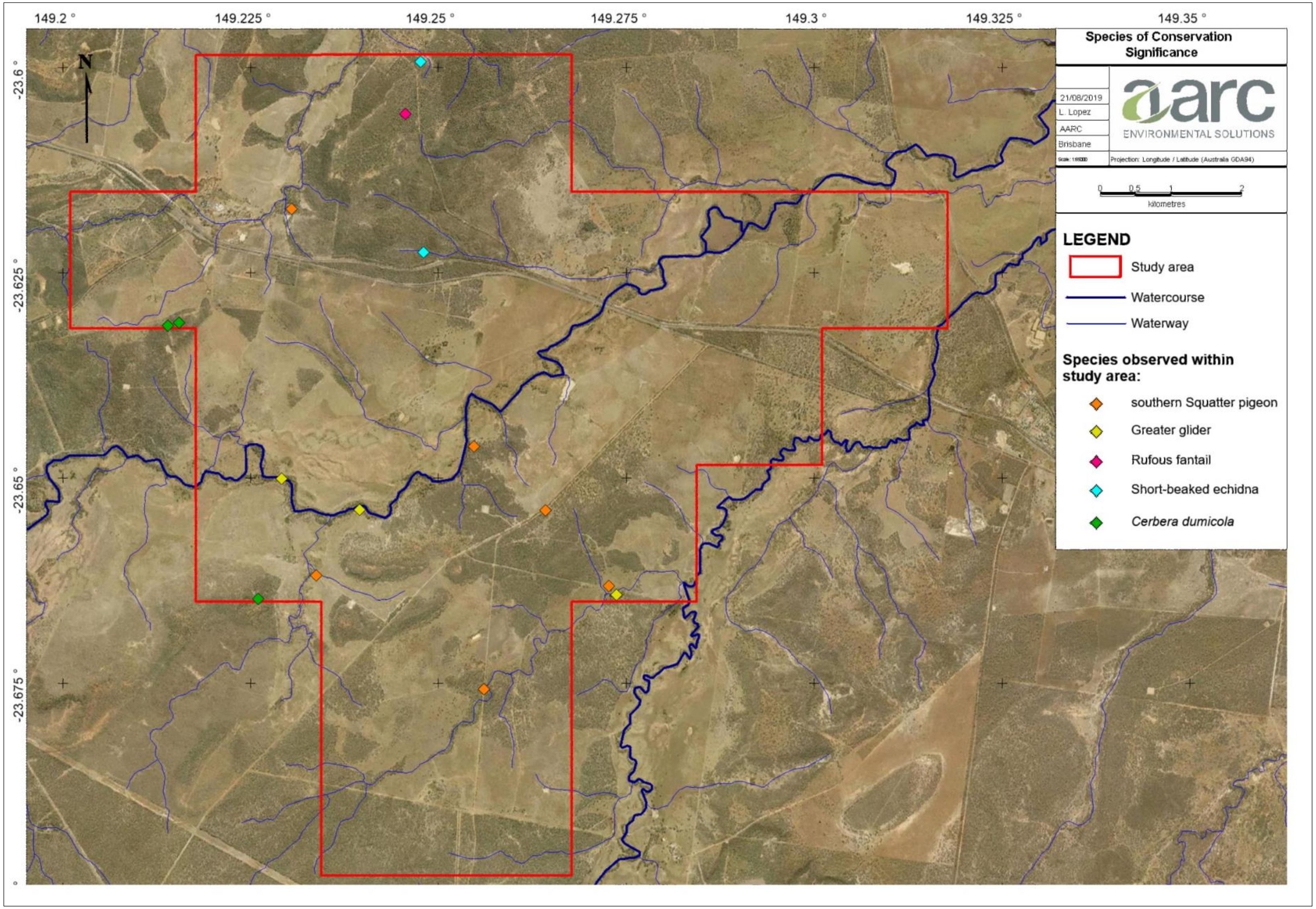


Figure 14 Species of Conservation Significance observed within the study area

Table 19 Fauna Species of Conservation Significance not identified in the study area

Species Name / Common Name	EVNT Listing		Likelihood of Occurrence Post Survey
	EPBC Act	NC Act	
Amphibians			
Adelotus brevis Tusked frog	NL	V	Potential The study area occurs within the vicinity of the known range of the Tusked frog, and suitable habitat is available year-round due to the presence of dams. Despite not being found during targeted field surveys (Aquatic survey, AARC 2019), it is a potential that the study area can support a population of Tusked frogs.
Reptiles			
Delma torquata Adorned delma	V	V	Potential Suboptimal habitat is present within the study area. However, field surveys revealed no evidence of this species occurring within the study area site.
Strophurus taenicauda *Golden-tailed gecko*	NL	NT	Potential Suitable habitat is present within the study area. However, field surveys revealed no evidence of this species occurring within the study area site.
Birds			
Calidris acuminate Sharp-tailed Sandpiper	Ma, Mi	SL	Potential There is the potential for this species to utilise the study area due to the presence of suitable habitat within the study area's boundary.

Species Name **Common Name**	**EVNT Listing**		**Likelihood of Occurrence Post Survey**
	EPBC Act	**NC Act**	
Calyptorhynchus lathami erebus Glossy black-cockatoo (northern)	-	V	Potential Suitable habitat occurs in the broader region and within the study area. This species is highly reliant on fodder species (*Allocasuarina* and *Casuarina* species). Within the study areas the species *Allocasuarina luehmannii* (Bull oak) was identified as present dominant in small patches. As such it is potential that the study area provides suitable habitat or food sources for this species.
Erythrotriorchis radiatus Red goshawk	V	E	Potential There is the potential for this species to utilise the study area due to the presence of suitable habitat within the study area's boundary. Additional suitable habitat is found throughout the surrounding region.
Hirundapus caudacutus White-throated needletail	Ma, Mi	SL	Potential There is the potential for this species to utilise the study area due to the presence of suitable habitat within the study area's boundary.
Grantiella picta Painted honeyeater	E	V	Unlikely This species is highly reliant on the presence of mistletoes in the canopy strata, no mistletoes were recorded during the terrestrial or aquatic field surveys. The study area is unlikely to provide suitable habitat for this species.
Lathamus discolour Swift Parrot	CE	E	Unlikely Limited suitable habitat occurs for this species was recorded along the watercourses within the study area. The study area occurs at the most upper limit of this species distribution.

Species Name **Common Name**	**EVNT Listing**		**Likelihood of Occurrence Post Survey**
	EPBC Act	**NC Act**	
Monarcha melanopsis Black-faced Monarch	Ma, Mi	SL	<u>Potential</u> There is the potential for this species to utilise the study area due to the presence of suitable habitat within the study area's boundary.
Motacilla flava Yellow wagtail	Ma, Mi	SL	<u>Potential</u> There is the potential for this species to utilise the study area due to the presence of suitable habitat within the study area's boundary.
Myiagra cyanoleuca Satin flycatcher	Ma, Mi	SL	<u>Potential</u> There is the potential for this species to utilise the study area due to the presence of suitable habitat within the study area's boundary.
Ninox strenua Powerful owl	-	V	<u>Unlikely</u> While there are hollow bearing trees along the watercourses within the study area, these hollows are generally small in nature and are unlikely to be of value to Powerful owls for nesting/shelter. Limited remnant vegetation has been mapped within the study area due to extensive clearing.
Pedionomus torquatus Plains wanderer	CE	V	<u>Unlikely</u> No native grasslands occur within the study areas boundary. This species is often absent from areas that are too dense or sparse. All open areas are heavily grazed and dominated by introduced pasture species.

Species Name **Common Name**	**EVNT Listing**		**Likelihood of Occurrence Post Survey**
	EPBC Act	**NC Act**	
Poephila cincta cincta Black-throated finch (white-rumped subspecies)	E	E	Unlikely No suitable habitat for this species occurs within the study area. Additionally, this species is not known from the area and was not detected during ecological surveys on site.
Turmix melanogaster Black-breasted button-quail	V	V	Unlikely No suitable habitat for this species was recorded within the study areas boundary.
Mammals			
Chalinolobus dwyeri *Large-eared pied bat*	V	V	Unlikely No sandstone gorges were recorded within the study area, the study area has also undergone extensive clearing limiting the extent of suitable habitat.
Onychogalea fraenata Bridle nailtail wallaby	E	E	Potential No preferred habitat such as Brigalow woodland and only small disconnected patches of Poplar box woodland have been identified in the study area. However, the only native population of this species is located directly north of the study area. This species could potentially utilise the habitat in the study area for foraging.
Phascolarctos cinereus Koala	V	V	Unlikely Suitable habitat is present within the study area. However, the amount of suitable habitat is limited on the study area and displays limited connectivity to the other known habitat preferences for the species. Field surveys revealed no evidence of this species occurring within the study area.

EPBC – *Environment Protection and Biodiversity Conservation Act 1999*
NC Act – *Nature Conservation Act 1992*
CE – Critically Endangered
V – Vulnerable
E – Endangered
C – Least Concern
SL – Special Least Concern
Mi - Migratory

7.0 POTENTIAL IMPACTS

Potential impacts of the Project (Figure 15) on terrestrial ecology values are described below. Mitigation measures and management strategies for the potential impacts are described in Section Figure 15. Sections 7.0 to 9.0 relate only to MSES values and do not assess potential impacts, mitigation and management strategies or environmental offset requirements for MNES values.

The timing and duration of the Project activities affect the magnitude of the overall impacts of the Project on the prescribed environmental matters within the study area. Vegetation clearance and land disturbance during the construction and operation of the mine are the primary direct impacts on the environmental values of the study area.

7.1 TERRESTRIAL FLORA

7.1.1 Vegetation Communities

The Project will include vegetation clearance and land disturbance during the construction and operation of the mine. The extent of land disturbance would be approximately 1953 ha, of which, approximately 711 ha of remnant vegetation clearing is required over the life of the Project.

Other potential impacts to vegetation communities include:

- Removal of habitat for terrestrial flora and fauna;

- Further habitat fragmentation and loss of connectivity. It is noted that existing vegetation clearing due to agricultural land use has already limited habitat connectivity due to the highly fragmented remnant vegetation remaining on site; and

- Potential for reduced condition of neighbouring vegetation communities due to the introduction of weeds or the release of contaminants associated with mine operations.

7.1.2 Flora Species of Conservation Significance and Habitat

Cerbera dumicola has been identified during the vegetation surveys in two very localised rocky areas associated with vegetation community VC 2 and VC 1 (Figure 14). This species was not identified elsewhere in the study area, within similar habitat types, during targeted searches.

The proposed mining activity proposes no impacts to populations of *Cerbera dumicola*.

7.1.3 Weed Species

Project development has the potential to create or enhance conditions for invasive weed species, that may spread and out-compete native and pasture species. Weed species may be introduced via the spread of seed on persons, vehicles and equipment. Weed species may quickly colonise disturbed areas if left untreated.

The introduction of weed species can reduce native species abundance and diversity through competition. Ultimately this can lead to the reduced condition of vegetation and native fauna habitat.

7.1.4 Wetlands

The Project has the potential to impact on wetlands via

- Direct clearing;
- Changes in hydrology;
- Erosion and sedimentation; and
- Contaminant release.

7.1.5 Groundwater Dependant Ecosystems

Where wetlands exhibit a degree of dependence on groundwater for survival, drawdown from the mine can result in a reduced ecosystem condition, changes to vegetation composition or dieback.

A GDE assessment was undertaken (3D Environmental 2020) in the study area. Data from this assessment together with the groundwater data obtained over several studies by JBT Consulting (2019 and 2020) were used in the assessment of the GDEs and the associated impact of drawdown.

Potential Impacts on GDEs within the study area

The GDEs identified within the study area are riverine type wetlands, including riparian vegetation on watercourses and floodplains.

The impacts identified to the GDEs within the study have been assessed within the GDE study (3D Environmental 2020) and summarised below:

- Direct clearing. The GDE located within the tributary of Springton Creek falls within the footprint of the mine and therefore subject to unavoidable vegetation clearing. Direct impacts on riparian vegetation (vegetation clearing) have been addressed in section 7.1.1 whilst impact mitigation as well as offsets requirements have been addressed in sections 8.1.1.1 and 9.1.1 respectively.
- Groundwater drawdown. Groundwater modelling estimated that the Project has the potential to cause a maximum drawdown of 5 m (steady-state post-mining drawdown) at some locations below the Charlevue and Springton Creeks (JBT 2019), on the Tertiary and alluvial sediments (regional groundwater table). This drawdown will not have an impact on the riparian habitat identified as GDE within Charlevue Creek based on the limited hydraulic connectivity between the regional groundwater table and the perched aquifer that supports the GDE (3D Environmental 2020). Further, considering that the Project's is situated downstream of the Charlevue Creek's GDE and there will be no loss of catchment area, it is unlikely the Project will reduce the surface flows that replenish the associated perched aquifer (3D Environmental 2020).

7.2 TERRESTRIAL FAUNA

7.2.1 Fauna Species of Conservation Significance and Habitat

Field surveys across the study area detected the presence of four fauna species of conservation significance. Three of these species are listed under the NC Act, the southern Squatter pigeon (*Geophaps scripta scripta*), the Greater glider (*Petauroides volans*) and the Short-beaked echidna (*Tachyglossus aculeatus*) whilst the Rufous fantail (*Rhipidura rufifrons*) is listed as Migratory species under the EPBC Act.

Potential impacts of the Project to threatened fauna species include:

- Direct clearing of habitat within the Project defined impact areas;

- Further habitat fragmentation and loss of connectivity, particularly along Charlevue Creek which provides partial connectivity to larger downstream riparian communities. It is noted that existing vegetation clearing due to agricultural land use has already limited connectivity within this community;

- Potential for fauna mortality through interactions with vehicles on roads and/or heavy machinery used for land clearing;

- Potential for habitat degradation through increased risk of release of contaminants or sediments into receiving environments within and downstream of the Project; and

- Potential for increase invasive flora and fauna.

Southern Squatter Pigeon (*Geophaps scripta scripta*)

Suitable habitat for the southern Squatter pigeon exists in open grassy woodland throughout the study area. Within this suitable habitat, fifteen birds were observed during the ecological survey period, the majority were observed during the spring survey in September 2017. The species is regionally abundant, having been observed outside of the study area on multiple occasions, with ecologists observing the species multiple times on local roads and elsewhere while traversing the local area. No breeding activity was observed in the study area.

It is unlikely that the proposed Project will have a significant impact on the southern Squatter pigeon; either the local population or the population in its entirety due to:

- The species being highly mobile;

- The abundance of equivalent and more suitable habitat outside of the study area in adjacent areas;

- The observed high local abundance of the southern Squatter pigeon within and surrounding the study area; and

- The likely suitable habitat to be provided by rehabilitated land, post mining.

Greater glider (*Petauroides volans*)

The Greater glider preferred habitat consists of taller, montane, moist eucalypt forests with relatively old trees and abundant hollows. It also favours forests with a diversity of eucalypt species, due to seasonal variation in its preferred tree species (TSSC 2016a). Critical microhabitat is an abundance of large hollows of large, old trees for daily denning shelters and breeding purposes. The species is absent from cleared areas and has little ability to disperse between fragments across cleared areas, with habitat connectivity critical to species survival (TSSC 2016a).

Habitat of the Great glider within the study area is confined to the Eucalypt riparian woodlands such as along the Charlevue Creek. This woodland suits the Greater glider's preferred habitat of tall open woodland containing hollows with a sparse shrub layer.

It is unlikely that the proposed Project will have a significant impact on the Greater glider; either the local population or the population in its entirety due to:

- No significant impact proposed to habitat within the study area, specifically Charlevue Creek. Proposed disturbance within this habitat is limited to the development of a small culvert crossing;

- The observed abundance of Greater gliders within the study area and within the broader Central Queensland region; and

- The abundance of equivalent and more suitable habitat outside of the study area in adjacent areas.

Short-beaked echidna (*Tachyglossus aculeatus)*

The Short-beaked echidna is found in a variety of habitat types including open forests, grasslands and heavily vegetated woodlands. Suitable habitat for the species exists across the study area.

It is unlikely that the proposed Project will have a significant impact on the Short-beaked echidna, either the local population or the population in its entirety due to:

- The known abundance and wide-ranging distribution of the species;

- The presence of ample equivalent or better suited habitat surrounding the Project;

- The relatively small extent of impact proposed by the Project; and

- The likely suitable habitat to be provided by rehabilitated land, post mining.

Rufous fantail (*Rhipidura rufifrons*)

The Rufous fantail is generally found in rainforest, dense wet forests, swamp woodlands and mangroves, preferring deep shade, and is often seen close to the ground. During migration, it may be found in more open habitats, such as those within the study area.

It is unlikely that the proposed Project will have a significant impact on the Rufous fantail, either the local population or the population in its entirety due to:

- The rufous fantail is a common and secure species (Blakers, Davies & Rielly 1984);

- The study area does not contain the preferred habitat type for the species;

- The species is highly mobile and likely only passing through the Project on its migratory path;

- No known breeding sites or nesting habitat was identified on the study area; and

- Ample equivalent or higher quality habitat exists surrounding the study area.

7.2.2 Pest Species

Pest species compete with and prey on native fauna. Construction and operation of the Project increases the risk of pest species on the study area through:

- Generation of food and other waste that may attract pests; and

- Creation of artificial ponding areas providing habitat for pest species such as cane toads.

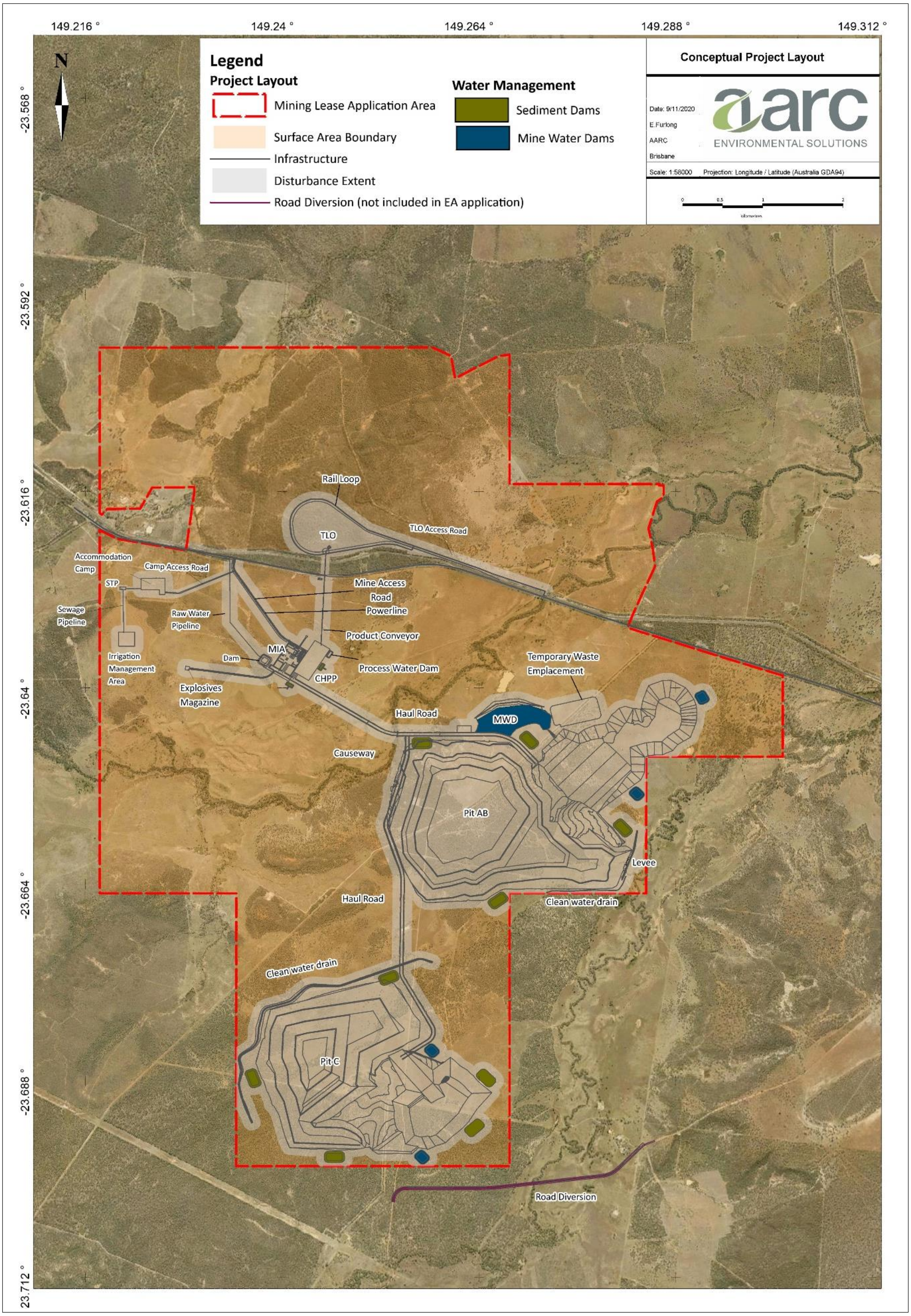


Figure 15 Conceptual Project Layout

8.0 MITIGATION AND MANAGEMENT STRATEGIES

8.1.1 Terrestrial Flora

8.1.1.1 Vegetation Communities

To minimise and mitigate impacts to vegetation communities on the Project area the following management strategies will be implemented:

- Clearing of land and vegetation will be limited to areas defined in the Project approval and required for safe operation.
    - An internal Permit to Disturb system will be implemented to minimise the chances of unauthorised clearing;
    - Areas to be cleared will be clearly defined and demarked to equipment operators;
- Inductions and training materials provided to employees will identify the environmental values of the site as well as the company procedures for managing impacts within its authority;
- Rehabilitation will be undertaken progressively and will aim to return the land to the pre-mining land use where possible;
- Where impact to Matters of State Environmental Significance cannot be avoided and are authorised by the Project approval, environmental offsets will be provided.

8.1.1.2 Flora Species of Conservation Significance

Suitable habitat for the *Cerbera dumicola* exists to the west of the Project, within the MLA. The proposed mine construction and development will not impact on the populations. However, to minimise potential impacts on this species the following management strategies will be implemented for the Project:

- Any direct clearing of this species, or clearing within 100m of a known location of this species or within a high-risk area (as per the protected plants flora survey trigger map), will follow the requirements of the Queensland protected plants legislative framework;
- An internal Permit to Disturb system will be implemented to minimise the chances of unauthorised clearing and impacts to the populations within the MLA;
- Inductions and training materials provided to employees will identify the environmental values of the site as well as the company procedures for managing impacts within its authority; and
- Existing populations will be monitored for abundance, distribution and health over the mine life.

8.1.1.3 Weed Species

To control the abundance and spread of weed species the following management strategies will be implemented:

- A pest and weed management plan will be prepared and implemented prior to construction;
- As required, weeds within the MLA will be controlled using herbicides and other recommended methods;

- Inductions and training materials provided to employees will assist the identification of common weeds and will include procedures for reporting; and
- Access to vehicle wash down facilities will be provided for vehicles at risk of spreading weeds.

8.1.1.4 Wetlands / GDEs

Wetlands / GDEs include Riverine vegetation on the MLA, particularly riparian vegetation associated with Charlevue and Springton Creeks. In addition, a HES wetland is located to the south east of the Project. To manage potential impacts on wetlands, the following will be undertaken:

- Sediment and erosion control structures will be installed and maintained near all at risk areas to prevent sediment release to wetlands;
- A Receiving Environment Monitoring Program (REMP) will be implemented and will include monitoring of water, sediments, riparian / riverine vegetation health and biological indicators in aquatic environments;
- The release of Mine Affected Water, will be in accordance with the quality controls provided by the model mining conditions;
- The development of a site Water Management System (WMS) and associated Erosion and Sediment Control Plan (ESCP); and
- Groundwater bores adjacent to Charlevue Creek (DW7076W) and Springton Creek (DW7292W1), will be fitted with dataloggers. This data will allow the assessment of the range of water levels within the alluvium and the response of groundwater levels within the alluvium to rainfall recharge, stream flow events and mining activities.

8.1.2 Terrestrial Fauna

8.1.2.1 Fauna Species of Conservation Significance

Fauna species of conservation significance under the NC Act associated with the Project site include; the southern Squatter pigeon (*Geophaps scripta scripta*), the Greater glider (*Petauroides volans*), the Short-beaked echidna (*Tachyglossus aculeatus*) and the Rufous fantail (*Rhipidura rufifrons*) (migratory). To ensure no significant impact to these species, the following strategies will be implemented:

- An internal Permit to Disturb system will be implemented to minimise the chances of unauthorised clearing and impacts to the threatened fauna within the MLA;
- Inductions and training materials provided to employees will identify the environmental values of the site as well as the company procedures for managing impacts within its authority;
- Vehicles speeds will be limited within the MLA, to minimise the risk of collision;
- Vegetation clearing will be done in a staged manner, allowing time for fauna to escape the area; and
- Pre-clearing inspections will be undertaken by qualified staff to minimise the risk of fauna mortality.

It should be noted that the Rufous fantail is listed migratory under the EPBC Act and is not listed under the NC Act. For the purpose of this assessment, only listed species under the NC Act are further assessed, and therefore the Rufous fantail has not been discussed further.

8.1.2.2 Pest Species

To prevent the introduction of pest species and to control their spread, the following management strategies will be implemented for the Project:

- A pest and weed management plan will be prepared and implemented prior to construction;
- Rubbish and food scraps will be managed so as not to encourage pest species;
- Inductions and training materials provided to employees will assist the identification of common pests and will include procedures for reporting; and
- Control of Feral cats and other animals will be undertaken within the MLA.

9.0 PROJECT ENVIRONMENTAL OFFSETS

The offsets framework requires environmental offsets to be delivered where an activity is likely to result in a significant residual impact on a prescribed environmental matter. The *QEOP Significant Residual Impact Guideline* (DES 2014b) is used to determine whether residual impacts are considered to be significant.

Prescribed environmental matters (MSES) are listed in Schedule 2 of the Environmental Offsets Regulation. The following prescribed matters were mapped or identified within the Project area by the terrestrial ecology surveys:

- Regulated vegetation including:
    - Regional Ecosystems (REs) that are listed as Endangered or Of Concern (under the *Vegetation Management Act 1999* (VM Act));
    - REs located within the defined distance from the defining banks of a relevant watercourse or relevant drainage feature identified on the Regulated Vegetation Management Watercourse and Drainage Feature Map (as certified under the VM Act); or
    - REs mapped as essential habitat on the Essential Habitat Map (as certified under the VM Act) for flora and fauna listed as Endangered and Vulnerable (under the *Nature Conservation Act 1992* (NC Act)).
- Remnant REs that contain an area of land required for ecosystem functioning (a connectivity area);
- Protected wildlife habitat, which includes;
    - Habitat for Endangered, Vulnerable and Special Least Concern animals (under the NC Act);

9.1 ASSESSMENT OF PRESCRIBED MATTERS IDENTIFIED IN THE STUDY AREA

9.1.1 Regulated Vegetation

The ground verified vegetation map identified the following regulated vegetation categories, under the VM Act:

- REs that are listed as Of Concern (under the VM Act); and
- REs that are located within the prescribed distance from the defining banks of a relevant VM Act watercourse.

The *QEOP Significant Residual Impact Guideline* (DES 2014a) covers vegetation clearing in excess of thresholds of between 0.5 ha and 5 ha, depending on the structural category of the vegetation. RE 11.3.2 is defined as sparse (DES 2019c) and as such, clearing 2.57 ha is considered for being over the 2 ha threshold. Similarly, REs located within the defined distance from the defining banks of a VM Act watercourse proposed to be cleared for the Project is in excess of the larger 5 ha threshold, and no further breakdown is defined (Table 20).

Figure 16 illustrates the distribution of vegetation in relation to proposed disturbance areas, whilst Figure 17 summarises the regulated vegetation present within the proposed disturbance.

Table 20 Summary of regulated vegetation within the proposed disturbance

RE	VM Act Status	Proposed Disturbance (ha)	Threshold	Significant Residual Impact
RE 11.3.2	OC	2.57	2 ha	Yes
REs located within the defined distance from the defining banks of a VM Act watercourse	-	58.32	5 ha	Yes

Notes: * within complete study area

The Project is likely to result in a significant residual impact to MSES, through the clearing of regulated vegetation above the significant residual impact thresholds.

9.1.2 Conservation Significant Species, Protected Wildlife Habitat and Essential Habitat

The *Queensland Environmental Offsets Policy Significant Residual Impact Guideline* (DEHP 2014a) outlines the criteria for identifying when an impact on prescribed environmental matters (MSES) may be significant. The significant impact criteria provide a trigger for consideration of offsets (DEHP 2014a).

As stated in the *Environmental Offsets Regulation 2014* an area of habitat (e.g. foraging, roosting, nesting or breeding habitat) for an animal that is Endangered, Vulnerable or a Special Least Concern is considered Protected Wildlife Habitat under the *Environmental Offsets Regulation 2014* (DEHP 2014a).

As previously discussed, four listed EVNT species under the NC Act were present within the study area, Greater glider, southern Squatter pigeon, Short-beaked echidna and the plant species *Cerbera dumicola.* The DES has mapped essential habitat for three of those species (with the exception of the Short-beaked echidna) in accordance to the VM Act (Figure 18).

The Project is not a prescribed activity mentioned in schedule 1, item 7(e) of the Environmental Offsets Regulation (2014) (Section 2.6) and as such essential habitat of the Near Threatened listed species *Cerbera dumicola* does not constitute a prescribed matter.

An assessment following the Significant residual impact criteria for Vulnerable wildlife habitat (including essential habitat) has been conducted for the Greater glider and the southern Squatter pigeon. Similarly, an assessment for the Special Least Concern animal wildlife habitat has been conducted for the Short-beaked echidna.

Impacts to essential habitat for the Near Threatened plant species *Cerbera dumicola* does not require assessment under the *Queensland Environmental Offsets Policy Significant Residual Impact Guideline* (DEHP 2014a) and is not an offsetable matter.

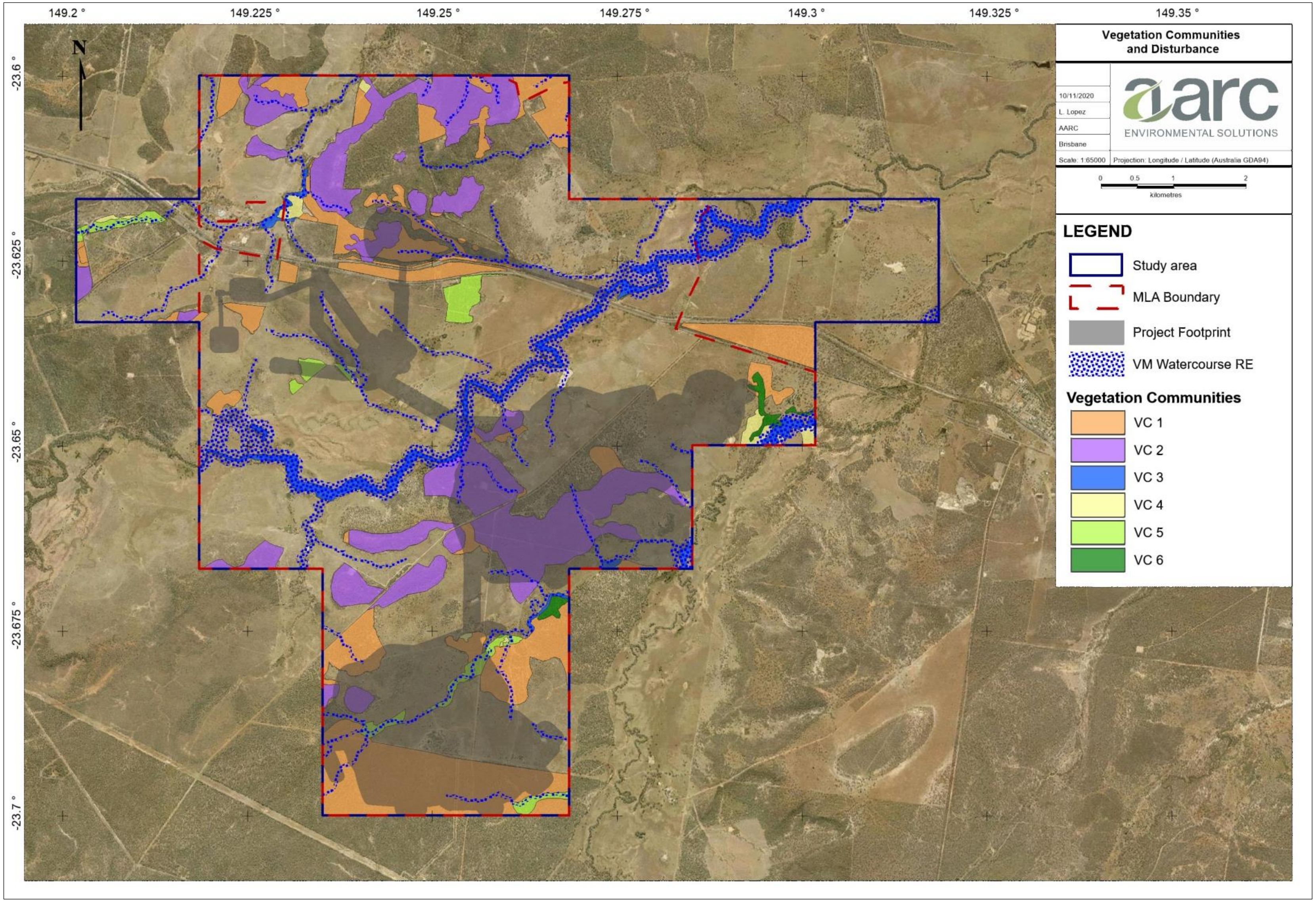


Figure 16 Vegetation Communities and Disturbance

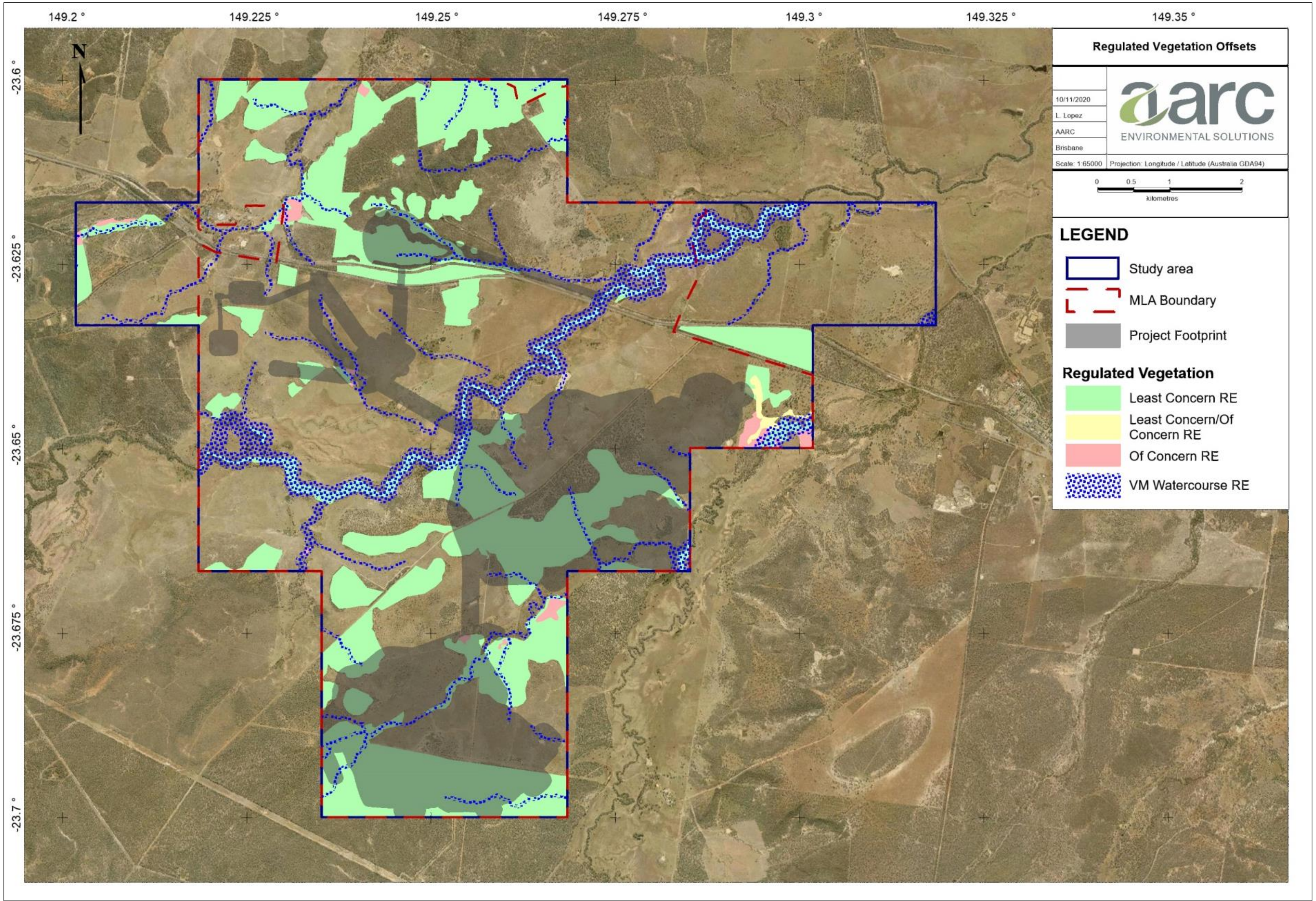


Figure 17 Regulated Vegetation Offsets Requirements

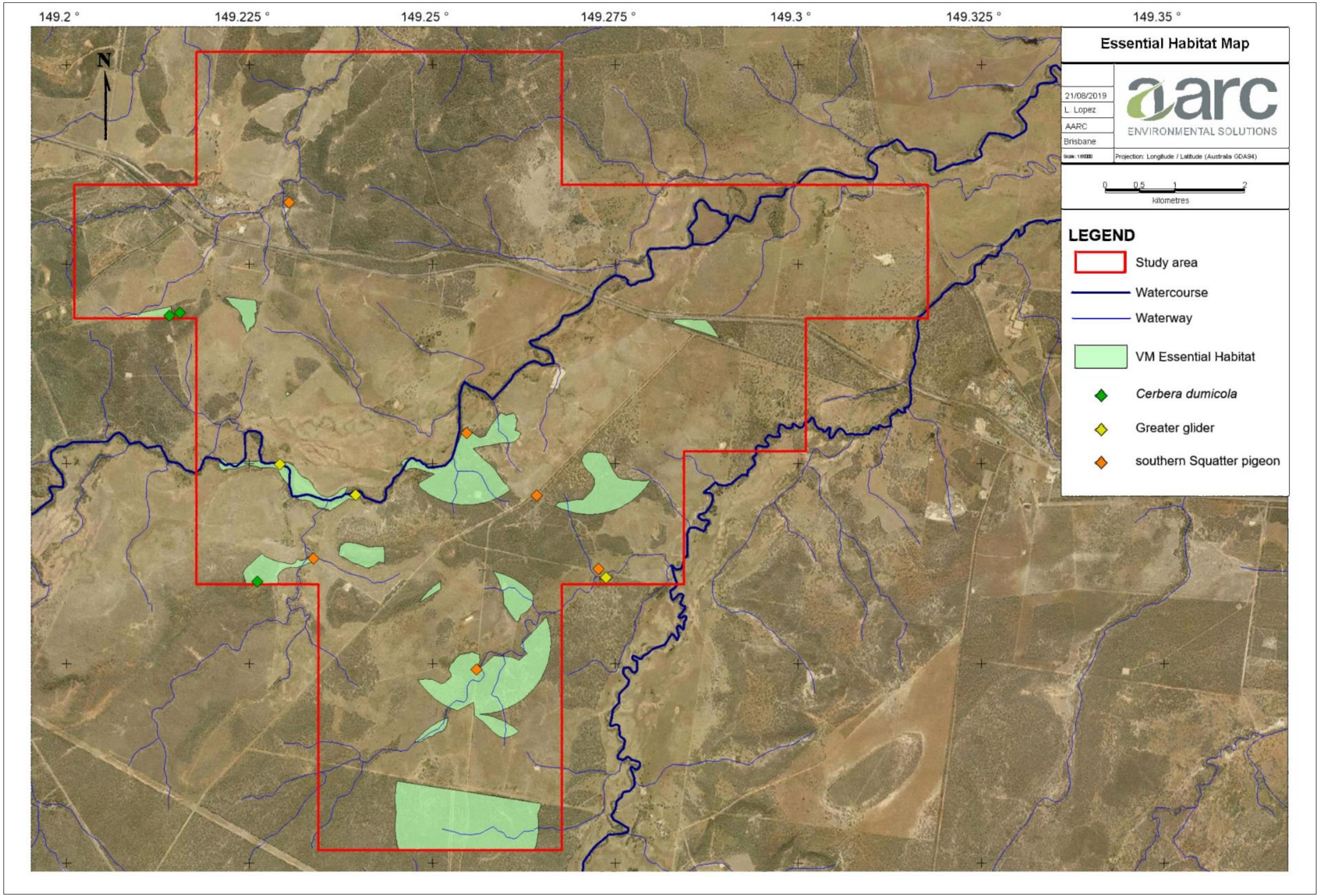


Figure 18 Essential Habitat (VM Act)

Significant Residual Impact Assessment on Vulnerable Species Under the NC Act

When assessed against the significant residual impact criteria, the Project is considered unlikely to result in any significant impact on the southern Squatter pigeon. An assessment of the potential impact of the Project on the southern Squatter pigeon using significant residual impact criteria is presented in Table 21.

When assessed against the significant impact guidelines (Table 22), the Project is considered unlikely to result in a significant impact on the Greater glider. The Project will not fragment available habitat to the extent of fragmenting the Greater glider population. There is considerable alternative habitat available in the surrounding region, and dispersal opportunities will not be impacted as habitat corridors will be retained.

Table 21 MSES Impact Assessment of the Project on the southern Squatter pigeon

Significant Impact Criteria	Impact Assessment
Will the action lead to a long-term decrease in the size of a local population of a species?	No, the Project would not fragment potential habitat for this species to the extent that it would decrease the size of local population of the species.
Will the action reduce the extent of occurrence of the species?	No, the species is highly mobile and individuals in the same area would have access to more suitable habitat through connecting open grasslands. The Project would not fragment potential habitat for this species to the extent that it would reduce the extent of occurrence of the species.
Will the action fragment an existing population?	No, this species is highly mobile and individuals in the same area would have access to more suitable habitat through connecting open grasslands. The Project includes measures to prevent significant impacts on this species. This Project will not result in the fragmentation of an existing population into two or more populations.
Will the action result in genetically distinct populations forming as a result of habitat isolation adversely?	No, the Project would not result in habitat isolation for the southern Squatter pigeon to the extent that this species will form genetically distinct populations.
Will the action disrupt ecologically significant locations (breeding, feeding, nesting, migration or resting sites) of a species?	No, this species is mobile, and the surrounding habitat provides suitable sites for breading, feeding, nesting, migration or resting activities. Given the minimal disturbance to suitable habitat for this species and the interconnectedness of habitats, the Project would not disrupt ecologically significant locations for this species.
Will the action result in invasive species that are harmful to the species becoming established in the species habitat?	No, while the southern Squatter pigeon is vulnerable to predation from introduced pest species; pest management strategies will be implemented to minimise the risk of introduced pest species predating on this species.
Will the action introduce disease that may cause the population to decline, or interfere with the recovery of the species?	No diseases are known for the species that could be caused by mining activities and cause the species' population to decline, nor would actions associated with mining activities interfere substantially with the recovery of the species.

Table 22 MSES Impact Assessment of the Project on the Greater glider

Significant Impact Criteria	Impact Assessment
Will the action lead to a long-term decrease in the size of a local population of a species?	No, the Project would not fragment potential habitat for this species to the extent that it would decrease the size of local population of the species.
Will the action reduce the extent of occurrence of the species?	No, the Project would not fragment potential habitat for this species to the extent that it would reduce the extent of occurrence of the species.
Will the action fragment an existing population?	No, the clearance of suitable habitat will impact individuals of a local population. This Project will not result in the fragmentation of an existing population into two or more populations.
Will the action result in genetically distinct populations forming as a result of habitat isolation adversely?	No, the Project would not result in habitat isolation for the Greater glider to the extent that this species will form genetically distinct populations.
Will the action disrupt ecologically significant locations (breeding, feeding, nesting, migration or resting sites) of a species?	No, this species is mobile, and the surrounding habitat provides suitable sites for breading, feeding, nesting, migration or resting activities. *E. tereticornis* (Blue gum) provides hollows and offers optimal habitat for Greater gliders. Given the minimal disturbance to suitable habitat for this species and the interconnectedness of habitats, the Project would not disrupt ecologically significant locations for this species.
Will the action result in invasive species that are harmful to the species becoming established in the species habitat?	No, while the Greater glider is vulnerable to predation from introduced pest species; pest management strategies will be implemented to minimise the risk of introduced pest species predating on this species.
Will the action introduce disease that may cause the population to decline, or interfere with the recovery of the species?	No diseases are known for the species that could be caused by mining activities and cause the species' population to decline, nor would actions associated with mining activities interfere substantially with the recovery of the species.

Significant Residual Impact Assessment for Special Least Concern (non-migratory) Species Under the NC Act

When assessed against the significant residual impact criteria, the Project is considered unlikely to result in any significant impact on the Short-beaked echidna. An assessment of the potential impact of the Project on the Short-beaked echidna using significant residual impact criteria is presented in Table 23.

Table 23 MSES Impact Assessment of the Project on the Short-beaked echidna

Significant Impact Criteria	Impact Assessment
Will the action lead to a long-term decrease in the size of a local population of a species?	No, the Project would not fragment potential habitat for this species to the extent that it would decrease the size of local population of the species.

Significant Impact Criteria	Impact Assessment
Will the action reduce the extent of occurrence of the species?	No, the species can be found in a variety of habitat types including open forests, grasslands and heavily vegetated woodlands. It's distribution spans across Australia, including Tasmania and is classified as a habitat generalist (Van Dyck et al. 2013). Suitable alternative habitat occurs throughout the broader region and immediately surrounding the study area.
Will the action fragment an existing population?	No, this Project will not result in the fragmentation of an existing population into two or more populations.
Will the action result in genetically distinct populations forming as a result of habitat isolation adversely?	No, the Project would not result in habitat isolation for the species to the extent that this species will form genetically distinct populations.
Will the action disrupt ecologically significant locations (breeding, feeding, nesting, migration or resting sites) of a species?	No, the surveys did not identify any unique habitat or significant breeding populations on the study area. This species presence relies on the abundance of ants which are its only food source.

9.1.3 HES Wetland

One HES wetland was identified to occur approximately 4 km east of the study area (Section 5.4). The *Queensland Environmental Offsets Policy: Significant Residual Impact Guideline* (DEHP 2014) is designed to assist in determining whether or not the impacts of a project will or is likely to have a significant residual impact on a MSES.

When assessed against the MSES significant residual impact guidelines, the Project is considered unlikely to result in a significant residual impact on the HES wetland to the east of the study area.

Table 24 MSES Wetland Significant Residual Impact Assessment

Significant Residual Impact Criteria	Ecological Assessment
Will the action result in areas of the wetland being destroyed or artificially modified?	No, the Project will not result in the wetland being destroyed or artificially modified. The HES wetland is located approximately 3.6 km east of the Project.
Will the action result in a measurable change in water quality of the wetland, for example a change in the level of the physical and/or chemical characteristics to a level that exceeds the water quality guidelines for the waters?	No, the Project will not result in a measurable change in water quality of the wetland. The wetland is not connected to the surface waters of the Project and does not have the potential to be affected by controlled water releases from the Project.
Will the action impact on the habitat or lifecycle of native species, including invertebrate fauna and fish species, dependant upon the wetland being seriously affected?	No, the Project will not impact the habitat or lifecycle of native species dependent upon the wetland given there would not be any impacts to the wetland habitat as a result of the Project.
Will the action result in a substantial and measurable change in the hydrological regime or recharge zones of the wetland? For example a substantial change to the volume, timing, duration and frequency of ground and surface water flows to and within the wetland?	No, the Project will not result in a substantial and measurable change in the hydrological regime of this wetland. Potential groundwater drawdown is not likely to affect this site since the wetland groundwater system is very localised and it perched above the regional groundwater system (JBT 2019).

Will the action result in an invasive species that is harmful to the environmental values of the wetland being established (or an existing invasive species being spread) in the wetland?	No, while the wetland is vulnerable to impacts from invasive species; pest and weed management strategies will be implemented to minimise the risk of introduced pest species (such as feral pigs, Sus scrofa) and invasive weed species (such as parthenium (Parthenium hysterophorus) impacting upon the HES wetland.

9.2 OFFSETS REQUIREMENTS

The prescribed matters identified within the Project area and potentially impacted by the proposed disturbance are summarised in Table 25 to determine the Project's MSES offset requirements.

Table 25 Summary of Assessment of Prescribed Matters

MSES	Total Impact Area (ha)	Impact Assessment	Offset Requirement
Of Concern RE11.3.2	2.57	Clearing is non-linear and exceeds the clearing threshold.	Offsetting Required
REs located within the defined distance from the defining banks of a VM Act watercourse	58.32	Clearing of watercourse vegetation is required. The clearing widths and areas exceed significant impact guidelines. REs supporting watercourse vegetation includes RE 11.3.25, 11.5.2, 11.3.2 and 11.7.2	Offsetting Required
Essential habitat	197.23	Greater glider: Significant impact assessment for the greater glider was completed under *MSES: Queensland Environmental Offsets Policy Significant Residual Impact Guideline* (DEHP 2014a). It was found there would be no significant impact to the species and its habitat (Section 9.1.2).	Not Required
	303.88	southern Squatter pigeon: Significant impact assessment for the southern Squatter pigeon was completed under *MSES: Queensland Environmental Offsets Policy Significant Residual Impact Guideline* (DEHP 2014a). It was found there would be no significant impact to the species and its habitat (Section 9.1.2).	Not Required
Connectivity area*	710.72	The Landscape Fragmentation and Connectivity Tool* was applied to the proposed extent of disturbance area. The results found that significant impact would occur to connectivity at both local scale and to core remnant areas.	Offsetting Required
Wildlife Habitat for Vulnerable species	13.35	Greater glider: 13.35 ha of suitable habitat is proposed to be cleared, which is 7.9% of the suitable habitat available within the study area. The Project will not fragment the habitat or local population, there is considerable habitat available in the surrounding region, and dispersal	Not Required

MSES	Total Impact Area (ha)	Impact Assessment	Offset Requirement
		opportunity will not be impacted; by retaining corridors. Significant impact assessment for the greater glider was completed under *MSES: Queensland Environmental Offsets Policy Significant Residual Impact Guideline* (DEHP 2014a). It was found there would be no significant impact to the species and its habitat (Section 9.1.2).	
	710.72	southern Squatter pigeon: Significant impact assessment for the southern Squatter pigeon was completed under *MSES: Queensland Environmental Offsets Policy Significant Residual Impact Guideline* (DEHP 2014a). It was found there would be no significant impact to the species and its habitat (Section 9.1.2).	Not Required
Wildlife Habitat for Special Least Concern species.	710.72	Short-beaked echidna: Significant impact assessment for the Short-beaked echidna was completed under *MSES: Queensland Environmental Offsets Policy Significant Residual Impact Guideline* (DEHP 2014a). It was found there would be no significant impact to the species and its habitat (Section 9.1.2).	Not Required

* Landscape Fragmentation and Connectivity Tool is based on current government mapping.

A summary of MSES environmental offset requirements to be delivered under the QEOP is provided in Table 26, including the total extent of impact area to be offset.

Table 26 MSES Offset Requirements

MSES	Area to be Impacted (ha)	Habitat Description
RE 11.3.2 *Eucalyptus populnea* (Poplar box) woodland on alluvial plains	2.57	This vegetation community was characterised by *Eucalyptus populnea* (Poplar box) woodland on alluvial plains. It was represented in several small to moderate patches within the study area and is subject to pressures from grazing, exotic species invasion.
REs located within the defined distance from the defining banks of a VM Act watercourse.	58.32	A number of VM Act watercourses traverse the Project area. Impacts will occur to watercourse vegetation that is associated with RE 11.3.25, 11.5.2, 11.3.2 and 11.7.2
Connectivity area*	710.72	The Landscape Fragmentation and Connectivity Tool determined that there is significant impact to the connectivity of the remnant vegetation within the Project.

* Landscape Fragmentation and Connectivity Tool is based on current government mapping.

Distribution of MSES requiring offsets in association with the footprint of Gemini Project is illustrated in Figure 17.

It is recommended that Magnetic South deliver the offset requirements agreed in the EA prior to disturbance of the area, as outlined in the Environmental Offset Strategy for the Project (AARC 2020b). Offsets may be delivered as a financial settlement, proponent-driven offset (i.e. a land-based offset or Direct Benefit Management Plan) or a combination of proponent-driven offset and financial settlement offset.

10.0 REFERENCES

3D Environmental (2020) 'Gemini Project – Groundwater Dependent Ecosystem Assessment' V2, prepared for Magnetic South Pty Ltd.

AARC Environmental Solutions Pty Ltd (AARC) (2020a) 'Gemini Project: Aquatic Ecology Assessment', prepared for Magnetic South Pty Ltd.

AARC Environmental Solutions Pty Ltd (AARC) (2020b) 'Gemini Project: Offset Strategy', prepared for Magnetic South Pty Ltd.

Atlas of Living Australia (ALA) (2018). *Atlas of Living Australia website.* Available from: <http://www.ala.org.au>

AVH (2019). The Australasian Virtual Herbarium, Council of Heads of Australasian Herbaria, <http://avh.chah.org.au>

Barker, M. (1995). Phaius australis, in Species Management Manual. Department of Natural Resources, Brisbane.

Blakers, M., S.J.J.F. Davies & P.N. Reilly (1984). The Atlas of Australian Birds. Melbourne, Victoria: Melbourne University Press.

Boland D.J., Brooker M.I.H., Chippendale G.M., Hall N., Hyland B.P.M., Johnson R.D., Kleinig D.A., McDonald M.W., Turner J.D. (2006) Forest Trees of Australia. CSIRO Publishing, Collingwood.

Brophy J.J., Craven L.A. and Doran J.C. 2013. Melaleucas: their botany, essential oils and uses. ACIAR Monograph No. 156. Australian Centre for International Agricultural Research: Canberra. 415 pp.

Brooks J.D. & Smith J.W. (1969). *The diagenesis of plant lipids during the formation of coal, petroleum and natural gas—II. Coalification and the formation of oil and gas in the Gippsland Basin*. Geochimica et Cosmochimica Acta, 33(10), 1183-1194.

Bureau of Meteorology (BOM) (2018). *Queensland River Basins*. Available from: <http://www.bom.gov.au/qld/flood/brochures/qld/map.pdf>

Bureau of Meteorology (BoM) (2019) Groundwater Dependant Ecosystem Atlas, Commonwealth of Australia, Canberra, available from <http://www.bom.gov.au/water/groundwater/gde/map.shtml>, accessed May 2019.

Churchill, S. (2008). *Australian Bats,* Reed New Holland, Sydney.

Cooper RM, McAllan IAW and Curtis BR (2014). The Atlas of the Birds of NSW and the ACT. Mini-Publishing, Gordon, New South Wales.

Cropper, S (1993), *Management of endangered plants*, CSIRO Publications, Melbourne.

Department of Agriculture and Fisheries (DAF) (2016), *Mimosa bush, Vachellia farnesiana*, Department of Agriculture and Fisheries, Queensland Government.

Department of Agriculture and Fisheries (DAF) (2016b), *Cane toad, Buffo marinus*, Department of Agriculture and Fisheries, Queensland Government.

Department of Agriculture and Fisheries (DAF) (2018), *Restricted invasive plants of Queensland*, Department of Agriculture and Fisheries, Queensland Government.

Department of Agriculture and Fisheries (DAF) (2019) Invasive plant and animal fact sheets Available from: <https://www.daf.qld.gov.au/business-priorities/biosecurity/invasive-plants-animals/fact-sheets#pest_animals>

Department of Environment and Heritage Protection (DEHP) (2014a). *Queensland Environmental Offsets Policy, Significant Residual Impact Guideline,* Department of Environment and Science, Brisbane. Available from: < https://environment.des.qld.gov.au/assets/documents/pollution/management/offsets/significant-residual-impact-guide.pdf>

Department of Environment and Heritage Protection (DEHP) (2014b). *Species Profile Search*. Department of Environment and Science, Brisbane. Available from: <https://environment.ehp.qld.gov.au/species-search/>

Department of Environment and Science (DES) (2018a). *Queensland Environmental Offsets Policy (Version 1.6),* Biodiversity Integration and Offsets, Ecosystem Outcomes, Department of Environment and Science, State of Queensland. https://ehp.qld.gov.au/assets/documents/pollution/management/offsets/offsets-policyv1-6

Department of Environment and Science (DES) (2018b). *Plants, animals, soils, water and more, WetlandInfo,* Department of Environment and Science, State of Queensland., Available from: <https://wetlandinfo.des.qld.gov.au/wetlands/ecology/components/>

Department of Environment and Science (DES) (2018c). *A Biodiversity Planning Assessment for the Brigalow Belt Bioregion. Version 2.1, Summary Report.* Department of Environment and Science, State of Queensland. Available from: <https://www.qld.gov.au/__data/assets/pdf_file/0029/68186/bb-bpa-summary-report.pdf>

Department of Environment and Science (DES) (2019a), *Protected plants flora survey trigger map*, Department of Environment and Science, State of Queensland. Available from: <https://apps.des.qld.gov.au/map-request/flora-survey-trigger/>

Department of Environment and Science (DES) (2019b), *Wetland maps under the Environmental Protection Act 1994*, Department of Environment and Science, State of Queensland. Available from: <https://environment.des.qld.gov.au/ecosystems/wetlands/referable-wetlands-maps.html>

Department of Environment and Science (DES), Queensland Herbarium (2019c), *Regional Ecosystem Description Database (REDD) (V 11.1)*, Department of Environment and Science, Queensland Government, Brisbane.

Department of Environment and Science (DES) (2019d), *Flora Survey Guidelines - Protected Plants; Nature Conservation Act 1992*, Department of Environment and Science, Queensland Government, Brisbane.

Department of the Environment, Water, Heritage and the Arts (DEWHA) (2009), *Weeping Myall Woodlands - EPBC Act policy statement 3.17 - Nationally threatened species and ecological communities*. Department of the Environment, Water, Heritage and the Arts, Commonwealth of Australia, Canberra.

Department of Science, Information Technology and Innovation (DSITI) (2015), *Queensland Groundwater Dependant Ecosystem Mapping Method, Version 1.1*, Department of Science, Information Technology and Innovation, Queensland Government, Brisbane.

Department of Natural Resources, Mines and Energy (DNRME) (2018), *General guide to the vegetation clearing codes Accepted development vegetation clearing codes*, Queensland Government. Available from: <https://www.dnrme.qld.gov.au/__data/assets/pdf_file/0008/1396988/landholders-guide-to-veg-clearing-codes.pdf>

Department of Environment (DoE) (2013), *Significant impact guidelines 1.1: Matters of National Environmental Significance,* Department of Environment and Energy, Commonwealth of Australia, Canberra.

Department of the Environment and Energy (DoEE) (2010a), *Survey guidelines for Australia's threatened bats; Guidelines for detecting bats listed as threatened under the Environment Protection and Biodiversity Conservation Act 1999*, Department of the Environment and Energy, Commonwealth of Australia, Canberra.

Department of the Environment and Energy (DoEE) (2010b), *Survey guidelines for Australia's threatened birds: Guidelines for detecting birds listed as threatened under the Environment Protection and Biodiversity Conservation Act 1999*, Department of the Environment and Energy, Commonwealth of Australia, Canberra.

Department of the Environment and Energy (DoEE) (2011a), *Survey guidelines for Australia's threatened mammals: Guidelines for detecting mammals listed as threatened under the Environment Protection and Biodiversity Conservation Act 1999*, Department of the Environment and Energy, Commonwealth of Australia, Canberra.

Department of the Environment and Energy (DoEE) (2011b), *Survey guidelines for Australia's threatened reptiles: Guidelines for detecting reptiles listed as threatened under the Environment Protection and Biodiversity Conservation Act 1999*, Department of the Environment and Energy, Commonwealth of Australia, Canberra.

Department of the Environment and Energy (DoEE) (2015). *Environment Protection and Biodiversity Conservation Act 1999: Protected Matters Search Tool*. Department of the Environment, Canberra. Available from: <http://www.environment.gov.au/topics/about-us/legislation/environment-protection-and-biodiversity-conservation-act-1999/protected>

Department of the Environment and Energy (DoEE) (2018), *Species Profile and Threats Database*, Department of the Environment, Canberra. Available from:<http://www.environment.gov.au/sprat

Eyre T.J., Ferguson D.J., Hourigan C.L., Smith G.C., Mathieson M.T., Kelly A.L., Venz M.F., Hogan L.D. & Rowland J. (2018). Terrestrial Vertebrate Fauna Survey Guidelines for Queensland Version 3.0. Department of Science, Information Technology, Innovation and the Arts, Queensland Government, Brisbane.

Ford, G. (2017-2018) Microbat Call Identification Report – prepared for AARC Environmental Solutions, Balance Environmental, Toowoomba.

Geoscience Australia (2018) Province and Sedimentary Basin Geology - Bowen Basin. Available from: http://www.ga.gov.au/scientific-topics/energy/province-sedimentary-basin-geology/petroleum/onshore-australia/bowen-basin

Glossy Black Conservancy (2010). Glossy black-cockatoo Conservation Guidelines for South-Eastern Queensland and far North-Eastern New South Wales. Glossy Black Conservancy.

Goff FG, Dawson GA & Rochow JJ (1982), *Site examination for threatened and endangered plant species*, Environmental Management, vol. 6: 307-316.

Hutton A.C. (2009). *Geological Setting of Australasian Coal Deposits.* Australasian Coal Mining Practice, pp. 40-84.

Independent Expert Scientific Committee (IESC) (2019) Assessing Groundwater-Dependent Ecosystems: IESC Information Guidelines Explanatory Note, Department of Environment and Energy, Commonwealth of Australia, Canberra.

JBT Consulting Pty Ltd, (2019) 'Groundwater Impact Assessment Gemini Coal Project', prepared for Magnetic South Pty Ltd.

JSTOR, Global Plants (2018), Herbarium collections, http://plants.jstor.org/

Lundie-Jenkins, G and Lowry, J 2005. Recovery plan for the bridled nailtail wallaby (Onychogalea fraenata) 2005-2009. Report to the Department of Environment and Heritage (DEH), Canberra.

Mutton A.J. (2003). Queensland Coals - Physical and Chemical Properties, Colliery and Company Information. Department of Natural Resources and Mines, Queensland Government, Brisbane. Available from: <https://www.dnrm.qld.gov.au/?a=267497>

Morcombe, M. 2002. Field Guide to Australian Birds. Steve Parish Publishing, Archerfield, Queensland.

Menkhorst P. & Knight F. (2011). *A field guide to the mammals of Australia*, Third Edition. Oxford University Press. South Melbourne, Victoria.

Nature Conservation Act 1992, Department of Environment and Science (DES), Queensland Government

Nature Conservation (Wildlife) Regulation 2006. Department of Environment and Science (DES), Queensland Government.

Neldner, V.J., Wilson, B.A., Dillewaard, H.A., Ryan, T.S. and Butler, D.W. (2019) Methodology for Survey and Mapping of Regional Ecosystems and Vegetation Communities in Queensland. Version 5.0. Updated April 2019. Queensland Herbarium, Queensland Department of Science, Information Technology and Innovation, Brisbane. 124 pp.

Pizzey, G. and Knight, F (2007). The Field Guide to the Birds of Australia, HarperCollins Publishers, Pty, Ltd., Pymble, New South Wales.

Rowland, J. 2013. Tusked frog, Adelotus brevis. Targeted species survey guidelines. Queensland Herbarium, Department of Environment and Science, Brisbane. Available from: < https://www.qld.gov.au/__data/assets/pdf_file/0014/67100/tusked-frog.pdf>

Smith A.P. Lindenmayer D (1988) Tree Hollow Requirements of Leadbeater's Possum and Other Possums and Gliders in Timber Production Ash Forests of the Victorian Central Highlands. Wildlife Research 15, 347-362.

Threatened Species Scientific Committee (TSSC) (2008), *Commonwealth Conservation Advice Delma torquata*. *(Collared Delma)*. Department of the Environment and Energy, Commonwealth of Australia, Canberra.

Threatened Species Scientific Committee (TSSC) (2016a), *Commonwealth Conservation Advice Petauroides volans*. Department of the Environment and Energy, Commonwealth of Australia, Canberra.

Threatened Species Scientific Committee (TSSC) (2016b), *Commonwealth Conservation Advice Macroderma gigas*. Department of the Environment and Energy, Commonwealth of Australia, Canberra.

Threatened Species Scientific Committee (TSSC) (2018), *Commonwealth Conservation Advice Antechinus argentus silver-headed antechinus*. Department of the Environment and Energy, Commonwealth of Australia, Canberra.

Threatened Species Scientific Committee (TSSC) (no date), *Draft Conservation Advice (incorporating listing advice) for the Poplar Box Grassy Woodlands on Alluvial Plains,* Department of the Environment and Energy, Commonwealth of Australia, Canberra.

Van Dyck, S., Gynther, I. and Baker, A. (eds.) (2013). *Field Companion to The Mammals of Australia*. New Holland; Sydney.

Vegetation Management Act 1999, Department of Environment and Science (DES), Queensland Government

Wang, J. (1995). *Homoranthus decumbens* Species Management Profile, Flora and Fauna Information System. 2. Queensland Department of Natural Resources, Brisbane.

Wilson, S. (2005). *A Field Guide to the Reptiles of Queensland*. Reed New Holland, Sydney.

Appendix A Database Searches

Appendix B Likelihood of Occurrence for Threatened Ecological Communities (TEC)

Likelihood of Occurrence for Threatened Ecological Communities

Community Name	Database searches		Desktop likelihood determination
	PMST	**Corresponding REs mapped within EPC**	
Brigalow (*Acacia harpophylla* dominant and co-dominant)	**Known** to occur (0-10 km)	11.3.1	Likely Brigalow TEC is common throughout central QLD in small patches. It is known to occur within a 10 km buffer of the study area. One RE that corresponds to the TEC has been mapped by DES as occurring on the study area. It is likely that this TEC will be identified within the study area during RE mapping validation.
Natural grasslands of the Queensland Central Highlands and northern Fitzroy Basin	**May** occur (0-10 km)	None	Unlikely This TEC may occur within a 10 km buffer of the study area according to the PMST. There are no REs corresponding to this TEC mapped by DES within the study area.
Coolabah – Black Box Woodlands of the Darling Riverine Plains and the Brigalow Belt South Bioregions	**May** occur (0-10 km)	None	Unlikely Search with PMST has identified that this TEC may occur within a 10 km buffer of the study area. None of the REs identified within the study area correspond with this TEC and therefore it is unlikely that this TEC will be found within the study area.
Weeping Myall Woodlands	**Likely** to occur (0-10 km)	11.3.2	Unlikely Weeping Myall TEC is uncommon and is only known to form minor components of two possible REs. It is considered likely to occur within a 0 – 10 km buffer of the study area. One RE that has the potential to contain minor components corresponding to this TEC has been mapped by DES as occurring on the study area. No records of *Acacia pendula* (Weeping Myall) were returned in a 50 km search of the Project using Wildlife Online. It is considered unlikely that this TEC will occur on the study area.
Semi-evergreen vine thickets of the Brigalow Belt (North and South) and Nandewar Bioregions	**Likely** to occur (10-50 km)	None	Unlikely Vine thicket TEC is not known to occur within 10 km of the study area and is only considered likely to occur within a 10 – 50 km buffer of the Project. No REs that correspond to the TEC have been mapped by DES as occurring on the study area.

Community Name	Database searches		Desktop likelihood determination
	PMST	Corresponding REs mapped within EPC	
Poplar Box Grassy Woodlands on Alluvial Plains	Not identified at time of search	11.3.2	Likely Poplar Box TEC was added to the list of TECs protected by the EPBC Act effective from 4 July 2019. One RE that corresponds to the TEC has been mapped by DES as occurring on the study area, *Eucalyptus populnea* woodland on alluvial plains (RE 11.3.2).

Appendix C Likelihood of Occurrence for Flora Species of Conservation Significance

Likelihood of Occurrence for Fauna Species of Conservation Significance

Species Name / Common Name	EVNT Listing: EPBC Act	EVNT Listing: NC Act	Database Searches: PMST	Database Searches: Wildlife Online Records	Preferred Habitat	Desktop Likelihood of Occurrence
Acacia grandiflora	V	LC	Species or species habitat **known** to occur within area (10 – 50 km)	6 *10 - 50 km*	*Acacia grandifolia* grows in hilly terrain on hillslopes of varying aspects and slope. The species also occurs on hillcrests, gullies and plains. Soil is usually shallow and well drained and is described as sandy loam to clay loam in texture derived from sandstones and acidic volcanics. Altitudes are predominantly between 200 and 370 metres. The vegetation is tall woodland or open forest with a range of floristic associations. The most frequently recorded tree species are *Eucalyptus crebra, Corymbia citriodora, C. trachyphloia, E. maculata* and *E. exserta* (QCRA/FRA, 1998; Queensland Herbarium 2011, cited in DES 2018b).	Unlikely This species has been recorded 6 times within 50 km of the Project. Potential suitable habitat is not likely to occur within the Project due to the elevation requirements of the species. The Project is located outside of the species distribution range.
Acacia storyi	-	NT	-	17 *10 - 50 km*	*Acacia storyi* typically grows on sandy and shallow skeletal soils over sandstone and grows in open forests. This species is associated with *Eucalyptus teriticornis* and *Aristida* spp. The species was considered occasional in two populations from Blackdown Tableland National Park, west of Rockhampton in central Queensland (DES 2018b).	Unlikely This species has been recorded 17 times within 50 km of the Project and potential habitat is likely to occur within the Project. However, the species range is very restricted, and the majority of the known populations protected within the Blackdown Tablelands NP, to the southwest of the Project.
Aristida annua	V	V	Species or species habitat **likely** to occur within area (10 – 50 km)	No Records	This species is restricted to Eucalypt woodland on black clay and basalt soils (DoEE 2018).	Unlikely This species was returned in the 50 km PMST search as likely to occur, however has no records within 50 km of the Project on Wildlife Online or Atlas of Living Australia database (ALA). Potential habitat is unlikely to occur within the Project due to the absence of suitable soil types.

C

Species Name / Common Name	EVNT Listing		Database Searches		Preferred Habitat	Desktop Likelihood of Occurrence
	EPBC Act	NC Act	PMST	Wildlife Online Records		
Baeckea trapeza	-	NT	-	7 *10 - 50 km*	*Baeckea trapeza* grows at altitudes around 700 – 800m and on sandy soil in open Eucalyptus forest. This species is confined to the Blackdown Tableland (DES 2018b).	Unlikely This species has been recorded 7 times within 50 km of the Project and potential habitat is likely to occur within the Project. However, the species range is very restricted, and the majority of the known populations area protected within the Blackdown Tablelands NP, to the southwest of the Project.
Bertya opponens	V	V	Species or species habitat **likely** to occur within area (10 – 50 km)	No Records	Recorded growing in a variety of community types including mixed shrubland, Lancewood woodland, Mallee woodland, Eucalyptus / Acacia open forest with shrubby understorey, Eucalyptus / Callitris open woodland and semi-evergreen vine-thicket. Soils are recorded as generally shallow sandy loams or red earths associated mostly with sandstone, but also with rhyolite, shale and metasediments (DoEE 2018).	Potential This species was returned in the 50 km PMST search as likely to occur, however has no records within 50 km of the Project on Wildlife Online, ALA or Australian Virtual Herbarium (AVH). Due to the presence of Lancewood woodland within the study area and the proximity to the edge of the species distribution, the species potentially could be found within the study area.
Bertya pedicellata	-	NT	-	3 *10 - 50 km*	*Bertya pedicellata* grows on rocky hillsides in range of community types including eucalypt forest or woodland, Acacia woodland or shrubland and open heathland or vine thicket communities. The soils on which this species grow on are mainly skeletal to shallow sandy, sandy clay or clay loams overlaying rhyolite, trachyte or sandstone substrates (DES 2018b).	Potential This species has been recorded 3 times within 50 km of the Project. Even though there are no records of the species in the vicinity of the Project, this is located within the species distribution range. Potential suitable habitat may occur within the Project.

Species Name Common Name	EVNT Listing		Database Searches		Preferred Habitat	Desktop Likelihood of Occurrence
	EPBC Act	NC Act	PMST	Wildlife Online Records		
Cadellia pentastylis Ooline	V	V	Species or species habitat **likely** to occur within area (0-10 km)	4 *10 - 50 km*	Ooline occurs in a range of vegetation types including dry rainforest, semi-evergreen vine thickets and sclerophyll communities including, Brigalow-Belah, Poplar Box and Bendee communities (Pollock 1999; DEWHA 2008; cited in DES 2014b). Ooline often occurs on the edges of sandstone and basalt escarpments, 200 - 500m above sea level. Ooline grows on the moderately fertile soils preferred for agriculture and pasture development (Pollock 1999; DEWHA 2008; cited in DES 2014b).	Unlikely This species has been recorded four times within 50 km of the Project. Potential suitable habitat is not likely to occur within the Project due to the elevation requirements of the species. The Project is located outside of the species distribution range.
Cerbera dumicola	-	NT	-	2 *0 - 10 km* 6 *10 - 50 km*	*Cerbera dumicola* occurs across a range of habitats in central and southern Queensland. Associated vegetation and species include: sandstone hills in open *E. umbra subsp. carnea*; on plateaus, in woodland of *Acacia shirleyi* with *Corymbia dolichocarpa*; acidic soils in mine rehabilitation area; woodland of *A. catenulata* and *A. shirleyi* with *E. thozetiana* on a slope of sand/clay soil; semi-deciduous notophyll-microphyll vine forest of Brachychiton australis, *Gyrocarpus americanus, Flindersia australis, Pleiogynium timorense, Drypetes deplanchei* and *Sterculia quadrifida* on rhyolite hillslopes; open-woodland of *E. melanophloia* with occasional Acacia shirleyi, E. populnea and *E. brownii*; semi-evergreen vine thicket with *Corymbia citriodora* and *Corymbia aureola* emergents; woodland of *A. rhodoxylon* on brown, sandy loam; and in *Corymbia tessellaris - Acacia aneura* open woodland (Queensland Herbarium, 2011; cited in DES 2018).	Likely This species has been been recorded twice within 10 km of the Project, and six times within 50 km. Potential suitable habitat is likely to occur within the Project.

C

Species Name Common Name	EVNT Listing EPBC Act	 NC Act	Database Searches PMST	 Wildlife Online Records	Preferred Habitat	Desktop Likelihood of Occurrence
Commersonia pearnii	-	E	-	2 *10 - 50 km*	*Commersonia pearnii* occurs in open forests and woodlands with a range of canopy species. This species grows on sandstone escarpments and tablelands with shallow, medium to coarse-grained soils. This species is restricted to Blackdown Tableland in central Queensland (DES 2014b).	<u>Unlikely</u> This species is restricted to the Blackdown Tablelands NP. Potential suitable habitat is not likely to occur within the Project.
Corunastylis pedersonii	-	V	-	1 *0 - 50 km*	This species has been recorded in Queensland from a single location in the Blackdown Tableland NP, on coarse decomposed sandstone. Seepage area on rock ledge with sedges, moss and *Drosera* sp. (AVH 2019). Specimens from New South Wales were recorded from Undulating country. Reddish/brown sandy clay loam soil over sandstone. Shrubby *Eucalyptus crebra* woodland with *Melaleuca uncinata.*	<u>Unlikely</u> This species has been recorded once within 50 km of the Project, in the Blackdown Tableland NP. Potential suitable habitat is not likely to occur within the Project due to the absence of suitable soil types.
Corunastylis valida	-	V	-	1 *10 - 50 km*	This species has been recorded in Queensland from a single location in the Blackdown Tableland NP, on coarse decomposed sandstone. Sparse woodland dominated by Banksia sp. (AVH 2019).	<u>Unlikely</u> This species has been recorded once within 50 km of the Project, in the Blackdown Tableland NP. Potential suitable habitat is not likely to occur within the Project due to the absence of suitable soil types.

Species Name **Common Name**	**EVNT Listing**		**Database Searches**		**Preferred Habitat**	**Desktop Likelihood of Occurrence**
	EPBC Act	**NC Act**	**PMST**	**Wildlife Online Records**		
Cycas ophiolitica Marlborough blue	E	E	Species or species habitat **likely** to occur within area (10 – 50 km)	No Records	*Cycas ophiolitica* inhabits eucalypt open forest and woodland communities with a grassy understorey. They occur on hill tops or steep slopes, at altitudes of 80-620m above sea level. It grows on shallow, stony, red clay loams or sandy soils (DES 2018b).	Unlikely This species was returned in the 50 km PMST search as likely to occur, however has no records within 50 km of the Project on Wildlife Online or ALA. Potential suitable habitat is unlikely to occur within the Project.
Daviesia discolor	V	V	Species or species habitat **likely** to occur within area (10 – 50 km)	6 *10 - 50 km*	This species is distributed in three localities in Queensland; Blackdown Tableland NP, Mount Walsh area near Biggeden, and in Carnarvon National Park (north of Mount Playfair) (DoEE 2018; Queensland Herbarium 2012). *Daviesia discolor* typically occurs from coastal hills to mountain slopes and ridges and grows between 50 – 1100m in altitude, mostly on fine-textured soils, which may be derived from acid volcanic or metamorphic rocks. Specifically, on the Blackdown Tableland NP, this species occurs on sandy soil derived from sandstone and on lateritic clay at altitudes of 600 – 900m, in open eucalypt forest dominated by species such as *Eucalyptus sphaerocarpa* and *E. nigra* (Queensland Herbarium 2012, cited in DES 2018b).).	Unlikely This species has been recorded within 50 km of the Project in the Blackdown Tableland NP. Potential suitable habitat is not likely to occur within the Project due to the absence of suitable soil types and elevation.

Species Name Common Name	EVNT Listing		Database Searches		Preferred Habitat	Desktop Likelihood of Occurrence
	EPBC Act	NC Act	PMST	Wildlife Online Records		
Daviesia quoquoversus	-	V	-	2 *10 - 50 km*	*Daviesia quoquoversus* occurs in open forests on sandy soil derived from sandstone. This species is restricted to south-east Queensland and only found in Blackdown Tableland NP (Queensland Herbarium 2012, cited in DES 2018b).	Unlikely This species has been described as restricted to the Blackdown Tableland NP. Potential suitable habitat is not likely to occur within the study area due to the absence of suitable soil types.
Dichanthium queenslandicum King bluegrass	E	V	Species or species habitat **may** occur within area (10 – 50 km)	No Records	This species occurs on black cracking clay in tussock grasslands mainly in association with other species of Bluegrasses. It is mostly confined to the natural Bluegrass grasslands of central and southern Queensland (DoEE 2018).	Unlikely The species has not been recorded within 50 km of the Project. The species is mostly confined to natural Bluegrass grasslands and not in grazed land. The study area lacks on suitable habitat.
Dichanthium setosum Bluegrass	V	-	Species or species habitat **likely** to occur within area (0 – 10 km) Species or species habitat **likely** to occur within area (10 – 50 km)	No Records	Occurs in grassy woodland and open forests in inland Australia. Associated with heavy basaltic black soils and stony red-brown hard-setting loam with clay subsoil and is found in moderately disturbed areas such as cleared woodland, grassy roadside remnants, grazed land and highly disturbed pasture (DoEE 2018).	Unlikely The species has not been recorded within 50 km of the Project. The species is mostly confined to natural Bluegrass grasslands and not in grazed land. The study area lacks on suitable habitat.

Species Name Common Name	EVNT Listing		Database Searches		Preferred Habitat	Desktop Likelihood of Occurrence
	EPBC Act	NC Act	PMST	Wildlife Online Records		
Eucalyptus raveretiana Black ironbox	V	LC	Species or species habitat **likely** to occur within area (10 – 50 km)	No Records	Occurs on alluvial soils, loams, light clays or cracking clays in open forests and woodlands along watercourses and occasionally on river flats (DES 2018b).	<u>Unlikely</u> Potential suitable habitat may occur within the study area. This species was returned in the 50 km PMST search as likely to occur, however has not been recorded within 50 km of the Project. The species is unlikely to occur within the study area as it is only known from coastal regions of eastern Queensland, with the nearest records north and east of Coppabella.
Gastrodia crebrifolia	-	V	-	1 *10 - 50 km*	*Gastrodia crebriflora* is an orchid that grows in loose colonies on protected slopes in tall open forest, often close to fallen trees. This species occurs on soils that are sands derived from decomposed sandstone. Endemic to Queensland (Jones 1991 cited in DES 2018b).	<u>Unlikely</u> This species has been recorded once within 50 km of the study area, in the Blackdown Tableland NP. However, the study area is located outside the known distribution of the species.
Homoranthus decumbens	E	V	Species or species habitat **known** to occur within area (10 – 50 km)	No Records	*Homoranthus decumbens* occurs in tall shrubland or heath up to 800m above sea level. It occurs on the edge of sandstone cliffs or in shallow sandy soils containing lateritic (iron-rich) pebbles (Wang 1995).	<u>Unlikely</u> This species was returned in the 50 km PMST search as known to occur, however, it has not been recorded within 50 km of the Project on Wildlife Online or ALA. The closest record of the species is from near Taroom, over 200 km south of the Project. Potential suitable habitat is unlikely to occur within the study area.

C

Species Name **Common Name**	**EVNT Listing**		**Database Searches**		**Preferred Habitat**	**Desktop Likelihood of Occurrence**
	EPBC Act	**NC Act**	**PMST**	**Wildlife Online Records**		
Livistona fulva	-	V	-	12 *10 - 50 km*	*Livistona fulva* occurs mainly along sandstone cliff-lines, on rocky foot-slopes below cliffs, in shallow rocky gullies of the Blackdown Tableland NP, and in deep sandstone gorges below major waterfalls around the edge of the plateau. Grows in moderately tall eucalypt forest, typically dominated by *Eucalyptus sphaerocarpa*. Most occurrences are recorded at altitudes 300 – 600m above sea level (DES 2018b). This species is found in the Blackdown Tablelands NP.	<u>Unlikely</u> This species has been described as occur mainly in the Blackdown Tableland NP. Potential suitable habitat is not likely to occur within the study area due to the absence of suitable soil types and low elevation.
Logania diffusa	V	V	Species or species habitat **likely** to occur within area (0-10 km)	2 *10 - 50 km*	*Logania diffusa* occurs in heathland and eucalypt open forest. It grows in sandy or sandy clay soil with sandstone outcropping and loose surface stones on escarpments. This species grows at altitudes of 600 – 780m above sea level. This species is restricted to the Blackdown Tableland NP (DES 2014b).	<u>Unlikely</u> This species has been described as restricted to the Blackdown Tableland NP. Potential suitable habitat is not likely to occur within the Project due to the absence of suitable soil types and low elevation.
Macrozamia platyrhachis	E	E	Species or species habitat **likely** to occur within area (0-10 km)	30 *10 - 50 km*	*Macrozamia platyrhachis* is scattered locally and abundantly in eucalypt woodland or open forest at altitudes between 300 – 780m above sea level. Mid- and under-stories of the vegetation may be relatively dense but is variably dependent on fire history. This species grows on deep sandy soils, derived from sandstone and is mainly found on Blackdown Tableland NP and has occurrence recorded in areas slightly south of township of Dingo (DES 2018b).	<u>Unlikely</u> This species has been recorded mainly within 50 km of the Project, in the Blackdown Tableland NP. The study area with its highest elevation at 200m above sea level, lacks the suitable habitat for this species.

Species Name **Common Name**	**EVNT Listing**		**Database Searches**		**Preferred Habitat**	**Desktop Likelihood of Occurrence**
	EPBC Act	**NC Act**	**PMST**	**Wildlife Online Records**		
Melaleuca groveana	-	NT	-	4 *10 - 50 km*	*Melaleuca groveana* grows on exposed rocky ridges, high mountain slopes and the summit of mountains at altitudes 340 – 600m above sea level. This species typically occurs on in heaths and eucalypt woodlands and forests with heath understoreys. It is also found in tall open forest with a grassy understorey and in microphyll vine forests. It has been previously recorded growing on red sandy loams, brown loams, skeletal rocky soils and sandy soils over sandstone rock. This species is found in fragments from Port Stephens (NSW) to the Blackdown Tableland NP (DES 2014b).	Unlikely This species has been recorded within 50 km of the Project, in the Blackdown Tableland NP. The study area with its highest elevation at 200m above sea level, lacks the suitable habitat for this species.
Melaleuca pearsonii	-	NT	-	12 *10 - 50 km*	*Melaleuca pearsonii* occurs in Blackdown Tableland NP. Grows near rivers, in rocky gullies and in wallum vegetation in creek beds (Brophy et al. 2013).	Unlikely This species has been described as occurring in the Blackdown Tableland NP. Potential suitable habitat is not likely to occur within the study area.

Species Name Common Name	EVNT Listing EPBC Act	 NC Act	Database Searches PMST	 Wildlife Online Records	Preferred Habitat	Desktop Likelihood of Occurrence
Phaius australis	E	E	Species or species habitat **known** to occur within area (0-10 km)	3 *10 - 50 km*	*Phaius australis* grows in areas where soils are almost always damp, but not flooded for lengthy periods. Sands are generally the underlying soil type. *P. australis* are usually found in coastal habitats between swamps and forests or in suitable areas further inland. This includes swampy sclerophyll forest dominated by melaleucas, swampy forest that often have scleorphyll emergents, or fringing open forest and melaleuca swamp forest associated with rainforest species. *P. australis* has also been recorded in wallum, sedgeland, rainforest and closed forest. They often grow in deep shade but can also occur in full sun. This species occurs at higher altitudes in northern Queensland (Barker 1995).	Unlikely Despite being described from coastal habitats, this species has been recorded 3 times within 50 km of the study area in the Blackdown Tableland NP. Potential suitable habitat is not likely to occur within the Project.
Plectranthus blakei	-	NT	-	10 *10 - 50 km*	*Plectranthus blakei* has been only recorded from sandstone rock outcrops and ledges in association with *Hoya australis* and *Clandrina* in the Blackdown Tableland NP (JSTOR 2018).	Unlikely This species has only been recorded in the Blackdown Tableland NP. However, the study area is located outside the known distribution of the species.

C

Species Name Common Name	EVNT Listing		Database Searches		Preferred Habitat	Desktop Likelihood of Occurrence
	EPBC Act	NC Act	PMST	Wildlife Online Records		
Pseudanthus pauciflorus subsp. arenicola	-	NT	-	1 *10 - 50 km*	This species occurs in crevices on vertical or near vertical rock faces and sandstone cliffs within dry sclerophyll woodland (DSITI 2015) and is endemic to the Blackdown Tableland NP (DES 2018b).	Unlikely This species has been described as being endemic to the Blackdown Tableland NP. Potential suitable habitat does not occur within the study area.
Rutidosis glandulosa	-	NT	-	7 *10 - 50 km*	*Rutidosis glandulosa* is known from approximately 15 populations across six distinct localities, which includes Blackdown Tableland NP. This species mainly occurs on sandy or gravelly well drained soil in grassy open eucalypt woodland. Around Blackdown Tableland NP, this species appears to be growing in open forest dominated by *Eucalyptus interstans, E. sphaerocarpa* and *Angophora leiocarpa*. (DES 2018b).	Unlikely The study area is located outside of the species distribution, which extends from Stanthorpe to the Blackdown Tableland NP, to the west of the study area. Potential suitable habitat is not likely to occur within the Project.
Sannantha brachypoda	-	V	-	1 *10 - 50 km*	*Sannantha brachypoda* has been described from loamy, sandy or rocky soils and from gorges and creek lines (AVH 2019).	Unlikely This species has been recorded once within 50 km of the study area, in the Blackdown Tableland NP. Potential suitable habitat does not occur within the study area.

Species Name Common Name	EVNT Listing EPBC Act	NC Act	Database Searches PMST	Wildlife Online Records	Preferred Habitat	Desktop Likelihood of Occurrence
Solanum adenophorum	-	NT	-	10 *10 - 50 km*	*Solanum adenophorum* occurs mostly in brigalow woodland and on very gently inclined slopes. It also occurs in gidgee (*Acacia cambagei*) scrub on deep cracking clay soils (DES 2018e). Occurrence records show that this species is from south and south-west of Marlborough to Rockhampton and also found in small populations north and north-east of Wagga Wagga, NSW (ALA 2018).	Potential The Project is located south of the distribution range of the species. All records near the Project are located within Taunton NP. Potential suitable habitat may occur within the study area in small patches.
Solanum dissectum	E	E	Species or species habitat **known** to occur within area (0-10 km)	3 *10 - 50 km*	*Solanum dissectum* occurs in open forest and woodland of brigalow (Acacia harpophylla) or *Eucalyptus thozetiana* on solodic clay soils (Queensland Herbarium 2012, cited in DES 2018b).	Potential This species was returned in the 50 km PMST search as known to occur, however, the closest record of the species is from west of Blackdown Tableland NP. Potential suitable habitat may occur within the study area in small patches.
Solanum elachophyllum	-	E	-	1 *0 - 10 km* 14 *10 - 50 km*	*Solanum elachophyllum* grows on fertile cracking-clay soils in open forest of *Eucalyptus thozetiana, Acacia harpophylla,* with understorey *of Geijera parviflora, Casuarina cristata, Macropteranthes leichhardtii, Eucalyptus cambageana*, or woodland of *E. creba* and *E. tenuipes* (DES 2018b). Occurrence of this species has been recorded in areas from south-west of Mackay to south-west of Gladstone.	Likely The Project is located within the species distribution. Potential suitable habitat may occur within the study area in small patches.

C

Species Name / **Common Name**	**EVNT Listing**		**Database Searches**		**Preferred Habitat**	**Desktop Likelihood of Occurrence**
	EPBC Act	**NC Act**	**PMST**	**Wildlife Online Records**		
Solanum johnsonianum	E	E	Species or species habitat **may** occur within area (10 – 50 km)	No Records	*Solanum johnsonianum* is distributed within communities dominated or co-dominated by *Acacia harpophylla* (Brigalow), on heavy cracking soils. Other associated species include *Eucalyptus thozetiana* with understorey of *Geijera parviflora* (Bean, 2004; Queensland Herbarium, 2012, cited in DES 2018b).	Unlikely The Project is located south of the distribution of the species. Potential suitable habitat may occur within the study area in small patches. There are no records of the species within 50 km of the Project.

Appendix D Likelihood of Occurrence for Fauna Species of Conservation Significance

Likelihood of Occurrence for Fauna Species of Conservation Significance

Scientific Name Common Name	Status		Database Searches		Habitat and Distribution	Desktop Likelihood of Occurrence
	EPBC Act	NC Act	PMST	Wildlife Online Records		
Amphibians						
Adelotus brevis Tusked frog	-	V	-	10 (10-50 km)	The Tusked frog Inhabits wet eucalypt forest, rainforest, and sometimes dry eucalypt forest, where it can be found in close proximity to suitable breeding habitat such as ponds and slow-moving sections of streams. Also recorded from dams and garden ponds in urban and peri-urban areas (Rowland 2013).	<u>Potential</u> The study area occurs within the vicinity of the known range of the Tusked frog and there is a possibly the study area provides areas of suitable habitat. However, the closest records of the species in the area are from Blackdown Tableland NP, located over 20km southwest of the study area.
Reptiles						
Delma torquata Collared Delma	V	V	Species or species habitat **likely** to occur within area (0-10 km)	1 (10-50 km)	The Collared Delma normally inhabits eucalypt dominated woodland and open forest where it is associated with suitable micro-habitats (exposed rocky outcrops). The ground cover is predominantly native grasses, such as Kangaroo Grass (*Themeda triandra*), Barbed-wire Grass (*Cymbopogon refractus*), Wiregrass (*Aristida* sp.) and Lomandra (*Lomandra* sp.) (Peck & Hobson, 2007, cited in TSSC 2008).	<u>Potential</u> This species was returned in the 10 km PMST search as may occur. This species is known to occur between 10 and 50 km, at the Blackdown Tablelands NP. However, desktop searches identified marginal suitable habitat for this species in the study area.
Denisonia maculate Ornamental snake	V	V	Species or species habitat **may** to occur within area (0-10 km)	2 (10-50 km)	The Ornamental Snake's preferred habitat is within, or close to, habitat that is favoured by its prey - frogs. The species is known to prefer woodlands and open forests associated with moist areas, particularly gilgai (melon-hole) mounds and depressions in Queensland Regional Ecosystem Land Zone 4, but also lake margins and wetlands (Agnew 2010 pers. comm.; Brigalow Belt Reptiles Workshop 2010; Wilson & Knowles 1988	<u>Unlikely</u> This species was returned in the 10 km PMST search as may occur, and as known to occur between 10 and 50 km. Desktop searches did not identify suitable habitat for this species.

D

Scientific Name Common Name	Status		Database Searches		Habitat and Distribution	Desktop Likelihood of Occurrence
	EPBC Act	NC Act	PMST	Wildlife Online Records		
					cited in DEE 2018). Gilgai formations are found where deep-cracking alluvial soils with high clay contents occur (Brigalow Belt Reptiles Workshop 2010, cited in DoEE 2018).	
Egernia rugosa Yakka skink	V	V	Species or species habitat **known** to occur within area (0-10 km)	No records	Dry open forests, woodlands and rocky areas in the Brigalow Belt, where it occurs in fallen timber, wood piles, uprooted trees, deep rock crevices, deeply eroded gullies or disused rabbit warrens (DoEE 2018).	<u>Unlikely</u> This species or species habitat was returned in the 10 km PMST search as known to occur, however no records were returned in the database and online searches. There nearest ALA records are from over 50km west of the study area. Some marginally suitable habitat may be found on the study area.
Furina dunmalli Dunmall's snake	V	V	Species or species habitat **may** occur within area (0-10 km)	No records	Dunmall's Snake inhabits a broad range of habitats including; Forests/woodlands on black alluvial cracking clay/clay loams. Dominant vegetation includes Brigalow *(Acacia harpophylla)*, Wattles *(A. burowii, A. deanii, A. leioclyx)*, native Cypress *(Callitris spp.) or* Bull-oak *(Allocasuarina luehmannii), Corymbia citriodora, Eucalyptus crebra* and *E. melanophloia, and Callitris glaucophylla* (DoEE 2018).	<u>Unlikely</u> This species was returned in the 10 km PMST search as may occur, however no records were returned in the database and online searches. There nearest ALA records are from over 50km west of the study area. Desktop searches identified potentially suitable habitat for this species on the study area.
Strophurus taenicauda Golden-tailed gecko	-	NT	-	10 (10-50 km)	The Golden-tailed Gecko inhabits dry sclerophyll forests featuring ironbarks, cypress pine and brigalow. It is described as an arboreal species sheltering behind loose dead bark, in hollows, or clinging to exposed slender branches in dapple sunlight (Wilson 2005).	<u>Potential</u> This species has been recorded within 50 km of the study area. The study area contains suitable habitat for this species.
Birds						
Actitis hypoleucos	Ma	SL	Species or species habitat	No records	Varied coastal and interior wetlands – narrow muddy edges of billabongs, river pools,	<u>Unlikely</u>

D

Scientific Name Common Name	Status		Database Searches		Habitat and Distribution	Desktop Likelihood of Occurrence
	EPBC Act	NC Act	PMST	Wildlife Online Records		
Common Sandpiper			**may** occur within area (0-10 km)		mangroves, among rocks and snags, reefs or rocky beaches (Morcombe 2002).	This species has not been recorded on the study area and has no records within 50 km of the study area on Wildlife Online or ALA. Suitable habitat for this species is unlikely to be available on the study area.
Anseranas semipalmata Magpie Goose	Ma	-	Species or species habitat **may** occur within area (0-10 km)	No records	The Magpie Goose occupies large seasonal wetlands and well-vegetated dams with rushes and sedges; wet grasslands and floodplains (Pizzey & Knight 2007).	<u>Unlikely</u> This species has not been recorded within 50 km or the study area. Some seasonal habitat may occur on the study area, however preferred habitat is distributed on coastal margins.
Apus pacificus Fork-tailed swift	Ma, Mi	SL	Species or species habitat **likely** to occur within area (0-10 km)	No records	Low to very high airspace over varied habitat, rainforest to semi-desert, most active just ahead of summer storm fronts (Morcombe 2002).	<u>Unlikely</u> This species has not been recorded within 50 km of the study area on Wildlife Online or ALA. Potential habitat may occur on the study area, however occurrence is highly concentrated on coastal margins, and sporadic through inland Australia.
Ardea alba Great egret	Ma	-	Species or species habitat **likely** to occur within area (0-10 km) Breeding **known** to occur within area (10-50 km)	No records	Common throughout Australia, with the exception of the most arid areas. Known to prefer shallow water, particularly when flowing, but may be seen on any watered area, including damp grasslands (Morcombe 2002).	<u>Potential</u> This species has not been recorded within 50 km of the study area on Wildlife Online or ALA. Seasonally suitable habitat is likely to occur on the study area and in the greater region.
Ardea ibis Cattle egret	Ma	-	Species or species habitat **may** occur within area (0-10 km)	No records	Widespread and common in north, north-eastern and south-eastern Australia. The species is found in grasslands, woodlands and wetlands, and is not common in arid areas. Utilises pastures and croplands, especially where drainage is poor. Will also	<u>Potential</u> This species has not been recorded within 50 km of the study area on Wildlife Online or ALA. Potential suitable habitat is

D

Scientific Name Common Name	Status		Database Searches		Habitat and Distribution	Desktop Likelihood of Occurrence
	EPBC Act	NC Act	PMST	Wildlife Online Records		
					forage in garbage dumps, and often associates with livestock (Morcombe 2002).	available on the study area and in the greater region.
Calidris acuminate Sharp-tailed sandpiper	Ma, Mi	SL	Species or species habitat **may** occur within area (0-10 km) Species or species habitat **likely** to occur within area (10-50 km)	No records	Fresh or salt wetlands – the muddy edges of wetlands and dams (Morcombe 2002). In Queensland, they are recorded in most regions, being widespread along much of the coast and are very sparsely scattered inland, particularly in central and south-western regions (DoEE 2018).	<u>Potential</u> This species was returned in the 10 km PMST search as may occur, and as likely to occur between 10 and 50 km. No records of presence were recorded within 50km of the study area. Species occurrence is concentrated on coastal margins, but still common throughout inland Australia where suitable habitat is available. Limited seasonal habitat may occur in the study area.
Calidris ferruginea Curlew sandpiper	CE, Mi, Ma	E	Species or species habitat **may** occur within area (0-10 km)	No records	Inhabiting wetland environments, the Curlew sandpiper is commonly found on sandy shores, lagoons, tidal mudflats, saltmarshes, swamps, lakes, and sewage farms (Pizzey and Knight 2007). They forage at the edge of shallow pools and can wade through water 15-60 mm deep (DoEE 2018). Whilst small numbers have been recorded living inland around ephemeral and permanent lakes, dams and bores, the majority reside along the coast roosting on dry shingle, sand, or shell beaches. This species is distributed around most of the coastline of Australia.	<u>Unlikely</u> Habitat within the study area is not suited for this species as the study area is not coastal and will not provide the resources required to sustain this species. Although this species has been recorded in association with inland waterbodies, it is very rare.
Calidris melanotos Pectoral sandpiper	Ma, Mi	SL	Species or species habitat **may** occur within area (0-10 km)	No records	Usually coast wetlands, both fresh and saline, but also inland on permanent and temporary wetlands; utilises sites with mudflats, fringing vegetation, swamps with heavy overgrowth of vegetation (Morcombe 2002).	<u>Unlikely</u> This species was returned in the 10 km PMST search as may occur, however as no records were returned in the database and online searches. The nearest ALA records are near Mackay and Yeppoon. Potentially

D

Scientific Name Common Name	Status		Database Searches		Habitat and Distribution	Desktop Likelihood of Occurrence
	EPBC Act	NC Act	PMST	Wildlife Online Records		
						marginal suitable habitat is likely to occur within the study area.
Calyptorhynchus lathami erebus Glossy black-cockatoo (northern)	-	V	-	19 (10-50 km)	The Glossy black-cockatoo (northern) prefers woodland areas dominated by she-oak Allocasuarina or open sclerophyll forests and woodlands with a stratum of Allocasuarina beneath Eucalyptus, Corymbia or Angophora. This species occurs in the north and central east coast of Queensland, including Blackdown Tableland (Glossy Black Conservancy 2010).	Potential Wildlife online records indicate 19 occurrences of this species within 10 to 50 km of the study area. The PMST did not identify this species as it is not listed under the EPBC Act. Suitable habitat occurs in the broader region but has not been mapped as present within the study area.
Cuculus optatus Oriental Cuckoo	Mi	SL	Species or species habitat **may** occur within area (0-10 km)	No records	Rainforest margins, monsoon forest, vine scrubs, riverine thickets, wetter, densely canopied eucalypt forests, paperbark swamps and mangroves (Morcombe 2002).	Unlikely This species was returned in the 10 km PMST search as may occur, however no records were returned in the database and online searches. Suitable habitat is unlikely to occur within the study area.
Chrysococcyx osculans Black-eared cuckoo	Ma	-	Species or species habitat **likely** to occur within area (0-10 km)	No records	This species inhabits areas of dry open forests, scrublands, mallee, mulga, lignum, and riverside thickets. This species is widespread across the mainland of Australia.	Potential This species was returned in the 10 km PMST search as likely to occur, however no records were returned in the database and online searches. Potential habitat for this species may occur within the study area.
Erythrotriorchis radiatus Red goshawk	V	E	Species or species habitat **known** to occur within area (0-10 km)	15 (10-50km)	The red goshawk prefers a mix of vegetation types with its habitat including tall open forest, woodland, lightly treed savannah and the edge of rainforest. In partly cleared parts of eastern Queensland, it is associated with gorge and escarpment country (DES 2018b).	Potential Wildlife Online records identify 15 occurrences of this species within 10 to 50 km. PMST identified species/species habitat as known to occur within 10 km of the study area.

D

Scientific Name Common Name	Status		Database Searches		Habitat and Distribution	Desktop Likelihood of Occurrence
	EPBC Act	NC Act	PMST	Wildlife Online Records		
Gallinago hardwickii Lathams snipe	Ma, Mi	SL	Species or species habitat **may** occur within area (0-10 km)	-	This species prefers open freshwarer wetlands, typically with low dense vegetation. Can be found in a variety of vegetation communities including but not limited to tussock grasslands, coastal and alpine heathlands, tea-tree scrub and open forests.	Unlikely This species was returned in the 10 km PMST search as may occur, no records were returned in the database and online searches. Limited suitable habitat is likely to occur within the study area.
Geophaps scripta scripta Squatter pigeon (southern)	V	V	Species or species habitat **known** to occur within area (0-10 km)	14 (0-10 km) 44 (10-50 km)	Open grassy woodlands on sandy soils interspersed with low gravelly ridges, never far from water (Morcombe 2002).	Likely This species has been recorded several times within 10 km of the study area. Suitable habitat exists within the study area. The species is typically locally abundant in areas where it is known from and not cryptic in nature.
Grantiella picta Painted honeyeater	V	V	Species or species habitat **may** occur within area (0-10 km)	3 (10-50 km)	The Painted honeyeater typically occupies habitats on deep, productive soils and is reliant on abundant mistletoes as a food source. It favours Acacia dominant woodlands (particularly Brigalow dominant) and often uses Belah and Bulloak woodlands and riparian woodlands of Black Box and River Red Gum. The species' breeding range is largely restricted to inland NSW and south of Roma.	Potential Thre records identified this species as occurring between 10 and 50 km from the study area. Desktop searches identified potential suitable habitat for this species along creek lines/watercourses within the study area.
Haliaeetus leucogaster White-bellied Sea-Eagle	Ma	-	Species or species habitat **likely** to occur within area (0-10 km)	No records	Coastal habitats (especially those close to the sea-shore) and around terrestrial wetlands. Habitat characterised by the presence of large areas of open water (larger rivers, swamps, lakes, the sea). Birds have been recorded in (or flying over) a variety of terrestrial habitats (DoEE 2018).	Unlikely This species was returned in the 10 km PMST search as likely to occur, but no records within 50 km of the study area. Seasonally suitable habitat may occur within the study area.

D

Scientific Name Common Name	Status		Database Searches		Habitat and Distribution	Desktop Likelihood of Occurrence
	EPBC Act	NC Act	PMST	Wildlife Online Records		
Hirundapus caudacutus White-throated needletail	Ma, Mi	SL	Species or species habitat **known** to occur within area (10-50 km)	No records	This species in Australia is primarily aerial but does show preferences for certain habitats. This species is found in associated with wooded areas, including open forests and rainforests.	<u>Potential</u> This species was returned in the 50 km PMST search as known to occur. Database searches did not identify any records of this species occurring within 50 km of the study area.
Lathamus discolor Swift parrot	CE	E	-	1 (10-50 km)	This species distribution covers eastern NSW, South-east Queensland, Victoria and Tasmania. This species migrates to south-eastern Queensland during Autumn and Winter. This species forages within eucalypt forests and woodlands.	<u>Potential</u> This species was not identified by the PMST. One record of this species exists within 10 to 50 km from the study area. Limited suitable habitat occurs for this species along the creek lines and watercourses within the study area. The study area occurs at the most upper limit of this species distribution.
Merops ornatus Rainbow bee-eater	Ma	-	Species or species habitat **may** occur within area (0-10 km)	No records	Open forests and woodlands, shrublands, various cleared or semi-cleared habitats, including farmland and areas of human habitation. Open, cleared or lightly timbered areas that are often located in close proximity to permanent water (DoEE 2018).	<u>Potential</u> This species was listed as may occur within 10 km on the PMST search. Database searches did not identify any records of this species occurring within 50 km of the study area. The study area is likely to contain suitable habitat for this species.
Monarcha melanopsis Black-faced monarch	Ma, Mi	SL	Species or species habitat **likely** to occur within area (0-10 km)	No records	Rainforests, mangroves, eucalypt forests and woodlands (Morcombe 2002).	<u>Potential</u> This species was returned in the 10 km PMST search as likely to occur, however has not been recorded in the 50 km Wildlife Online search. Suitable habitat potentially occurs within the study area.
Monarcha trivirgatus	Ma, Mi	SL	Species or species habitat	No records	Distribution is focused along the eastern coastline of Queensland and NSW. This	<u>Unlikely</u>

D

Scientific Name Common Name	Status		Database Searches		Habitat and Distribution	Desktop Likelihood of Occurrence
	EPBC Act	NC Act	PMST	Wildlife Online Records		
Spectacled monarch			**may** occur within area (10-50 km)		species inhabits areas of wet forests and mangroves.	This species was returned in the 10 km PMST search as may occur, however has not been recorded in the 50 km Wildlife Online search. The study area occurs at the limit of this species range and its preferred habitat is unlikely to occur within the study area.
Motacilla flava Yellow wagtail	Ma, Mi	SL	Species or species habitat **may** occur within area (0-10 km)	No records	Open habitats, often near water; in Queensland it is usually coastal (Morcombe 2002).	Potential This species was returned in the 10 km PMST search as may occur, however no records were returned in the database and online searches. Suitable habitat has the potential to occur within the Project, though likely only seasonally.
Myiagra cyanoleuca Satin flycatcher	Ma, Mi	SL	Species or species habitat **may** occur within area (0-10 km)	No records	Forests and woodlands, mangroves, coastal heath scrubs; in breeding season favours dense, wet gullies of heavy eucalypt forests (Morcombe 2002).	Potential This species was returned in the 10 km PMST search as may occur, but no database records within 50 km. Limited suitable habitat may occur within the study area.
Neochmia ruficauda ruficauda Star finch	E	E	Species or species habitat **likely** to occur within area (0-10 km)	No records	The Star finch occurs in grasslands and grassy woodlands, near permanent water, and often in or near suburban areas (Curtis et al. 2012). The Star Finch is endemic to central Queensland (DoEE 2018).	Unlikely This species was returned in the 10 km PMST search as likely to occur, but no database records within 50 km. Limited to no suitable habitat for this species is likely to occur within in the study area.
Ninox strenua Powerful owl	-	V	-	3 (10-50 km)	This species prefers tall open woodlands and forests. Powerful owls require large hollows to nest. This species inhabits areas along watercourses.	Potential Three records of this species have been recorded between 10 and 50 km from the study area. This species is not listed under the EPBC Act as such did not come up in

D

Scientific Name Common Name	Status		Database Searches		Habitat and Distribution	Desktop Likelihood of Occurrence
	EPBC Act	NC Act	PMST	Wildlife Online Records		
						the PMST. This species is likely to use only marginal habitat features along major watercourses within the study area.
Numenius madagascariensis Eastern curlew	CE, Mi	E	Species or species habitat **may** occur within area (10-50 km)	No records	Tidal mudflats, sand spits of estuaries, mangroves, lake shores and ocean beaches (Morcombe 2002).	Unlikely This species has not been recorded within 50 km of the study area on Wildlife Online. Suitable habitat is unlikely to be present on the study area due to the study area lying outside suitable coastline environs, with only scattered records inland.
Pedionomus torquatus Plains wanderer	CE	V	-	1 (10-50 km)	The Plains wanderer is a ground-dwelling bird species that inhabits native grasslands. This species is often absent from areas that are too dense or sparse.	Potential This species was not identified in the PMST, and only one record of this species was identified within 10 to 50 km from the study area. Desktop searches identified no native grasslands within the study area boundary.
Psephotus pulcherrimus Paradise parrot	PE	EX	-	9 (10-50 km)	Historically this species occurred in central and southern Queensland. This species inhabited undulating river valleys in sparse open eucalypt woodlands and forests.	Unlikely This species is now extinct. Historic records are from over 50 years ago.
Poephila cincta cincta Black-throated finch (white-rumped subspecies)	E	E	Species or species habitat **may** occur within area (0-10 km)	4 (10-50 km)	This species inhabits open grassy woodlands and forests (Curtis et al. 2012), scrubby plains and Pandanus flats with deep cover of grasses. Its habitat is never far from water. It is known to occur south of Townsville, particularly around Townsville and Charters Towers (DoEE 2018).	Potential This species was returned in the 10 km PMST search as may occur. Wildlife Online records identify four occurrences of this species within 10 to 50 km.
Rhipidura rufifrons Rufous fantail	Ma	SL	Species or species habitat	No records	In east and southeast Australia, the Rufous Fantail mainly inhabits wet sclerophyll forests. They are also recorded from parks and	Unlikely

D

Scientific Name Common Name	Status		Database Searches		Habitat and Distribution	Desktop Likelihood of Occurrence
	EPBC Act	NC Act	PMST	Wildlife Online Records		
			may occur within area (0-10 km)		gardens when on passage. In north and northeast Australia, they often occur in tropical rainforest and monsoon rainforests, including semi-evergreen mesophyll vine forests, semideciduous vine thickets or thickets of Melaleuca spp. (DoEE 2018).	This species was returned in the 10 km PMST search as may occur, but no database records within 50 km. Limited suitable habitat is unlikely to occur within the study area.
Rostratula australis Australian painted snipe	E, Ma	V	Species or species habitat **may** occur within area (0-10 km)	No records	This species is found in shallow inland wetlands, either freshwater or brackish, which are either permanently or temporarily filled, throughout many parts of Australia (DoEE 2018).	Unlikely This species was returned in the 10 km PMST search as may occur, and as likely to occur between 10 and 50 km. No records of presence were recorded within 50 km of the study area. The study area is unlikely to provide potential habitat for this species.
Turnix melanogaster Black-breasted button-quail	V	V	Species or species habitat **may** occur within area (0-10 km)	7 (10-50 km)	The preferred habitat for the black-breasted button-quail includes vine thickets and rainforests that are periodically water-stressed such as semi-evergreen vine thicket, low microphyll vine forest, *Araucarian microphyll* or notophyll vine forest, Brigalow and Belah low thickets or woodlands with a dense understorey and little groundcover and littoral habitats.	Potential This species was returned in the 10 km PMST search as may occur, and as likely to occur between 10 and 50 km. Seven records of this species have been registered within 10 to 50 kms. Potential suitable habitat may occur within the study area.
Mammals						
Antechinus argentus Silver-headed antechinus	E	V	-	23 (10-50 km)	The silver-headed antechinus is known from three isolated subpopulations located in centraleastern Queensland - the plateau at the eastern escarpment of Kroombit Tops NP. located 70 km south-west of Gladstone; Blackdown Tableland National Park, located 220 km west of Gladstone (Mason et al. 2016); and Bulburin National Park (A Baker pers. comm. 2017b; H Hines pers. comm.	Unlikely Records of this species were reported from within 50 of the Project, however, this species is known from only 3 subpopulations located over 150 km south of the Project. The species was not returned in the PMST search as potential species or habitat occurring within the Project area.

D

Scientific Name Common Name	Status		Database Searches		Habitat and Distribution	Desktop Likelihood of Occurrence
	EPBC Act	NC Act	PMST	Wildlife Online Records		
					2017), located 80 km south-east of Gladstone (TSSC 2018).	
Chalinolobus dwyeri Large-eared pied bat	V	V	Species or species habitat **may** occur within area (0-10 km)	2 (10-50 km)	This species occurs in areas with extensive cliffs and caves, primarily in the Central Queensland sandstone belt. Suitable habitat consists of sandstone gorges in tall open eucalypt forest, dry sclerophyll forests and woodlands, rainforest edges, wet sclerophyll forest and *Callitris* dominant forest.	<u>Potential</u> This species was returned in the 10 km PMST search as may occur, and as likely to occur between 10 and 50 km. The study area potentially contains suitable habitat for this species.
Dasyurus hallucatus Northern quoll	E	-	Species or species habitat **likely** to occur within area (0-10 km)	No records	The northern quoll lives in a range of open woodland and open forest types preferring rocky areas. Northern quolls have also been recorded in vine forest, mangroves, sugarcane farms and urban areas. Their greatest breeding success is known to occur at sites near water (DES 2018b).	<u>Unlikely</u> This species was returned in the 10 km PMST search as likely to occur. The study area may contain small areas of suitable habitat for this species. No confirmed records of this species have been found to occur within 50 km of the study area.
Macroderma gigas Ghost bat	V	E	Species or species habitat **likely** to occur within area (0-10 km)	No records	Ghost bats currently occupy habitats ranging from the arid Pilbara to tropical savanna woodlands and rainforests. During the daytime they roost in caves, rock crevices and old mines. (TSSC 2016b). They occupy the northern tropical areas of Queensland, Northern Territory and Western Australia.	<u>Unlikely</u> This species was returned in the 10 km PMST search as likely to occur. The study is unlikely to contain suitable habitat for this species and is located outside of the species distribution. No confirmed records of this species have been found to occur within 50 km of the study area.
Nycophilus corbeni Corben's long-eared bat	V	V	Species or species habitat **may** occur within area (0-10 km)	No records	This species is found across semi-arid southern Australia to southern Queensland and inhabits a range of dry woodland and shrubland communities in arid and semi-arid regions. This bat species roosts mostly in tree hollows (Menkhorst & Knight 2011).	<u>Unlikely</u> This species was returned in the 10 km PMST search as may occur, however, the study area is located outside of the species distribution. No records of presence were recorded within 50 km of the study area. Based on desktop mapping investigations areas containing hollow bearing trees are

D

Scientific Name Common Name	Status		Database Searches		Habitat and Distribution	Desktop Likelihood of Occurrence
	EPBC Act	NC Act	PMST	Wildlife Online Records		
						likely limited to along watercourses within the study area.
Onychogalea fraenata Bridled nail-tail wallaby	E	E	Species or species habitat **known** to occur within area (0-10 km)	15 (0-10 km) 41 (10-50 km)	Within Taunton National Park, bridled nailtail wallabies are found in open grassy eucalypt woodland dominated by poplar box (*Eucalyptus populnea*), dense acacia forest dominated by brigalow (*Acacia harpophylla*), transitional vegetation intermediate between the woodland and forest areas of very dense brigalow regrowth (Lundie-Jenkins, G., & J. Lowry 2005)	Likely Despite not being reported on the Wildlife online search for 10km, this species is known to occur in the Taunton NP. Desktop searches identified potential suitable habitat for this species in small isolated patches throughout the study area.
Petauroides Volans Greater glider	V	V	Species or species habitat **likely** to occur within area (0-10 km)	1 (0-10 km) 71 (10-50 km)	Eucalypt dominated habitats, ranging from low, open forests on the coast to tall forests in the ranges and low woodland westwards of the Dividing Range (DES 2018b).	Likely Based on desktop mapping investigations areas containing hollow bearing trees are likely limited to along watercourses within the study area. One Wildlife online records of presence was recorded within 10 km of the study area, and 71 records exist within 10 to 50 kms.
Phascolarctos cinereus Koala	V	V	Species or species habitat **likely** to occur within area (0-10 km)	1 (0-10 km) 14 (10-50 km)	The Koala inhabits Eucalypt forests and woodlands on the east coast of Australia (Curtis et al. 2012). Koalas require areas of eucalypt species that are highly connected, to ensure shelter from predators.	Potential The study area occurs within the known range of the Koala and provides possible areas of suitable habitat along a narrow strip of *Eucalyptus* spp following the watercourses in the study area. One Wildlife online record of presence was recorded within 10 km of the study area, and 14 records exist within 10 to 50 kms.

D

Scientific Name Common Name	Status		Database Searches		Habitat and Distribution	Desktop Likelihood of Occurrence
	EPBC Act	NC Act	PMST	Wildlife Online Records		
Pteropus poliocephalus Grey-headed flying-fox	V	-	Foraging, feeding or related behaviour **may** occur within area (10-50 km)	No records	Roost in native vegetation near water, including mangrove, rainforest, melaleuca or casuarina (Churchill 2008). Typically commute within 15 km to feed on flowering and fruiting plants, including blossoms of various species of eucalypt, angophora, tea-tree and banksia (DES 2018b).	<u>Unlikely</u> No records within 50 km of the study area on Wildlife Online or ALA. Seasonally suitable foraging habitat may exist within the study area, however, no known records or roosts occur within 50 km.

D

Appendix E Fauna Survey Sites

Site Name	DF01
Associated Project Site	Dingo West
Site Location (Zone, Easting, Northing)	55 727223 7381160
Habitat type	Habitat type 2
Associated RE	11.7.2
Habitat Description	*Acacia* spp. woodland with *Eucalyptus crebra* as emergent on lateritic duricrust.
Disturbance Present	Moderate to light grazing and evidence of old fire.
Dominant Vegetation Species	Dominant Trees: *Acacia sherleyi* (Lancewood), *Acacia rhodoxylon (Rosewood)* and *Eucalyptus crebra* as emergent. Dominant Shrubs: *Erythroxylum australe,* and saplings of the canopy species. Dominant Ground Cover: *Calyptochloa gracilima* and *Aristida caput-medusae*

Site Name	DF02
Associated Project Site	Dingo West
Site Location (Zone, Easting, Northing)	55 K 727380 7382738
Habitat type	Habitat type 3
Associated RE	11.3.25
Habitat Description	*Eucalyptus tereticornis* open woodland in floodplain between main creek and drainage line.
Disturbance Present	Adjacent land cleared, moderate grazing, erosion nearby and invasive species (Parthenium weed, Rubber vine and Velvet tree pear).
Dominant Vegetation Species	Dominant Trees: *Eucalyptus tereticornis* and *Cassia brewsterii* Dominant Shrub: *Cassia brewsterii* Dominant Ground Cover: *Megathyrsus maximus*

E

Site Name	DF03
Associated Project Site	Dingo West
Site Location (Zone, Easting, Northing)	55 K 726387 7383525
Habitat type	Habitat type 1
Associated RE	11.5.2
Habitat Description	*Eucalyptus crebra* and *Acacia rhodoxylon* on sandy plains.
Disturbance Present	Moderate grazing, evidence of old fire and invasive species (Harrisia cactus and Velvet tree pear).
Dominant Vegetation Species	Dominant Trees: *Eucalyptus crebra* and *Acacia rhodoxylon* Dominant Shrubs: *Erythroxylum australe* Dominant Ground Cover: *Cleistochloa sp. (Duaringa K.B.Adison 42)* and *Aristida caput-medusae*

Site Name	DF04
Associated Project Site	Dingo West
Site Location (Zone, Easting, Northing)	55 K 729993 7383135
Habitat type	Habitat type 3
Associated RE	11.5.2/11.3.25
Habitat Description	Floodplain next to creek line with *Eucalyptus crebra* on the floodplain and *E. tereticornis* woodland by the creek line.
Disturbance Present	Tracks, erosion, moderate grazing and invasive species (Rubber vine)
Dominant Vegetation Species	Dominant Trees: *Eucalyptus tereticornis, Eucalyptus crebra* and *Bauhinia carronii* Dominant Shrubs: *Bauhinia carronii* and *Terminalia oblongata* Dominant Ground Cover: *Dichantium sericeum* and *Megathyrsus maximus*

Site Name	DF05
Associated Project Site	Dingo West
Site Location (Zone, Easting, Northing)	55 K 728432 7382299
Habitat type	Habitat type 3
Associated RE	11.3.25
Habitat Description	*Eucalyptus tereticornis* and *Bauhinia carronii* woodland on floodplain between creek lines.
Disturbance Present	Moderate grazing and invasive species (Velvet tree pear).
Dominant Vegetation Species	Dominant Trees: *Eucalyptus tereticornis* and *Bauhinia carronii* Dominant Shrubs: *Bauhinia carronii* and *Carissa spinarum* Dominant Ground Cover: *Cenchrus ciliaris*

E

Site Name	DF06
Associated Project Site	Dingo West
Site Location (Zone, Easting, Northing)	55 K 729350 7388339
Habitat type	Habitat type 2
Associated RE	11.7.2
Habitat Description	*Acacia rhodoxylon* woodland on undulating soil with ephemeral drainage lines.
Disturbance Present	Road nearby, dieback, invasive species (Velvet tree pear).
Dominant Vegetation Species	Dominant Trees: *Acacia rhodoxylon* Dominant Shrubs: *Owenia acidula, Erythroxylum australe* and *Carissa spinarum* Dominant Ground Cover: *Aristida caput medusae*

E

Site Name	DF07
Associated Project Site	Dingo West
Site Location (Zone, Easting, Northing)	55 K 729388 7387547
Habitat type	Habitat type 1
Associated RE	11.5.2
Habitat Description	*Eucalyptus crebra* and *Corymbia clarksoniana* on undulating terrain on top of hill besides an ephemeral drainage feature.
Disturbance Present	Agriculture (clearing prior 1986 pers. comm.), road nearby, evidence of fire (big fire around 2014 less than 100m away, across the road) and invasive species (Velvet tree pear).
Dominant Vegetation Species	Dominant Trees: *Eucalyptus crebra*, *Corymbia clarksoniana*, *Alphitonia excelsa*, *Acacia leiocalyx* subsp. *leiocalyx* and *Acacia rhodoxylon* Dominant Shrubs: *Petalostigma pubescens, Erythroxylum australe* and *Carissa spinarum* Dominant Ground Cover: *Cenchrus ciliaris* and native grasses

E

Site Name	DF08
Associated Project Site	Dingo West
Site Location (Zone, Easting, Northing)	55 K 728436 7387550
Habitat type	Habitat type 2
Associated RE	11.7.2
Habitat Description	*Acacia lanceolata* and *Acacia rhodoxylon* woodland with *Eucalyptus crebra* as emergent at foothill of a rocky scarpment.
Disturbance Present	Moderate disturbance due to a nearby track (not in use any longer because of erosion), some evidence of selective logging, moderate grazing and invasive species (Velvet tree pear)
Dominant Vegetation Species	Dominant Trees: *Eucalyptus crebra*, *Acacia shirleyi, Acacia rhodoxylon* Dominant Shrubs: *Psydrax forsteri* Dominant Ground Cover: *Calyptochloa gracilima*

Site Name	DF09
Associated Project Site	Dingo West
Site Location (Zone, Easting, Northing)	55 K 731322 7387731
Habitat type	Habitat type 1
Associated RE	11.5.2
Habitat Description	*Allocasuarina luehmannii* with *Eucalyptus crebra* and *Corymbia clarksoniana* on sand plains with ephemeral drainage features.
Disturbance Present	Tracks nearby, moderate grazing, clearing land nearby, evidence of fire and invasive species (Velvet tree pear).
Dominant Vegetation Species	Dominant Trees: *Eucalyptus crebra, Allocasuarina luehmannii* and *Corymbia clarksoniana* Dominant Shrubs: *Melaleuca nervosa* and *Petalostigma pubescens* Dominant Ground Cover: *Aristida calycina* and *Eragrostis lacunaria*

Site Name	DF10
Associated Project Site	Dingo West
Site Location (Zone, Easting, Northing)	55 K 727566 7386375
Habitat type	Habitat type 4
Associated RE	11.3.2
Habitat Description	*Eucalyptus populnea woodland on* alluvial plains.
Disturbance Present	Adjacent to dam for cattle, heavy presence of stock, tracks nearby, erosion on drainage features and invasive species (Harrisia cactus, Velvet tree pear and Mother of Millions (small infestation)).
Dominant Vegetation Species	Dominant Trees: *Eucalyptus populnea* Dominant Shrubs: *Erythroxylum australe, Archidendropsis basaltica* and *Carissa spinarum* Dominant Ground Cover: Poaceae sp. (grazed)

Site Name	DF11
Associated Project Site	Dingo West
Site Location (Zone, Easting, Northing)	55 K 730436 7381462
Habitat type	Habitat type 2
Associated RE	11.7.2
Habitat Description	*Acacia rhodoxylon* woodland on sandy plains with emergent *Eucalyptus crebra*.
Disturbance Present	Agriculture (clearing) and roads and tracks nearby.
Dominant Vegetation Species	Dominant Trees: *Acacia rhodoxylon* Dominant Shrubs: *Carissa spinarum* Dominant Ground Cover: *Aristida calycina*

E

Site Name	DF12
Associated Project Site	Dingo West
Site Location (Zone, Easting, Northing)	55 K 731898 7381098
Habitat type	Habitat type 3
Associated RE	11.3.25
Habitat Description	*Eucalyptus tereticornis* woodland fringing drainage lines.
Disturbance Present	Agriculture (clearing) and roads and tracks nearby and evidence of fire.
Dominant Vegetation Species	Dominant Trees: *Eucalyptus tereticornis* Dominant Shrubs: *Acacia cretata* Dominant Ground Cover: *Bothriochloa ewartiana*

E

Site Name	DF13
Associated Project Site	Dingo West
Site Location (Zone, Easting, Northing)	55 K 729657 7377985
Habitat type	Habitat type 1
Associated RE	11.5.2
Habitat Description	*Eucalyptus*.*crebra* woodland with *Allocasuarina luehmannii* in the understorey.
Disturbance Present	Agriculture (clearing) and roads and tracks nearby and evidence of fire.
Dominant Vegetation Species	Dominant Trees: *Eucalyptus crebra* and *Allocasuarina luehmannii* Dominant Shrubs: *Acacia cretata* and *Corymbia clarksoniana* sapplings Dominant Ground Cover: *Themeda triandra*

E

Site Name	DF14
Associated Project Site	Dingo West
Site Location (Zone, Easting, Northing)	55 K 730367 7380949
Habitat type	Habitat type 4
Associated RE	11.3.2
Habitat Description	*Eucalyptus populnea* and *Eucalyptus melanophloia* woodland on alluvial plains.
Disturbance Present	Agriculture (clearing) and roads and tracks nearby and evidence of fire.
Dominant Vegetation Species	Dominant Trees: *Eucalyptus crebra* and *Eucalyptus melanophloia* Dominant Shrubs: *Acacia cretata* and *Alphitonia excelsa* Dominant Ground Cover: *Heteropogon contortus*

E

Site Name	DF15
Associated Project Site	Dingo West
Site Location (Zone, Easting, Northing)	55 K 729597 7378351
Habitat type	Habitat type 4
Associated RE	11.3.2
Habitat Description	*Eucalyptus populnea* open woodland on alluvial plains.
Disturbance Present	Agriculture (clearing) and roads and tracks nearby, heavy grazing (farmer's dam in the vicinity) and evidence of fire.
Dominant Vegetation Species	Dominant Trees: *Eucalyptus populnea* and *Atalaya hemiglauca* Dominant Shrubs: *Atalaya hemiglauca* and *Owenia acidula* Dominant Ground Cover: *Aristida perniciosa*

E

Appendix F Herbarium Identifications

Appendix G Bat Call Analysis

Appendix H Flora Species List

Family	*Scientific Name*	Common Name	NC Act Status	EPBC Act Status	VC1	VC2	VC3	VC4
Acanthaceae	*Brunoniella australis*		LC	-			x	x
Acanthaceae	*Pseuderanhenum variable*	Pastel flower	LC	-		x	x	
Acanthaceae	*Rostellularia adscendens*	Pink tongues	LC	-	x		x	x
Amaranthaceae	*Alternanthera nana*	Hairy joyweed	LC	-	x			
Amaranthaceae	*Gomphrena celosioides*	Gomphrena weed	I	-	x			x
Amaranthaceae	*Sclerolaena birchii*	Galvanised burr	LC	-				x
Amaranthaceae	*Maireana microphylla*		LC	-				x
Amaryllidae	*Crinum flaccidum*	Murray lily	LC	-	x			
Apocynaceae	*Alstonia constricta*	Bitterbark	LC	-		x	x	
Apocynaceae	*Carissa spinarum*	Currant bush	LC	-	x	x	x	x
Apocynaceae	*Cerbera dumicola*		NT	-		x		
Apocynaceae	*Cryptostegia grandiflora*	Rubber vine	RI	-			x	
Apocynaceae	*Parsonsia eucalyptophylla*	Gargaloo	LC	-		x		
Apocynaceae	*Parsonsia straminea*	Monkey rope	LC	-	x	x	x	
Asparagaceae	*Eustrephus latifolius*	Wombat berry	LC	-			x	
Asparagaceae	*Laxmannia gracilis*	Slender wire lily	LC	-	x			
Asparagaceae	*Lomandra longifolia*		LC	-		x	x	x
Asteraceae	*Asteraceae* sp.				x			
Asteraceae	*Bidens pilosa*		I	-			x	
Asteraceae	*Chrysocephalum apiculatum*	Yellow buttons	LC	-	x			
Asteraceae	*Cyanthillium cinereum*		LC	-	x	x	x	x
Asteraceae	*Emilia sonchifolia*		I	-				
Asteraceae	*Emilia sonchifolia var. sonchifolia*		I	-			x	
Asteraceae	*Parthenium hysterophorus*	Parthenium weed	RI	WoNS			x	
Asteraceae	*Pterocaulon redolens*		LC	-	x			
Asteraceae	*Pterocaulon sphacelatum*	Applebush	LC	-			x	
Asteraceae	*Senecio brigalowensis*		LC	-			x	
Asteraceae	*Sonchus oleraceus*	Common sowthistle	I	-			x	
Asteraceae	*Sphaeromorphaea subintegra*		LC	-				x
Boraginaceae	*Ehretia membranifolia*	Weeping koda	LC	-			x	x
Cactaceae	*Harrisia martinii*		RI	-				x

H

Family	*Scientific Name*	Common Name	NC Act Status	EPBC Act Status	VC1	VC2	VC3	VC4
Cactaceae	*Opuntia tomentosa*	Velvety tree pear	RI	WoNS	x			x
Caesalpiniaceae	*Bauhinia carronii*		LC	-			x	
Caesalpiniaceae	*Cassia brewsterii*		LC	-	x		x	
Caesalpiniaceae	*Senna aciphylla*	Australia senna	LC	-				x
Caesalpiniaceae	*Senna occidentalis*	Coffee senna	I	-	x		x	
Campanulaceae	*Wahlenbergia glabra*		LC	-	x			
Capparaceae	*Capparis canescens*		LC	-	x			
Capparaceae	*Capparis lasiantha*	Nipan	LC	-	x			x
Capparaceae	*Capparis mitchellii*		LC	-				x
Caryophyllaceae	*Polycarpea corymbosa var. minor*		LC	-	x			
Casuarinaceae	*Allocasuarina luehmannii*	Bull oak	LC	-	x			
Celastraceae	*Denhamia cunninghamii*	Yellow berry bush	LC	-				x
Celastraceae	*Denhamia oleaster*		LC	-				x
Chenopodiaceae	*Chenopodiaceae sp.*				x			
Chenopodiaceae	*Enchylaena tomentosa*	Ruby saltbush	LC	-				x
Chenopodiaceae	*Salsola australis*		LC	-				x
Chesalpiniaceae	*Chamaecrista rotundifolia var. rotundifollia*		I	-	x			
Colchicaceae	*Iphigenia indica*		LC	-			x	
Combretaceae	*Terminalia oblongata*		LC	-			x	
Commelinaceae	*Commelina diffusa*	Wandering jew	LC	-	x		x	
Commelinaceae	*Murdannia graminea*	Murdannia	LC	-	x			x
Convolvulaceae	*Evolvulus alsinoides*	Tropical speedwell	LC	-	x	x	x	
Convolvulaceae	*Ipomea polymorpha*	Wooly glycine	LC	-	x			
Convolvulaceae	*Ipomoea plebeia*	Bellvine	LC	-			x	
Crassulaceae	*Bryophyllum sp.*	Mother of millions	RI	-				
Cucurbitaceae	*Cucumis anguria var. anguria*	West Indian gherkin	I	-	x			
Cyperaceae	*Cyperaceae* sp.				x			
Cyperaceae	*Cyperus concinnus*		LC	-				

H

Family	Scientific Name	Common Name	NC Act Status	EPBC Act Status	VC1	VC2	VC3	VC4
Cyperaceae	*Cyperus fulvus*		LC	-	x			
Cyperaceae	*Cyperus gracilis*		LC	-			x	x
Cyperaceae	*Fimbristylis* sp.		LC	-	x			
Cyperaceae	*Fimbristylis dichotoma*	Common fringe-rush	LC	-	x			
Erythroxylaceae	*Erythroxylum australe*	Cocaine bush	LC	-	x	x		x
Euphorbiaceae	*Euphorbia tannensis subsp eremophila*		LC	-	x	x		
Euphorbiaceae	*Ricinus communis*	Castor oil bush	I	-				
Fabaceae	*Crotalaria medicaginea*	Trefoil rattlepod	LC	-	x			
Fabaceae	*Crotalaria pallida**		I	-				x
Fabaceae	*Desmodium macrocarpum*		LC	-	x			
Fabaceae	*Erythrina vespertilio*	Bat wing coral tree	LC	-			x	
Fabaceae	*Glycine sp. (Marburg K.A.Williams 83006)**		LC	-			x	
Fabaceae	*Glycine tabacina*	Glycine pea	LC	-				
Fabaceae	*Glycine tomentella*	Woolly glycine	LC	-	x			
Fabaceae	*Indigofera colutea*	Sticky indigo	LC	-				x
Fabaceae	*Indigofera linnaei*	Birdsville indigo	LC	-				x
Fabaceae	*Jacksonia rhadinochloa*	Miles dogwood	LC	-			x	
Fabaceae	*Macroptilium atropurpureum*	Siratro	I	-			x	
Fabaceae	*Medicago* sp.		I	-				x
Fabaceae	*Neptunia gracilis*		LC	-				x
Fabaceae	*Rhynchosia minima*		LC	-			x	x
Fabaceae	*Stylosanthes aspera*		I	-	x			
Fabaceae	*Stylosanthes glabra*		I	-			x	
Fabaceae	*Stylosanthes scrabra*		I	-	x		x	x
Fabaceae	*Vigna lanceolata*		LC	-	x		x	
Fabaceae	*Zornia* sp.		LC	-	x			
Goodeniaceae	*Goodenia disperma*		LC	-	x			

H

Family	*Scientific Name*	Common Name	NC Act Status	EPBC Act Status	VC1	VC2	VC3	VC4
Goodeniaceae	*Goodenia rotundifolia*		LC	-	x		x	
Goodeniaceae	*Goodenia* sp.				x			
Hemerocallidaceae	*Dianella longifolia*		LC	-	x			
Hypericaceae	*Hypericum gramineum*		LC	-			x	
Lauraceae	*Cassytha pubescens*	Downy devil's twine	LC	-				x
Malvaceae	*Abutilon oxycarpum*	Straggly lantern-bush	LC	-				x
Malvaceae	*Grewia retusifolia*		LC	-		x		
Malvaceae	*Hibiscus divaricatus*		LC	-	x			
Malvaceae	*Hibiscus sturtii var sturtii*		LC	-	x			
Malvaceae	*Malvastrum americanum*	Malvastrum	I	-	x		x	x
Malvaceae	*Sida atherophora*		LC	-	x	x	x	x
Malvaceae	*Sida playtcalyx**	Lifesaver burr	LC	-				
Malvaceae	*Sida cordifolia*		I	-	x	x	x	x
Malvaceae	*Sida rhombifolia*	Paddy's lucerne	I	-	x		x	
Malvaceae	*Sida sp. (Aramac E.J.Thompson+JER192)*		LC	-	x	x	x	
Malvaceae	*Sida spinosa*	Spiny sida	I	-			x	
Malvaceae	*Sida subspicata*			-	x	x	x	
Meliaceae	*Owenia acidula*	Emu apple	LC	-				
Mimosaceae	*Acacia* sp.					x		
Mimosaceae	*Acacia* (sappling)				x			
Mimosaceae	*Acacia cretata*		LC	-	x	x	x	x
Mimosaceae	*Acacia excelsa*	Ironwood	LC	-	x			
Mimosaceae	*Acacia leiocalyx subsp. leiocalyx*		LC	-	x			
Mimosaceae	*Acacia pendula**	Myall	LC	-				x
Mimosaceae	*Acacia rhodoxylon*	Ring rosewood	LC	-	x	x	x	x
Mimosaceae	*Acacia sherleyi*	Lancewood	LC	-	x	x		
Mimosaceae	*Acalypha eremorum*	Soft acalypha	LC	-			x	

H

Family	*Scientific Name*	Common Name	NC Act Status	EPBC Act Status	VC1	VC2	VC3	VC4
Mimosaceae	*Archidendropsis basaltica*	Red lancewood	LC	-				x
Mimosaceae	*Vachellia farnesiana*	Mimosa bush	I	-				
Moraceae	*Ficus opposita*	Sandpaper fig	LC	-			x	
Myrtaceae	*Corymbia clarksoniana*		LC	-	x	x	x	x
Myrtaceae	*Corymbia dallachiana*		LC	-				x
Myrtaceae	*Corymbia tesselaris*	Moreton bay ash	LC	-	x		x	x
Myrtaceae	*Eucalyptus* (sappling)		LC	-			x	
Myrtaceae	*E. crebra/E. populnea (hybrid)*		LC	-			x	
Myrtaceae	*Eucalyptus crebra*	Narrow-leaved red ironbark	LC	-	x	x	x	
Myrtaceae	*Eucalyptus exserta*	Queensland peppermint	LC	-	x			
Myrtaceae	*Eucalyptus melanophloia*		LC	-				x
Myrtaceae	*Eucalyptus populnea*	Poplar box	LC	-	x		x	x
Myrtaceae	*Eucalyptus tereticornis*	River blue gum	LC	-			x	x
Myrtaceae	*Melaleuca* sp.			-			x	
Myrtaceae	*Melaleuca nervosa*		LC	-	x			
Nyctaginaceae	*Boerhavia dominii*	Tarvine	LC	-				x
Oleaceae	*Jasminum didymum*		LC	-				x
Oxalidaceae	*Oxalis corniculata*	Yellow wood sorrel	I	-	x	x	x	
Pentapetaceae	*Melhania oblongifolia*		LC	-				x
Phyllanthaceae	*Phyllanthaceae sp.*							
Phyllanthaceae	*Phyllanthus virgatus*		LC	-	x	x	x	x
Picrodendraceae	*Petalostigma pubescens*	Quinine tree	LC	-	x	x	x	x
Poaceae	*Alloteropsis cimicina*		LC	-	x		x	
Poaceae	*Aristida* sp.			-	x			
Poaceae	*Aristida calycina*		LC	-	x	x		x
Poaceae	*Aristida caput-medusae*		LC	-	x	x	x	
Poaceae	*Aristida gracilipes*		LC	-				x

H

Family	***Scientific Name***	**Common Name**	**NC Act Status**	**EPBC Act Status**	**VC1**	**VC2**	**VC3**	**VC4**
Poaceae	*Aristida jerichoensis*		LC	-	x		x	
Poaceae	*Aristida perniciosa*		LC	-				x
Poaceae	*Aristida pruinosa*		LC	-				
Poaceae	*Bothriochloa decipiens*		LC	-	x		x	
Poaceae	*Bothriochloa ewartiana*	Desert bluegrass	LC	-			x	x
Poaceae	*Bothriochloa pertusa*		I	-			x	
Poaceae	*Calyptochloa gracilima*		LC	-	x	x	x	
Poaceae	*Cenchrus ciliaris*	Buffel grass	I	-	x	x	x	x
Poaceae	*Chrysopogon fallax*		LC	-	x	x	x	
Poaceae	*Cleistochloa sp. (Duaringa K.B.Adison 42)*		LC	-	x	x		
Poaceae	*Cymbopogon refractus*	Barbed-wire grass	LC	-	x			
Poaceae	*Cynodon dactylon*	Native couch	I	-	x			x
Poaceae	*Dichanthium sericeum*	Queensland bluegrass	LC	-			x	
Poaceae	*Digitaria brownii (dead)**		LC	-	x			
Poaceae	*Digitaria diminuta*		LC	-		x	x	
Poaceae	*Digitaria divaricatissima*	Spreading umbrella grass	LC	-			x	
Poaceae	*Digitaria sp* (not enough material for a positive ID)				x			
Poaceae	*Dinebra ligulata*		LC	-		x		
Poaceae	*Enneapogon lindleyanus*		LC	-		x	x	x
Poaceae	*Enteropogon acicularis*	Curly windmill grass	LC	-	x			
Poaceae	*Entolasia stricta*	Wiry panic	LC	-		x	x	
Poaceae	*Eragrostis sp. (not enough material to ID)*				x			
Poaceae	*Eragrostis elongata*		LC	-	x			
Poaceae	*Eragrostis lacunaria*	Purple lovegrass	LC	-	x	x	x	x
Poaceae	*Eragrostis sororia*	Woodland lovegrass	LC	-	x		x	x
Poaceae	*Eriachne mucronata*		LC	-	x			

H

Family	*Scientific Name*	Common Name	NC Act Status	EPBC Act Status	VC1	VC2	VC3	VC4
Poaceae	*Eriochloa procera*	Slender cupgrass	LC	-				x
Poaceae	*Eulalia aurea*	Silky browntop	LC	-	x			
Poaceae	*Heteropogon contortus*	Black spear grass	LC	-		x	x	x
Poaceae	*Megathyrsus maximus*		I	-	x		x	
Poaceae	*Melinis repens*	Red natal grass	I	-	x		x	x
Poaceae	*Panicum decompositum*		LC	-			x	
Poaceae	*Panicum effusum*		LC	-			x	x
Poaceae	*Paspalidium caespitosum*	Brigalow grass	LC	-	x	x		x
Poaceae	*Paspalidium constrictum**		LC	-			x	
Poaceae	*Paspalidium* sp.				x			
Poaceae	*Perotis rara*	Comet grass	LC	-	x		x	
Poaceae	*Sporobolus caroli*	Fairy grass	LC	-	x	x	x	x
Poaceae	*Sporobolus creber*	Western rat's tail Grass	LC	-				x
Poaceae	*Themeda triandra*	Kangaroo grass	LC	-			x	x
Poaceae	*Urochloa mosambicensis*	Sabi grass	LC	-	x	x	x	x
Poaceae	*Urochloa* sp.				x		x	
Poaceae	*Poaceae sp. (grazed)*				x			x
Polygonaceae	*Duma florulenta*		LC	-				x
Portulacaceae	*Portulaca bicolor*		LC	-				
Portulacaceae	*Portulaca filifolia*		LC	-			x	
Portulacaceae	*Portulaca pilosa*		I	-				
Proteaceae	*Grevillea striata*	Beefwood	LC	-	x		x	
Pteridaceae	*Cheilanthes sieberi subsp sieberi*	Poison rock fern	LC	-			x	
Pteridaceae	*Cheilanthes* sp.							
Rhamnaceae	*Alphitonia excelsa*	Soap tree	LC	-	x	x	x	x
Rhamnaceae	*Ventilago viminalis*	Supplejack	LC	-				
Rubiaceae	*Coelospermum reticulatum*		LC	-	x	x	x	
Rubiaceae	*Everistia vacciniifolia*		LC	-	x		x	

H

Family	*Scientific Name*	Common Name	NC Act Status	EPBC Act Status	VC1	VC2	VC3	VC4
Rubiaceae	*Psydrax forsteri*		LC	-	x	x		
Rubiaceae	*Psydrax johnsonii*		LC	-			x	x
Rubiaceae	*Psydrax oleifolia*		LC	-		x		
Rubiaceae	*Spermacoce brachystema*		LC	-	x		x	
Rubiaceae	*Coelospermum reticulatum*		LC	-				x
Rutaceae	*Flindersia dissosperma*		LC	-				
Rutaceae	*Rutaceae* sp.							x
Sapindaceae	*Atalaya hemiglauca*	Whitewood	LC	-			x	x
Scrophulariaceae	*Myoporum acuminatum*	Coastal boobialla	LC	-				
Stylidiaceae	*Stylidium eriorhizum*		LC	-				
Verbenaceae	*Glandularia aristigera*	Mayne's pest	I	-				
Violaceae	*Afrohybanthus stellarioides*		LC	-	x	x	x	
Violaceae	*Afrohybanthus enneaspermus*		LC	-				x

*	Possibly this species
LC	Least Concern
NT	Near Threatened
I	Introduced
WoNS	Weed of National Significance
RI	Restricted invasive plant

H

Appendix I Fauna Species List

Family	Scientific Name	Common Name	NC Act/LP Act	EPBC Act	2017 - Autumn							2017 - Spring								2018 - Autumn					
					OPPS	DF01	DF02	DF03	DF04	Total	OPPS	DF05	DF06	DF07	DF08	DF09	DF10	Total	OPPS	DF11	DF12	DF13	DF14	DF15	Total
Amphibians																									
Bufonidae	*Rhinella marina*	Cane toad	I	-			5		8	13		13	4				8	25			5	1		10	16
Hylidae	*Litoria rubella*	Naked tree frog	LC	-						0		1						1			1				1
Hylidae	*Litoria caerulea*	Common green tree frog	LC	-			7		2	9								0			1			1	2
Hylidae	*Litoria latopalmata*	Broad-palmed frog	LC	-			1			1								0							0
Hylidae	*Litoria inermis*	Bumpy rocket frog	LC	-	1					1	1							1			1		2	6	9
Limnodynastidae	*Limnodynastes salmini*	Salmon-striped frog	LC	-						0		1						1							0
Limnodynastidae	*Limnodynastes tasmaniensis*	Spotted grass frog	LC	-						0		2						2			2		3		5
Limnodynastidae	*Platyplectrum ornatum*	Ornate burrowing frog	LC	-			249	2	25	276		1						1			3		5		8
				TOTAL AMPHIBIANS	**1**	**0**	**262**	**2**	**35**	**300**	**1**	**18**	**4**	**0**	**0**	**0**	**8**	**31**	**0**	**0**	**13**	**1**	**10**	**17**	**41**
Reptiles																									
Elapidae	*Cryptophis boschmai*	Carpentaria snake	LC	-						0				2				2					1		1
Elapidae	*Demansia psammophis*	Yellow-faced whip snake	LC	-						0		1						1							0
Elapidae	*Furina ornata*	Orange-naped snake	LC	-						0							1	1							0
Elapidae	*Hoplocephalus bitorquatus*	Pale-headed snake	LC	-					1	1								0							0
Elapidae	*Pseudonaja textilis*	Eastern Brown snake	LC	-	1					1	1	1						2							0
Pythonidae	*Aspidites melanocephalus*	Black headed python	LC	-																					
Agamidae	*Pogona barbata*	Bearded dragon	LC	-		1				1	1							1		1		1			2
Agamidae	*Diporiphora australis*	Tommy roundhead	LC	-						0				2		4		6				3			3
Varanidae	*Varanus tristis orientalis*	Freckled monitor	LC	-						0							1	1							0
Carphodactylidae	*Nephrurus asper*	Prickly knob-tailed gecko	LC	-						0					1			1							0
DIiplodactylidae	*Diplodactylus vittatus*	Eastern stone gecko	LC	-						0				1				1							0
DIiplodactylidae	*Lucasium steindachneri*	Box-patterned gecko	LC	-						0						2		2							0
Gekkonidae	*Heteronotia binoei*	Bynoe's gecko	LC	-		1		4	2	7			1	2	2	1	2	8		1					1
Gekkonidae	*Gehyra dubia*	Dubious dtella	LC	-				1	1	2					1		1	2						1	1
Pygopodidae	*Lialis burtonis*	Burton's legless lizard	LC	-		1				1								0							0
Scincidae	*Carlia munda*	Shade-litter rainbow skink	LC	-						0								0			1				1
Scincidae	*Carlia rubigo*	Orange-flanked rainbow-ski	LC	-		4	1	4	3	12		3		3	3			9				2			2
Scincidae	*Cryptoblepharus pulcher*	Elegant snake-eyed skink	LC	-				1		1			1					1							0
Scincidae	*Morethia boulengeri*	South-eastern morethia	LC	-						0		1						1							0
Scincidae	*Ctenotus robustus*	Eastern striped skink	LC	-						0								0		1			2	2	5
Scincidae	*Morethia taeniopleura*	Fire-tailed skink	LC	-				2		2								0							0
Scincidae	*Pygmaescincus timlowi*	Dwarf litter-skink	LC	-						0				1				1			2				2
				LIZARDS	**0**	**7**	**1**	**12**	**6**	**26**	**1**	**4**	**2**	**9**	**7**	**7**	**4**	**34**	**0**	**3**	**3**	**6**	**2**	**3**	**17**
				SNAKES	**1**	**0**	**0**	**0**	**1**	**2**	**1**	**2**	**0**	**2**	**0**	**0**	**1**	**6**	**0**	**0**	**0**	**0**	**1**	**0**	**1**
				TOTAL REPTILES	**1**	**7**	**1**	**12**	**7**	**28**	**2**	**6**	**2**	**11**	**7**	**7**	**5**	**40**	**0**	**3**	**3**	**6**	**3**	**3**	**18**

Family	*Scientific Name*	Common Name	NC Act/LP Act Status	EPBC Act status	2017 - Autumn							2017 - Spring								2018 - Autumn						
					OPPS	DF01	DF02	DF03	DF04	Total	OPPS	DF05	DF06	DF07	DF08	DF09	DF10	Total	OPPS	DF11	DF12	DF13	DF14	DF15	Total
Birds																									
Acanthizidae	*Gerygone olivaceae*	White-throated gerygone	LC	-		2	2	1	2	7		1	1	1	1	2		6			1				1
Acanthizidae	*Smicrornis brevirostris*	Weebill	LC	-						0				1			1	2		1			1	1	3
Accipitridae	*Aquila audax*	Wedge-tailed eagle	LC	-	1					1	2							2	13		1				14
Accipitridae	*Haliastur sphenurus*	Whistling kite	LC	-	1					1	1							1				1			1
Accipitridae	*Milvus migrans*	Black kite	LC	-	1					1	1							1	10				1		11
Aegothelidae	*Aegotheles cristatus*	Australian owlet nightjar	LC	-						0			1	1	2			4		1		1			2
Alcedinidae	*Todiramphus macleayii*	Forest kingfisher	LC	-						0		2			2	2	2	8			1				1
Anatidae	*Anas superciliosa*	Pacific black duck	LC	-						0		1						1							0
Ardeidae	*Ardea modesta*	Eastern great egret	LC	-	1					1	1							1							0
Ardeidae	*Ardea pacifica*	White-necked heron	LC	-						0		1						1							0
Ardeidae	*Egretta novaehollandiae*	White-faced heron	LC	-	1					1	1							1							0
Artamidae	*Cracticus nigrogularis*	Pied butcherbird	LC	-		2	2			4		1	2		2			5		2			2		4
Artamidae	*Cracticus tibicen*	Australian magpie	LC	-		2	2	1	2	7			1		1	1		3			2	1	1	1	5
Artamidae	*Cracticus torquatus*	Grey butcherbird	LC	-		1		1	2	4		1	2	2	2		2	9		3			1		4
Burninidae	*Burhinus grallarius*	Bush stone-curlew	LC	-						0			1		2			3							0
Cacatuidae	*Cacatua galerita*	Sulphur-crested cockatoo	LC	-			1		1	2				1				1			1				1
Cacatuidae	*Calyptorhynchus banksii*	Red-tailed black-cockatoo	LC	-			1			1								0							0
Cacatuidae	*Eolophus roseicapilla*	Galah	LC	-						0		1						1							0
Cacatuidae	*Nymphicus hollandicus*	Cockatiel	LC	-	1					1	1							1	1						1
Campephagidae	*Coracina novaehollandiae*	Black-faced cuckoo-shrike	LC	-		1				1		1	1					2					1	1	2
Campephagidae	*Coracina papuensis*	White-bellied cuckoo-shrike	LC	-						0					1			1							0
Campephagidae	*Lalage tricolor*	White-winged triller	LC	-						0	1							1							0
Caprimulgidae	*Eurostopodus argus*	Spotted nightjar	LC	-	1					1	1							1							0
Charadriidae	*Vanellus miles*	Masked lapwing	LC	-						0		1						1							0
Contropodidae	*Centropus phasianinus*	Pheasant coucal	LC	-						0						1		1							0
Columbidae	*Geopelia humeralis*	Bar-shouldered dove	LC	-				1	1	2			1	1	1			3							0
Columbidae	*Geopelia striata placida*	Peaceful dove	LC	-		1		2	2	5		1	1	2	2	2	2	10					1		1
Columbidae	***Geophaps scripta scripta***	**southern Squatter pigeon**	**V**	**V**	2				1	3	9						2	11	1						1
Columbidae	*Ocyphaps lophotes*	Crested pigeon	LC	-				1	1	2			2	2	1		1	6							0
Columbidae	*Phaps chalcoptera*	Common bronzewing	LC	-						0					1			1							0
Corcoracidae	*Corcorax melanorhamphos*	White-winged chough	LC	-						0	1							1							0
Corcoracidae	*Struthidea cinerea*	Apostlebird	LC	-	1					1	1			1			2	4			1	1			2
Corvidae	*Corvus coronoides*	Australian raven	LC	-		2	1	2	2	7		2	1		2		1	6					1		1
Cuculidae	*Scythrops novaehollandiae*	Channel-billed cuckoo	LC	-						0				1				1							0

Family	*Scientific Name*	Common Name	NC Act/LP Act Status	EPBC Act status	2017 - Autumn							2017 - Spring								2018 - Autumn					
					OPPS	DF01	DF02	DF03	DF04	Total	OPPS	DF05	DF06	DF07	DF08	DF09	DF10	Total	OPPS	DF11	DF12	DF13	DF14	DF15	Total
Dromaiidae	*Dromaius novaehollandiae*	Emu	LC	-	1					1	1							1	20						20
Estrildidae	*Taeniopygia bichenovii*	Double-barred finch	LC	-		1	1	2		4		2		1				3			1				1
Estrildidae	*Taeniopygia guttata*	Zebra finch	LC	-						0								0							0
Falconidae	*Falco berigora*	Brown falcon	LC	-	1					1	1							1							0
Falconidae	*Falco cenchroides*	Nankeen kestrel	LC	-	1					1								0							0
Halcyonidae	*Dacelo novaeguineae*	Laughing kookaburra	LC	-			1	1	8	10		1		2	1		1	5			1				1
Maluridae	*Malurus lamberti*	Variegated fairy-wren	LC	-			1			1				1				1							0
Maluridae	*Malurus melanocephalus*	Red-backed fairywren	LC	-						0		2						2					1	1	2
Meliphagidae	*Entomyzon cyanotis*	Blue-faced honeyeater	LC	-		1				1		1						1							0
Meliphagidae	*Lichenostomus virescens*	Singing honeyeater	LC	-				1		1								0							0
Meliphagidae	*Lichmera indistincta*	Brown honeyeater	LC	-						0		1						1							0
Meliphagidae	*Manorina flavigula*	Yellow-throated miner	LC	-	1					1	1							1							0
Meliphagidae	*Manorina melanocephala*	Noisy miner	LC	-		1			2	3		1					2	3		1	1			1	3
Meliphagidae	*Melithreptus albogularis*	White-throated honeyeater	LC	-		1	2	1		4						1		1							0
Meliphagidae	*Philemon citreogularis*	Little friarbird	LC	-						0								0		1		1			2
Meliphagidae	*Philemon corniculatus*	Noisy friarbird	LC	-		2				2		1				2		3		1		1			2
Meropidae	*Merops ornatus*	Rainbow bee-eater	LC	Ma		1				1		2	1	2		1		6							0
Monarchidae	*Grallina cyanoleuca*	Magpie-lark	LC	-		1	1			2		1	1				2	4			2				2
Monarchidae	*Myiagra inquieta*	Restless flycatcher	LC	-				1		1		1						1							0
Monarchidae	*Myiagra rubecula*	Leaden flycatcher	LC	-						0		2	1	2	1	2		8		1				1	2
Neosittidae	*Daphoenositta chrysoptera*	Varied sittella	LC	-						0	1					1		2							0
Oriolidae	*Oriolus sagittatus*	Olive-backed oriole	LC	-		1				1					1	1		2							0
Oriolidae	*Sphecotheres vieilloti*	Australasian figbird	LC	-						0		1						1							0
Otididae	*Ardeotis australis*	Australian bustard	LC	-						0	1							1							0
Pachycephalidae	*Colluricincla harmonica*	Grey shrike-thrush	LC	-		1		1		2		1		1				2				1			1
Pachycephalidae	*Pachycephala rufiventris*	Rufous whistler	LC	-				1		1				2		2		4				2			2
Pardalotidae	*Pardalotus striatus*	Striated pardalote	LC	-		2	1	2	2	7		2	2	1		2		7		2	2		2	1	7
Phasianidae	*Coturnix ypsilophora*	Brown quail	LC	-	1					1	1							1							0
Pelecanidae	*Pelecanus conspicillatus*	Australian pelican	LC	-						0	1							1							0
Petroicidae	*Microeca fascinans*	Jacky winter	LC	-	1					1	1							1							0
Podargidae	*Podargus strigoides*	Tawny frogmouth	LC	-						0	5		1		1			7							0
Pomatostomidae	*Pomatostomus temporalis*	Grey-crowned babbler	LC	-				1		1				1	1	1	1	4				1	1		2
Psittacidae	*Aprosmictus erythropterus*	Red-winged parrot	LC	-	1					1	2							2			1			1	2
Psittacidae	*Platycercus adscitus*	Pale-headed rosella	LC	-				1		1		1	1			1	1	4		1		1			2
Psittaculidae	*Trichoglossus moluccanus*	Rainbow lorikeet	LC	-		2		1	1	4		1	1	1			1	4			2				2
Rhipiduridae	*Rhipidura albiscapa*	Grey fantail	LC	-		2	1	2	2	7		1		1				2							0
Rhipiduridae	***Rhipidura rufifrons***	**Rufous fantail**	**SL**	Mi, Ma						0	1							1							0
Strigidae	*Ninox boobook*	Southern boobook	LC	-					1	1	1	1		1	1			4				2			2
Alcedinidae	*Dacelo leachii*	Blue-winged kookaburra	LC	-						0								0			1				1
Artamidae	*Artamus leucorynchus*	White-breasted woodswallo	LC	-						0								0			1				1

Family	*Scientific Name*	Common Name	NC Act/LP Act Status	EPBC Act status	2017 - Autumn						2017 - Spring								2018 - Autumn						
					OPPS	DF01	DF02	DF03	DF04	Total	OPPS	DF05	DF06	DF07	DF08	DF09	DF10	Total	OPPS	DF11	DF12	DF13	DF14	DF15	Total
Corvidae	*Corvus orru*	Torresian crow	LC	-						0								0		1		1	1		3
Gruidae	*Grus rubicunda*	Brolga	LC	-						0								0	4						4
Coraciidae	*Eurystomus orientalis*	Dollarbird	LC	-						0								0						1	1
Megaluridae	*Cincloramphus cruralis*	Brown songlark	LC	-						0								0	2						2
Rhipiduridae	*Rhipidura leucophrys*	Willie wagtail	LC	-		1	1	2		0								0			1		1	1	3
Nectariniidae	*Dicaeum hirundinaceum*	Mistletoe bird	LC	-						0								0			1		1	1	3
Threskiornithidae	*Threskiornis spinicollis*	Straw-necked ibis	LC	-			1			1								0							0
Tytonidae	*Tyto alba*	Barn owl	LC	-		2	2			4								0							0
Tytonidae	*Tyto javanica*	Eastern barn owl	LC	-						0								0					1		1
				TOTAL BIRDS	**17**	**30**	**21**	**26**	**30**	**120**	**37**	**36**	**22**	**29**	**26**	**22**	**21**	**193**	**51**	**15**	**21**	**14**	**16**	**11**	**128**
Mammals																									
Macropodidae	*Macropus giganteus*	Eastern grey kangaroo	LC	-	1			2		3	2							2	128						128
Macropodidae	*Notamacropus dorsalis*	Black-striped wallaby	LC	-						0	1			7				8							0
Macropodidae	*Osphranter robustus*	Wallaroo	LC	-	1					1	1				1		3	5	24						24
Macropodidae	*Notamacropus rufogriseus*	Red-necked wallaby	LC	-						0								0	15						15
Macropodidae	*Wallabia bicolor*	Swamp wallaby	LC	-						0	0						1	1							0
Muridae	*Pseudomys delicatulus*	Delicate mouse	LC	-	1	1				2	0							0							0
Phalangeridae	*Trichosurus vulpecula*	Common brushtail possum	LC	-			1			1								0							0
Muridae	*Hydromys chrysogaster*	Rakali / water rat	LC	-						0								0			1				1
Potoroidae	*Aepyprymnus rufescens*	Rufous rat-kangaroo	LC	-						0	1				3			4							0
Pseudocheiridae	***Petauroides volans***	**Greater glider**	**V**	**V**			1			1		1						1			2				2
Tachyglossidae	***Tachyglossus aculeatus***	**Short-beaked echidna**	**SL**	-	1					1	3		1					4							0
Canidae	*Canis lupus dingo*	Dingo	**C2**	-	1					1	1							1							0
Felidae	*Felis catus*	Feral cat	**C2**	-						0	1	2					1	4			1				1
Leporidae	*Oryctolagus cuniculus*	Rabbit	**C2**	-	1					1	2				2			4							0
Muridae	*Mus musculus*	House mouse	**I**	-		2	1	1	1	5						1	1	2					1		1
Suidae	*Sus scrofa*	Feral pig	**C2**	-	1				1	2	1							1							0
Pteropodinae	*Pteropus scapulatus*	Little red flying fox	LC	-						0					3			3							0
Rhinolophidae	*Rhinolophus megaphyllus*	Eastern horseshoe bat	LC	-				U		1			U		U		U	3		U					1
Vespertilionidae	*Chalinolobus gouldii*	Gould's wattled bat	LC	-		U	U	U	U	4		U	U	U	A	U	U	6		U	U	U	U		4
Vespertilionidae	*Chalinolobus nigrogriseus/Scortorepens greyii*																			A	A	A	A		4
Vespertilionidae	*Vespadelus troughtoni/Chalinolobus morio*																						A		1
	Taphozous troughtoni/Ozimops lumsdenae																			A	A	A	A		4
	Saccolaimus flaviventris/Ozimops lumsdenae																			A	A	A	A		4
	Saccolaimus flaviventris/Chaerephon jobensis																			A		A			1

Family	*Scientific Name*	Common Name	NC Act/LP Act Status	EPBC Act status	2017 - Autumn OPPS	DF01	DF02	DF03	DF04	Total	OPPS	2017 - Spring DF05	DF06	DF07	DF08	DF09	DF10	Total	OPPS	2018 - Autumn DF11	DF12	DF13	DF14	DF15	Total
Vespertilionidae	*Chalinolobus picatus/Vespadelus baverstocki*																				A		A		2
Vespertilionidae	*Chalinolobus picatus/Scotorepens greyii*																			A	A	A	A		4
Vespertilionidae	*Chalinolobus gouldii/Scotorepens balstoni*																			A	A	A	A		4
	Chalinolobus gouldii/Ozimops ridei																			A	A	A	A		4
Vespertilionidae	*Chalinolobus morio*	Chocolate wattled bat	LC	-			U			1							U	1							0
Vespertilionidae	*Chalinolobus nigrogriseus*	Hoary wattled bat	LC	-			A	A		2								0			U	U			2
Vespertilionidae	*Chalinolobus picatus*	Little pied bat	LC	-		U	A	U	U	4		U	A	U	U	U	U	6		U	U	U	U		4
Vespertilionidae	*Nyctophilus geoffroyi*		LC	-																					
Vespertilionidae	*Nyctophilus sp. (N. geoffroyi or N. gouldi)*		LC	-						0		U	U	U	U		U	5		U	U	U			3
Vespertilionidae	*Scotorepens balstoni*	Western broad-nosed bat	LC	-		U	A	U		3		A		A	A	A	A	5			U	U			2
Vespertilionidae	*Scotorepens greyii*	Little broad-nosed bat	LC	-		U	U	U		3		U	A	U	U	U	U	6		U	U	U	U		4
Vespertilionidae	*Vespadelus baverstocki*	Inland forest bat	LC	-						0			A	A		A	A	4			U	U	U		3
Vespertilionidae	*Vespadelus troughtoni*	Eastern cave bat	LC	-				U		1		U			U		U	3							0
Miniopteridae	*Miniopterus orianae oceanensis*		LC	-						0								0		U	U		U		3
Miniopteridae	*Miniopterus schreibersii oceane*	Eastern bent-wing bat	LC	-		U	U	U		3		U	U	U		U	U	5							0
Molossidae	*Austronomus australis*	White-striped free-tailed Bat	LC	-		U	U	U	U	4		U						1							0
Molossidae	*Chaerephon jobensis*	Northern free-tailed bat	LC	-		U	U	U	U	4		U	U	U	U	U	U	6		U	U	U	U		4
Molossidae	*Mormopterus (Setirostris) eleryi*	Hairy-nosed free-tailed bat	LC	-						0		A				A	A	3							0
Molossidae	*Ozimops lumsdenae*	Northern free-tailed bat	LC	-			U	U	U	3		U	U	U	U	U	U	6		U	U	U	U		4
Molossidae	*Ozimops petersi*	Inland free-tailed bat	LC	-						0		U	U	A	A	U	U	6							0
Molossidae	*Ozimops ridei*	Ride's free-tailed bat	LC	-		U	A	U	U	4		U	U	U	A	U	U	6		U	U	U	U		4
Emballonuridae	*Saccolaimus flaviventris*	Yellow-bellied sheathtail-ba	LC	-		A	U	A	U	4		U	U	U	U	U	U	6		U	U	U	U		4
Emballonuridae	*Taphozous troughtoni*	Troughton's sheathtail-bat	LC	-						0		A					A	2							0
FERAL/DOMESTICATED/INTRODUCED SPECIES					**3**	**2**	**1**	**1**	**2**	**9**		**2**	**0**	**0**	**2**	**1**	**2**	**12**	**5**	**0**	**1**	**0**	**1**	**0**	**2**
NATIVE MAMMALS (NON-BATS)					**4**	**1**	**2**	**2**	**0**	**9**		**1**	**1**	**7**	**4**	**0**	**3**	**24**	**172**	**0**	**3**	**0**	**0**	**0**	**175**
BATS					**0**	**9**	**12**	**13**	**7**	**41**		**15**	**12**	**12**	**15**	**12**	**17**	**83**	**0**	**17**	**19**	**18**	**17**	**0**	**71**
TOTAL MAMMALS					**7**	**12**	**15**	**16**	**9**	**59**		**18**	**13**	**19**	**21**	**13**	**22**	**119**	**167**	**17**	**23**	**18**	**18**	**0**	**243**

LC - Least Concern
SL - Special Least Concern
V - Vulnerable
I - Introduced

Blue - Pests
A - Ambiguous identification
U - Unambiguous identification
- probable identification of species from hair samples

* species identified from tracks, scats or other traces
^ Probable species ID from bat calls

Family	Scientific Name	Common Name	NC Act/LP Act Status	EPBC Act status	Bat Survey Autumn 2018											
					HP 1	HP 2	HP 3	HP 4	HP 5	HP 6	HP 7	HP 8	MN 1	MN 2	MN 3	Total
Pteropodinae	*Pteropus scapulatus*	Little red flying fox	LC	-												
Rhinolophidae	*Rhinolophus megaphyllus*	Eastern horseshoe bat	LC	-												
Vespertilionidae	*Chalinolobus gouldii*	Gould's wattled bat	LC	-						1						1
Vespertilionidae	*Chalinolobus nigrogriseus/Scortorepens greyii*															
Vespertilionidae	*Vespadelus troughtoni/Chalinolobus morio*															
	Taphozous troughtoni/Ozimops lumsdenae															
	Saccolaimus flaviventris/Ozimops lumsdenae															
	Saccolaimus flaviventris/Chaerephon jobensis															
Vespertilionidae	*Chalinolobus picatus/Vespadelus baverstocki*															
Vespertilionidae	*Chalinolobus picatus/Scotorepens greyii*															
Vespertilionidae	*Chalinolobus gouldii/Scotorepens balstoni*															
	Chalinolobus gouldii/Ozimops ridei															
Vespertilionidae	*Chalinolobus morio*	Chocolate wattled bat	LC	-							1					1
Vespertilionidae	*Chalinolobus nigrogriseus*	Hoary wattled bat	LC	-												
Vespertilionidae	*Chalinolobus picatus*	Little pied bat	LC	-						1						1
Vespertilionidae	*Nyctophilus geoffroyi*		LC	-							1					1
Vespertilionidae	*Nyctophilus sp. (N. geoffroyi or N. gouldi)*		LC	-												
Vespertilionidae	*Scotorepens balstoni*	Western broad-nosed bat	LC	-												
Vespertilionidae	*Scotorepens greyii*	Little broad-nosed bat	LC	-					5	2	1	1			2	11
Vespertilionidae	*Vespadelus baverstocki*	Inland forest bat	LC	-												
Vespertilionidae	*Vespadelus troughtoni*	Eastern cave bat	LC	-												
Miniopteridae	*Miniopterus orianae oceanensis*		LC	-												
Miniopteridae	*Miniopterus schreibersii oceanensis*	Eastern bent-wing bat	LC	-												
Molossidae	*Austronomus australis*	White-striped free-tailed Bat	LC	-												
Molossidae	*Chaerephon jobensis*	Northern free-tailed bat	LC	-												
Molossidae	*Mormopterus (Setirostris) eleryi*	Hairy-nosed free-tailed bat	LC	-												
Molossidae	*Ozimops lumsdenae*	Northern free-tailed bat	LC	-												
Molossidae	*Ozimops petersi*	Inland free-tailed bat	LC	-												
Molossidae	*Ozimops ridei*	Ride's free-tailed bat	LC	-												
Emballonuridae	*Saccolaimus flaviventris*	Yellow-bellied sheathtail-ba	LC	-												
Emballonuridae	*Taphozous troughtoni*	Troughton's sheathtail-bat	LC	-												
				BATS					**5**	**4**	**3**	**1**			**2**	**15**
				TOTAL MAMMALS												

LC - Least Concern

Appendix J Weed Species and Management Plans

Restricted invasive plant

Harrisia cactus

Moonlight cactus

Harrisia martinii, Harrisia tortuosa and *Harrisia pomanensis*

Harrisia cactus can form dense infestations that will reduce pastures to a level unsuitable for stock. Harrisia cactus will choke out other pasture species when left unchecked.

The spines are a problem for stock management, interfering with mustering and stock movement.

Harrisia cactus produces large quantities of seed that is highly viable and easily spread by birds and other animals. As well as reproducing from seed, harrisia cactus has long trailing branches that bend and take root wherever they touch the ground. Any broken-off portions of the plant will take root and grow.

Legal requirements

Harrisia cactus (*Harrisia martinii, Harrisia tortuosa* and *Harrisia pomanensis*) are restricted invasive plants under the *Biosecurity Act 2014*. It must not be given away, sold, or released into the environment without a permit. The Act requires everyone to take all reasonable and practical steps to minimise the risks associated with invasive plants and animals under their control. This is called a general biosecurity obligation (GBO). This fact sheet gives examples of how you can meet your GBO.

Queensland Government

At a local level, each local government must have a biosecurity plan that covers invasive plants and animals in its area. This plan may include actions to be taken on certain species. Some of these actions may be required under local laws. Contact your local government for more information.

Description

Harrisia cactus is a perennial. The spiny fleshy stems are jointed and form tangled mats about half a metre high. Many branches often lie flat and take root where they touch the ground. Each section is ribbed lengthwise with six ribs; each rib has low, thick, triangular humps at regular intervals. These humps have cushions of grey felty hairs, three to five short spines lying flat, and one to three erect, stiff, very sharp spines 2.5–3 cm long.

The large flowers open at night. Flowers are pink and funnel-shaped with a tinge of white. These grow singly near the ends of the stems on a scaly but spineless slender grey-green tube 12–15 cm long.

Round, red fruits 4–5 cm across have scattered bumps with hairs and spines. Numerous small black seeds are embedded in the white, juicy pulp of the fruit, which splits open when ripe.

Harrisia cactus roots are of two types. Shallow feeding roots up to 3 cm thick and 30 cm to 2 m long grow mostly horizontally off a crown, up to 15 cm below ground level. Swollen tuberous storage roots descend to a depth of 15–60 cm.

Life cycle

Harrisia cactus bears a bright red fruit containing 400–1000 small black seeds. Plants are easily established from seed and germinate soon after rain.

Seedlings quickly produce a swollen tuberous food storage root that develops as the plant grows. Branches take root where they touch the ground and new plants will grow from broken branches and sections of underground tubers.

Counts of tubers in dense cactus infestations have shown over 125 000 per hectare. Each plant houses many dormant underground buds that are all capable of reshooting when the tip growth dies; any small portion of the tuberous root left in the soil will grow.

Methods of spread

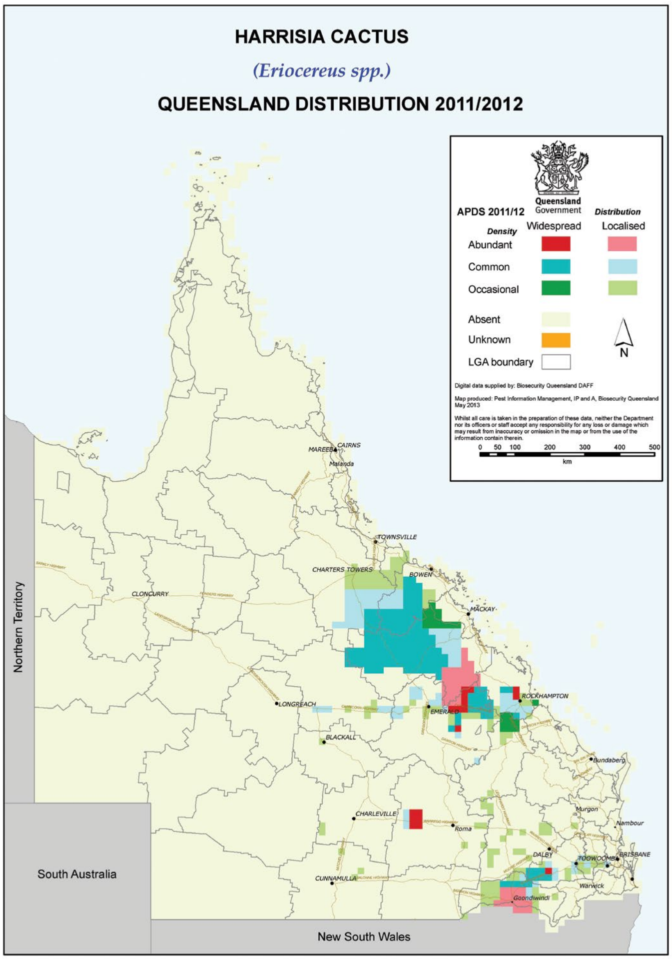
Fruit and seed are readily eaten by birds, mammals and to a lesser extent by feral pigs.

Habitat and distribution

Harrisia cactus is a native of Argentina and Paraguay, South America. It was introduced to Australia as a pot plant in the 1890s. In 1935 it was first recognised as a serious pest in the Collinsville district and by the 1950s was rapidly spreading south.

Harrisia cactus is mainly a pest of brigalow and associated softwood country. However, infestations are now appearing in box and ironbark stands and also in pine forests.

Map 1. Distribution of harrisia cactus in Queensland



The cactus is shade tolerant and reaches its maximum development in the shade and shelter of brigalow scrub, though established infestations can persist once scrub is pulled.

Harrisia cactus is found in the Collinsville, Nebo, Moranbah, Dingo, Blackwater and Goondiwindi districts, with minor infestations occurring at Millmerran, Greenmount, Gatton, Ipswich, Rockhampton, Rannes, Mount Morgan, Alpha and Mitchell.

Control

Managing harrisia cactus

The GBO requires a person to take reasonable and practical steps to minimise the risks posed by harrisia cactus. This fact sheet provides information and some options for controlling harrisia cactus.

Control of this plant is difficult as it has a deep underground tuberous root system and use of a combination of physical, biologic and herbicide controls is recommended.

Physical control

Dig out plants completely and burn. Ensure that all tubers that can grow are removed and destroyed.

Ploughing is not considered an effective means of control unless followed by annual cropping.

Biological control

Two introduced insects have become established in the field:

- a stem-boring longicorn beetle (*Alcidion cereicola)*
- a mealy bug (*Hypogeococcus festerianus*).

The stem-boring beetle only attacks older woody stems. In the Collinsville area, large beetle colonies developed and contributed to the collapse of dense areas of cactus. Populations of *Alcidion cereicola* have declined with the reduction in the cactus in recent years.

The most successful biological control agent is the mealy bug *Hypogeococcus festerianus* which is now present in harrisia cactus in Collinsville, Dingo, Moranbah, Blackwater, Nebo, Charters Towers and Goondiwindi districts, with small colonies established at Alpha, Capella, Rannes, Gatton, Greenmount, Millmerran and Rockhampton.

How mealy bug works

The mealy bug aggregates and feeds in the tips of stems and buds, where it limits growth and causes distortion. This results in the knotting of the stem. The plant's response is to utilise energy reserves within the tuber system to produce new growth. Eventually the plant dies, as it is unable to support the continuous high energy demands.

Dry weather reduces the effectiveness of the mealy bug. When dry, the plant's tuber system becomes dormant. Consequently, mealy bug damage does not result in new growth and the energy reserves within the plant are not affected. Instead the bug may damage all vegetative parts and eventually die out. The tuber will remain dormant until adequate moisture returns, when it will reshoot.

How to spread the bug

Mealy bug disperses naturally via wind, although landholder assistance is necessary for its continuous spread, particularly between patches. The bug is manually spread by cutting infected stems and placing them into healthy plants. The best pieces for starting new colonies are large knobs of twisted and distorted cactus that contain many mealy bugs well protected inside knots. Stem tips covered by white, woolly masses of bug are also good. To collect the bug, cut infected stems approximately 15 cm from the distorted knob and place segments in green, plump sections of the healthy plant. Avoid placing mealy bug in stressed or dried out stems. Small cactus plants require at least one large knot, with larger plants requiring three knots per plant. Where possible, landholders should infest every cactus clump as this ensures a rapid reduction in growth and fruiting potential. When cactus infestations are light, chemical control may be a preferable option.

Cut pieces can be transported in boxes or open vehicles. They are not delicate, but are best kept in the shade. Avoid keeping them in large heaps, in direct sunlight, under tarpaulins or in closed containers for long periods. Such conditions will promote rotting of the stems, leading to poor results or failures. Ideally, stems should be put out within three days and a maximum of five days.

When to infest

Best results come by infesting new areas during spring and early summer, from September to December. Maximum growth and spreading occurs in the summer months of December to February. During the drier and colder months of April to August the mealy bug does not die, but little growth and multiplication occurs. Introduction of mealy bug during autumn and winter will not be lost, but little effect is seen until the following summer.

How soon to expect results

Mealy bugs are generally more active and effective on harrisia cactus growing underneath shrubs and trees, so results will be seen more quickly in these areas than in cactus growing in the open. Best results are obtained when infesting plants that have actively growing new shoots.

During wet summers in northern and central Queensland, the growing points of stems will begin to curl after about six weeks.

By the end of the first summer, damage (severe twisting) will be widespread in infested plants. If the initial infestation was sufficiently heavy, no fruit or growth will occur during the second year, and the cactus will begin to die during the third year. Seedlings and regrowth shoots will continue to be present but by the end of the fourth year there should be very little cactus left.

In the southern portion of the state, where temperatures are lower, the mealy bug still provides control but the process takes longer. However, the mealy bug will do better on cactus in the open, rather than in the shade, as temperatures are higher in the open.

Herbicide control

Foliar application of registered herbicides provides effective control, but can be costly over large areas. Before using any herbicide always read the label carefully. All herbicides must be applied strictly in accordance with the directions on the label (see to Table 1).

Further information

Further information is available from your local government office, or by contacting Biosecurity Queensland on 13 25 23 or visit www.biosecurity.qld.gov.au.

Table 1. Herbicides for the control of harrisia cactus

Situation	Herbicide	Rate	Comments
Non-crop land and rights-of-way	Dichlorprop as K salt (600 g/L)	1 L/60 L water	Good soil moisture essential Spray plant when actively growing to run-off point A follow-up treatment may be necessary
Native pastures, rights-of-way, commercial and industrial areas	Metsulfuron-methyl (600 g/kg) (e.g. Brush-Off®)	20 g/100 L water + surfactant	Spray plant when actively growing to run-off point A follow-up treatment may be necessary
Agricultural non-crop areas, commercial and industrial areas, fence lines, forestry, pastures and rights-of-way	Triclopyr as butotyl (240 g/L) + Picloram as ioe (120 g/L) (e.g. Access®)	1 L/60 L diesel	Spray plant when actively growing Apply as overall spray, wetting all areas of the plant to ground level
Non-agricultural areas (native pastures), commercial and industrial areas and rights-of-ways	Aminopyralid as K salt 375 g/kg + Metsulfuron methyl 3 g/kg (e.g Stinger)	40 g/100 L water	Spray to thoroughly wet using 1000 to 1400 L/ha Follow-up treatment may be necessary
Commercial and industrial areas, around buildings and rights-of-way	Triclopyr as butotyl 75 g/L + Metsulfuron-methyl 28 g/L (e.g. Zelam Brush Weed®)	500 mL/100 L	Spray to thoroughly wet using 1000 to 1500 L/ha Follow-up treatment may be necessary
Agricultural non-crop areas, commercial and industrial areas, forests, pastures and rights-of-way	Triclopyr as tea 200 g/L + Picloram as tipa 100 g/L (e.g. Slasher) or Triclopyr as tea 200 g/L + Picloram as tipa 100 g/L + Aminopyralid 25 g/L (e.g. Tordon RegrowthMaster) (e.g. Tordon DSH®)	2.5 L/100 L water	Spray plant when actively growing (September–March) Treat all stems thoroughly

Read the label carefully before use. Always use the herbicide in accordance with the directions on the label.

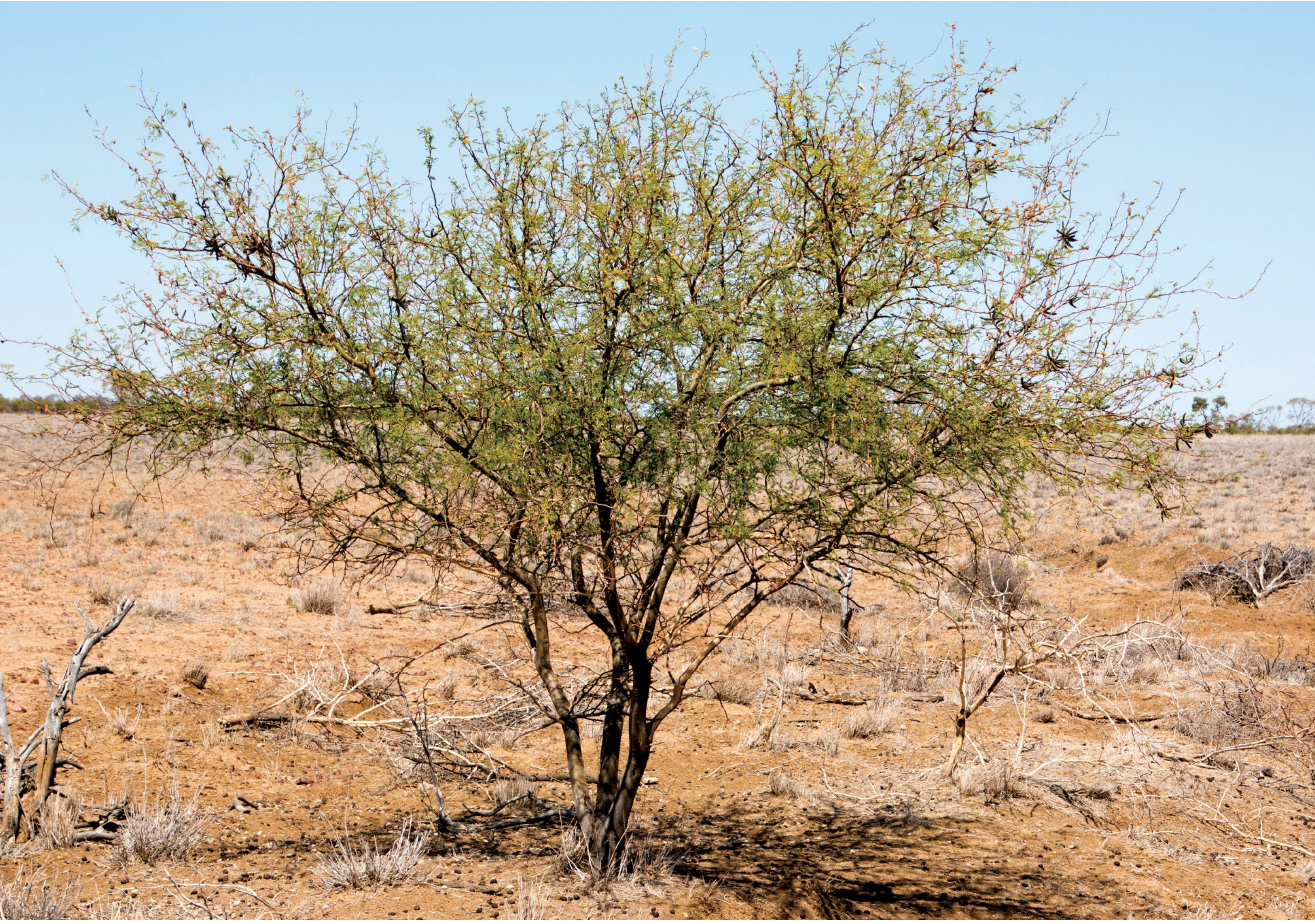
This fact sheet is developed with funding support from the Land Protection Fund.

Department of Agriculture and Fisheries
Biosecurity Queensland

Invasive plant

Mimosa bush

Acacia farnesiana



Mimosa bush can spread readily and grow quickly. As it often forms thorny thickets, it can be a considerable nuisance during mustering and can also hinder stock access to water.

Mimosa does offer shade in open downs country and can be useful as a supplement to grass during the dry season. It may therefore be a useful plant in some areas if its spread can be controlled to prevent thicket formation. The maintenance of healthy pasture competition is the best mechanism to achieve this.

Legal requirements

Mimosa bush is not a prohibited or restricted invasive plant under the *Biosecurity Act 2014*. However, by law, everyone has a general biosecurity obligation (GBO) to take reasonable and practical steps to minimise the risks associated with invasive plants and animals under their control.

Local governments must have a biosecurity plan that covers invasive plants and animals in their area. This plan may include actions to be taken on certain species. Some of these actions may be required under local laws. Contact your local government for more information.

Queensland Government

Description

Mimosa bush is a rounded shrub or small tree generally growing 2 to 3 m high, occasionally to 5 m. It often forms thorny thickets, and is nearly always multi-stemmed. The branches grow in a zigzag shape and are usually a grey-brown colour with prominent white spots.

Leaves are a ferny type, with 1–6 pairs of leaf 'branches' each with 5–20 pairs of narrow, rounded leaflets 4–8 mm long. Leaves are sometimes more of a yellowish green than a pure green. Thorns are found in pairs at the base of each leaf and can grow up to 10 cm long.

Golden yellow to orangeish flowers are ball-shaped, about 1 cm across, and grow on stalks, usually two stalks at the base of each leaf. Flowers develop into clusters of cigar-shaped pods, slightly curved and up to 6 cm long. The pods are dark brown or black and woody at maturity, with seeds embedded in the pith. Pods do no split open and tend to stay on the plant for a length of time.

Mimosa bush can be confused with the declared weeds mesquite (*Prosopis* spp.) and prickly acacia (*Vachellia nilotica*), particularly when young (see the 'identification of prickle bushes' fact sheet from www.biosecurity.qld.gov.au).

Distribution

Mimosa bush, a native of central and south America, is naturalised in Australia. Mimosa bush is widespread in Queensland, and found in all but the wettest and driest parts of the State. Seeds sprout readily and plants grow rapidly. Mimosa bush does well in dry localities and on loamy or sandy soils, forming thickets along watercourses. Mimosa bush withstands drought well, is readily eaten by stock, and has good regrowth after grazing.

Mimosa bush is not a long-lived plant. It is readily attacked by many native insects and is prone to dieback on an irregular basis. In some parts of the world mimosa bush is cultivated for perfume production.

Control

Basal bark spray

For stems up to 15 cm diameter, carefully spray completely around base of plant to a height of 30 cm above ground level. Thoroughly spray into all crevices. Larger trees may be controlled by spraying to a greater height, up to 100 cm above ground level.

The best time for treatment is during autumn when plants are actively growing and soil moisture is good.

Cut stump treatment

At any time of year, cut stems off horizontally as close to the ground as possible. Immediately (within 15 seconds) swab cut surface with herbicide mixture.

Bore drains

Channels and drains must be empty of water. Spray a one metre strip into the mud in channel or drain. Wait at least three days for diuron to bond to mud before slowly allowing water in again. Water must not be used in domestic water supply or supplied to desirable shade trees for 7–14 days after re-opening the drain.

Further information

Further information is available from your local government office, or by contacting Biosecurity Queensland on 13 25 23 or visit www.biosecurity.qld.gov.au.

Table 1. Herbicides for the control of mimosa bush

Situation	Herbicide	Rate	Optimum time	Comments
Basal bark/ cut stump	Fluroxypyr eg. Starane Advanced®, etc Triclpyr + picloram e.g. Access®	Refer to product label	Basal bark: for plants up to 5 cm basal diameter	
	Triclpyr + picloram e.g. Access®	1 L/60 L diesel	Basal bark: for plants up to 5 cm basal diameter	Ensure all stems on multi-stemmed plants are treated.
Soil application	Tebuthiuron (PERMIT 13891) e.g. Tebulan 200GR herbicide®, Graslan herbicide®, etc	2.0 g/m2 or 20 kg/ha		For use in pastures, roadside and rights of way. Application just prior to rainfall gives best results. Avoid damage to off target species – refer to herbicide label for product restraints and critical comments.
High volume spray	500 g/L clopyralid present as the triisopropanol amine (PERMIT 11638) e.g. Lontrel herbicide®, Nufarm Archer®, Farmoz Victory herbicide®, etc	500 mL of product per 100 L of water (plus non-ionic surfactant at 0.1%)	Spray when plants are actively growing and in full leaf	For use in pastures, rights of way, powerline areas. Full covering of foliage with spray is essential. Withholding period: do not graze treated areas, or cut for stock feed, for seven days after application.
Bore drains	Diuron e.g. Diuron 500SC®, etc	Refer to product label	Do not apply between 1 December and 30 March each year.	Do not apply more than once per calendar year. Do not open drains for 72 hours following treatment. Do not apply if heavy rains are predicted within three days of application. Application should be limited to 1 m strips along the sides of bore drains. Withholding period – do not allow animals to drink water from treated bore drains for three days, before slaughter for human consumption

Read the label carefully before use. Always use the herbicide in accordance with the directions on the label.

This fact sheet is developed with funding support from the Land Protection Fund.

Restricted invasive plant

Mother-of-millions

Bryophyllum delagoense (syn. *B. tubiflorum, Kalanchoe delagoensis*) and *Bryophyllum × houghtonii*

Mother-of-millions are native to Madagascar and are escaped ornamental plants. Five species are commonly naturalised in Queensland. It is well adapted to dry areas because of its succulent features.

As the name suggests, one plant can reproduce a new generation from masses of embryoids (plantlets) that are formed on the leaf edges. This makes these plants hard to eradicate and follow up controls are essential.

These plants, especially their flowers, are poisonous to stock and occasionally cause a significant number of cattle deaths. The plant flowers from May to October (during the drier months of the year) and the scarcity of feed at this time may cause cattle to consume lethal amounts of mother-of-millions.

Legal requirements

Mother-of-millions is a restricted invasive plant under the *Biosecurity Act 2014*. It must not be given away, sold, or released into the environment without a permit.

Bryophyllum pinnatum (resurrection plant, live-leaf) is not a restricted invasive plant. However the Act requires everyone to take all reasonable and practical steps to minimise the risks associated with invasive plants and animals under their control. This is called a general biosecurity obligation (GBO). This fact sheet gives examples of how you can meet your GBO.

At a local level, each local government must have a biosecurity plan that covers invasive plants and animals in its area. This plan may include actions to be taken on certain species. Some of these actions may be required under local laws. Contact your local government for more information.

Description

Mother-of-millions are erect, smooth, fleshy succulent plants growing to 1 m or more in height.

All species form tall flower spikes in winter with clusters of bell-shaped flowers. Each species has a distinctive leaf shape, but all produce small plantlets along the edges of the leaves. These plantlets drop readily, develop roots and establish quickly to form a new colony.

Bryophyllum delagoense syn. *B. tubiflorum* and *Kalanchoe delagoensis* (common mother-of-millions, mission bells, Christmas bells) has grey-brown, fleshy, tubular-like leaves with up to seven projections at the tip of each leaf. The flowers are orange-red and occur in a cluster at the top of a single stem. Seeds can germinate for some years.

Bryophyllum × houghtonii syn. *B. daigremontianum × B. delagoense, Kalanchoe × houghtonii* (hybrid or crossbred mother-of-millions) has similar flowers arranged in a branched cluster at the top of the stem. Its leaves are boat shaped with thick stalks and notches along the edges of the leaves.

A third species, *Bryophyllum pinnatum (*resurrection plant, live-leaf) has yellow-green, oval, fleshy leaflets with wavy edges and up to five leaflets per leaf. Its flowers are yellowish-green, often tinged with pink, and occur in loose clusters on stalks growing at intervals along the upper portion of the stem.

Life cycle

Mother-of-millions flowers in Winter and reproduces by seed and by tiny plantlets that are produced at the tips of its fleshy (succulent) leaves. Dislodged leaves and broken leaf parts can also take root and give rise to new plants.

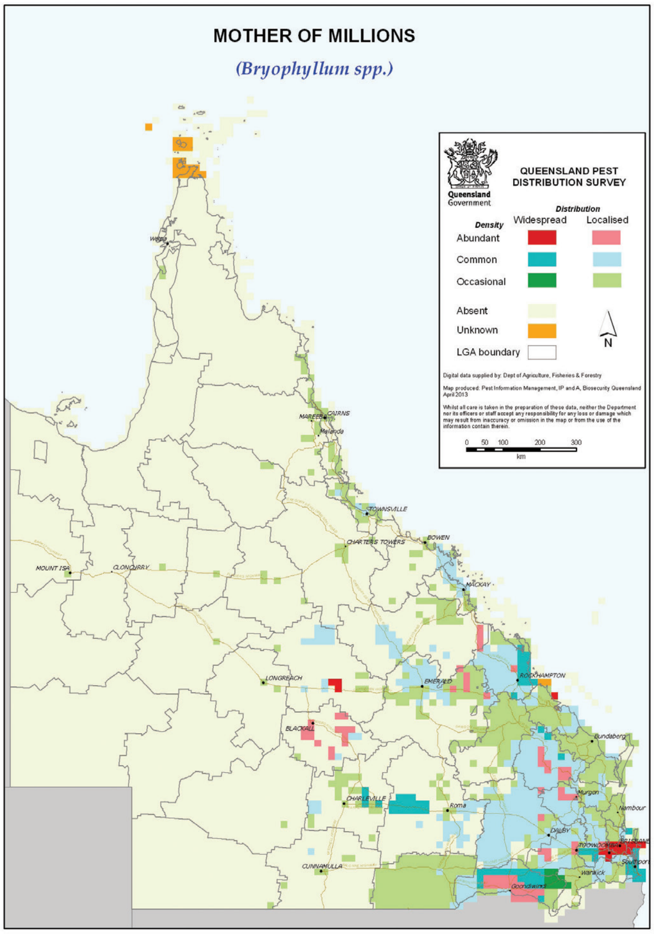
Methods of spread

Mother-of-millions is commonly spread by garners and in garden waste. The tiny seeds are probably wind and water dispersed and its leaves and plantlets may also be dislodged and spread by animals, vehicles, machinery, soil and slashers.

Habitat and distribution

Native to Madagascar, these popular succulent garden plants have escaped culitvation and spread in various areas of Queensland. They have become a problem in pasture lands in the central highlands around Clermont, Emerald and Dingo, and the Burnett, Moreton and Darling Downs scrub regions. The plants establish well in leaf litter or other debris on shallow soils in shady woodlands, and often grow on roadsides, along fence lines and around old rubbish dumps. They can spread from these areas, especially in flood, and establish if pastures are run down.

Map 1. Distribution of mother-of-millions in Queensland



They are adapted to dry conditions and can survive long periods of drought.

Toxicity

These plants are toxic, especially their flowers, and occasionally cause a significant number of cattle deaths. When cattle are under stress or in unusual conditions they are more likely to eat plants that they would not normally eat. Shifting cattle to new paddocks, moving stock through infested rubbish dumps and wastelands, and reduction of availability of feed due to flood or drought can all contribute to cattle eating mother-of-millions and being poisoned.

Poisoned cattle show signs of dullness, loss of appetite, diarrhoea and heart failure. Some cattle may drool saliva or dribble urine. There are two responses to poisoning:

- acute—where cattle die within a day
- chronic—where cattle may take up to five days to die.

Some cattle may make a slow recovery if insufficient plant material was eaten.

Poisoned cattle must be treated within 24 hours of consuming the plant. The treatment is intense and needs to be given by a veterinarian, or under their direction, because of the drugs and materials used.

Control

Managing mother-of-millions

The GBO requires a person to take reasonable and practical steps to minimise the risks posed by mother-of-millions. This fact sheet provides information and some options for controlling mother-of-millions.

Prevention and early detection

The best form of weed control is prevention. Always treat weed new infestations when small—do not allow weeds to establish. Weed control is not cheap, but it is cheaper to do it now rather than next year, or the year after. Proper planning ensures better value for each dollar spent.

Permanent control of mother-of-millions infested areas is best ensured by establishing more desirable plants in that location to compete successfully with future mother-of-millions seedlings and plantlets. This is best achieved through soil preparation, replanting, fertilising and using the area more productively.

Ensure scattered infestations and small dumping areas on properties are regularly checked and cleaned up. Day-today hygiene management will help prevent establishment of these weeds.

Co-operative control upstream and downstream of problem areas will help prevent re-infestation from other areas.

To prevent poisoning, keep stock (especially hungry stock) away from infested areas until the plants are controlled.

Mechanical control

For small areas, pull up plants by hand and burn on a wood heap. Alternatively, bag the plants and dump them in a bin, the contents of which are buried at council refuse tips rather than being recycled into mulch.

Fire

When suitable (e.g. after grading firebreaks), burn infestations and the accompanying debris on which mother-of-millions plants thrive. This is the most economical form of control, encourages grass competition and lessens the problem for following years, requiring only spot spraying with selective herbicides.

Biological control

The South African citrus thrip is present in Queensland and is quite widespread through the south of the state. The thrip damages the outer tissue of the mother-of-millions plant and also lays its eggs under the outer tissue. Where high populations of thrips exist, the number of viable plantlets and flowers forming on mother-of-millions is reduced.

The thrips populations vary from year to year, according to mother-of-millions populations and climate. The South African citrus thrips should not be seen as a long term control strategy—only a control option to complement other techniques such as herbicide treatment and burning.

The department is undertaking further research to identify potential biological control agents to support with management.

Herbicide control

Before using any herbicide always read the label carefully. All herbicides must be applied strictly in accordance with the directions on the label. Where the addition of a wetting agent is recommended, always use a commercial wetting agent or surfactant.

Mother-of-millions may be controlled with herbicides at ny time of the year, but infestations are easiest to see in winter when the plants are in flower. Treating infestations at this time of year also has the benefit of preventing new seeds from developing on common mother-of-millions.

Table 1 details the herbicides registered for mother-of-millions control.

Further information

Further information is available from your local government office, or by contacting Biosecurity Queensland on 13 25 23 or visit www.biosecurity.qld.gov.au.

Bryophyllum x *houghtonii* (left) and *Bryophyllum delagoense* (right)

South African citrus thrips damage to mother-of-millions

Table 1. Herbicides for the control of mother-of-millions

Situation	Herbicide	Rate	Comments
Pastures and non-crop land	2,4-D acid (e.g. Affray 300)	7 L/1000 L water per ha 70 mL/10 L water	High volume foliar spray (handgun) High volume foliar spray (knapsack)
Pastures, rights-of-way and industrial	2,4-D amine 700 g/L (e.g. Amicide Advance 700)	360 mL/100L water	Hand gun and knapsack only. Thorough coverage is essential. Use a surfactant (e.g. Nufarm Activator) (consult label).
Pastures, rights-of-way, non-crop land, forests, non-agricultural land and commercial and industrial areas	Triclopyr 300 g/L + Picloram 100 g/L (e.g. Conqueror) or Triclopyr 300 g/L + Picloram 100 g/L + Aminopyralid 8 g/L (e.g. Grazon Extra)	500 mL/100 L water 50 mL/10 L water	High volume foliar spray (hand gun, knapsack). Always add a wetting agent (e.g. BS-1000 or Chemwet 1000) at 100 mL/100 L water. Apply at flowering.
	Fluroxypyr 200 g/L (e.g. Flagship 200)	600 mL/100 L water + sufactant (consult label)	Apply to seedlings and young plants before flowering.
	Fluroxypyr 333 g/L (e.g. Starane Advanced)	360 mL/100 L water + sufactant (consult label)	
	Fluroxypyr 400 g/L (e.g. Comet 400)	300 mL/100 L water + sufactant (consult label)	

Notes
Thorough, even coverage of leaves and plantlets is necessary.
Note that many 2,4-D products are not registered for control of mother-of-millions in Queensland. Only use products registered for the purpose.

Read the label carefully before use. Always use the herbicide in accordance with the directions on the label.

This fact sheet is developed with funding support from the Land Protection Fund.

Restricted invasive plant

Parthenium

Parthenium hysterophorus

Parthenium is a vigorous species that colonises weak pastures with sparse ground cover. It will readily colonise disturbed, bare areas along roadsides and heavily stocked areas around yards and watering points. Parthenium can also colonise brigalow, gidgee and softwood scrub soils. Its presence reduces the reliability of improved pasture establishment and reduces pasture production potential.

Parthenium is also a health problem as contact with the plant or the pollen can cause serious allergic reactions such as dermatitis and hay fever.

Parthenium is listed as a Weed of National Significance.

Legal requirements

Parthenium is a restricted invasive plant under the *Biosecurity Act 2014*. It must not be given away, sold, or released into the environment without a permit. The Act requires everyone to take all reasonable and practical steps to minimise the risks associated with invasive plants and animals under their control. This is called a general biosecurity obligation (GBO). This fact sheet gives examples of how you can meet your GBO.

At a local level, each local government must have a biosecurity plan that covers invasive plants and animals in its area. This plan may include actions to be taken on certain species. Some of these actions may be required under local laws. Contact your local government for more information.

Queensland Government

Description

Parthenium is an annual herb with a deep tap root and an erect stem that becomes woody with age. As it matures, the plant develops many branches in its top half and may eventually reach a height of 2 m.

Its leaves are pale green, deeply lobed and covered with fine soft hairs.

Small creamy white flowers occur on the tips of the numerous stems. Each flower contains four to five black seeds that are wedge-shaped, two millimetres long with two thin, white scales.

Life cycle

Parthenium normally germinates in spring and early summer, produces flowers and seed throughout its life and dies around late autumn. However, with suitable conditions (rain, available moisture, mild temperatures), parthenium can grow and produce flowers at any time of the year. In summer, plants can flower and set seed within four weeks of germination, particularly if stressed.

Methods of spread

Parthenium seeds can spread via water, vehicles, machinery, stock, feral and native animals and in feed and seed. Drought conditions aid the spread of seed with increased movements of stock fodder and transports.

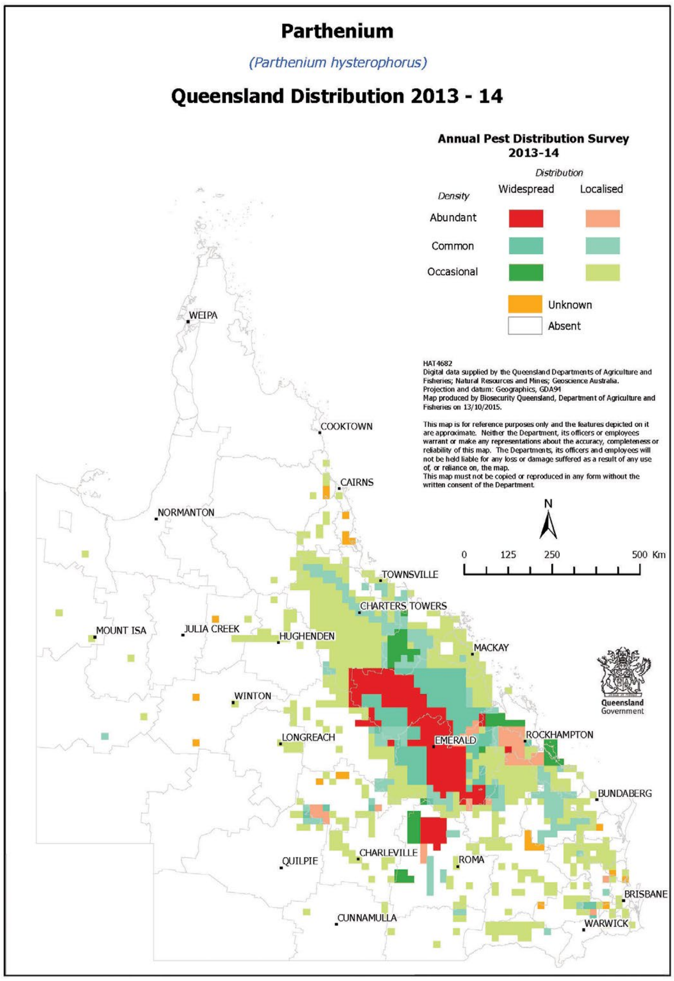
Habitat and distribution

Parthenium is capable of growing in most soil types but becomes most dominant in alkaline, clay loam soils.

The plant is well established in Central Queensland and present in isolated infestations west to Longreach and in northern and southern Queensland.

Infestations have also been found in northern and central parts of New South Wales and it is capable of growing in most states of Australia.

Map 1. Distribution of parthenium in Queensland



Control

Managing parthenium

The GBO requires a person to take reasonable and practical steps to minimise the risks posed by parthenium. This fact sheet provides information and some options for controlling parthenium.

Prevention and weed seed spread

Pastures maintained in good condition, with high levels of grass crown cover, will limit parthenium colonisation. Drought, and the subsequent reduced pasture cover, creates the ideal window of opportunity for parthenium colonisation when good conditions return.

Vehicles and implements passing through parthenium infested areas should be washed down with water. Particular care should be taken with earthmoving machinery and harvesting equipment. The wash down procedure should be confined to one area, so that plants that establish from dislodged seed can be destroyed before they set seed.

Extreme caution should be taken when moving cattle from infested to clean areas. Avoid movement during wet periods as cattle readily transport seed in muddy soil. On arrival, cattle should be held in yards or small paddocks until seed has dropped from their coats and tails prior to their release into large paddocks. Infestations around yards can be easily spotted and controlled whereas infestations can develop unnoticed in large paddocks.

Particular care should be taken when purchasing seed, hay and other fodder materials. Always keep a close watch for the emergence of parthenium or other weeds on areas where hay has been fed out.

Property hygiene is important. Owners of clean properties should ensure that visitors from infested areas do not drive through their properties. If your property has parthenium on it, ensure that it is not spread beyond the boundary or further within the property.

Manual control

Hand pulling of small areas is not recommended. There is a health hazard from allergic reactions and a danger that mature seeds will drop off and increase the area of infestation.

Pasture management

Grazing management is the most useful method of controlling large-scale parthenium infestations. Maintain pastures in good condition with high levels of ground and grass crown cover. This may require rehabilitation of poor pastures, followed by a sound grazing maintenance program.

Sown pasture establishment—Poor establishment of sown pastures can allow parthenium colonisation.

Pasture agronomy—Aerial seeding prior to scrub pulling is normally beneficial.

Overgrazing—High grazing pressure caused by drought or high stock numbers decreases the vigour and competitiveness of pastures and allows the entry and spread of parthenium. Maintenance of correct stock numbers is most important in controlling parthenium.

Pastures spelling—In situations of serious infestation, pasture spelling is essential for rehabilitation. Total spelling is much more effective than simply reducing the stocking rate. However, overgrazing of the remainder of the property must be avoided.

The most appropriate time for pasture spelling is the spring–summer growing period, with the first 6–8 weeks being particularly important. If the condition of perennial grasses (native or sown) is low, spelling for the entire growing season may be required or introduced grasses may need to be re-sown. Herbicide treatment can hasten the rehabilitation process by removing a generation of parthenium seedlings and allowing grass seedlings to establish without competition. In the presence of parthenium, grass establishment is poor.

Grazing during winter should not increase the parthenium risk. Most tropical grasses are dormant and can tolerate moderate grazing during this period. However, parthenium may germinate and grow at this time.

Fencing—One of the main problems in controlling parthenium is the large paddock size and the variability of country within paddocks. The resulting uneven grazing pressures encourage parthenium to colonise the heavily grazed country. Ideally, similar land types should be fenced as single units. Fencing can be used to great effect to break up large paddocks, allowing more flexible management such as pasture spelling or herbicide application, options not available previously.

Burning—Burning is not promoted as a control strategy for parthenium. However, research suggests that burning for pasture management (e.g. woody weed control) should not result in an increased infestation if the pasture is allowed to recover prior to the resumption of grazing. Stocking of recently burnt areas known or suspected to contain parthenium decreases pasture competition and favours parthenium, ultimately creating a more serious infestation.

Biological control

The combined effects of biological control agents reduced the density and vigour of parthenium and increased grass production.

There are currently a number of insect species and two rust pathogens that have been introduced to control parthenium—a selection of these are outlined below. *Epiblema strenuana* is a moth introduced from Mexico established in all parthenium areas. The moth's larvae feed inside the stem, forming galls that stunt the plant's growth, reduce competitiveness and seed production.

Listronotus setosipennis is a stem-boring weevil from Argentina but is of limited success in reducing parthenium infestations.

Zygogramma bicolorata is a defoliating beetle from Mexico which is highly effective where present. It emerges in late spring and is active until autumn.

Smicronyx lutulentus (Mexico) lays eggs in the flower buds where the larvae feed on the seed heads. *Conotrachelus albocinereus* (stem-galling weevil from Argentina) produces small galls and is still becoming established in Queensland.

Bucculatrix parthenica (leaf mining moth from Mexico) larvae feed on leaves, leaving clear windows in the leaf. *Carmentia ithacae* is a stem boring moth from Mexico which is becoming established at favourable sites in the northern Central Highlands.

Puccinia abrupta is a winter rust from Mexico that infects and damages leaves and stems. It is currently established over a wide area from Clermont south. It requires a night temperature of less than 16 degrees and 5–6 hours of leaf wetness (dew). Sporadic outbreaks occur where weather conditions are suitable.

Puccinia melampodii is a summer rust from Mexico that weakens the plant by damaging the leaves over the summer growing season. It is currently established and spreading at a number of sites from north of Charters Towers to Injune in the south.

Herbicide control

Non-crop areas

Parthenium should be sprayed early before it can set seed. A close watch should be kept on treated areas for at least two years.

Small and/or isolated infestations should be treated immediately. Herbicide control will involve a knockdown herbicide to kill plants that are present and a residual herbicide to control future germinations. Repeated spraying may be required even within the one growing season to prevent further seed production.

Extensive infestations will require herbicide treatment in conjunction with pasture management. Timing of spraying is critical so that parthenium is removed when plants are small and before seeding has occurred. Grasses should be actively growing and seeding so that they can recolonise the infested area.

Table 1. shows the herbicides registered for parthenium control and application rates. All herbicides must be applied strictly in accordance with the directions on the label.

Cropping areas

Controlling parthenium in cropland requires selective herbicide use and/or crop rotations. For further information on parthenium control in crops consult your local biosecurity officer.

Further information

Further information is available from your local government office, or by contacting Biosecurity Queensland on 13 25 23 or visit www.biosecurity.qld.gov.au.

Table 1. Herbicides for the control of parthenium

Situation	Herbicide	Rate	Comments
Pastures, rights-of-way and industrial land	2,4-D as amine 625 g/L (e.g. Ken-Amine 625)	320 mL/100 L water	Spot spray Apply to young actively growing plants, ensuring thorough coverage
	2,4-D as amine 700 g/L (e.g. Amicide Advance 700)	285 mL/100L water	
Non agricultural areas (native pastures), commercial and industrial areas, rights-of-way	Aminopyralid 375 g/kg plus metsulfuron-methyl 300 g/kg (Stinger)	10 g/100 L water plus wetting agent Consult label	Spray to thoroughly wet all foliage but not to cause run-off
Fields and fallow, various crops (see label)	Atrazine 500 g/L (e.g. Kenso Atrazine 500)	3.6–6 L/ha Rate varies with situation Consult label	Boom spray. Pre and post emergent application Restrictions apply. Consult label for details of specific conditions. Max 3 kg a.i./ha/yr
Roadside and rights-of-way		6 L/ha	Boom spray. Pre and post emergent application Restrictions apply. Consult label for details of specific conditions. Max 3 kg a.i./ha/yr
Fields and fallow, various crops (see label)	Atrazine 900 g/kg (e.g. Atradex WG)	2–3.3 kg/ha Rate varies with situation Consult label	Boom spray. Pre and post emergent application Restrictions apply. Consult label for details of specific conditions. Max 3 kg a.i./ha/yr
Roadside and rights-of way		3.3 kg/ha	Boom spray. Pre and post emergent application. Restrictions apply. Consult label for details of specific conditions. Max 3 kg a.i./ha/yr
Non-crop areas, commercial and industrial areas, pastures and rights-of-way	2,4-D 300 g/L + picloram 75 g/L (e.g. Tordon 75-D)	125 mL/100 L	Spot spray during rosette stage Use at least 3000 L/ha in dense infestations Consult label
		3 L/ha	Boom spray during rosette stage Consult label
Native pastures, rights-of-way, commercial and industrial land	metsulfuron methyl 600g/L (e.g. Associate)	5 g/100 L water + wetter	Hand gun. Spray to thoroughly wet all foliage but not to cause runoff
		7 g/ha + wetter	Boom spray. For pastures only. Treat in rosette stage. Consult label for details
Wheat, barley, triticale and cereal rye		5–7 g/h	Boom spray. Lower rate up to 4-leaf stage, higher rate 4-leaf stage to rosette
Native pastures, rights-of-way, commercial and industrial land	Triclopyr 75 g/L + metsulfuron-methyl 28 g/L (e.g. Zelam Brush Weed)	125 mL/100 L water	Spot spray plants from rosette to flowering Consult label for critical comments
Commercial and industrial areas, rights-of-way, around agricultural buildings	Hexazinone 750 g/kg (e.g. Velpar DF)	1 kg/ha 2 g/10 L/20 m^2	Boom spray or spot spray
Around agricultural buildings	Hexazinone 250 g/L (e.g. Velpar L)	3.5 L/ha or 7 L/10 L/20 m^2	
Grass pastures, fallows, various crop and non-crop situations (consult label for details	Dicamba 500 g/L (e.g. Kamba 500) Dicamba 700 g/kg	Rates vary with situation Consult label	Boom spray or spot spray Consult label for details and critical comments

A number of the listed herbicides are available as different formulations, but some may not be registered for parthenium. Check the label for registration, rate and critical comments. Only use products that list parthenium on the label. The registered rates are for non-crop uses. Consult label for in-crop recommendations. For power hand spray or knapsack use, spray plants to the point of runoff.

Read the label carefully before use. Always use the herbicide in accordance with the directions on the label.

This fact sheet is developed with funding support from the Land Protection Fund.

Restricted invasive plant

Opuntioid cacti

Austrocylindropuntia, Cylindropuntia and *Opuntia* species

Three types (genera) of opuntioid cacti have naturalised in Australia and are now considered Weeds of National Significance: *Austrocylindropuntia, Cylindropuntia* and *Opuntia*. They are drought resistant because of their succulent nature, their lack of leaves and their thick, tough skins. These features result in plants that use the majority of their internal tissues for water storage and their outer parts to reduce water loss and damage by grazing and browsing animals. They can remain vigorous in hot, dry conditions that cause most other plants to lose vigour or even die. Some species develop underground bulbs that enable the plant to resist fire and mechanical damage.

Dense infestations compete with native vegetation, limiting the growth of small shrubs and groundcover species. The plant's sharp spines or barbs can cause injury to stock and native animals and contaminate wool and hides, reducing or preventing grazing activities and productivity.

Large stands of cacti provide harbour for pest animals, such as foxes and rabbits and, due to their spiny nature, can limit access for stock mustering and recreational activities. The spines are capable of causing serious injury to animals and humans.

Queensland Government

Legal requirements

All Cholla cacti (*Cylindropuntia* spp.) and prickly pear (*Opuntia* spp.) not listed below are prohibited invasive plants and the *Biosecurity Act 2014* requires that all sightings to be reported to Biosecurity Queensland within 24 hours. By law, everyone has a general biosecurity obligation (GBO) to take all reasonable and practical steps to minimise the risk of these cacti spreading until they receive advice from an authorised officer.

The following species are restricted invasive plants under the Act. The Act requires that all sightings of these cacti must be reported to Biosecurity Queensland within 24 hours of the sighting. By law, everyone has a GBO to take all reasonable and practical steps to minimise the risk of spread of these cacti until they receive advice from an authorised officer.

- Hudson pear (*Cylindropuntia rosea* and *C. trunicata*)
- Jumping cholla (*Cylindropuntia prolifera*)
- Bunny ears (*Opuntia microdasys*)
- Riverina pear (*Opuntia elata*)

The following species are restricted invasive plants under the *Biosecurity Act 2014*. They must not be given away, sold, or released into the environment without a permit. The Act requires everyone to take all reasonable and practical steps to minimise the risks associated with invasive plants and animals under their control. This is called a general biosecurity obligation (GBO). This fact sheet gives examples of how you can meet your GBO.

- Cane cactus (*Austrocylindropuntia cylindrical*)
- Eve's pin cactus (*Austrocylindropuntia subulata*)
- Coral cactus (*Cylindropuntia fulgida*)
- Devil's rope pear (*Cylindropuntia imbricata*)
- Snake cactus (*Cylindropuntia spinosior*)
- Common pest pear, spiny pest pear (*Opuntia stricta* Syn. *O. inermis)*
- Drooping tree pear (*Opuntia monacantha* Syn. *O. vulgaris*)
- Tiger pear (*Opuntia aurantiaca*)
- Velvety tree pear (*Opuntia tomentosa*)
- Westwood pear (*Opuntia streptacantha*)

Indian fig (*Opunia ficus-indica*) is not prohibited or restricted invasive plant.

At a local level, each local government must have a biosecurity plan that covers invasive plants and animals in its area. This plan may include actions to be taken on certain species. Some of these actions may be required under local laws. Contact your local government for more information.

Description

Opuntioid cacti vary significantly in their form and habit, ranging from low-growing shrubs under 50 cm to erect trees up to 8 m tall.

Plants are normally leafless succulent shrubs. Stems are divided into segments (pads or joints) that are flat and often incorrectly called leaves.

Young shoots have true leaves resembling small fleshy scales that fall off as the shoot matures.

Flowers are large, normally seen during spring and can be yellow, orange, red, pink, purple or white depending on the species. Fruits vary between species and can be red, purple, orange, yellow or green.

Areoles (spots with clusters of spines) are found on both the pads (joints, segments) and fruit. In addition to spines, areoles often have clusters of sharp bristles (glochids) and tufts of fibre ('wool'). Each areole contains a growing point that can produce roots or shoots.

Hudson pear *(Cylindropuntia rosea and C. tunicata)*

Densely branched cactus up to 1.5 m tall and 3 m wide. Spines are extremely sharp, 4.5 cm long, enclosed in whitish papery sheaths. Spines on *C. rosea* are white and *C. tunicata* are brown. Flowers on *C. rosea* are pink-purple, and on *C. tunicata* they are pink-yellow, 5 cm wide. Stem segments are green to grey-green, cylindrical, 90 cm long, 4 cm wide. Fruit is oval-shaped, up to 4.5 cm long, yellow when ripe.

Jumping cholla (*Cylindropuntia prolifera*)

Low shrub 0.4 to 1 m tall. Spines 7–11, 1–2 cm long, light to dark brown, interlacing, white to light tan sheath firmly attached. Flowers are rose to magenta, 25–30 mm wide. Stem segments are dull green to greenish grey, whorled or subwhorled, cylindrical, 4–15 cm long, 4–5 cm wide, waxy flaky surface when dry. Prominent tubercles and segments easily detached. Fruit obovoid to globose, solitary or forming chains, up to 20–50 mm long, green. Seed not seen in Australia.

Bunny ears *(Opuntia microdasys)*

Dense shrub 40–60 cm tall, occasionally more. Stems are pad-like, 6–15 cm long, 4–12 cm wide. No central stem, pads always grow in pairs, giving appearance of bunny ears. Has no spines, but instead has numerous white or yellow glochids (hair-like prickles), 2–3 mm long, in dense clusters. Flowers are yellow, 3 cm wide. Fruits are fleshy, globular, 3 cm long, red-purple.

Riverina pear *(Opuntia elata)*

Branched shrub with erect branches to 2 m tall. Spines absent or 1–3 short spines, whitish yellow present at some areoles. Flowers are orange, 3–4 cm wide. Stem segments are glossy green, sometimes with a purple tinge (especially around the areoles and margins). Often more than 2 cm thick, 5–25 cm long. Fruit club shaped, up to 6 cm long, purplish red.

Cane cactus *(Austrocylindropuntia* ***cylindrica)***

Dark green shrub, 0.5–1.5 m tall. Branches 35–40 mm diameter. Leaves on new growth, deciduous, 3–5 mm long, but up to 10 mm on regrowth. Spines without papery sheath, 3–6 major ones per areole, 9–25mm long, and 3–4 minor ones, to 5.5 mm long. Flowers are red to red-orange. Fruit solitary or in small chains of 2–4. 30–60 mm long, dark green to yellow-green.

Eve's pin cactus *(Austrocylindropuntia subulata)*

Robust shrub to 3 m tall. Branches 40–50 mm diameter. Spines without papery sheath, 1 per areole on new growth, additional smaller ones (up to five) developing in successive years, mostly 35–70 mm long. Flowers are pink. Stem segments are glossy green, sometimes with a purple tinge (especially around the areoles and margins). Often more than 2 cm thick, 5–25 cm long. Fruit large, solitary or in small chains of 2–4, green, 50–135 mm long.

Coral cactus ***(Cylindropuntia fulgida)***

Coral cactus grows as a branching shrub 1–1.5 m high. The stems of coral cactus are divided into green cylinder-like pads that are fist-like and obtuse at their apex. Mature coral cactus pads widen, become distorted and wavy, and resemble a piece of coral. Areoles along the pads have a number of short white spines.

Coral cactus produces small (1–2 mm wide) scarlet flowers. The fruit is yellow-green and 2–5 cm wide.

Devil's rope pear ***(Cylindropuntia imbricata)***

This open-branching shrub grows 1.5–3 m high. The stems are divided into hairless, dull green, cylindrical pads that vary up to 37 cm in length and are 3.5–5 cm thick. The pads have a series of short raised ridges that give them a twined, rope-like appearance. The areoles are found on these ridges and produce 3–11 pale yellow or white spines, with the longest being 2.5 cm long. Papery sheaths cover these spines.

The flowers are a dull, red-purple colour and found at the ends of pads. The yellow fruit resembles a small, 5 cm wide custard apple and has a spineless areole at the top.

Snake cactus ***(Cylindropuntia spinosior)***

This open-branching shrub grows 1–2 m high. The stems are divided into hairless, dull green, cylindrical pads that vary up to 20 cm in length and are 3.5–5 cm thick. The pads have a series of short raised ridges that give them a twined rope-like appearance. The areoles are found on the bottom of these ridges and produce 5–10 pale yellow to brown spines, with the longest being 3 cm long.

The flowers are light red to dark rose and commonly 5–7 cm wide. Snake cactus produces fruit that is yellow and 2–5 cm wide.

Common pest pear, Spiny pest pear ***(Opuntia stricta)***

This bushy, spreading plant grows up to 1.5 m high and forms large clumps. The stems are divided into oval, blue-green spineless pads 20 cm long and 10 cm wide. Areoles are in diagonal lines along the pads 2.5 cm to 5 cm apart and have a cushion of brown wool containing bristles but usually no spines. When spines occur they are stout, yellow and up to 4 cm long.

Flowers that are 7.5 cm wide, bright lemon yellow and green at the base. The fruit is oval-shaped, has a deep cavity on one end and tapers at the other. It is purple, 6 cm long and 3 cm wide, with carmine-coloured (dark red) seeds and a fleshy pulp.

Drooping tree pear ***(Opuntia monacanta)***

This erect succulent shrub with fibrous roots grows up to 5 m high but is usually 2–3 m high. The branches are divided into glossy light green pads up to 45 cm long, 15 cm wide and 1.5 cm thick. The dark grey trunk grows up to 25 cm in diameter. Drooping tree pear gets its name because the upper segments tend to droop. The areoles on the older pads have 1–5 sharp spines about 5 cm long.

Small, scale-like leaves are found on areoles of very young pads and are quickly shed as the pad grows. Drooping tree pear produces yellow flowers that are 6 cm wide and have red markings on the back. The fruit is pear-shaped and 4–7 cm long with a green skin. The flesh of the fruit is red and pulpy and contains round seeds that are yellow or pale brown. The fruits have areoles with tufts of fine, barbed bristles.

Tiger pear ***(Opuntia aurantiaca)***

This succulent low shrub with underground tubers usually grows 30–60 cm high. The stems are divided into very spiny, slightly flattened pads that are 1–30 cm long and 1–5 cm wide. The stems are dark green to purple and red in colour. The areoles have 3–7 brown barbed spines up to 4 cm long surrounded by tufts of short, fine bristles. The pads detach easily and are transported on the skins of animals. Small and scale-like leaves are found on areoles of immature pads.

Tiger pear produces 6 cm wide yellow flowers. The rarely formed fruits are pear-shaped and about 2.5 cm long. When ripe, they are red with purple markings.

Velvety tree pear ***(Opuntia tomentosa)***

This tree-like plant forms a central woody trunk over 40 cm wide and grows up to 5 m high. The stems are divided into oblong pads that are dull green and velvety to touch due to the dense covering of short fine hairs. The pads are 15–35 cm long, 8–12 cm wide and 1.5–2 cm thick.

Young plants have 2–4 white or pale yellow spines located in the areoles with one spine reaching a length of 2.5 cm. The areoles usually become spineless as the plant matures. A more spiny variety does exist and has more than 50 spines in each areole on the trunk.

The flowers are a deep orange. The fruit is egg-shaped, about 5 cm long and 3 cm wide, and dull red. The top of the fruit is saucer-shaped with circular lines that meet in the centre and give the fruit a shrivelled appearance. The fruit produces many seeds within a reddish pulp.

Westwood pear or Cardona pear *(Opuntia streptacantha)*

Westwood pear is a shrub-like or tree-like plant that forms clumps by branching from the base and is usually 2–4 m high. The stems are divided into almost circular dull green pads, 25–30 cm long and 15–20 cm wide. The areoles have white spines that vary in number and size when the plant matures.

Young pads have 2–5 white spines 1–2 cm long, accompanied by two hair-like spines 0.5 cm long in the lower part of the areole. Spines increase in number (up to 20) and size (5 cm long) in areoles along the trunk of the plant.

The flowers are yellow and fruits are barrel-shaped, 6 cm long and 5 cm wide with a flat top. The fruit has a purple skin and a rind that is 1 cm thick. Fruits contain red seeds buried in a dark red (carmine) pulp.

Habitat and distribution

Native to the Americas, Opuntioid species are found throughout most Australian states and territories and there is potential for further spread.

In Queensland Opuntioid species are mainly found in low rainfall areas but can be are found in gardens,along beaches and on off shore island.

Life cycle

Opuntioids reproduce both sexually and asexually. Birds and other animals readily eat the many seeded fruits and deposit seeds in their droppings. The seeds have hard seed coats that allow them to survive heat and lack of water. Asexual reproduction (cloning) of cacti occurs when pads (joints, segments) or fruits located on the ground take root and produce shoots.

Methods of spread

Animals and floods move broken pads long distances. These pads can survive long periods of drought before weather conditions allow them to set roots. People can spread cacti for ornamental plantings.

Control

Managing opuntioid cacti

The GBO requires a person to take reasonable and practical steps to minimise the risks posed by opuntioid cacti. This fact sheet provides information and some options for controlling opuntioid cacti.

Mechanical and fire control

Mechanical control using machinery is difficult because prickly pear pads can easily re-establish. A hot fire is an effective control method for dense prickly pear infestations. Before burning, consult Biosecurity Queensland to see if this practice is suitable for your pasture and land management practices.

Biological control

Investigations into biological control agents against prickly pear began in 1912. Over 150 insect species were studied throughout the world, with 52 species selected for transport to Queensland. Following intensive host specificity testing, 18 insects and one mite were released in Queensland. Nine insects and the mite remain established in Queensland. These species are:

Cactoblastis cactorum, a stem-boring moth

- *Dactylopius ceylonicus*, a cochineal mealy bug
- *Dactylopius opuntiae*, a cochineal mealy bug
- *Dactylopius confusus*, a cochineal mealy bug
- *Dactylopius tomentosus*, a cochineal mealy bug
- *Dactylopius austrinus*, a cochineal mealy bug
- *Chelinidea tabulata*, a cell-sucking bug
- *Tucumania tapiacola*, a stem-boring moth
- *Archlagocheirus funestus*, a stem-boring beetle
- *Tetranychus opuntiae*, prickly pear red spider mite.

These biological control agents continue to keep several prickly pear species under control. It is important to remember not all the agents attack all species.

The most successful of these agents were the moth *Cactoblastis cactorum* and five cochineal mealy bugs—*Dactylopius ceylonicus, D. opuntiae, D. confusus, D. tomentosus* and *D. austrinus*. The other agents are still around but not in sufficient numbers to provide control.

Cactoblastis cactorum (cactoblastis moth)

Larvae of this moth were introduced from Argentina in 1925. Cactoblastis proved to be the most effective agent against the common and spiny pest pears, destroying massive infestations in Australia. Larvae keeps these two pest pears controlled to an acceptable level most of the time, although it is less effective in some coastal and far western areas.

The larvae collectively eat out the contents of the pads, leaving empty pad skins and piles of mushy droppings. The orange and black larvae are occasionally observed on the outsides of pads. Cactoblastis also attacks most types of prickly pear but is not effective against them.

Dactylopius spp. (cochineal insects)

All female cochineal insects are small, sessile mealy bugs that spend their adult lives permanently attached to their host plants sucking plant juices. They are covered by a fine, white, waxy secretion and when crushed yield a carmine colouring. The adult males are small, free-flying insects that do not feed.

Dactylopius ceylonicus (monacantha cochineal, Argentine cochineal)

This South American mealy bug was released in 1914 and 1915 to control drooping tree pear. It destroyed the dense infestations existing at that time. It is specific to drooping tree pear and today remains the only effective biological control agent for drooping tree pear. This insect needs to be distributed manually.

Dactylopius opuntiae (prickly pear cochineal)

This mealy bug was introduced from Mexico and southern United States between 1920 and 1922. It is effective against common pest pear, spiny pest pear, velvety tree pear and Westwood pear and remains the main biological control agent against velvety tree pear and Westwood pear. This insect spreads slowly in nature and can be assisted manually.

Dactylopius confusus (prickly pear cochineal)

This mealy bug was introduced from Florida and released in 1933 against spiny pest pear. It remains effective against spiny pest pear in central Queensland but spreads slowly. This insect can be spread manually.

Dactylopius tomentosus (devil's rope pear cochineal)

This mealy bug was introduced from southern United States in 1925 and 1926. It is effective against devil's rope pear but works slowly.

Dactylopius austrinus (tiger pear cochineal)

This mealy bug was introduced from Argentina in 1932. It is specific to and effective against tiger pear. It rapidly reduces tiger pear populations but dies out in a paddock after the destruction of tiger pear. It needs to be reintroduced after tiger pear regrows.

Chelinidea tabulata (prickly pear bug)

This plant-sucking bug was introduced from Texas in 1921. It was effective against dense common pest pear before *Cactoblastis cactorum* was but is now relatively ineffective. This insect also attacks most other prickly pears. The adult is a pale brown bug up to 20 mm long that leaves characteristic round bleached spots on the surface of the cactus.

Tucumania tapiacola (prickly pear moth-borer)

This moth was introduced from Argentina in 1934 against tiger pear. Its solitary larvae feed internally and eat out tiger pear pads with limited effect. It has been observed attacking common pest pear and harrisia cactus.

Archlagocheirus funestus (tree pear beetle)

This stem-boring beetle was introduced from Mexico in 1935. It was effective against velvety tree pear and Westwood pear but has become rare since the dense stands of these prickly pears have gone.

Tetranychus opuntiae (prickly pear spider mite)

This mite was introduced from southern United States and Mexico in 1922. It was effective against common pest pear but is now rare and difficult to find. It causes distinctive scar tissue formation around areoles.

Distributing biological control agents

Cactoblastis

Cactoblastis can be spread manually by distributing eggs or larvae. Cactoblastis moths lay chains of eggs (eggsticks) on prickly pear pads from January to February and from September to November. The eggsticks are distinguished from spines by their curved appearance.

1. Collect the fragile eggsticks carefully.
2. Glue single eggsticks to small pieces of paper using a starch-based adhesive.
3. Pin the egg papers to prickly pear pads. (Eggs take up to one month to hatch.)
4. Collect pads or plants in which larvae are obviously still active.
5. At a release site place all the collected plant material in a small part of the infestation.
6. Subsequent generations of moths will disperse through the infestation.
7. Follow up the biological control with either herbicide or mechanical treatment.

Cochineals

Because several cochineal insects affect some prickly pears and not others, it is essential to know what prickly pear you wish to control.

1. Identify your prickly pear type.
2. Find the same prickly pear type which is being attacked by a cochineal.
3. Collect pads of the prickly pear with the insects.
4. Place affected pads against unaffected prickly pears at the release site.
5. Follow up the biological control with either herbicide or mechanical treatment.

Tiger pear cochineal

Tiger pear cochineal is easy to multiply quickly after collection.

1. Carefully collect a reasonable quantity of unaffected tiger pear in a container (box or bucket).
2. Place a few pieces of cochineal-affected tiger pear into the same container.
3. Cover the container with a cloth and store under cover for a few weeks.
4. Check the cactus occasionally.
5. When most of the tiger pear in the container has cochineal, it is ready to distribute.
6. At the release site place affected pads against unaffected prickly pears.
7. Follow up the biological control with either herbicide or mechanical treatment.

Note: It is best to multiply tiger pear cochineal before release.

Herbicide control

Herbicide options available for the control of optuntioid cacti in Queensland are shown in Table 1.

Landholders and contractors should check if the property is in a hazardous area as defined in the *Agricultural Chemicals Distribution Control Act 1966* prior to spraying.

Further information

Further information is available from your local government office, or by contacting Biosecurity Queensland on 13 25 23 or visit www.biosecurity.qld.gov.au.

Table 1. Herbicides for the control of opuntioid cacti

Pest name	Situation	Herbicide	Rate	Method
Common prickly pear	Agricultural non-crop areas, commercial and industrial areas, fence lines, forestry, pastures and rights-of-way	Triclopyr 240 g/L + picloram 120 g/L (e.g. Access)	1 L/60 L diesel	Basal bark/cut stump Apply as an overall spray, wetting all areas of plant to ground level
	Agricultural non-crop areas, commercial and industrial areas, forests, pastures and rights-of-way	Triclopyr 300 g/L + picloram 100 g/L (e.g. Conqueror) or Triclopyr 300 g/L + picloram 100 g/L + aminopyralid 8g/L (Grazon Extra)	500 mL/100 L	Apply as a thorough foliage spray
		Triclopyr 600 g/L) e.g. Garlon 600)	3 L/100 L or 0.8 L/60 L diesel	
Coral cactus	Agricultural non-crop areas, commercial and industrial areas, fence lines, forestry, pastures and rights-of-way	Triclopyr 240 g/L + picloram 120 g/L (e.g. Access)	1 L/60 L diesel	Basal bark/cut stump Apply as an overall spray, wetting all areas of the plant to ground level
	Pastures, rights-of-way, commercial/industrial areas	Triclopyr 240 g/L + picloram 120 g/L (e/g/ Access)	1 L/60 L diesel See permit PER13812 (expires 30/11/2017)	Paint stump immediately after cutting or spray basal bark
Tiger pear	Agricultural non-crop areas, commercial and industrial areas, fence lines, forestry, pastures and rights-of-way	Triclopyr 240 g/L + picloram 120 g/L (e.g. Access)	1 L/60 L diesel	Basal bark/cut stump Apply as an overall spray, wetting all areas of plant to ground level
	Agricultural non-crop areas, commercial and industrial areas, forests, pastures and rights-of-way	Triclopyr 600 g/L (e.g. Garlon 600)	3 L/100 L water or 0.8 L/60 L diesel	Apply as a thorough foliage spray
Drooping tree pear	Agricultural non-crop areas, commercial and industrial areas, fence lines, forestry, pastures and rights-of-way	Triclopyr 300 g/L + picloram 100 g/L (e.g. Conqueror) or Triclopyr 300 g/L + picloram 100 g/L + aminopyralid 8g/L (Grazon Extra)	500 mL/100L water	
	Non-crop areas around buildings, commercial and industrial areas, domestic and public service areas, rights-of-way	Amitrole 250 g/L + ammonium thiocyanate 220 g/L (e.g. Amitrole T)	1 mL/3 cm (inject) or 1 L/25 L (small plants/regrowth)	Tree pears may take up to 12 months to die Resparying may be needed in some cases Consult label
Velvety tree pear	Agricultural non-crop areas, commercial and industrial areas, fence lines, forestry, pastures and rights-of-way	Triclopyr 240 g/L + picloram 120 g/L (e.g Access)	1 L/60 L diesel	Basal bark/cut stump Apply as an overall spray, wetting all areas of plant to ground level
	Non-crop areas around buildings, commercial and industrial areas, domestic and public service areas, rights-of-way	Amitrole 250 g/L + ammonium thiocyanate 220 g/L (e.g. Amitrole T)	1 mL/3 cm (inject) or 1 L/25 L (small plants/regrowth)	Tree pears may take up to 12 months to die Resparying may be needed in some cases Consult label
Spiny pest pear Westwood pear Devil's rope pear Snake cactus	Agricultural non-crop areas, commercial and industrial areas, fence lines, forestry, pastures and rights-of-way	Triclopyr 240 g/L + picloram 120 g/L (e.g. Access)	1 L/60 L diesel	Basal bark/cut stump Apply as an overall spray, wetting all areas of plant to ground level

Snake cactus (*Cylindropuntia spinosior*)

Coral cactus (*Cylindropuntia fulgida*)

Hudson pear (*Cylindropuntia rosea*)

Jumping cholla (*Cylindropuntia prolifera*)

Prickly pear (*Opuntia stricta*)

Bunny ears (*Opuntia microdasys*)

Tiger pear (*Opuntia aurantiaca*)

Riveria pear (*Optunia elata*)

Devil's rope pear (*Cylindropuntia imbricata*)

Drooping tree pear (*Opuntia monacanta*)

This fact sheet is developed with funding support from the Land Protection Fund.

Restricted invasive plant

Rubber vine

Cryptostegia grandiflora and *Cryptostegia madagascarensis*

Rubber vine's ability to quickly spread and colonise areas makes it a threat to many areas of northern Australia. Due to this ability, rubber vine is listed as a Weed of National Significance.

Rubber vine generally invades waterways first, where the seeds germinate in moist silt layers after rain. The plant smothers riparian vegetation and forms dense, sometimes impenetrable, thickets.

This decreases biodiversity and prevents access to both stock and native animals. It also creates habitat for feral animals. Infestations expand outward from waterways, hillsides and pastures, resulting in loss of grazing land and increased difficulty in mustering stock.

Rubber vine is poisonous to stock, though seldom eaten. Most deaths due to rubber vine occur after stock have been stressed, or when other feed is scarce.

Queensland Government

Legal requirements

Rubber vine (*Cryptostegia grandiflora*) and ornamental rubber vine (*Cryptostegia madagascarensis*) are restricted invasive plants under the *Biosecurity Act 2014*. They must not be given away, sold, or released into the environment without a permit. The Act requires everyone to take all reasonable and practical steps to minimise the risks associated with invasive plants and animals under their control. This is called a general biosecurity obligation (GBO). This fact sheet gives examples of how you can meet your GBO.

At a local level, each local government must have a biosecurity plan that covers invasive plants and animals in its area. This plan may include actions to be taken on certain species. Some of these actions may be required under local laws. Contact your local government for more information.

Description

Rubber vine is a vigorous climber with twining, whip-like shoots that can grow unsupported as an untidy, multi-stemmed shrub 1–2 m high, or it can scramble up to 30 m high in trees. The stems, leaves and unripe pods exude a white, milky sap when broken or cut.

Leaves are dark green and somewhat glossy, 6–10 cm long, 3–5 cm wide, and in opposite pairs.

Flowers are large and showy, with five white to light purple petals arranged in a funnel shape.

The seed pods are rigid and grow in pairs at the end of a short stalk. The pods are 10–12 cm long, 3–4 cm wide and each can contain up to 450 brown seeds. Each seed has a tuft of long, white, silky hairs, which enable easy dispersal by wind and water.

Ornamental rubber vine (*Cryptostegia spilanthoides*) is a shrub up to 3 m tall, if unsupported and stems can climb to 10 m if supported. Bark is sparsely dotted with corky patches. Leaves are dark green, glossy, with pale underside, 2–11 cm long, 1.5–5.5 cm wide, arranged in opposite pairs. Plant produces milky latex sap when leaves, fruit or branches are cut.

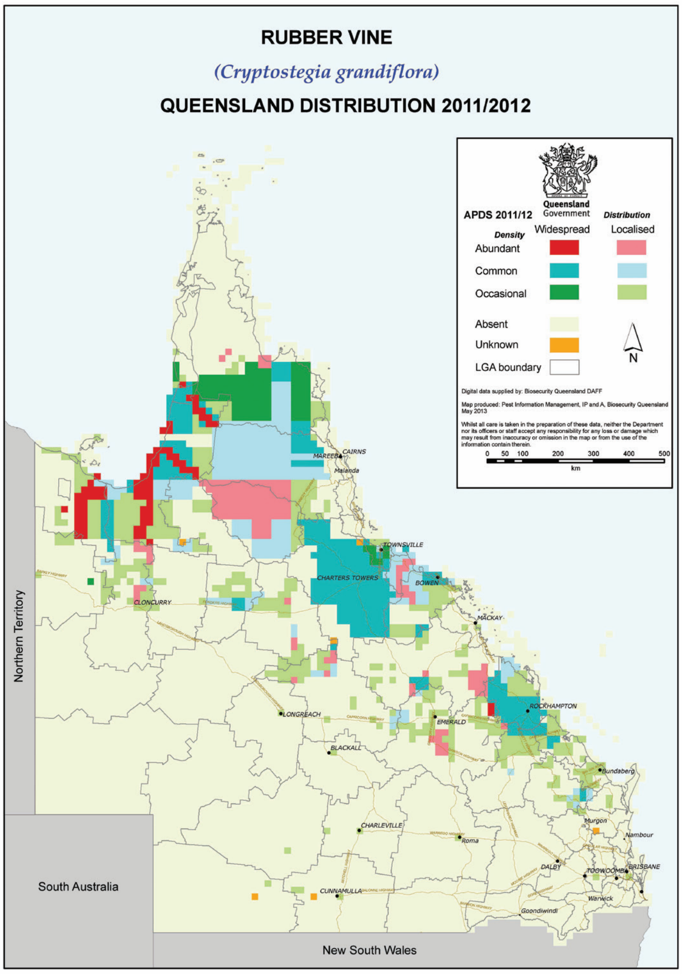
Flowers are pink-purple, 4–6 cm long, found near branchlet ends. Pods are 7–9 cm long, contain seeds 5–5.9 mm long, 1.8–3.5 mm wide, topped with silky tuft of white hairs.

Life cycle

Rubber vine flowers at any time of year if sufficient moisture is available. Usually, June and July are the only non-flowering months. Plant stem diameter must be approximately 20 mm before flowering can occur.

Seed pod formation occurs from spring to late autumn, with peak seed production corresponding to maximum flowering. Eventually, pods dry out and split open, with pod-splitting occurring approximately 200 days after formation.

Map 1. Distribution of rubber vine in Queensland



Seeds are scattered by wind, but also carried downstream by water. Approximately 95% of seed is viable, although germination requires favourable temperature and soil moisture conditions.

Methods of spread

Rubber vine seeds spread by wind and water.

Habitat and distribution

Rubber vine is native to Madagascar, but is now widely distributed throughout tropical and subtropical regions of the world.

The plant was introduced to Australia as an ornamental shrub in 1875 or earlier, and was popular in north Queensland mining settlements due to its luxuriant growth even under harsh conditions. Weedy infestations were recorded around Charters Towers early this century.

Rubber vine prefers areas where annual rainfall is 400–1400 mm, and is well adapted to a monsoonal climate.

Infestations of rubber vine are now found throughout river systems of southern Cape York and the Gulf of Carpentaria, south along the coast to the Burnett River, and isolated infestations occur as far south as Gatton and as far west as the Northern Territory border.

Infestations are common throughout central Queensland, while in western Queensland there are infestations in the Mount Isa, Longreach and Aramac areas. Isolated infestations have been reported in Western Australia.

Control

Managing rubber vine

The GBO requires a person to take reasonable and practical steps to minimise the risks posed by rubber vine. This fact sheet provides information and some options for controlling rubber vine.

Effective control of rubber vine can be achieved by a number of methods, alone or in combination depending on the situation and the severity of infestation. All areas treated must be periodically checked and any regrowth treated or the initial treatment efforts will be wasted.

Rubber vine seed is most commonly spread by wind and running water.

It is thus difficult to prevent seed coming onto uninfested land if there is rubber vine anywhere in the area. Your goal should be to prevent rubber vine from establishing and forming dense infestations. It is essential to regularly inspect all areas of your property, paying particular attention to creeks and gullies.

This is most important where prevailing winds are known to blow from infested areas, or where infestations occur upstream.

Any isolated plants located should be treated promptly.

All control of rubber vine will require follow-up treatments to keep your property clean. As rubber vine spreads quickly, small infestations should be controlled first to prevent them from becoming major problem areas. Dense infestations are difficult and costly to treat.

Follow-up treatment must be budgeted for within the overall control program. Techniques need to be integrated for successful rubber vine management. Consideration should be given to coordinating control over a catchment area.

Five suggested strategies for controlling rubber vine in scattered, medium, and dense infestations are outlined in Table 2.

Fire

Rubber vine infestations can be very effectively controlled by burning. Preparing and managing fuel load prior to burning, and following up in a timely manner after the fires, are critical to the overall success of the program.

It is recommended that you perform two successive annual burns. The first fire will open up the infestation to increase grass growth (fuel load) while killing rubber vine plants. The second fire will clean up the regrowth that occurs after the first fire.

An appropriate fire regime is an effective tool for managing rubber vine over the long term, as well as being an effective follow-up to other control methods.

Mechanical control

Several mechanical techniques are effective in controlling rubber vine. The type of infestation will determine the technique required.

- Scattered or medium-density infestations: Where possible, repeated slashing close to ground level is recommended.
- Dense infestations: During winter, stick-raking or blade-ploughing reduces the bulk of the infestation. Pasture should be sown and windrows burned to kill residual seed. Follow-up treatment is essential. It is important to comply with the relevant state and/or local government native vegetation legislation, and it should be noted that causing even accidental death of vegetation can be a breach of this legislation.

Biological control

Two biological control agents are successfully established, and their impact depends on abundance. Both agents cause abnormal defoliation, creating an ‘energy sink’, which appears to reduce seed production. These agents usually do not kill established rubber vine plants.

Diseases

Rubber vine rust (*Maravalia cryptostegiae*) is established over a wide area. Yellow spores form under the leaves and are spread mainly by the wind.

It is most active over summer, abundance being directly related to leaf wetness, which is dependent on rainfall and dew. Over summer, a generation is completed every seven days. Rust activity is reduced over the dry season.

Continued heavy infection causes defoliation, appears to reduce seed production, can kill small seedlings and causes dieback of the whip-like stems. Established plants are not killed.

Insects

Also established is the moth *Euclasta whalleyi*, whose larvae are leaf feeders. Observation indicates the moth prefers stressed plants, either from limited soil moisture or high levels of rust infection.

The moth’s period of activity is the dry season. A native fly parasite and a disease can reduce the localised abundance of the *Euclasta* larvae.

The larvae are tapered at both ends, grow up to 30 mm long, and are grey-brown with orange dots along their sides. Fine silken threads and black, bead-like droppings are often found near the larval feeding damage.

The creamy-brown moths are active at night and rest at a 45° angle from a surface, with their wings folded. The life cycle from egg to adult takes 21–28 days.

Defoliation reduces the smothering effect on other vegetation and causes an increase in leaf litter and promotes increased grass growth amongst rubber vine, increasing fuel loads required for fire management. Decreased flower and pod production should reduce the ability of rubber vine to spread.

Herbicide control

Basal bark spray

This method gives a high level of control although it is not as effective on multi-stemmed plants as it is difficult to spray each stem completely around the base.

Thoroughly spray around the base of the plant to a height of 20–100 cm above ground level, spraying higher on larger plants.

Optimum results are attained when the plant is actively growing.

Cut stump treatment

This is the most successful method of herbicide control, but also the most labour intensive. The following points should be followed carefully:

- cut the stem off as close to the ground (within 15 cm) as possible; for smaller plants use a machete or similar; larger plants may require a chainsaw
- make sure the cut is horizontal
- immediately spray or swab the cut surface
- a cost-effective method for scattered to medium-density infestations is the use of a brush-cutter.

Soil application

Because of the high risk of killing non-target vegetation, including trees and pasture plants, soil-applied herbicides play a role in controlling rubber vine only in specific situations.

It is important to comply with the relevant state and/ or local government native vegetation legislation, and it should be noted that causing even accidental death of vegetation can be a breach of this legislation.

The following points should be followed carefully:

- do not use residual herbicides within a distance of two or three times the height of desirable trees
- do not use Graslan along waterways or land with greater than a 20^{0} slope
- a minimum of 50–80 mm of rainfall is required before residual herbicides are taken up by the plant.

Further information

Further information is available from your local government office, or by contacting Biosecurity Queensland on 13 25 23 or visit www.biosecurity.qld.gov.au.

Table 1. Herbicides for the control of rubber vine

Situation	Herbicide	Rate	Comments
Agricultural non-crop areas, commercial and industrial areas, forests, pastures and rights-of-way	Triclopyr 300 g/L + Picloram 100 g/L + Aminopyralid 8 g/L (Grazon Extra) or Triclopyr 300 g/L + Picloram 100 g/L (e.g. Conqueror)	350–500 mL/ 100 L water	High volume spray Actively growing plants not infected with rust Use the higher rate for dense stands higher than 1.5 m tall at flowering (consult label)
Native pastures, rights-of-way, commercial and industrial areas	Metsulfuron-methyl 600 g/kg (e.g. Associate, Ken-Met 600)	15 g/100 L water	High volume spray on actively growing plants Apply to actively growing bushes up to 3 m tall, October through April Wetting agent is critical Complete coverage is essential May damage pasture legumes (consult label)
Agricultural non-crop areas, commercial and industrial areas, forests, pastures and rights-of-way	2,4 D 300 g/L + Picloram 75 g/L (e.g. Tordon 75-D, Commander 75-D)	1.3 L/100 L water	Treat actively growing plants Thoroughly wet leaves and soil around base of plant Less effective than other treatments
Around agricultural buildings and other farm non-crop situations, commercial, industrial, and public service areas, rights-of-way and waster land, away from desirable vegetation	Imazapyr 250 g/L (e.g. Unimaz 250 SL)	4 mL/L water	High volume application to actively growing plants (consult label)
Non agricultural areas (native pastures) commercial and industrial areas and rights-of-way	Aminopyralid 375 g/kg plus Metsulfuron-methyl 300 g/kg (e.g. Stinger)	30 g/100L water plus wetting agent (consult label)	Apply to bushes up to 3 m in height Apply from October to April when bushes are actively growing. Ensure thorough spray coverage of all foliage and leaders Incomplete coverage will result in regrowth
Native pastures, rights-of-way, commercial and industrial areas	Triclopyr 75 g/L + Metsulfuron-methyl 28 g/L (e.g. Zelam Brush Weed)	375 mL/100L	Spray actively growing plants up to 3 m tall, from October to April. Thoroughly spray all foliage and leaders. Incomplete coverage will result in regrowth
Agricultural non-crop areas, commercial and industrial areas, fencelines, forestry, pastures and rights-of-way	Triclopyr 240 g/L + Picloram 120 g/L (e.g. Access)	1 L/60 L diesel	Basal bark plants up to 5 cm basal diameter Treat at any time Thoroughly spray around base of plant
Agricultural non-crop areas, commercial and industrial areas, forests, pastures and rights-of-way	Triclopyr 600 g/L (e.g. Garlon 600, Triclopyr 600)	1 L/60 L diesel	Basal bark Treat at any time Thoroughly spray around base of plant
Agricultural non-crop areas, commercial and industrial areas, fencelines, forestry, pastures and rights-of-way	Triclopyr 240 g/L + Picloram 120 g/L (e.g. Access)	1 L/60 L diesel	Cut stump Apply immediately cut is made
Agricultural non-crop areas, commercial and industrial areas, forests, pastures and rights-of-way	Triclopyr 600 g/L (e.g. Garlon 600, Triclopyr 600)	1 L/60 L diesel	Basal bark size and larger plants
Non-crop areas, including: native vegetation, conservation areas, gullies, reserves and parks	Picloram 44.7 g/L + aminopyralid 4.47 g/L (Vigilant II)	Undiluted	Cut stump as close to the ground as possible. Apply immediately according to label instructions
Pastures, rights-of-way and industrial	2,4-D as amine 700 g/L (e.g. Amicide Advance 700)	145 mL/10L water	Cut stump Apply immediately
Other formulations of 2,4-D are also registered for cut-stump treatment of rubber vine. Consult labels for registration details, rates and critical comments.			
	Hexazinone# 250g /L (e.g. Bobcat®SL, Velpar®L)	2 mL/spot, 3 spots for each bush (tree)	Soil application# prior to rain See warning below. #Must place spots around bush. Less effective on sandy soils
	Tebuthiuron# 200 g/kg (e.g. Graslan, Tebuthiuron 200)	1.5 g/m^2	Soil application# prior to rain Application prior to rain by hand or backpack spreader
	Triclopyr 300 g/L + Picloram 100 g/L+ Aminopyralid 8 g/L (Grazon Extra) or Triclopyr 300 g/L + Picloram 100 g/L (e.g. Conqueror, Grass-up)	3–5 L/ha	Aerial application (helicopter only) to actively growing plants Triclopyr 300 g/L + Picloram 100 g/L
	Tebuthiuron# 200 g/kg registered for aerial application (e.g. Graslan)	7.5–15 kg/ha	Aerial application prior to rain Triclopyr 300 g/L + Picloram 100 g/L

Warning: Soil testing is highly recommended prior to application of these herbicides, as rate and efficacy are dependant on soil type.
DO NOT USE SOIL APPLIED HERBICIDES (HEXAZINONE AND GRASLAN) WITHIN A DISTANCE OF TWO TO THREE TIMES THE HEIGHT OF DESIRABLE TREES.
DO NOT USE GRASLAN NEAR WATERWAYS OR LAND WITH GREATER THAN A 20° SLOPE.

Read the label carefully before use. Always use the herbicide in accordance with the directions on the label.

Table 2. Suggested strategies for the control of rubber vine

Situation	Initial treatment	Follow-up	Comments
Scattered infestations	Basal bark/ cut stump	Follow-up with basal bark/ cut stump as necessary	Cut stump method preferred where possible
	Foliar spray	Follow-up basal bark/ cut stump/foliar spray as necessary	Only foliar spray when there is nil to little rust on the leaves of the plants
	Fire	Follow-up basal bark/ cut stump/foliar spray as necessary	For scattered infestations usually recommended only if herbicides not desired, or if have other weeds can be controlled by fire or if fire is utilised to improve pastures
	Repeated slashing		
Medium infestations	Foliar spray	Treat regrowth, seedlings with basal bark/cut stump/ foliar spray	Fire and follow-up with basal bark/cut stump/foliar spray as necessary
	Fire	Fire 1 year later and follow-up basal bark/cut stump/ foliar spray as necessary	If fuel load is sufficient **CAUTION:** There are some native tree species which are susceptible to fire Check before burning
	Repeated slashing		
Dense infestations previously cleared areas	Stick rake or blade plough	Sow pasture – basal bark/ foliar spray – fire and basal bark/cut stump/foliar spray as necessary	First treatment clears bulk of rubber vine and kills roots; any regrowth or seedlings can then be treated; when grass growth allows fuel build up, fire used as control and individual plants later treated
	Fire	Fire one year later and follow-up basal bark/ cut stump/foliar spray as necessary	If fuel load is sufficient **CAUTION:** There are some native tree species which are susceptible to fire Check before burning
	Aerial spray	Fire 1–2 years later or follow-up with basal bark spray	Bulk of rubber vine killed with aerial spray; allow build up of fuel for fire or treat remaining plants with basal bark spray Contact 13 25 23 before use of this method
	Graslan		Where situation and soil type are suitable
Dense infestations along creeks and rivers	Basal bark/ cut stump	Fire or basal bark/cut stump/foliar spray	When bulk of rubber vine killed, allow fuel build up for fire or treat remaining plants individually
	Fire and sow pasture	Fire one year later and follow-up basal bark/cut stump/foliar spray as necessary	If there is a sufficient fuel load to carry a fire, it can open up dense infestations **CAUTION:** There are some native tree species which are susceptible to fire Check before burning

This fact sheet is developed with funding support from the Land Protection Fund.

Appendix K Pest Species and Management Plans

Invasive animal

Cane toad

Bufo marinus

The cane toad is not a declared pest in Queensland, so there is no legal requirement to control them.

Their original introduction in 1935 was to control agricultural pests, but they proved ineffective.

For the past 60 years, cane toads have been expanding their territory in Australia, and are capable of colonising at least four of the mainland Australian states.

As the toad's geographical range continues to expand, concern has increased about their detrimental environmental effects, particularly on the wetlands of the Northern Territory.

Studies into the feasibility of biological control have commenced.

Legal requirements

The cane toad is not a prohibited or restricted invasive animal under the *Biosecurity Act 2014*, however everyone has a general biosecurity obligation (GBO) to take reasonable and practical steps to minimise the risks associated with invasive plants and animals under their control.

Local governments have a biosecurity plan that covers invasive plants and animals in their area and may require additional actions to be taken on certain species; some of these may be applied under local laws. Refer to your local government for more information.

History of introduction and spread

The cane toad or giant toad is an amphibian, native to Central and South America. Cane toads have been introduced throughout the world as a biological control for insect pests of agriculture, most notably sugarcane.

A consignment of cane toads from Hawaii was released into Queensland cane fields in 1935. The introduction was surrounded by controversy as to the potential costs and benefits to Australia.

It was hoped that the toad would control Frenchi and greyback beetles—pests of economic importance to the sugarcane industry.

By 1941, however, it had become evident that the cane toad was exerting only limited control over its intended prey. There were two main reasons for this:

- Greyback beetles are only rarely in contact with the ground and Frenchi beetles invade cane fields at a time when the toads are absent due to a lack of protective cover.
- The cane toad has a wide-ranging and indiscriminate diet, and it was not solely dependant upon its intended prey.

The unlimited food source, suitable environment and low rates of predation allowed dynamic reproduction and spread. Toads were recorded in Brisbane only 10 years after release. The toad continues to thrive and has now invaded the Northern Territory and New South Wales (see Map 1).

Map 1. Distribution of the cane toad in Australia

The cane toad's advance is only limited by environmental factors, such as the availability of water for breeding, tolerable temperatures, suitable shelter and availability of food.

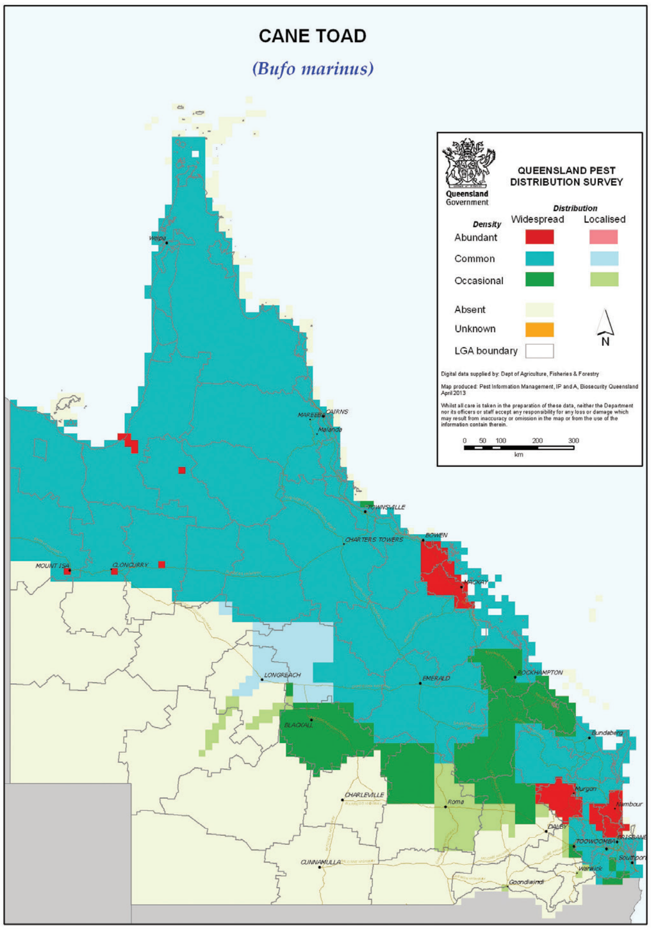
Toads at the frontier of their range of expansion may be larger than those in established populations. This is most probably due to greater food supply, combined with a lower incidence of disease.

Description

In comparison with native frog and toad species, adult cane toads have a distinctive head and face, and are large and heavily built creatures (adults may grow to 20 cm).

Following their aquatic larval stages (eggs and tadpoles), cane toads are generally encountered at night near any source of light. Cane toads are ground-dwelling—they are poor climbers and unable to jump very high.

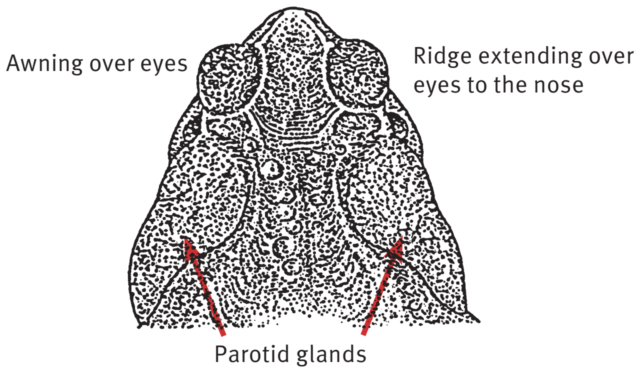
Map 2. Distribution of the cane toad in Queensland



A definite visor or awning extends over each eye and a high angular bony ridge extends from the eyes to the nose.

The parotid glands (see Figure 1) are perhaps the most characteristic feature of the adult cane toad. These glands are large, protuberant, and are situated on the head behind each ear. These glands carry a toxin.

Figure 1. Distinguishing features of the cane toad



The cane toad's hands and feet are relatively small and lack discs at the tips of the digits. Webbing is absent between the fingers but is distinct and leathery between the toes.

Colouring on the dorsal (upper) surface may be brown, olive-brown or reddish-brown. The ventral (under) surface varies from white to yellow and is usually mottled with brown.

Warts are present on all cane toads; however, males possess more than females. Warts are dark brown at the caps.

Mating

Mating can occur at any time of the year and depends only on available food and permanent water. The mating call is a continuous purring trill that sounds like a running motor.

In situations where females are scarce or absent, male cane toads may have the ability to undergo a sex change to become fertile females; however, this has not been proved.

Eggs

Both cane toads and native frogs spawn in slow-moving or still water, but their eggs can be easily distinguished.

Cane toad eggs are laid in long, gelatinous ‘strings’ with the developing tadpoles appearing as a row of small black dots along the length. The strings are unique to cane toads, generally appearing as blobs of jelly attached to water plants or debris. Native frogs generally produce egg clusters as mounds of foam floating on the water surface.

Compared with native species, cane toad egg production is dynamic and a single clutch can contain up to 35 000 eggs. Remove any cane toad eggs found in the water and allow to dry out.

Figure 2. Drawing of toad spawn from Wildlife of greater Brisbane

Tadpoles

The cane toad is the only species in Australia that has a pure black tadpole. Native frogs have lighter-coloured undersides with a great range of colours and markings—cane toad tadpoles may turn paler colours to almost transparent at night.

Cane toad tadpoles are small and usually congregate in vast, slow-moving shoals. This ‘shoaling’ behaviour is uncharacteristic of most native species.

Unlike cane toad tadpoles, native species develop lungs at an early stage and periodically rise to the surface in order to exchange their lung gasses. Large groupings of tadpoles that do not break the water surface for air indicate cane toads.

Young toads

Following emergence from the water, the young toadlets usually congregate around the moist perimeter of the water body for about a week before they eventually disperse.

Young toads are very difficult to distinguish from the native *Uperoleiea* species, which also have parotid glands, but all *Uperolelea* species have bright red patches in the groin area.

Under ideal conditions toadlets may reach adult size within a year.

Toxicity

Bufo marinus produce venom in glands occurring in most of the skin on their upper surface. The venom is concentrated in the parotid glands as a creamy-white solution, which is released when the animal experiences extreme provocation or direct localised pressure (e.g. grasped by the mouth of a predator).

The parotid solution is highly toxic and when ingested it produces drastic acceleration of the heartbeat, shortness of breath, salivation and prostration. It is extremely painful if accidentally rubbed into the eye.

Ingestion of toads by domestic and most native animals can result in death. In some recorded cases, death has occurred within 15 minutes.

Field observations suggest that some predatory Australian species have learned how to feed safely on cane toads.

Birds have been observed flipping toads over to avoid the parotid glands. Predatory reptiles may have more trouble adapting, being unable to remove a toad from the mouth once they start feeding.

Impacts on wildlife

The cane toad is poisonous at all stages of its life cycle and most native frog larvae and many aquatic invertebrates are dramatically affected by their presence.

Cane toads are voracious feeders that consume a wide variety of insects, frogs, small reptiles, mammals and even birds. Perhaps the only limiting factor to the prey taken is the width of the cane toad’s mouth.

It has been suggested that cane toad competition for food and breeding grounds has been responsible for reducing the populations of some native frogs. However, many native frogs are arboreal (tree-dwelling) and occupy different niches. Cane toads don’t have the native frogs’ ability to ‘shut down’ during dry seasons when resources are limited.

Pressure from cane toads may displace native animals (frogs and other species) where they are already suffering due to manipulation of their habitat by humans and grazing animals. Animals that use waterholes as retreat sites during the dry season are especially vulnerable—toads will congregate here in large numbers.

Public health

Cane toads readily eat animal and human faecal material and, in areas of poor hygiene, they have been known to transmit disease such as salmonella.

Control

Control of cane toads is not enforced as there is currently no available effective broad scale control. Individuals and community groups have carried out removal campaigns to decrease numbers and slow the invasion front.

Fencing is recommended to keep toads out of ponds intended for native fish and frogs; a height of 50 cm is sufficient. Bird wire with 1 cm holes may keep toads out of an area.

Research indicates that spread can be delayed in semi-arid areas by blocking access to water holes.

Individual toads may be killed relatively humanely using a commercial spray available from hardware stores or may be stunned and decapitated (only by experienced operators). The removal of eggs from small water bodies such as frog ponds can be effective.

Researchers have successfully mitigated impacts in recently colonised areas by 'training' predators however, large scale application of this technique is difficult.

Further information

Further information is available from your local government office, or by contacting Biosecurity Queensland on 13 25 23 or visit www.biosecurity.qld.gov.au.

This fact sheet is developed with funding support from the Land Protection Fund.

Department of Agriculture, Fisheries and Forestry
Biosecurity Queensland

Fact sheet
PEST ANIMALS
PA2 October 2013

Declared animals of Queensland



Several animals are declared as Class 1, Class 2 or Class 3 pests under Queensland's *Land Protection (Pest and Stock Route Management) Act 2002*. Class 1 and 2 animals represent a threat to agriculture, primary industries, natural resources and the environment.

A Class 1 pest is one that is not commonly present in Queensland, and if introduced would cause an adverse economic, environmental or social impact. Class 1 pests established in Queensland are subject to eradication from the state. Landowners must take reasonable steps to keep land free of Class 1 pests. Other powers of the Act apply.

A Class 2 pest is one that is established in Queensland and has, or could have, a substantial adverse economic, environmental or social impact. The management of these pests requires coordination and they are subject to local government-, community- or landowner-led programs. Landowners must take reasonable steps to keep land free of Class 2 pests. Other powers of the Act apply.

Class 3 pests are established in Queensland. Landholders are not required to control a Class 3 declared pest animal on their land unless a pest control notice is issued by a local government because the pest is causing or has potential to cause an negative impact on an adjacent environmentally significant area.

It is an offence to supply a Class 3 pest. A permit for specific purposes may be issued by Biosecurity Queensland.

Other than the above requirements, declaration does not mean that management of declared species becomes the responsibility of the state, although the state may engage in publicity and awareness activities, research, coordination of control activities, or assistance with some pests in strategic areas.

Powers are provided for local governments and/or Biosecurity Queensland to request landowner control and to carry out enforcement activities where necessary.

Species not declared under the *Land Protection (Pests and Stock Route Management) Act 2002* may still be declared at a local government level under local laws. Species declared as Class 3 may be subject to local law and control outside environmentally significant areas.

The *Land Protection (Pest and Stock Route Management) Act 2002* also describes certain activities relating to Class 1 and 2 pest animals that are offences under the Act.

These activities relate to:

- introducing a pest animal to the state
- feeding a declared pest animal
- keeping a declared pest animal (except under permit by bona fide zoos and wildlife parks)
- releasing a declared pest animal.

The Chief Executive of the Department of Agriculture, Fisheries and Forestry may make an emergency declaration for an animal for a period of up to three months. An emergency declaration could be activated in the event of the discovery of a new and serious pest in Queensland.

Declared animals of Queensland

The following are classified as declared animals in Queensland:

Class 1 declared pest animals

All mammals, reptiles and amphibians are Class 1 pests except:

1. Class 2 declared pest animals
2. mammals, reptiles and amphibians indigenous to Australia, including marine mammals of the orders Pinnipedia, Sirenia or Cetacea
3. and the following non declared animals:
   - alpaca (*Lama pacos*)
   - Asian house gecko (*Hemidactylus frenatus*)
   - axolotl (*Ambystoma mexicanum*)
   - Bali cattle (*Bos javanicus* and *B. sondaicus*)
   - bison or American buffalo (*Bison bison*)
   - black rat (*Rattus rattus*)
   - camel (*Camelus dromedarius*)
   - cane toad (*Bufo marinus*)
   - cattle (*Bos* spp.)
   - chital (axis) deer (*Axis axis*) other than feral chital deer
   - domestic cat (*Felis catus*)
   - domestic dog (*Canis familiaris*)
   - domestic goat (*Capra hircus*)
   - domestic pig (*Sus scrofa*)
   - donkey (*Equus asinus*)
   - European hare (*Lepus capensis*)
   - fallow deer (*Dama dama*) other than feral
   - guanicoe (*Lama guanicoe*)
   - guinea pig (*Cavia porcellus*)
   - hog deer (*Axis porcinus*)
   - horse (*Equus caballus*)
   - house mouse (*Mus musculus*)
   - llama (*Lama glama*)
   - mule (*Equus caballus* x *Equus asinus*)
   - red deer (*Cervus elaphus*) other than feral red deer
   - rusa deer (*Cervus timorensis*) other than feral rusa deer
   - sewer rat (*Rattus norvegicus*)
   - sheep (*Ovis aries*)
   - wapiti deer (*Cervus canadensis*)
   - water buffalo (*Bubalus bubalis*)

Class 2 declared pest animals

- Australian plague locust (*Chortoicetus terminifera*)
- cat, other than a domestic cat (*Felis catus*)
- dingo (*Canis familiaris dingo*)
- dog, other than a domestic dog (*Canis familiaris*)
- European fox *(Vulpes vulpes)*
- European rabbit (domestic and wild breeds) (*Oryctolagus cuniculus*)
- feral chital deer (*Axis axis*)
- feral rusa deer (*Cervus timorensis*)
- feral pig (*Sus scrofa*)
- goat, other than a domestic goat (*Capra hircus*)
- migratory locust (*Locusta migratoria*)
- spur-throated locust *(Austracris guttulosa)*

Class 3 declared pest animals

- feral fallow deer (*Dama dama*)
- feral red deer (*Cervus elaphus*)

Introduction and keeping of declared animals

The Act provides for permits to be issued for the introduction and keeping of some declared animals under certain conditions. Most declared animals can only be kept at universities, bona fide zoos, game parks and wildlife parks. The keeping of most species of declared animals as pets is illegal and subject to penalty.

Control

The responsibility for controlling a declared animal rests with the landholder. However, Biosecurity Queensland and local governments provide expertise and technical information to assist landowners.

Further information

Further information is available from your local government office, or by contacting Biosecurity Queensland (call 13 25 23 or visit our website at www.biosecurity.qld.gov.au).

This fact sheet is developed with funding support from the Land Protection Fund.

Restricted invasive animal

Dingo

Canis familiaris dingo

The dingo is a primitive canid related to wolves and coyote. The dingo was not a part of the ancestral fauna of Australia. Though its origins are not clear, it is thought to have arrived in Australia 3500–4000 years ago.

It is the largest mammalian carnivore remaining in mainland Australia, and as such fills an important ecological niche. Females weigh about 12 kg and males 15 kg.

The dingo has been regarded as a serious predator of domestic stock since early European settlement in Australia.

Since European settlement domestic dogs have been released or escaped into the environment to cross with dingoes. These hybrids or crosses are colloquially call wild dogs (*Canis lupus familiaris*). Often the term wild dog covers both dingoes and dingo hybrids.

Wild dogs predate on livestock, native fauna and domestic pets.

Queensland Government

Legal requirements

The dingo is a restricted invasive animal under the *Biosecurity Act 2014*. It must not be moved, kept, fed, given away, sold, or released into the environment without a permit. The wild dog must not be moved, fed, given away, sold, or released into the environment without a permit.

The Act requires everyone to take all reasonable and practical steps to minimise the risks associated with invasive plants and animals under their control. This is called a general biosecurity obligation (GBO).

At a local level, each local government must have a biosecurity plan that covers invasive plants and animals in its area. This plan may include actions to be taken on certain species. Some of these actions may be required under local laws. Contact your local government for more information.

Description

Red, ginger and sandy-yellow are the dominant coat colours, though dingoes can also be pure white, black and tan or solid black.

It is not difficult to distinguish between most dingoes and hybrids. The presence of domestic genes is suggested by broken colours—brindling and patchiness in the normally pure white feet and chest patch and sable colouration (black hairs along the back and sides).

Dingoes have a more heavily boned skull and larger teeth (especially the canine) than domestic dogs of similar size.

Life cycle

Dingoes have only one breeding season per year (usually April to June), whereas domestic bitches have two or more oestrus cycles per year. However, unless seasons are particularly favourable, or human sources of food are intentionally or inadvertently provided, feral domestic dogs are unlikely to successfully rear two litters per year.

After a nine-week gestation, dingo pups (usually four to six) are born in a hollow log or cave den. Bitches tend to use the same den each year. Pups are suckled at four to six weeks and generally weaned at four months. When large enough to travel, pups are taken from the den to kills, and other dens many be used. The range of pups is increased as they are moved from den to den. In this way the pups are gradually moved around the bitch's home range.

Independence may occur as early as six months of age when parents abandon them, but this results in high juvenile mortality. Pups that become independent around 12 months appear to disperse voluntarily. Being larger and more experienced, mortality is then usually low.

Where dingoes live alone or in small groups (most pastoral and semi-settled areas), mature females will breed successfully each year.

By contrast, dominant female infanticide results in only one litter being successfully raised each year within groups containing several adult females (e.g. undisturbed areas such as the Simpson Desert). The dominant (alpha) female will kill all pups of the other females, and then use subordinate females to suckle and rear her litter.

Methods of spread

Dingoes in an undisturbed area generally belong to discrete packs (3–12 members), which occupy long-term, non-overlapping territories. The group rarely moves as a pack—rather, members meet and separate again throughout the day. Dingoes are most gregarious during the breeding season.

There is overlap of home ranges within a group. In contrast, boundaries between groups are more rigid, actively defended and infrequently crossed.

Olfactory communication (smell) is important in dingo social organisation. Dingo droppings are deposited along pads in specific areas where other dingoes will encounter them (creek crossings, intersections of roads and fences).

These 'scent posts' appear to delineate the home range boundary and act as a warning to neighbouring groups and individuals.

This strong site attachment of dingoes is contrary to the notion commonly held by property owners that dingoes will travel large distances to kill stock.

Habitat and distribution

Dingo numbers are believed to be higher today than in pre-European times. This is thought to be due to increased food availability via the introduced rabbit and cattle carcasses, and the development of permanent waters in arid areas of the state.

Dingoes/wild dogs are present in all parts of the state.

The distribution of the wild dog in relation to purebred dingoes varies throughout the state. In far western areas, most dingoes sighted appear to be 'pure', with characteristic white points and broad heads. Closer to settled areas a greater number of feral domestic dogs produce a generally hybrid population. It has been estimated that dingoes are 50% pure in south-eastern Queensland and 90–95% pure in south-western and central Queensland.

Radio tracking studies show dingoes occupy a discrete area known as a 'home range'. The dingo visits the edge of this area frequently.

The home range can vary in size according to the productivity of the country—from 9 km² in rainforest areas to 300 km² on the Nullarbor Plain.

The edge of the home range is commonly associated with a major topographic feature (e.g. an escarpment, a major ridge or stream).

The home range is not used uniformly. Activity is centred on areas with highest food density.

Hunting movement is slow and exploratory, in contrast to frequent rapid movement around the home range boundary.

Pads follow well defined paths and are most likely associated with sociality and home range boundary maintenance. Activity is highest at dusk and dawn.

Diet

Dietary research of stomach content and faecal scats has shown dingoes are opportunistic predators.

Medium-size animals such as kangaroos, wallabies, rabbits and possums consistently form the major part of the dingo diet.

Studies by the Western Australia Agriculture Protection Board show dingoes in undisturbed refuge areas killed and ate kangaroos strictly according to need.

On grazing country, however, 'dingoes harassed, bit or killed sheep in large numbers, often without eating any'. The consumption of these sheep carcasses was the exception rather than the rule. Even kangaroos in these areas were sometimes killed in 'play' type behaviour rather than for food.

Such dietary studies could suggest dingo predation of domestic stock is low. There is, however, a need for caution in using such studies to assess dingo impact on stock.

Grouping increases foraging efficiency and appears necessary to exploit larger prey. Dingoes cooperating in groups are more successful in hunting kangaroos than lone dingoes are. While lone dingoes can easily kill sheep, it is less likely a solitary dingo would successfully attack a calf in the presence of a defending cow.

Disease threat

Dingoes are vectors of canid diseases (e.g. distemper, parvovirus) and parasites. The hydatid parasite *Echinococcus granulosus* is a major problem of dogs and domestic stock. It can cause illness and occasionally death in humans.

The dingo could pose a serious risk if the exotic disease rabies was introduced to Australia.

Beneficial considerations

The establishment of watering points during post-European settlement has resulted in a huge increase in the kangaroo population, with consequent strong pasture competition with domestic livestock.

Though it is widely accepted that sheep production is near impossible in the presence of dingoes, many cattle producers will tolerate dingoes because of their believed suppression of kangaroo numbers.

Research has shown that in some cases the dingo has the potential to mitigate population growth of native species during abundant seasons and it could also be an important limiting factor for many feral animal populations (e.g. feral pigs and goats).

There is some evidence that destruction of the dingo could cause increases in other pests to the grazing industry and result in widespread degradation of environmentally sensitive areas. However, this has not been proven.

Further information

Further information is available from your local government office, or by contacting Biosecurity Queensland on 13 25 23 or visit www.biosecurity.qld.gov.au.

This fact sheet is developed with funding support from the Land Protection Fund.

Restricted invasive animal

Feral cat

Felis catus

A descendant of the African wild cat (*Felis silvestris lybica*), the common 'house' cat (*Felis catus*) has now been domesticated for about 4000 years. Although the domestic cat has a long history of association with humans, it retains a strong hunting instinct and can easily revert to a wild (feral) state when abandoned or having strayed from a domestic situation.

Semi-feral cats live around dump sites, alleys or abandoned buildings, relying on humans by scavenging rubbish scraps and sheltering in abandoned structures. The true feral cat does not rely on humans at all, obtaining its food and shelter from the natural environment.

Legal requirements

The feral cat is a restricted invasive animal under the *Biosecurity Act 2014*. This is a cat that is not domesticated. The feral cat must not be moved, fed, given away, sold, or released into the environment without a permit. The Act requires everyone to take all reasonable and practical steps to minimise the risks associated with invasive plants and animals under their control. This is called a general biosecurity obligation (GBO). This fact sheet gives examples of how you can meet your GBO.

Queensland Government

At a local level, each local government must have a biosecurity plan that covers invasive plants and animals in its area. This plan may include actions to be taken on certain species. Some of these actions may be required under local laws. Contact your local government for more information.

Description

The feral cat differs little in appearance from its domestic counterpart; however, when in good condition, the feral cat displays increased overall muscle development, especially noticeable around the head, neck and shoulders, which gives the animal a more robust appearance. The average body weight of male feral cats is 3–6 kg, while females weigh 2–4 kg. Body weights vary with condition, with some extremely large specimens documented.

Australian feral cats are predominantly short-haired, with coat colours that range between ginger, tabby, tortoiseshell, grey and black. White markings may be present on the feet, belly, chest and throat; completely white feral cats are extremely rare. In established populations, coat colours are the result of a natural, genetically selective process. Terrain, predators and the ability to capture prey limit coat colours to those that provide the most suitable camouflage and cause a predominance of these colours in subsequent offspring. Ginger cats are more likely to be found in the semi-arid and desert areas, while grey and black specimens generally predominate in scrub and more heavily timbered habitats.

The feral cat is most active at night, with peak hunting activity occurring soon after sunset and in the early hours before sunrise. At night the cat displays a distinctive green eyeshine under spotlight, making it easily distinguishable from other animals. During the day it will rest in any number of den sites, which may include hollow logs, dense clumps of grass, piles of debris, rabbit burrows, and even the hollow limbs of standing trees.

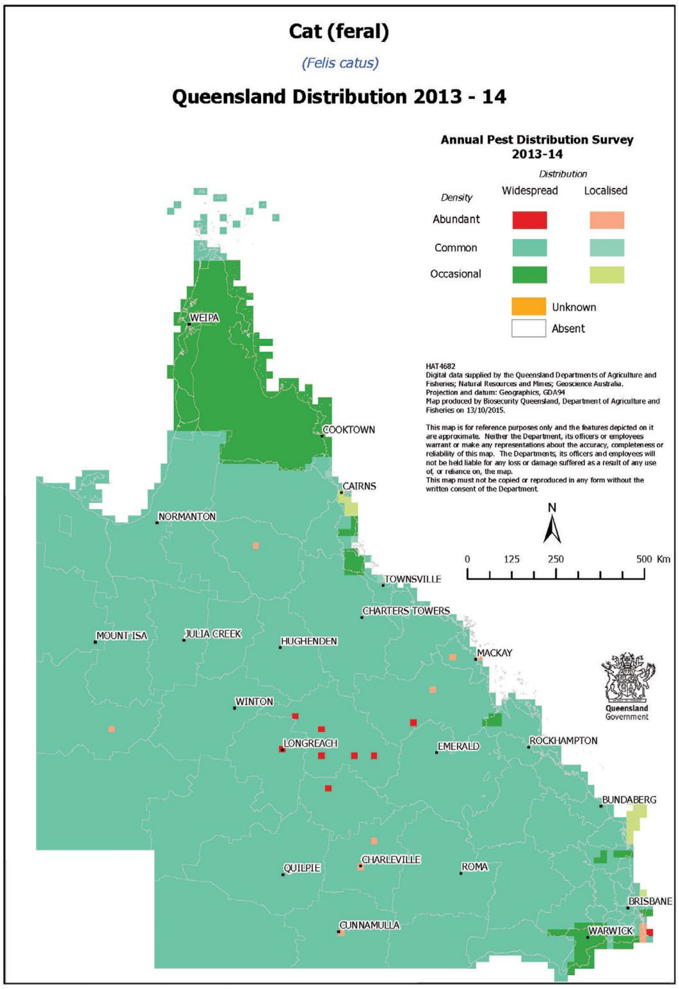
The most obvious and characteristic field signs of feral cats are their scats (droppings). Unlike the domestic cat, the feral cat does not bury its scats, but leaves them exposed at prominent sites to warn other cats of its territorial boundary.

Life cycle

Male cats attain sexual maturity at about 12 months, whereas females are capable of reproduction at approximately seven months. Annually, and under ideal conditions, an adult female can produce up to three litters—each of usually four kittens, but varying from two to seven.

As the breeding instinct is triggered by the increasing length of daylight, litters are less frequent in winter. Most reproduction occurs during the spring and summer months, and is generally limited to two litters per year. Birth follows a gestation period of 65 days, and kittens may be reared in a single den site or may be frequently shifted to other sites within the female's home range. Family and litter bonding begin to break down when the kittens are approximately seven months old. The female's ability to bear litters does not decrease with age, so reproduction continues for the course of her life.

Map 1. Distribution of feral cats in Queensland



Habitat and distribution

There is some evidence to suggest that the cat was present in Australia long before European settlement. This may have occurred as a result of Dutch shipwrecks and regular visits to northern Australia by early South-East Asian vessels as long as 500 years ago.

Post-settlement dispersal resulted from cats straying from areas of early colonisation. In the late 19th and early 20th centuries, large numbers of cats were purposely released in many rural areas to combat plague numbers of rabbits. Unwanted cats continue to be released into urban and rural areas by irresponsible pet owners.

The feral cat is now present Australia-wide, thriving under all climatic extremes and in vastly different types of terrain.

Feral cats maintain stable home ranges, the sizes of which depend upon the relative abundance of food and the availability of suitable den sites. Dominant male cats may have territories of up to 8 km^2, while the territories of females are smaller and may even be halved while kittens are being reared.

Scent glands are present on the chin, at the corners of the mouth, and in the anal region. Territorial boundaries are maintained by scent marking with the cheek glands, pole-clawing, urinating and leaving exposed faecal deposits.Although feral cats are often thought of as being solitary animals, studies show this behaviour is generally limited to hunting activities. At other times feral cats display a degree of social interaction that peaks during the breeding season. Group behaviour has been observed in semi-feral populations, and it has been suggested that such behaviour is exhibited also in feral populations.

Groups usually comprise several related adult females, their young of both sexes, and an adult male—whose range may include other groups of females. Young females usually remain in a group, while young males either leave or are driven from the group as they reach sexual maturity.

Impacts

Effects on wildlife

The energy expended by an adult male cat requires it to consume 5–8% of its body weight in prey per day, while females raising kittens require 20%. Based on these figures, one study concluded that 375 feral cats on Macquarie Island would consume 56 000 rabbits and 58 000 sea birds per year. Where present on the mainland, rabbits may comprise up to 40% of a feral cat's diet. Cats are successful as a control mechanism only when rabbit densities are low. At other times cat predation does little to halt the build-up or spread of rabbit populations; rabbits merely help to support a larger number of cats. When seasonal shortages of rabbits occur there is a corresponding rise in the number of native animals taken by cats.

The feral cat is an opportunistic predator, and dietary studies have shown that small mammals, birds, reptiles, amphibians, insects and even fish can be taken as prey. Cat predation is particularly harmful in island situations, and a number of species have become extinct due to the introduction of cats by early sealers and lighthouse keepers. On the mainland, native animals—which already suffer due to the destruction of their habitats by man and other introduced animals—may be endangered further by cat predation. Actual competition for prey can cause a decline in the numbers of native predatory species such as quolls, eagles, hawks and reptiles. Not only do native animals bear the brunt of predation, but they also suffer the effects of a parasite that reproduces only in the intestine of the cat. This disease (toxoplasmosis) is particularly harmful to marsupials, which may develop blindness, respiratory disorders, paralysis, and suffer the loss of offspring through abortion and stillbirths.

Exotic disease—rabies

Due to their widespread distribution, feral cats may prove to be a major vector for this fatal viral disease if it ever enters Australia. Overseas studies have revealed that wounds inflicted by rabid cats are more dangerous than those caused by rabid dogs. While the bites of rabid dog are generally inflicted on the arms and legs, the cat attacks the head of its victim, biting and clawing viciously. These head and facial bites reduce the time taken for the virus to enter the central nervous system, lessening the chance of success from subsequent remedial treatment.

Control

Managing feral cats

The GBO requires a person to take reasonable and practical steps to minimise the risks posed by feral cats. This fact sheet provides information and some options for controlling cats.

Exclusion fencing

Fencing is the only feasible method of control when special areas need protection from cats. Feral cats have been successfully prevented from climbing over netted fences that use an electrified wire mounted 15 cm from the top and 10 cm outward from the fence. Non-electrified fencing should incorporate a netted ceiling, or a curved overhang, which prevents the cat from climbing straight up and over the fence.

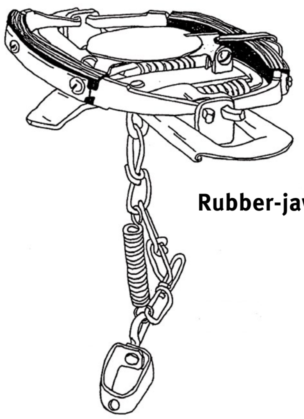
Trapping

Rubber-jawed, leg-hold traps (see below) can be laid in the same manner as they are laid for dingoes and foxes. Leg-hold traps can work well with true feral cats, which would normally avoid the live-capture box traps.

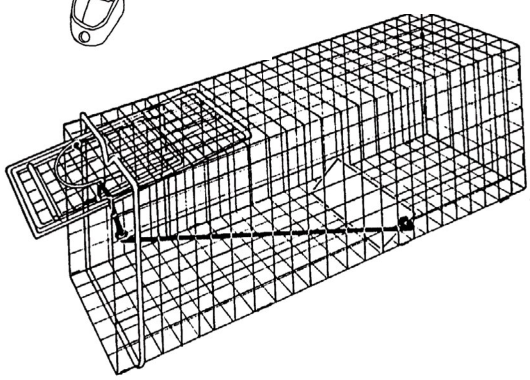
Ideal sites are those where territorial markers, such as faecal deposits and pole-clawing, are noticed. Tuna fish oil has shown some success as an attractant; however, feral cats seem more readily attracted to a site by some visual stimulus such as a bunch of bird feathers hung from a bush or stick.

Semi-feral urban cats are easily trapped in wire 'treadle-type' box traps (see diagram at right). Attractants/lures may be of meat or fish and should be placed so that they cannot be reached through the wire and be retrieved by clawing.

A number of local governments hire cat traps for the purpose of removing stray and feral cats in urban situations.



Rubber-jawed leg-hold trap



Treadle box trap

Lures

Audible recorded lures for feral cats and other predators are available through a number of sources. These recordings mimic the distress call of a small animal and can be used to draw a predator to a bait or trap site.

Shooting

Night shooting is assisted by the cat's distinctive, green eyeshine. Cats have been successfully attracted by the use of a fox whistle.

Poisoning

Fresh meat baits containing 1080 may be used for controlling feral cats under APVMA PERMIT14015. To obtain a copy of this permit visit www.apvma.gov.au.

Only authorised persons can supply 1080 baits to landholders.

Further information

Further information is available from your local government office, or by contacting Biosecurity Queensland on 13 25 23 or visit www.biosecurity.qld.gov.au.

This fact sheet is developed with funding support from the Land Protection Fund.

Restricted invasive animal

Feral pig

Sus scrofa

Pigs were introduced to Australia by early settlers. Subsequent accidental and deliberate releases resulted in the wild (feral) population establishing throughout Australia.

Feral pigs cause environmental and agricultural damage, spread weeds and can transmit exotic diseases such as leptospirosis and could spread foot-and-mouth disease.

Legal requirements

The feral pig is a restricted invasive animal under the *Biosecurity Act 2014*. It must not be moved, fed, given away, sold, or released into the environment without a permit. The Act requires everyone to take all reasonable and practical steps to minimise the risks associated with invasive plants and animals under their control. This is called a general biosecurity obligation (GBO). This fact sheet gives examples of how you can meet your GBO.

At a local level, each local government must have a biosecurity plan that covers invasive plants and animals in its area. This plan may include actions to be taken on certain species. Some of these actions may be required under local laws. Contact your local government for more information.

An animal ceases being considered an invasive restricted animal (feral) if a person is keeping it and has become a registerable biosecurity entity (RBE) to keep that designated animal. Feral pigs can be considered as designated animals if a person keeps them.

Description

Feral pigs are typically smaller, leaner and more muscular than domestic pigs with well developed shoulders and necks, and smaller, shorter hindquarters.

The body is usually covered in sparse, coarse hair and they have a longer, larger snout, longer tusks, a straighter tail and narrower back than domestic pigs. Feral pigs are mostly black, buff-coloured or spotted black and white.

Growth potential is similar to domestic pigs, although harsh environmental conditions tend to stunt development. Adult female feral pigs usually weigh 60–75 kg, while males usually weigh 90–110 kg. Older boars (razorbacks) can have massive heads and shoulders and a raised and prominent back bone that slopes steeply down to small hams and short hind legs. Some boars develop a crest or mane of stiff bristles extending from their neck down the middle of their back.

Life cycle

Under good seasonal conditions, breeding occurs all year and sows can produce two litters per year. Adult females have a 21–day oestrus cycle, with a gestation period of about 113 days, producing a litter of 4–10 piglets. Sows can make nests of available vegetation just before farrowing. Nests sometimes have a domed roof and are usually less than 2 km from available water. Piglets normally spend the first 1–5 days of life inside the nest, with the sow nearby. Weaning occurs after 2–3 months. Sexual maturity is reached when sows weigh about 25 kg, usually around six months of age.

Mortality of juveniles is high if the mother's dietary protein intake is low (up to 100% mortality in dry seasons). Adult mortality does not vary as much with seasonal conditions, but few animals live more than five years.

Social behaviour

Feral pigs are generally nocturnal, spending daylight hours sheltering in dense cover. Pigs are omnivorous, eating plants and animals and are extremely opportunistic feeders, exploiting any temporarily abundant food.

They prefer green feed and will eat grains, sugarcane and other crops, fruit and vegetables. They root extensively for tubers, worms and soil invertebrates.

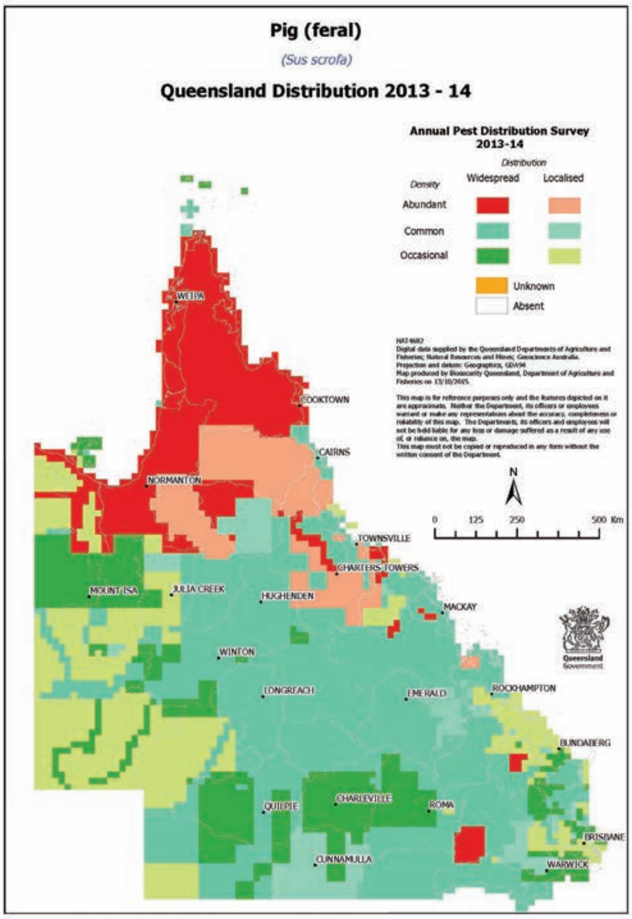
Feral pigs have relatively high energy and protein requirements, particularly during pregnancy and lactation and often move to other parts of their home range during pregnancy.

Habitat and distribution

Feral pigs are found in all habitat types in Queensland. The greatest concentrations of feral pigs are on the larger drainage basins and swamp areas of the coast and inland. In hot weather, pigs need to remain near water.

Population estimates can be achieved by spotlighting, aerial survey or the use of motion cameras.

Map 1. Distribution of feral pigs in Queensland



Evidence of feral pigs includes fresh digging or rooting of the ground, tracks and faeces on and off pads, mud or hair at holes in fences where pigs have pushed through, wallows, tusk marking and mud rubs on trees and fence posts and nests in vegetation made by sows before farrowing.

Female and juvenile pigs usually live in small family groups with a home range of 2–20 km^2. Adult males are typically solitary, with a home range of 8–50 km^2. Range size varies with season, habitat, food availability and disturbance. Herds of 400 pigs have been recorded in Cape York.

Impacts

Pigs can damage almost all crops from sowing to harvest, starting with uprooting seed and seedlings to feeding on or trampling mature crop.

They feed on seed, sugar cane and grain crops (except safflower), fruit (especially banana, mango, papaw, macadamia and lychee) and vegetable crops. Research has shown feral pigs can take up to 40% of lambs.

Pastures are damaged by grazing and rooting and pigs can also transport weeds. Wallowing pigs damage and foul the water in tanks and bore drains and silt up troughs. They can also damage fences and dam walls.

Pig activity degrades water quality and the habitat for small terrestrial and aquatic animals. It also creates erosion and allows exotic weeds to establish. Predation of native fauna does occur and examination of faeces has shown remains of marsupials, reptiles, insects, and ground-nesting birds and their eggs.

Feral pig wallow

Feral pig rooting

Feral pig damage to river banks

Feral pig damage to sugar cane

Diseases and parasites

Feral pigs can carry many infectious diseases and internal and external parasites. Some are endemic (already present), while others are exotic to Australia.

Many of the diseases can spread to domestic pigs, other livestock and humans. Feral pigs can transmit sparganosis, melioidosis, leptospirosis, Q fever and brucellosis to humans.

To prevent contracting these diseases it is advisable to either avoid handling feral pigs or use suitable protective clothing (mask, goggles, strong rubber gloves and plastic apron and boots) to minimise contamination with blood, urine and faeces. Rare or undercooked meat should not be eaten; thoroughly cook meat to avoid contracting pathogens. Raw feral pig meat and offal should not be fed to dogs as dogs can be infected with swine brucellosis. Dogs infected with swine brucellosis can also transmit the disease to humans.

Control

Managing feral pigs

The GBO requires a person to take reasonable and practical steps to minimise the risks posed by feral pigs. This fact sheet provides information and some options for controlling feral pigs.

Feral pigs are difficult to control because they are primarily nocturnal, breed rapidly, are generalist omnivores and have large home ranges and thus control programs need to be conducted over a wide area (often including several properties) to be effective.

Effective control requires an integrated, collaborative approach where all stakeholders participate in planning, implementation and evaluation of the actions taken.

Fencing

Though an expensive option, fencing can offer successful pig control especially for high value crops grown on small areas. Research has indicated that the most successful pig-proof fences are also the most expensive.

The most effective pig-proof fences use fabricated sheep mesh held close to the ground by plain or barbed wire and supported on steel posts.

Electrifying a conventional fence greatly improves its effectiveness if used before pigs have established a path through the fence.

Pigs will often charge an electric fence and unless the fence incorporates fabricated netting they often successfully breach the fence.

For crop protection or to avoid lamb predation, pig-proof fences need to be constructed before the pigs become a problem. Once pigs have adjusted to feeding on grain or lambs in a particular paddock fencing may be ineffective.

Trapping

Trapping is an important technique that is most useful in populated areas, on smaller properties (<5000 ha), and where there are low pig numbers. Trapping can be particularly useful in 'mopping up' survivors from baiting programs. It is most successful when food resources are limited.

Trigger mechanisms for pig traps can be made pig-specific and therefore pose little danger to wildlife or domestic animals.

Advantages

- This is the safest form of control and can be safely undertaken on closely populated areas.
- It's flexible and can be incorporated into routine property activities, making economical use of labour and materials.
- Carcasses can be safely disposed.
- Traps can be moved and re-used; good trapping makes use of opportunities as they arise.
- Normal pig behaviour is not altered, which allows a greater number of the total population in an area to be targeted.
- More humane to pigs and non-target species.
- The number of animals removed can be easily monitored.

Disadvantages

- Can be time consuming and expensive to construct and maintain.
- Must be checked regularly.
- Not practical for large-scale control.
- Some pigs are trap shy.

Tips

- Stop all activities that will disturb normal feeding (i.e. do not undertake any shooting or dogging).
- Pre-feeding (i.e. ensure that pigs are visiting trap and consuming bait) prior to activating traps is an essential part of successful trapping.
- Feeding sites should be placed where feral pigs are active (i.e. water points, holes in fences, areas containing old carcasses on which pigs have been feeding).
- Bait for traps must be food that pigs usually eat in that area. Pigs feeding on one crop (e.g. sugarcane) will often not take to alternative foods. However, new, novel baits are sometimes attractive (e.g. fermented grains).
- The trap can be built around the feeding site, with feeding within the trap undertaken for several nights before it is set.
- Set the trap every night and check each day. If the trap cannot be checked daily then shade and water must be provided.
- Continue to trap until no more pigs are caught. A change of bait can be tried. Again, feed for one or two nights before re-setting the trap.
- Traps may be left permanently in locations used by pigs and can be utilised when fresh signs of pigs appear.
- If the trap is to be moved, start feeding at the new site before re-locating the trap.

Design

There are several trap designs but all are principally an enclosed area with one-way gates (see Figure 1).

The main area of the trap can be any shape and be made from materials on the property. The best material is steel mesh with a grid 100 × 100 mm, with a minimum height of at least 1.5 m. Star pickets need to be placed no more than 1.5 m apart and imbedded far enough to ensure that adult pigs cannot push them over or lift them up out of the ground.

Alternative trap entrances

Funnel entrance

Formed by the two ends of the mesh forming a funnel, the ends are tied together at the top with wire or rope. The pig moves through the funnel forcing the bottom of the mesh ends apart and once it is in the trap the ends spring back together (see Figures 1 and 2).

Tripped gate entrance

A side-hinged gate is pulled shut by springs and is held open by many systems that can be triggered to allow the gate to swing shut. Often trip wires or other systems are used; most of these systems are not selective for feral pigs and can be triggered by any animal attracted to the bait. Once triggered the trap is no longer effective in trapping pigs.

Pig-specific trigger

By far the simplest and most effective trigger system has the gate held open by a bar (often a branch or piece of wood) which is hooked over the wire on the gate and on the side panel (see Figure 3). For a close up of the pig specific trigger (see Figure 4).

Pigs rooting for feed in the trap lift the bar allowing the gate to swing shut. The specific feeding habit of pigs insures they are the only animals that lift the trigger bar.

The gate may be latched to prevent pigs from opening the door once triggered. However, this will prevent more pigs pushing their way in to join those inside.

Shooting

Shooting pigs by helicopter is effective in areas where pigs exist in reasonable numbers and are observable from the air.

Ground shooting is not effective in reducing the pig population unless intense shooting is undertaken on a small, isolated and accessible population of pigs.

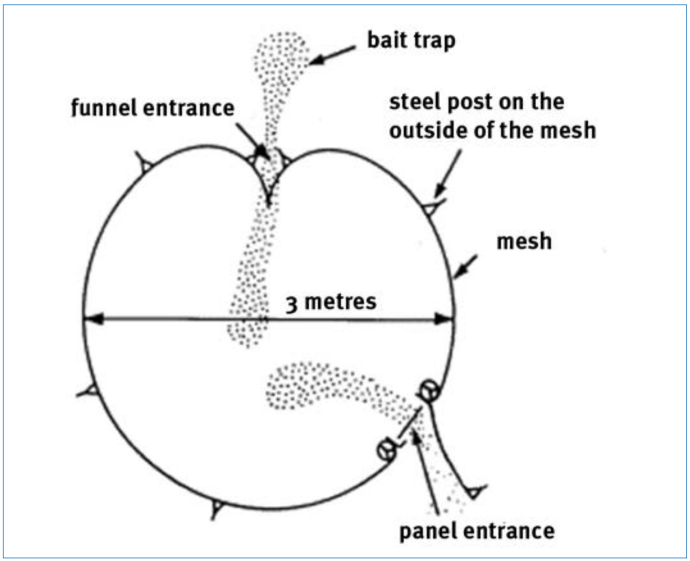


Figure 1. Alternative trap entrances – funnel entrance

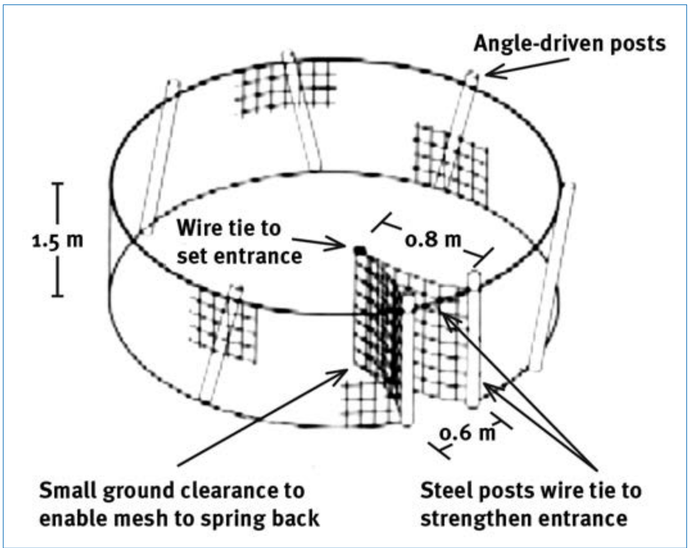


Figure 2. Silo trap with funnel entrance (14 m of silo mesh diameter about 4.5 m

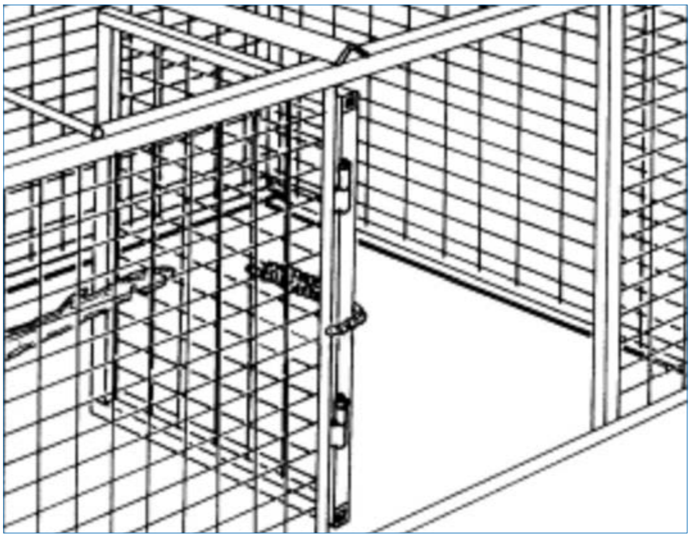


Figure 3. Pig-specific trigger

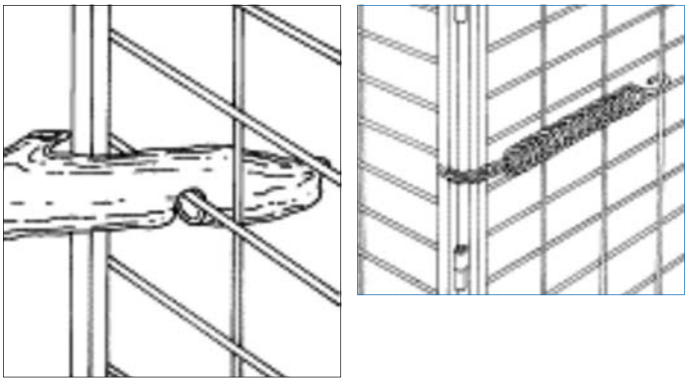


Figure 4. Close up of pig-specific trigger

Feral pig trap

Trapped feral pigs

Hog hopper – pig specific bait station

Poisoning

Poisoning is the most effective control method available that can quickly reduce a pig population.

Sodium fluoroacetate (1080) can only be supplied by people approved under the Health (Drugs & Poisons) Regulation 1996 for the purpose of controlling declared pest animals. Your local government office should be able to assist you.

Pre-feeding is the most important step in ground-based poisoning operations. Free feeding with non-poisoned bait should be performed for several days prior to laying poisoned baits.

By selecting bait wisely, landholders can be species-selective in their poisoning program and avoid many of the unintentional effects of secondary poisoning.

Bait material such as fermented grains are very attractive to pigs. It is a good idea to establish a free feeding routine so that pigs are the only animals feeding, which helps to keep other non-targets away from the feeding site.

Other options (like pig-specific feeders) are now commercially available, and can assist in reducing non-target species access to bait. Other options include burying baits; feral pigs are one of the few animals that will dig up bait.

Aerial poisoning is also available and typically used for broadscale control in western and northern regional areas. Bait is distributed from an aircraft. This is particularly useful for covering large, remote, areas or restricted ground access. Aerial poisoning is a proven and cost-effective method for reducing pig populations.

A phosphorous-based poison is also available for use in Queensland.

Further information

Further information is available from your local government office, or by contacting Biosecurity Queensland on 13 25 23 or visit www.biosecurity.qld.gov.au.

Biosecurity Queensland gratefully acknowledges the contribution from Choquenot, D., McIlroy, J. and Korn T. (1996) Managing Vertebrate Pests: Feral Pigs, Bureau of Resource Sciences, AGPS, Canberra. Commonwealth of Australia copyright reproduced by permission.

Feral pig exclusion fencing

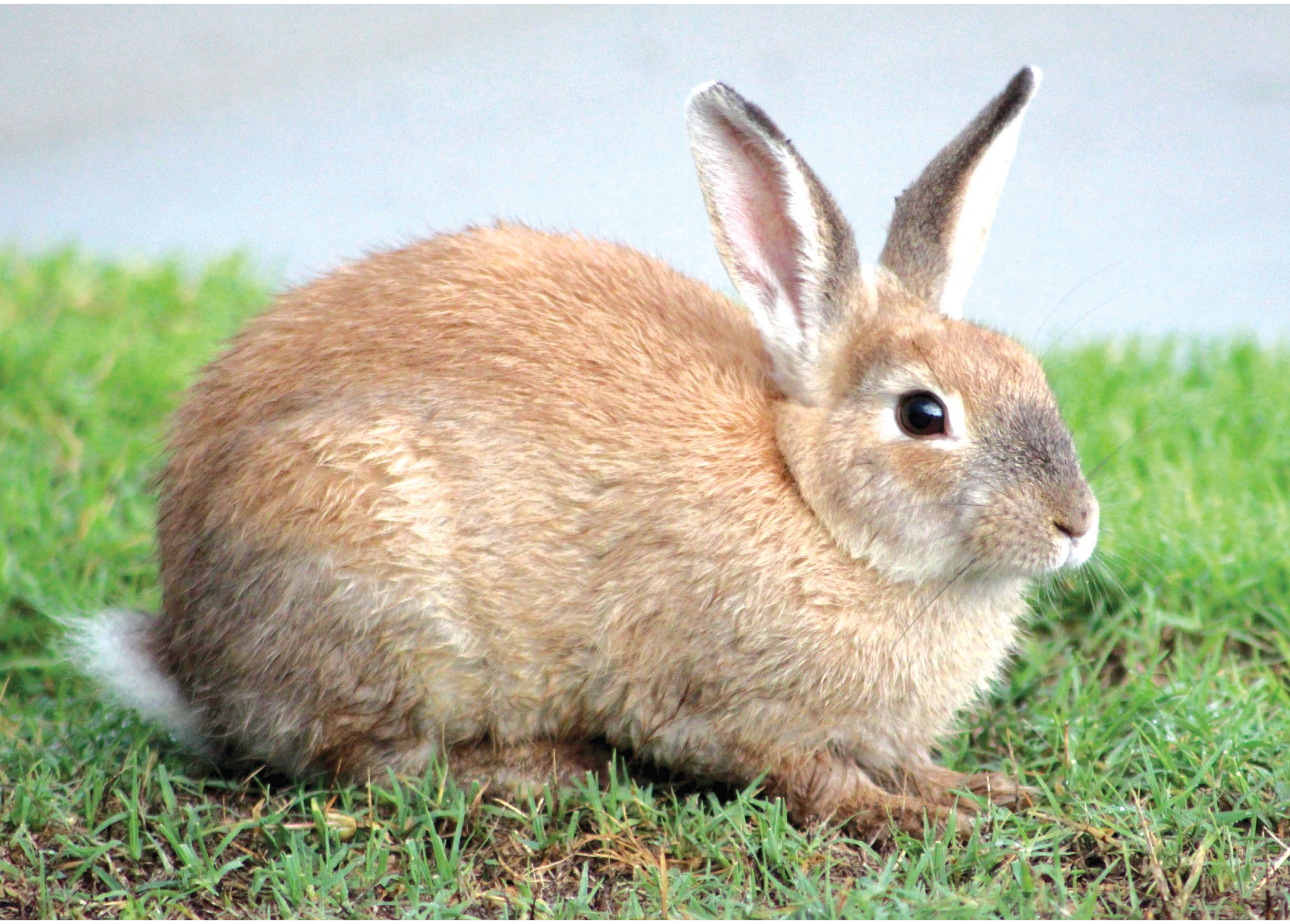
This fact sheet is developed with funding support from the Land Protection Fund.

Department of Agriculture, Fisheries and Forestry
Biosecurity Queensland

Restricted invasive animal

Rabbit

Oryctolagus cuniculus



Rabbits are one of Australia's major agricultural and environmental animal pests, costing the country between $600 million and $1 billion annually. They compete with native animals, destroy the landscape and are a primary cause of soil erosion by preventing regeneration of native vegetation.

Legal requirements

The rabbit is a restricted invasive animal under the *Biosecurity Act 2014*. It must not be moved, kept, fed, given away, sold, or released into the environment without a permit. The Act requires everyone to take all reasonable and practical steps to minimise the risks associated with invasive plants and animals under their control. This is called a general biosecurity obligation (GBO). This fact sheet gives examples of how you can meet your GBO.

At a local level, each local government must have a biosecurity plan that covers invasive plants and animals in its area. This plan may include actions to be taken on certain species. Some of these actions may be required under local laws. Contact your local government for more information.

Queensland Government

Pet rabbits

Introducing and selling rabbits in Queensland is not permitted (penalties apply). Limited numbers of permits for domestic rabbits are only available from Biosecurity Queensland for research purposes, public display, magic acts or circuses. Before a permit is granted, a number of guidelines need to be fulfilled.

Description

Rabbits are small mammals around 34–45 cm in length usually grey brown with pale belly fur, other colours include piebald, black and ginger. They have long ears 10 cm long and big eyes. They have long hind legs with hind feet measuring 9–11 cm and shor t front legs. The tail is fluffy brown with white underneath, 4–8 cm. Adult rabbits usually weigh around 1–2.1 kg. The male is called a buck, the female a doe and her young are called kittens.

Life cycle

Does (females) are pregnant for 28–30 days, but are able to mate within hours of giving birth. The average litter is 3–4 kittens but varies from two in a young doe, up to eight or more in a mature doe, and depends on the amount and quality of food available.

Five to six litters are possible in a good season. Young does can breed at four months of age if conditions are suitable.

Habitat and distribution

Rabbits prefer to live in warrens as protection against predators and extremes in temperature. However, they will sur vive in above-ground harbours such as logs, windrows and dense thickets of scrub (e.g. blackberr y and lantana) or under built harbour, old sheds and machiner y etc.

In newly colonised areas without warrens, rabbits tend to live in ‘scrapes’ (or ‘squats’)

Rabbits are adaptable and sometimes live in close association with people. They live in built environments such as:

- in and under buildings
- old machinery and storage containers
- in old dumps.

In rural environments rabbits frequently live in:

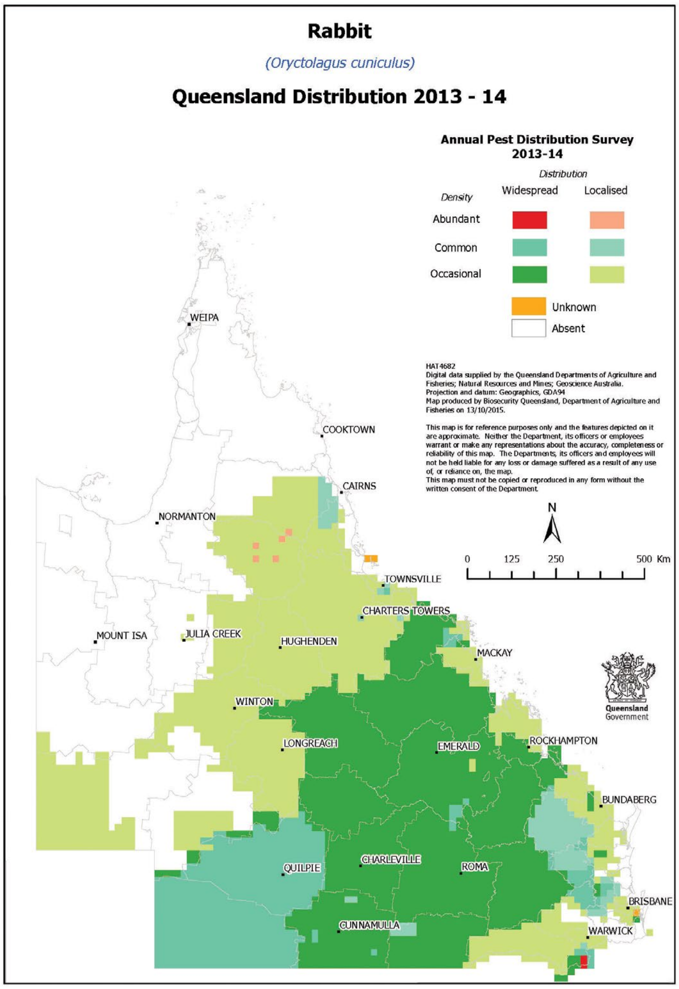
- felled timber and associated windrows
- tussock grasses and rocky areas
- warrens (if soils are easy to dig).

Control

Managing rabbits

The GBO requires a person to take reasonable and practical steps to minimise the risks posed by rabbits. This factsheet information and some options for controlling rabbits.

Map 1. Distribution of rabbits in Queensland



Effective rabbit control cycle

Rabbit control is best done as a joint exercise involving all land managers in the district. Integrated control methods, such as fumigating, ripping warrens and harbour destruction, are essential for the continued long-term reduction of rabbit numbers. Cost-effective, long-term results can be achieved in rabbit control by following a combination of the methods outlined below.

Prevention and early detection

Rabbits will generally eat around 15% of their body weight per day—approximately 250 g. This compares dramatically with the averages for stock—sheep and cattle eat around 3% of their body weight per day. So even a low number of rabbits can be removing large amounts of livestock feed.

For effective long-term rabbit control, concentrate on destroying source areas. Source areas will all have well-established warrens or ready-made structures that are cool and provide protection from predators. A source area must also have a good supply of green feed during the cooler seasons.

Manual control

Harbour destruction

Where there is abundant surface harbour, a high proportion of rabbits may live above ground rather than in underground warrens. Rabbits can make their homes in windrows, dense thickets of shrubs (such as blackberries and lantana) and even in old machinery.

To eliminate these above-ground breeding areas, it may be necessary to:

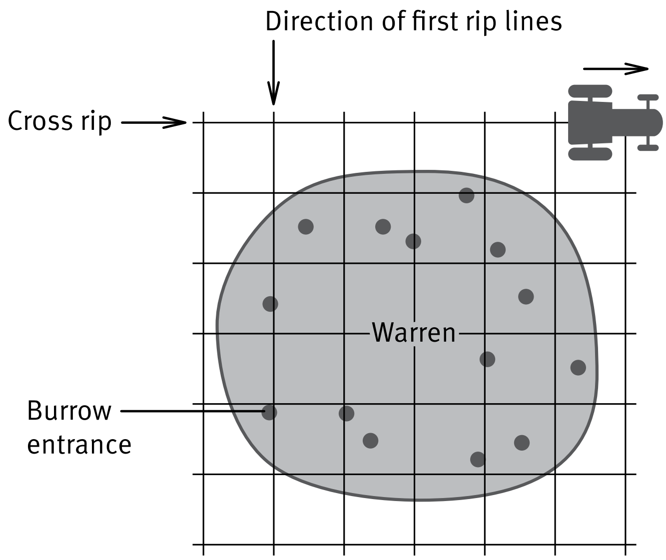
- burn windrows and log piles
- remove noxious weeds through chemical and physical control
- remove movable objects (such as old machinery) from paddocks.

Sometimes removing harbour can expose warrens underneath. If this happens, the warrens need to be ripped.

Mechanical control

Warren ripping

In areas where rabbits live in warrens, ripping is the most effective method of long-term control. Ripping is so successful because warrens can rarely be reopened and rabbits are unable to recolonise these areas.

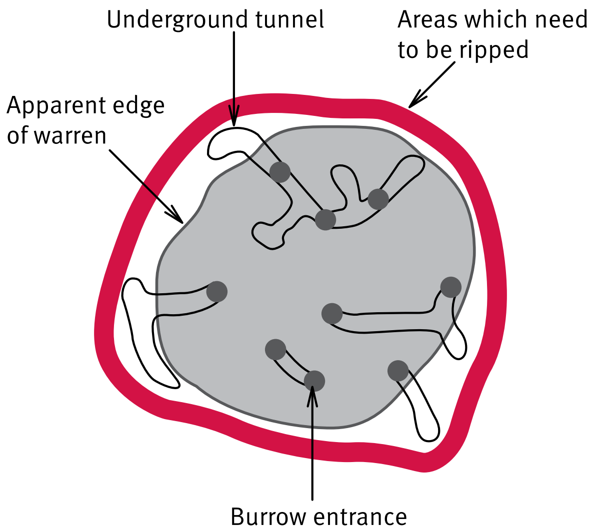


Direction to rip warrens (illustration courtesy Will Dobbie)

Tyne for ripping warrens (photo courtesy Mark Ridge)

To get the best results it is important to chase as many of the rabbits inside the warren as possible. Dogs can be used to drive rabbits into the warren before ripping starts.

The aim of ripping is to completely destroy the warren. It involves using a tractor with a tyned (sharp-pronged) implement—one tyne or many—that rips through the warren and collapses it. Larger tractors and dozers are more appropriate for properties with many warrens as they are able to move faster and rip wider.



Extent to rip warrens (illustration courtesy Will Dobbie)

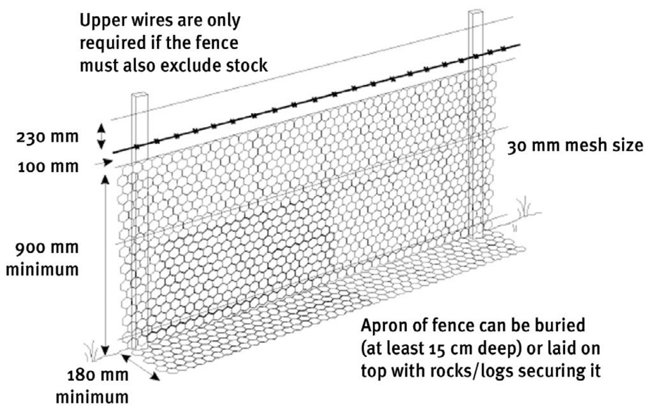
Obviously, ripping is not suitable for warrens located underneath buildings or on steep rocky country. In such cases, other methods (poison baiting, releasing virus or fumigating burrows) should instead be used to reduce rabbit numbers. Warrens should then be either filled in or covered to stop rabbits from re-establishing. Burrows can be blocked with small boulders or rocks.

Rock blocking rabbit hole

Exclusion fencing

Rabbit exclusion fences are built with the aim of keeping rabbits out of a particular area. It is appropriate for small, high-value areas that require protection. A fully fenced area will only remain rabbit-free in the long term if all rabbits are removed from the enclosed area after fencing and the fence is regularly maintained and checked for holes.

Electric fencing is a cheaper alternative, but it is not a complete physical barrier and is also prone to damage from other pest animals and stock.



Exclusion fence for rabbits (illustration courtesy DEWHA)

A rabbit-proof fence should be made of wire mesh netting (40 mm or smaller) and needs to be at least 900 mm high. The netting should also be buried to depth of at least 150 mm. Gates into the fenced area need to be rabbit-proof as well.

Trapping

Trapping is an extremely labour-intensive control method and requires a skilled operator to set the traps to successfully capture rabbits.

If you do plan to trap rabbits on your property, common sense and respect for animal welfare are essential. While there are currently no strict guidelines for the use of traps in Queensland, it is an area of growing concern for animal welfare advocates.

Cage trap

A cage trap has a lever that closes the cage when a rabbit steps on it. The rabbits are lured into the cage with bait—usually diced carrot. Traps need to be disabled and left open for two or three nights with bait leading into the cage. This entices rabbits to enter. A trap can be set once a rabbit has consumed a trail of bait all the way into that trap. Traps should be checked and emptied regularly—usually a couple of times a night.

This effective and humane technique is most useful for removing any remaining rabbits from places like hay sheds and after the shed has been fenced to prevent additional rabbits from entering and leaving. Free-feed then trap, and keep the shed rabbit-proof to prevent rabbits recolonising.

Barrel trap

A barrel trap is designed specifically for rabbits. It is cylindrical, made of light mesh, and is about 1 m long and 15 cm in diameter. The trap has one open end with two hinged trap doors along its side. The open end is placed in the burrow, and the hinged gates close and trap the rabbit after it enters from the burrow.

The trap can be left in the burrow entrance for a number of days. However, it must be checked at least daily so that if a rabbit has been caught it does not suffer and animal welfare responsibilities are met.

Barrel rabbit trap in hole

Biological controls

Rabbit hemorrhagic disease virus (also known as rabbit calicivirus disease)

RHDV is a virus specific to rabbits which works by infecting the lining of the throat, lungs, gut and liver.

RHDV relies primarily on direct rabbit-to-rabbit contact in order to spread. High rabbit numbers are therefore needed before this control method will be effective.

After RHDV has infected an area, it is important to use another method for follow-up control to increase the likelihood that the population is eradicated before it is able to develop resistance and increase its numbers again.

Resistance to RHDV depends primarily on the age of the rabbit. Therefore, it is better for RHDV to go through a rabbit population after rabbits have bred and the young are old enough to be affected by the virus. Rabbits that survive RHDV develop antibodies against the virus. Breeding females can also pass these antibodies on to the young (through antibodies in their milk), conferring temporary protection on rabbits up to 12 weeks old.

Myxomatosis

Myxomatosis is no longer produced as a laboratory strain but field strains are still known to recur and affect rabbit populations.

RHDV1-K5

Recent research by state and federal agencies has identified a new strain of RHDV (called RHDV-K5) that will aid in controlling rabbits that have immunity to current strains.

Shooting

Shooting is most useful when used to ‘mop up’ after other control methods (such as ripping). To get the best results, shoot at the time of day when rabbits are active. This is usually in the early morning, late afternoon or at night. The best and most economical firearm to use is a .22 calibre rifle.

If your property is within an urban area, you will need to comply with local government regulations and the *Police Powers and Responsibilities Act 2000*, which restrict the use of firearms.

Poison baiting

Baiting is not effective as a sole control method and will not eradicate an entire rabbit population. Numbers will quickly increase again, and you will have to continue baiting year after year with no permanent overall change in the rabbit population.

Rabbits can also become 'bait shy' and this method becomes less and less effective over time. Ideally, baiting is best used either before ripping/fumigation to reduce a population, or after ripping/fumigation as a 'mop-up'.

Baiting works best when rabbits are not breeding. During breeding season the majority of the population feeds over a larger-than-normal area, and it is the young rabbits that are most likely to take baits. While numbers will be reduced, animals of breeding age are not likely to be affected.

1080—sodium fluouroacetate

Pre-feeding is required when using 1080 because rabbits will not readily take new feed. The poison-free bait should be laid at least three times over a one-week period before the poisoned bait is laid. (1080-impregnated carrot baits are the most common form of bait used.) The practice helps to ensure that, when the poisoned bait is laid, it will be eaten by most of the rabbit population.

1080 can only be supplied through persons authorised under the Health Act. Your local Biosecurity officer or your local government office should be able to assist you.

Pindone

Pindone is an anticoagulant registered for rabbit control. This poison works by preventing blood from clotting. In Queensland, it is not recommended for broadacre use and is mainly used in urban areas and near farm buildings.

Pindone works best when given as a series of small doses/feeds over a period of three days. Although pre-feeding is not essential, it does enhance the bait uptake by shy rabbits as they get used to the feed prior to any poison bait being laid. To be effective, pindone requires multiple feeds so that the poison can build up to fatal levels in the rabbit's body. Feeding over a number of nights provides plenty of opportunity for most of the rabbit population to consume the required lethal dose. Rabbits poisoned with pindone will usually die within 10–20 days.

Pindone baiting does not work well when there is a lot of green pick around for rabbits.

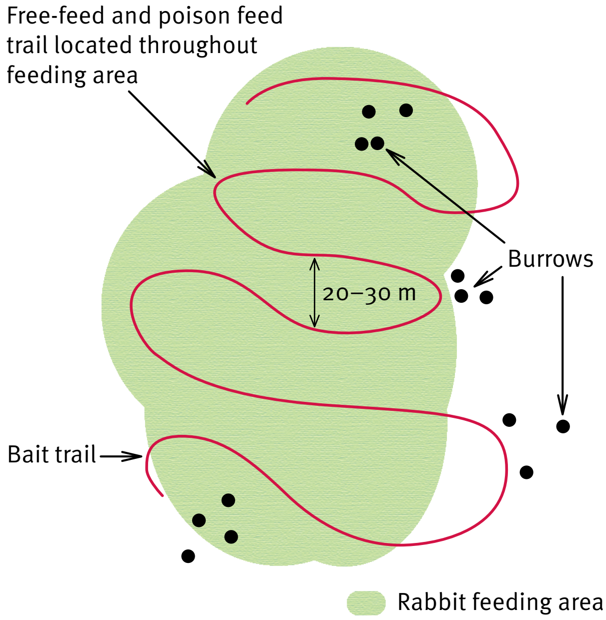
Poison bait trails

It is important that bait trails are laid properly to ensure the best results. 'Baitlayers' make it easier to put out bait trails at the correct rate, and they can be towed behind most 4WD vehicles, quad bikes and tractors.

When scratching and laying a trail, consider the following:

- Rabbits like freshly scratched/disturbed soil—this may be because rabbits are territorial and inspect newly disturbed soil, and/or the disturbed vegetation smell attracts them.
- Lay trails around warrens and in the areas where rabbits most often feed.
- Laying trails on slopes and hills requires care—it can cause erosion in some soils types (e.g. granite and traprock). Trails are best laid in a zigzag pattern in steep terrain to minimise erosion.
- A trail that has been scratched for the first feed is easy to follow for the rest of the baiting program.
- The soil should be turned only enough to scratch the surface—don't plough the ground.
- A trail that has been scratched too deep will spook the rabbits because they will not have full sight of their predators.
- Where vegetation is thick, or it is difficult to find the main feeding areas, lay bait trails in a grid pattern across the site.

As a general rule, avoid crossing the bait trail—it can cause confusion when you try to follow the same trail on subsequent occasions.



Method for laying a bait trail (illustration courtesy Animal Control Technologies)

Bait trials will be most effective if you follow these guidelines:

- Use good quality, non-contaminated bait material. (Simple rule: if you wouldn't eat it, the rabbit won't either.)
- Use enough feed to bait all the rabbits in the area. (The pre-feed will give an indication of the potential bait take.)
- Expect a greater uptake of pre-feed and bait material when vegetation is scarce, dried off or soured.
- Ensure that all the preparation equipment is clean and free of any chemical residues or smells—rabbits can be very shy of unusual odours.
- When there are kittens in a warren, lay the bait trail close to the warrens.

Fumigation

Fumigation is labour intensive and time consuming, and is not usually an effective method if used alone. However, as a 'mop-up' technique or control method for use in areas where ripping is not practical (e.g. steep and rocky terrain), it may be a good alternative.

Because this technique relies on directly affecting the rabbits, and does not affect the structure of the warren, it is crucial that as many rabbits as possible are underground when fumigation is carried out. Rabbits usually take refuge in their burrows from mid-morning to mid-afternoon and during hot weather so these are the best times to fumigate. Dogs can also be used to drive rabbits into their warrens.

For best results, fumigation should be carried out in two stages—initially, before the breeding season starts (as this reduces the breeding stock), and then again during the breeding season.

There are two types of warren fumigation—static and pressure. In Queensland, static fumigants are a more popular and safer option for controlling rabbits and will be explained below.

Static fumigation

This method is easy to use, and time- and cost-effective. Static fumigation comes in the form of aluminium phosphide (phosphine) tablets, which can be purchased from most agricultural suppliers. These tablets are small and round (about the size of a marble), and weigh 3 g. Trade names for phosphine include Pestex®, Quickphos® and Gastion®. General directions for the use of phosphine tablets appear below, but always refer to the manufacturer's specific recommendations for use.

To fumigate warrens using phosphine tablets:

1. Find all warren entrances—both active and inactive.
2. Cut back the warren entrance at right angles using a shovel.
3. Separately wrap two tablets in moistened absorbent paper (toilet paper/paper towels).
4. Insert the tablets as far down into the entrance as possible (polypipe and a push rod can be used to help push the tablets down).
5. Push some scrunched-up newspaper down the hole to block the entrance and then cover it up with soil and, if possible, a rock.
6. Treat all entrances to the warren (active and inactive) the same way.
7. Check warrens about a week after fumigation and re-fumigate any reopened entrances.

Once in the warren, the moistened tablets react with air to release a toxic gas, which spreads quickly throughout the warren. The phosphine gas itself is invisible and odourless but leakages from the warren can be detected by the smell of ammonia. (This is a safety mechanism that is built into the tablet.) Any leakages need to be blocked immediately.

Shooting

Shooting is most useful when used to 'mop up' after other control methods (such as ripping). To get the best results, shoot at the time of day when rabbits are active. This is usually in the early morning, late afternoon or at night. The best and most economical firearm to use is a .22 calibre rifle.

If your property is within an urban area, you will need to comply with local government regulations and the *Police Powers and Responsibilities Act 2000*, which restrict the use of firearms.

Further information

For further detailed reading information on specific rabbit control techniques or costing your rabbit control please refer to Rabbit control in Queensland; a guide for land managers. Download from the Biosecurity Queensland website at www.biosecurity.qld.gov.au

Further information is available from your local government office, or by contacting Biosecurity Queensland on 13 25 23 or visit www.biosecurity.qld.gov.au.

Wild rabbit

Escaped or dumped pet rabbits

This fact sheet is developed with funding support from the Land Protection Fund.

