GEMINI PROJECT
Site-Specific EA Application

MAGNETIC SOUTH PTY LTD
December 2020

VOLUME 4:

- Appendix K: Aquatic Ecology Assessment
- Appendix L: Air Quality and Greenhouse Gas Assessment
- Appendix M: Noise Impact Assessment
- Appendix N: Land-Based Effluent Disposal Assessment

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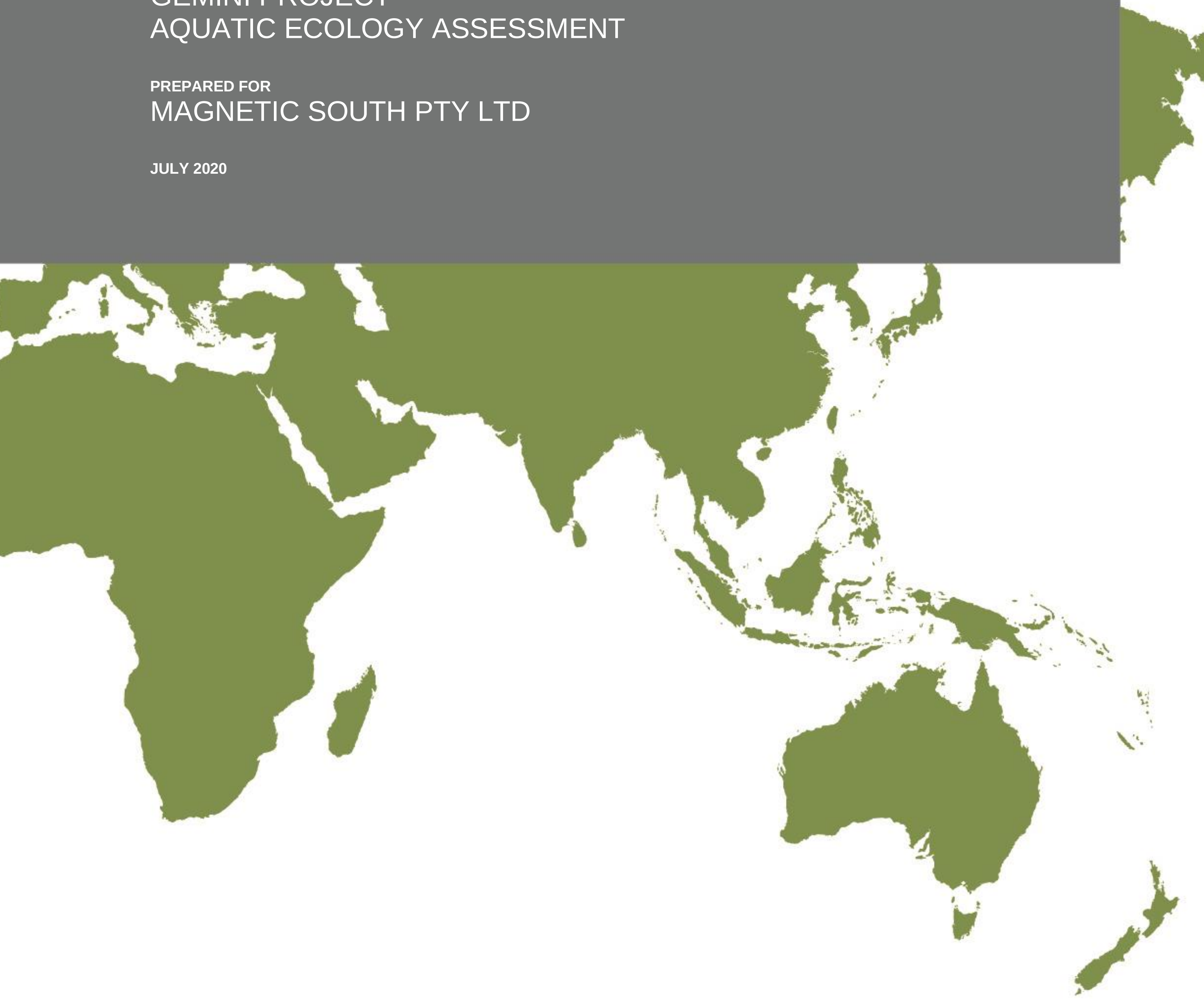
Appendix K Aquatic Ecology Assessment

GEMINI PROJECT
AQUATIC ECOLOGY ASSESSMENT

PREPARED FOR

MAGNETIC SOUTH PTY LTD

JULY 2020



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GEMINI PROJECT
AQUATIC ECOLOGY ASSESSMENT

INDEX

1.0 INTRODUCTION 1
1.1 SCOPE OF STUDY 1
1.2 PROJECT OVERVIEW 3
1.3 CURRENT LAND USE 4
1.4 LOCAL WATERWAYS AND TOPOGRAPHY 4
1.5 GEOLOGY 6
1.6 REGIONAL CLIMATE 6
2.0 RELEVANT LEGISLATION AND POLICY 7
2.1 ENVIRONMENT PROTECTION AND BIODIVERSITY CONSERVATION ACT 1999 7
2.2 NATURE CONSERVATION ACT 1992 7
2.3 BIOSECURITY ACT 2014 8
2.4 QUEENSLAND ENVIRONMENTAL OFFSETS FRAMEWORK 8
2.5 FISHERIES ACT 1994 9
2.6 ENVIRONMENTAL PROTECTION (WATER AND WETLAND BIODIVERSITY) POLICY 2019 10
3.0 DESKTOP ASSESSMENT 11
3.1 WETLAND HABITATS 11
3.2 WATERWAYS PROVIDING FOR FISH PASSAGE 12
3.3 SPECIES OF CONSERVATION SIGNIFICANCE 12
4.0 ENVIRONMENTAL VALUES AND OBJECTIVES 15
4.1 ENVIRONMENTAL VALUES 15
4.1.1 Stream Sediment Quality Objectives 15
4.1.2 Water Quality Objectives 15
5.0 METHODOLOGY 17
5.1 OVERVIEW OF FIELD SURVEYS 17
5.2 SAMPLING SITES 19
5.3 SURFACE WATER SAMPLING 25
5.4 STREAM SEDIMENT SAMPLING 25
5.5 CREEK ECOLOGY 25
5.5.1 Physical Assessment 25

5.5.2 Habitat Bioassessment ... 25
5.5.3 Condition Assessment ... 27
5.6 FAUNA SURVEY ... 27
5.6.1 Macroinvertebrate Sampling ... 27
5.6.2 Aquatic Fauna ... 28
5.6.3 Riparian Fauna ... 28
5.7 FLORA SURVEY ... 30

6.0 RESULTS AND DISCUSSION ... 31
6.1 SURFACE WATER QUALITY ... 31
6.1.1 Charlevue Creek ... 31
6.1.2 Stanley Creek and Duckworth Creek ... 32
6.1.3 Springton Creek ... 32
6.2 STREAM SEDIMENT QUALITY ... 40
6.2.1 Metals ... 40
6.2.2 Particle Size Distribution ... 42
6.3 CREEK ECOLOGY ... 44
6.3.1 Physical Assessment ... 44
6.3.2 Habitat Bioassessment ... 45
6.3.3 Condition Assessment ... 45
6.4 FAUNA ... 47
6.4.1 Macroinvertebrate Populations ... 47
6.4.1.1 Total Abundance ... 47
6.4.1.2 Taxonomic Richness ... 48
6.4.1.3 PET Taxa Richness ... 48
6.4.1.4 SIGNAL Index ... 49
6.4.1.5 Percent Tolerant Taxa ... 50
6.4.1.6 SIGNAL 2 Bi-Plot ... 50
6.4.1.7 Community Composition – AusRivAS Predictive Modelling ... 51
6.4.2 Crustaceans ... 53
6.4.3 Fish ... 53
6.4.4 Semi-aquatic Fauna ... 54
6.4.5 Riparian Fauna ... 55
6.5 FLORA ... 55
6.6 WETLANDS ... 59
6.7 SUMMARY OF AQUATIC VALUES ... 59

7.0 POTENTIAL IMPACTS ... 60

8.0 MITIGATION STRATEGIES ... 62

9.0 PROJECT ENVIRONMENTAL OFFSETS ... 63

9.1 IMPACT ASSESSMENT: WATERWAYS PROVIDING FOR FISH PASSAGE 63
9.2 IMPACT ASSESSMENT: FITZROY RIVER TURTLE 65
9.3 OFFSETS REQUIREMENTS.. 66

10.0 REFERENCES 67

LIST OF APPENDICES

Appendix A Database Searches ....A
Appendix B Site Descriptions and Physical Assessment..B
Appendix C Macroinvertebrate Taxonomic List...C
Appendix D Aquatic and Semi-aquatic Fauna Species List...D
Appendix E Riparian Fauna Species List..E
Appendix F Flora Species List ....F
Appendix G Queensland Herbarium Identification Results .... G
Appendix H Weed Fact Sheets ....H

LIST OF FIGURES

Figure 1 Location of the Gemini Project study area... 2
Figure 2 Waterways and topography associated with the study area 5
Figure 3 Monthly mean temperature and rainfall for the study area (1999-2020) 6
Figure 4 Wetland habitats 13
Figure 5 Location of survey sites 22
Figure 6 Stream sediment quality: Particle size distribution (Stanley Creek and Duckworth Creek) 42
Figure 7 Stream sediment quality: Particle size distribution (Charlevue Creek).................. 43
Figure 8 Stream sediment quality: Particle size distribution (Springton Creek)................... 43
Figure 9 Habitat bioassessment (2020) 45
Figure 10 Macroinvertebrate total abundance 47
Figure 11 Macroinvertebrate taxonomic richness 48
Figure 12 Macroinvertebrate PET taxonomic richness... 49
Figure 13 Macroinvertebrate SIGNAL site indexes... 49
Figure 14 Macroinvertebrate percent tolerant taxa 50
Figure 15 Macroinvertebrate weighted SIGNAL 2 index biplot.. 51
Figure 16 Flora species richness 57
Figure 17 Site flora composition 58
Figure 18 Conceptual project layout 61

LIST OF TABLES

Table 1 Fauna species of conservation significance identified during desktop assessment 14
Table 2 Guideline values for stream sediment quality 15
Table 3 Guideline values for water quality objectives 16
Table 4 Survey rainfall 18
Table 5 Sampling site locations 21
Table 6 Survey methods (Stanley Creek and Duckworth Creek, Springton Creek) 23
Table 7 Survey methods (Charlevue Creek) 24
Table 8 Physical assessment methodology 26
Table 9 Key to AusRivAS habitat bioassessment scores 26
Table 10 Condition assessment methodology 27
Table 11 Water quality: Dissolved metals (Charlevue Creek) 34
Table 12 Water quality: Dissolved metals (Stanley and Duckworth Creeks; Springton Creek) 35
Table 13 Water quality: Physico-chemical parameters (Charlevue Creek) 36
Table 14 Water quality: Hydrocarbons (Charlevue Creek) 37
Table 15 Water quality: Physico-chemical parameters (Stanley and Duckworth Creeks; Springton Creek) 38
Table 16 Water quality: Hydrocarbons (Stanley and Duckworth Creeks; Springton Creek) . 39
Table 17 Stream sediment quality: Total metals 40
Table 18 Erosion observations (2020) 44
Table 19 Condition assessment 46
Table 20 AusRivAS predictive modelling: Bands for Queensland (western) model 52
Table 21 AusRivAS predictive modelling: Results 52
Table 22 Riparian zone condition 58
Table 23 Significant residual impact assessment: Waterways providing for fish passage ... 64
Table 24 Significant residual impact assessment: Fitzroy River turtle 65

LIST OF ABBREVIATIONS AND ACRONYMS

AARC	AARC Environmental Solutions Pty Ltd
ALA	Atlas of Living Australia
ANZECC	Australian and New Zealand Environment and Conservation Council
ARMCANZ	Agriculture and Resource Management Council of Australia and New Zealand
AusRivAS	Australian River Assessment System
Biosecurity Act	*Biosecurity Act 2014* (Queensland)
BoM	Bureau of Meteorology
CE	critically endangered
CHPP	coal handling preparation plant
DAF	Department of Agriculture and Fisheries (Queensland)
DAWE	Department of Agriculture, Water and the Environment (Commonwealth)
DES	Department of Environment and Science (Queensland)
DNRM	former Department of Natural Resources and Mines (Queensland)
DO	dissolved oxygen
E	endangered wildlife
EA	environmental authority
EC	electrical conductivity
EHP	former Department of Environment and Heritage Protection (Queensland)
EO Act	*Environmental Offsets Act 2014* (Queensland)
EO Regulation	*Environmental Offsets Regulation 2014* (Queensland)
EPBC Act	*Environment Protection and Biodiversity Conservation Act 1999* (Commonwealth)
EPC	exploration permit (coal)
EPP (Water and Wetland Biodiversity)	*Environmental Protection (Water and Wetland Biodiversity) Policy 2019*
ESA	Environmentally Sensitive Area
EV	environmental value
Ex	extinct wildlife
Fisheries Act	*Fisheries Act 1994* (Queensland)
GDA	Geocentric Datum of Australia
HES	high ecological significance
LC	least concern wildlife
LOR	limit of reporting
Magnetic South	Magnetic South Pty Ltd
Mi	migratory
MIA	mine infrastructure area

MLES	matter(s) of local environmental significance
MNES	matter(s) of national environmental significance
MSES	matter(s) of state environmental significance
N	nitrogen
NATA	National Association of Testing Authorities
NC Act	*Nature Conservation Act 1992* (Queensland)
NCWR	*Nature Conservation (Wildlife) Regulation 2006* (Queensland)
NL	not listed
NP	National Park
NT	near threatened wildlife
O/E	observed versus expected (macroinvertebrate taxa score)
ORP	oxygen reduction potential
P	phosphorus
PCI	pulverised coal injection
PET	Plecoptera, Ephemeroptera and Trichoptera
QEOP	*Queensland Environmental Offsets Policy 2014*
REMP	Receiving environment monitoring program
ROM	run-of-mine
SIGNAL	stream invertebrate grade number - average level
SILO	Scientific Information for Land Owners
SO	stream order
SO^{4-}	sulphate (turbidimetric)
SQG	sediment quality guideline
SS	suspended solids
TDS	total dissolved solids
the Project	Gemini Project
TLO	train load out
V	vulnerable wildlife
Water Act	*Water Act 2000* (Queensland)
WoNS	weed of national significance
WQO	water quality objective
WRM	WRM Water and Environment Pty Ltd

LIST OF SYMBOLS AND UNITS OF MEASUREMENT

%	percent
<	less than
>	greater than
≤	less than or equal to
°C	degrees Celsius
µg	microgram(s)
µm	micrometre(s)
µS	microSiemens
cm	centimetre(s)
g	gram(s)
ha	hectare(s)
kg	kilogram(s)
km	kilometre(s)
km^2	square kilometre(s)
kV	kilovolt(s)
L	litre(s)
m	metre(s)
mg	milligram(s)
mm	millimetre(s)
Mtpa	million tonnes per annum
NTU	nephelometric turbidity unit

1.0 INTRODUCTION

AARC Environmental Solutions Pty Ltd (AARC) was commissioned by Magnetic South Pty Ltd (Magnetic South) to prepare an Aquatic Ecology Assessment for the Gemini Project (the Project), located approximately 110 km east of Emerald and 125 km west of Rockhampton in the Bowen Basin of central Queensland (Figure 1). The small rural townships of Bluff and Dingo are located approximately 15 km west and 3 km east of the Project, respectively. The Project is a proposed metallurgical open-cut coal mine and associated infrastructure, producing pulverised coal injection (PCI) coal and coking coal products to export for steel production.

This assessment represents a technical study supporting the Project's application for an environmental authority (EA), which was submitted to the Queensland Department of Environment and Science (DES) in October 2019. DES responded to Magnetic South in January 2020, requesting additional information to support the ongoing approval process. This report represents an update to the initial assessment, incorporating an additional field study and expanded study area.

An assessment of aquatic ecological values was conducted within exploration permit (coal) (EPC) 881, as well as select off-lease upstream and downstream influences (herein referred to as the study area).

1.1 SCOPE OF STUDY

To assess the ecological values of aquatic ecosystems within the study area, the following scope of works was undertaken:

- desktop assessment to identify aquatic species of conservation significance known, or with potential, to occur in the region;

- field surveys for, and analyses of; surface water quality, stream sediment quality, and macroinvertebrates populations in accordance with the *Australian River Assessment System (AusRivAS) Physical Assessment Protocol* (Parsons, Thoms & Norris 2002), the *Queensland AusRivAS Sampling and Processing Manual* (DNRM 2001) and the *Monitoring and Sampling Manual: Environmental Protection (Water) Policy 2009* (DES 2018b);

- field surveys to identify aquatic and riparian flora and fauna species inhabiting the study area, particularly species of conservation significance[1]; employing standard methodologies derived from the *Terrestrial Vertebrate Fauna Survey Guidelines of Queensland (Version 3.0)* (Eyre et al. 2018) and *Methodology for Survey and Mapping of Regional Ecosystems and Vegetation Communities in Queensland (Version 4.0)* (Neldner et al. 2017); and

- preparation of this assessment report describing the aquatic 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.

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[1] 'Species of conservation significance' when referred to within this document are references to species listed under the Queensland *Nature Conservation Wildlife Regulation 2006* as near threatened, vulnerable or endangered, or under the Commonwealth *Environmental Protection and Biodiversity Conservation Act 1999* as vulnerable, endangered, critically endangered, or migratory.

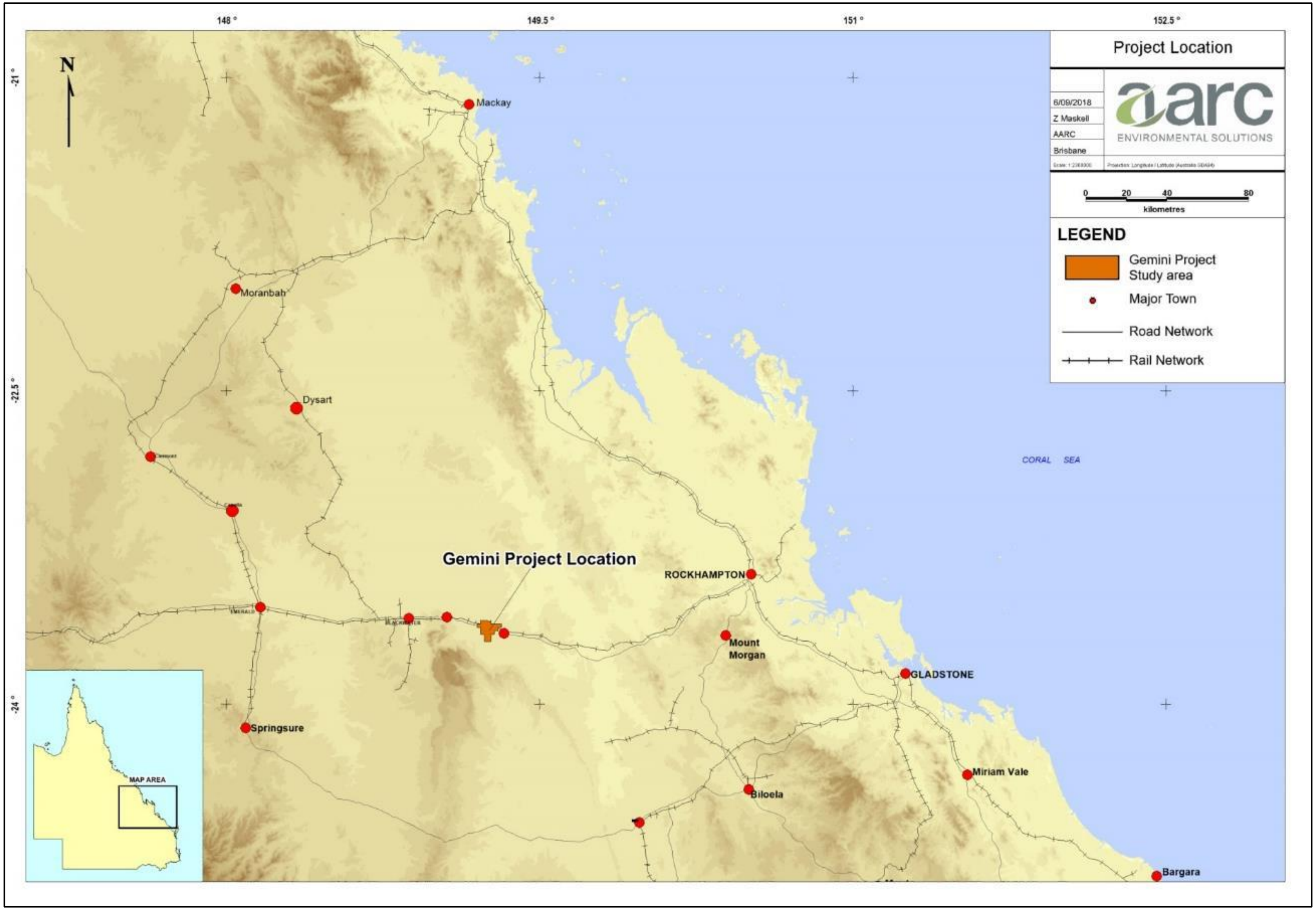

Figure 1 Location of the Gemini Project study area

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 stockpiles, product coal stockpiles and a rejects bin/overflow for 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 a construction/production period of approximately 20 years;
- progressive placement of waste rock in:
  - emplacements, adjacent to and near the open-cut voids; and
  - 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), with material sourced from local quarries where required;
- disposal of CHPP rejects (coarse and fine rejects) in out-of-pit emplacements, and in-pit behind the advancing mine face;
- 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, 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 Aurizon rail network, Ergon's electricity network, the Capricorn Highway, and Gladstone export coal terminals.

1.3 CURRENT LAND USE

The land within the study area is currently used for low intensity cattle grazing and resource exploration activities. The Capricorn Highway and a number of publicly gazetted roads including Charlevue, Cooinda, Red Hill, Normanby, and Ellesmere roads dissect the study area.

Located directly north of the study area is Taunton National Park (NP), a scientific reserve under the Queensland *Land Act 1994*, with the aim of protecting a population of *Onychogalea fraenata* (bridled nail-tail wallaby). A small section (approximately 2.5 ha) of Taunton NP overlaps with the study area.

1.4 LOCAL WATERWAYS AND TOPOGRAPHY

The study area lies within the Fitzroy River Basin, which encompasses an area of 142,545 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.

Charlevue Creek traverses the study area in a north-easterly direction. This watercourse begins within the boundaries of Blackdown Tablelands NP, flowing north-east before joining with Springton Creek downstream of the Project. Stanley Creek cross the north-west of the study area before joining with Duckworth Creek, also downstream of the Project. Springton Creek crosses the south-east of the study area, and receives both Charlevue Creek and Duckworth Creek, before flowing into the Mackenzie River. The Dawson River and Mackenzie River later join to form the Fitzroy River, eventually flowing into the Pacific Ocean approximately 46 km north of Gladstone.

Several first and second order streams occur across the study area, all of which flow into one of the three major creeks traversing the study area, and contributing to the Springton Creek catchment. The extent and location of the waterways within the study area is displayed in Figure 2.

Springton Creek and Charlevue Creek are defined watercourses under the Queensland *Water Act 2000* (Water Act). Within the study area, Springton Creek and Charlevue Creek are fifth order streams. Stanley Creek is a second order stream.

The topography of the study area is representative of the surrounding region, varying from flat to low undulations. The landscape is influenced by Charlevue Creek which has a lower elevation than the surrounding landscape, with elevations within the study area ranging between 120 m and 150 m AHD.

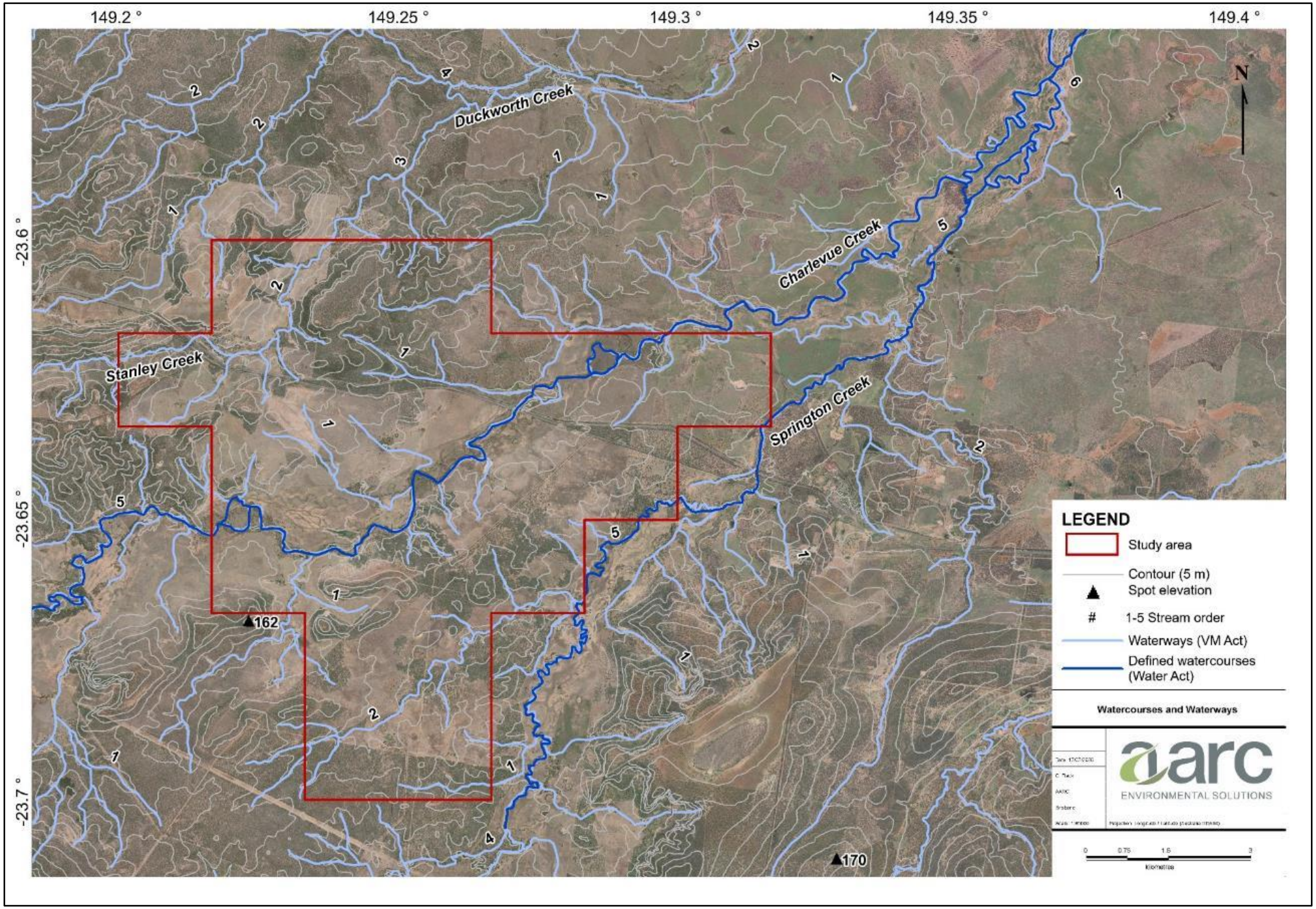

Figure 2 Waterways and topography associated with the study area

1.5 GEOLOGY

The geology of the region is dominated by its position within the Bowen Basin, one of Queensland's largest depositional regions, formed during a period of rifting and subsidence, lasting from the Early Permian to 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).

1.6 REGIONAL CLIMATE

The regional climate is classified as sub-tropical, characterised by hot, humid summers and moderately dry winters. It falls within a seasonal rainfall zone typified by wet summers and low winter rainfall, with a total annual rainfall between 650-1200 mm (BoM 2020a).

Climate data for the study area has been sourced from Scientific Information for Land Owners (SILO) climate database, which operates by interpolating data from the Bureau of Meteorology (BoM) into a single point data drill.

Figure 3 shows predicted average temperature and rainfall for the area from January 1999 to May 2020. The data illustrates high summer rainfall for the study area between December and March; with approximately 62% of total annual rainfall occurring during these four months. April to September is comparatively dry, with mean monthly rainfall increasing throughout the spring season.

The hottest months typically occur between October and March (mean monthly maximum >30°C), whilst the coolest months occur between June and August (mean monthly minimum ≤10°C).

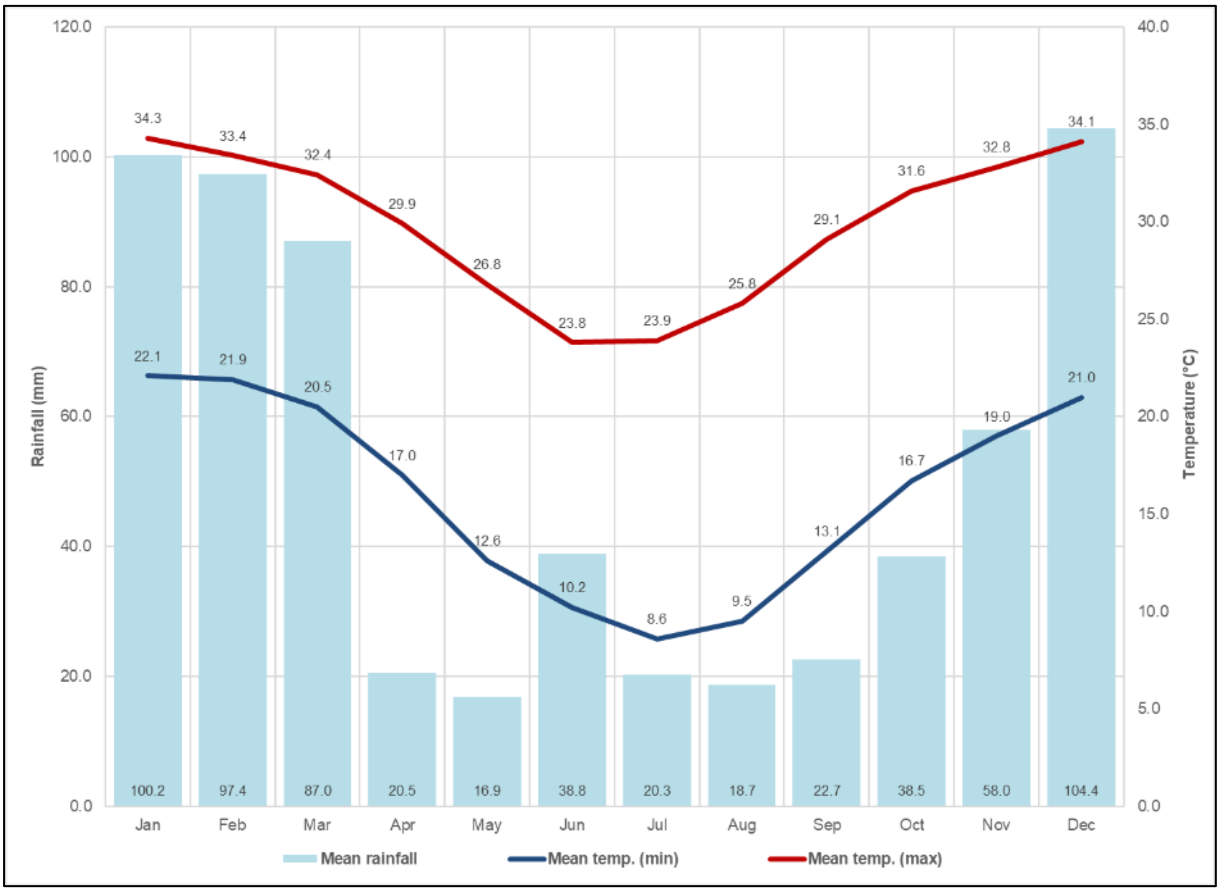

Figure 3 Monthly mean temperature and rainfall for the study area (1999-2020)

2.0 RELEVANT LEGISLATION AND POLICY

Commonwealth and Queensland legislation and policies relevant to the assessment of aquatic ecological values on the study area are discussed in the following sub-sections.

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 upon a matter of national environmental significance (MNES).

An EPBC Referral (2010/5775) was lodged in 2010 for the Gemini Project 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 (2010/5775).

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, which is defined as extinct wildlife (Ex); endangered wildlife (E); vulnerable wildlife (V); near threatened wildlife (NT); and least concern wildlife (LC). Species listed under the above classes are published in the associated *Nature Conservation (Wildlife) Regulation 2006* (NCWR).

'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.

2.3 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. feral animals 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:

1. 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.

2. A '**restricted matter'** is a biosecurity matter found in Queensland 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.

3. 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 QUEENSLAND ENVIRONMENTAL OFFSETS FRAMEWORK

Under a number of existing Queensland laws, offsets may be required for certain activities where there is an unavoidable impact on significant environmental values. To counterbalance this loss, offsets, which can include improvement and protection of alternative sites and/or actions that improve environmental viability, can provide a conservation outcome that is equivalent to the environmental value being lost at the impact site (DES 2020).

The Queensland environmental offsets framework consists of the:

1. *Environmental Offsets Act 2014* (EO Act);

2. *Environmental Offsets Regulation 2014* (EO Regulation);

3. *Queensland Environmental Offsets Policy (Version 1.8)* (QEOP) (DES 2020); and

4. *QEOP: Significant Residual Impact Guideline* (EHP 2014).

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* (EHP 2014) is used to determine whether residual impacts are considered to be significant. The EO Act defines the following to be a prescribed environmental matter:

- matters of national environmental significance (MNES);
- matters of state environmental significance (MSES); and
- matters of local environmental significance (MLES).

MNES are discussed in Section 2.1 (Environment Protection and Biodiversity Conservation Act 1999), whilst MLES are set out in local planning instruments. MSES are defined in Schedule 2 of the EO Regulation. MSES relevant to the terrestrial ecological environment of the Project are discussed and assessed in the *Gemini Project: Terrestrial Ecology Assessment* (AARC 2019). MSES relevant to the aquatic ecological assessment of the Project comprise:

- wetlands and watercourses including:
    - a wetland-
        - in a wetland protection area (as defined under the *Environmental Protection Regulation 2019*); or
        - of high ecological significance as shown on the map of Queensland wetland environmental values (as defined under the *Environmental Protection (Water and Wetland Biodiversity) Policy 2019*);
    - a wetland or watercourse in high ecological value waters (as defined under the *Environmental Protection (Water and Wetland Biodiversity) Policy 2019*);
- protected wildlife habitat, which includes;
    - areas that contain endangered or vulnerable plants (under the NC Act);
    - habitat for an animal that is endangered, vulnerable, or special least concern (under the NC Act);
- 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*); and
- marine plants (under the *Fisheries Act 1994*).

2.5 FISHERIES ACT 1994

The Queensland *Fisheries Act 1994* (Fisheries Act) protects all aquatic ecosystems from unauthorised disturbance. The main purpose of the Fisheries Act is to provide for:

- the protection of fisheries;
- the protection of marine fish;
- the protection of marine plants; and
- the facilitation of management plans.

As of the 3rd July 2017, the Fisheries Act requires waterway barrier works to be developed in accordance with the accepted development requirements. The accepted development requirements are those outlined in *Accepted development requirements for operational work that is constructing or raising waterway barrier works* (DAF 2018).

2.6 ENVIRONMENTAL PROTECTION (WATER AND WETLAND BIODIVERSITY) POLICY 2019

The *Environmental Protection (Water and Wetland Biodiversity) Policy 2019* (EPP (Water and Wetland Biodiversity)) is subordinate legislation under the *Environmental Protection Act 1994*.

The purpose of the EPP (Water and Wetland Biodiversity) is to achieve the object of the Act in relation to waters and wetlands. The purpose is achieved by:

- identifying environmental values (EVs) for waters and wetlands to be enhanced or protected;
- identifying management goals for waters;
- stating water quality guidelines and water quality objectives (WQOs) for enhancing or protecting the environmental values of waters;
- providing a framework for making consistent, equitable and informed decisions about waters; and
- monitoring and reporting on the condition of waters.

Waterways associated with the Project occur within the Mackenzie River sub-basin, with EVs and WQOs for all waters within this sub-basin specified in *Mackenzie River Sub-basin EVs and WQOs: Basin No. 130 (part), including all waters of the Mackenzie River Sub-basin* (EHP 2013b).

3.0 DESKTOP ASSESSMENT

A desktop assessment was conducted to collate information on aquatic ecological values identified in the region. These searches include previous surveys, community records and other sources. A review of databases was conducted to inform the specific field survey techniques to target aquatic flora and fauna species known from the region.

All database searches were based on either the lot/plan, the study area, or a central coordinate point, depending on the search capabilities of the database search undertaken. Database search results can be found in Appendix A (Database Searches). The following databases searches were undertaken:

1. Environmentally Sensitive Area (ESA) Mapping;
2. Regulated Vegetation Management Map and Supporting Map;
3. *WetlandMaps* Report;
4. Map of Referable Wetlands;
5. DES Environmental Reports:
    a. Biodiversity and Conservation Values;
    b. Matters of State Environmental Significance;
    c. Regional Ecosystems;
6. EPBC Act Protected Matters Report (10 km and 50 km search buffers); and
7. Wildlife Online Species List Extract (10 km and 50 km search buffers).

Additional resources that provide species records and related information such as the Atlas of Living Australia (ALA) and Queensland Museum were consulted where appropriate to support species likelihood of occurrence.

The following sub-sections discuss aquatic ecological values relevant to the study area identified within the desktop assessment.

3.1 WETLAND HABITATS

Three types of mapped waterbodies were identified during the desktop assessment, occurring as several small riverine, palustrine and lacustrine wetlands potentially present within the study area (Figure 4). All lacustrine and palustrine wetlands within the study area were identified as artificial (farm) dams or not present during previous terrestrial ecology surveys (AARC 2019). Riverine wetlands (corresponding with riverine vegetation) were previously identified in association with the Charlevue Creek and are discussed in the *Gemini Project: Terrestrial Ecology Assessment* (AARC 2019).

The study area is identified as having a sub-catchment conservation significance of medium in the Biodiversity and Conservation Values Report (aquatic conservation assessments). This indicates that wetlands in the study area have a combination of high and medium values amongst the assessment criteria.

One wetland of high ecological significance (HES), that also lies within a wetland protection area, occurs approximately 4 km south-east of the study area (Figure 4). This wetland, including potential impacts, has been addressed in the *Gemini Project: Terrestrial Ecology Assessment* (AARC 2019).

No wetlands of national or international importance have been recorded within the study area or surrounds.

3.2 WATERWAYS PROVIDING FOR FISH PASSAGE

Waterways, as defined by the Fisheries Act, include rivers, creeks, streams, watercourses, and inlets of the sea.

The ‘Queensland waterways for waterway barrier works’ mapping indicates the level of ‘risk’ associated with undertaking waterway barrier works within Queensland waterways. Waterways with higher stream orders, steeper slopes, higher flow rates, greater number of fish present and fish with stronger swimming abilities obtain a higher level of risk.

Charlevue Creek and Springton Creek are mapped as being at major risk of adverse impact from waterway barrier works on fish movement. Stanley Creek is mapped as being of moderate risk of adverse impact. Tributaries of these creeks within the study area are mapped as being of either low, moderate, or high risk of adverse impact from waterway barrier works on fish movement.

3.3 SPECIES OF CONSERVATION SIGNIFICANCE

No aquatic flora species of conservation significant were identified by the desktop assessment.

Four fauna species of conservation significance with potential to occur within 50 km of the study area were identified during the desktop assessment. An assessment of the likelihood of these species occurring within the study area was completed prior to conducting the field survey, for the purpose of determining target species and to guide field survey methodology. The detailed assessment was based on the knowledge of ecologists, habitat suitability and scientific literature, which determined that all four were considered unlikely to occur within the study area (Table 1).

Rheodytes leukops (Fitzroy River turtle) was previously identified as potentially being impacted by the former Dingo West Project by the EPBC Referral Decision (2010/5775). The potential impact of the Gemini Project on the Fitzroy River turtle is assessed in Section 9.2 (Impact Assessment: Fitzroy River Turtle).

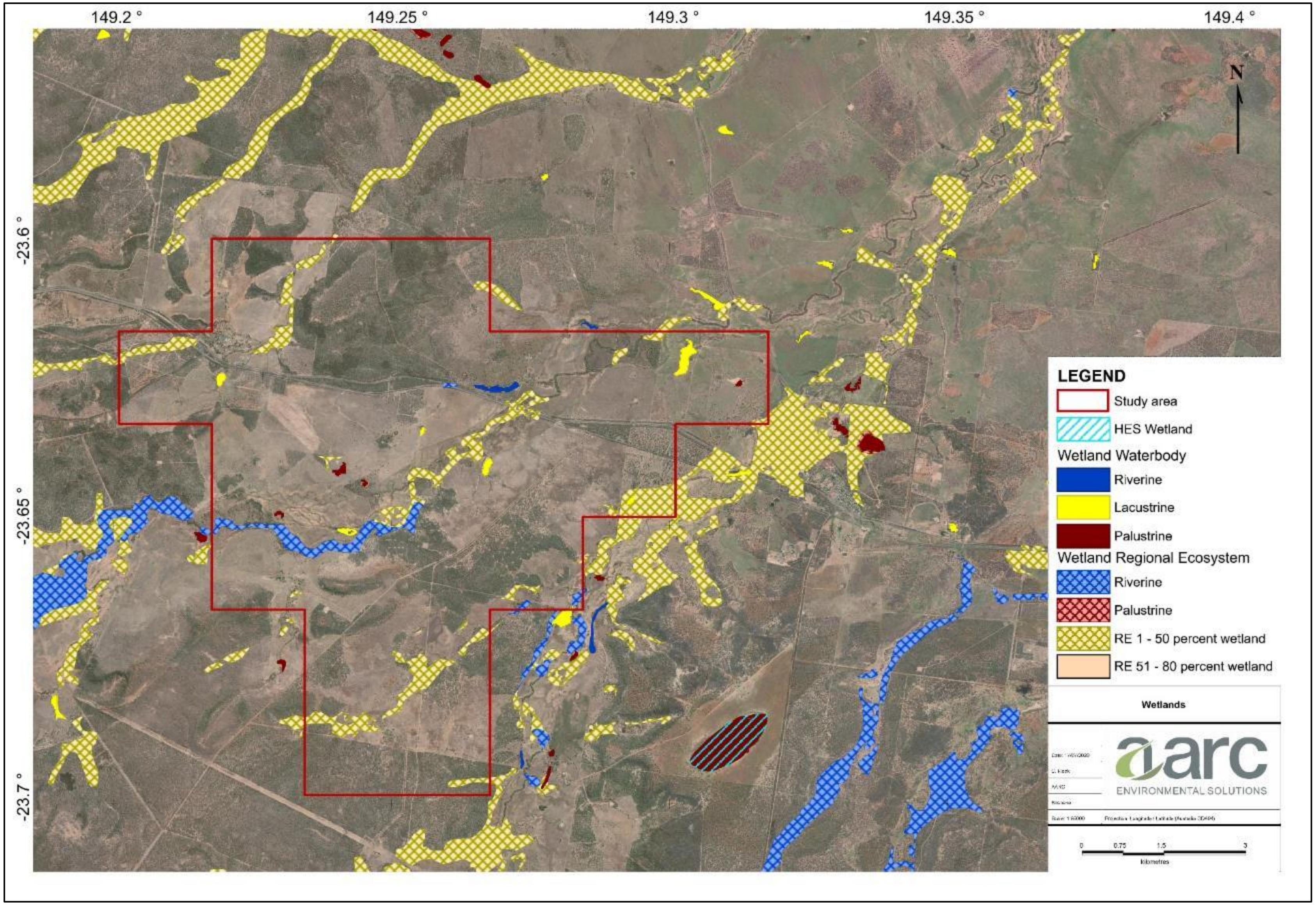

Figure 4 Wetland habitats

Table 1 Fauna species of conservation significance identified during desktop assessment

Species	Status		Database Searches		Habitat and Distribution	Desktop Likelihood of Occurrence
	EPBC Act	NC Act	Protected Matters	Wildlife Online		
Fish						
Maccullochella peelii Murray cod	V	NL	Species or species habitat **may** occur within area. *0-10 km.*	No records.	The Murray cod lives in a wide range of habitats, from clear, rocky streams to slow flowing, turbid rivers, and billabongs (DAWE 2020).	Unlikely This species was returned in the 10 km protected matters report as may occur. No records of this species occur within 50 km of the study area. The watercourses present within the study area are ephemeral in nature and only run during periods of high rainfall.
Reptiles						
Crocodylus porosus Salt water crocodile	Mi	V	Species or species habitat **likely** to occur within area. *10-50 km.*	No records.	Salt-water crocodiles are restricted to coastal waterways and floodplain wetlands within Queensland (DAWE 2020).	Unlikely This species was returned in the 10 km protected matters report as likely to occur. No records of this species occur within 50 km of the study area. Coastal waterways or floodplain wetlands do not occur within the study area.
Elseya albagula Southern snapping turtle	CE	E	Species or species habitat **likely** to occur within area. *0-10 km.* Species or species habitat **known** to occur within area. *10-50 km.*	2 (10-50 km)	The Southern snapping turtle is only found in the Burnett, Fitzroy, Raglan and Mary River drainages of south-east Queensland. It prefers permanent flowing water habitats where there are suitable shelters and refuges (e.g. fallen trees) (DAWE 2020).	Unlikely This species was returned in the 10 km protected matters report as likely occur, and as known to occur between 10 and 50 km. No records of this species occur within 10 km of the study area; however, two records occur between 10 and 50 km. No permanent flowing waterways occur within the study area.
Rheodytes leukops Fitzroy River turtle	V	V	Species or species habitat **likely** to occur within area. *0-10 km.* Species or species habitat **known** to occur within area. *10-50 km.*	1 (10-50 km)	The Fitzroy River turtle is limited to the Fitzroy River catchment in central Queensland. Previously thought to prefer shallow (<2.0 m) riffle zones with high water velocities, the species is now known to occupy large pools (>1 km long and >2 m deep) and reservoirs. This species will nest in alluvial sand-loam riverbanks (Curtis et al. 2012).	Unlikely This species was returned in the 10 km protected matters report as likely occur, and as known to occur between 10 and 50 km. No records of this species occur within 10 km of the study area; however, one record occurs between 10 and 50 km. A review of ALA records indicate this species is associated with the waters of the Mackenzie River and Fitzroy River. No suitable riffle or large pool habitat occurs within the study area.

Notes:		
	NL	not listed
	Mi	migratory
	CE	critically endangered

4.0 ENVIRONMENTAL VALUES AND OBJECTIVES

4.1 ENVIRONMENTAL VALUES

The waterways of the study area fall within the Mackenzie River catchment, with the *Environmental Protection (Water) Policy 2009: Central Queensland Map Series (WQ130 - Mackenzie River Sub-basin, part of basin 130)* (EHP 2013a) identifying several waterways on and surrounding the study area.

Environmental values are defined as the qualities of water that make it suitable for supporting aquatic ecosystems and a variety of human water uses. EHP (2013b) identifies ten EVs in the Mackenzie River sub-basin. Two of these are deemed relevant for the waters surrounding the study area:

1. protection of aquatic ecosystem values; and

2. suitability for stock watering.

The waters within and directly surrounding the study area are defined as moderately disturbed waters (EHP 2013b).

4.1.1 Stream Sediment Quality Objectives

Baseline levels of metals in stream sediments are important indicators of the accrual of any pollutants. Stream sediment quality objectives for the study area are adopted from the default guidelines values for sediment quality (ANZECC & ARMCANZ 2000) (Table 2).

Table 2 Guideline values for stream sediment quality

Parameter	Guideline Value (mg/kg)	
	Low Value	High Value
Arsenic	20	70
Cadmium	1.5	10.0
Chromium	80	370
Copper	65	270
Lead	50	220
Mercury	0.15	1.00
Nickel	21	52
Zinc	200	410

4.1.2 Water Quality Objectives

Water quality objectives are provided to support and protect the different EVs identified for waters within the Mackenzie River southern tributaries (EHP 2013b). WQOs are provided in two main parts:

1. for the purposes of protecting the aquatic ecosystem EV; and

2. for EVs other than aquatic ecosystems (human use EVs such as stock watering).

The guideline WQOs (EHP 2013b) for the protection of aquatic ecosystems and for stock watering are provided in Table 3.

Table 3 Guideline values for water quality objectives

Management Intent (level of protection)	WQOs to protect EV	
	Parameter	Guideline Value
Aquatic ecosystem *(moderately disturbed)*	**Water**	
	Ammonia as nitrogen	<20 µg/L
	Oxidised nitrogen	<60 µg/L
	Organic nitrogen	<420 µg/L
	Total nitrogen	<775 µg/L
	Filterable reactive phosphorus	<20 µg/L
	Total phosphorus	<160 µg/L
	Chlorophyll a	<5.0 µg/L
	Dissolved oxygen	85–110% saturation
	Turbidity	<50 NTU
	Suspended solids	<110 mg/L
	pH	6.5–8.5
	Conductivity (EC) baseflow	<310 µS/cm
	Conductivity (EC) high flow	<210 µS/cm
	Sulphate	<10 mg/L
	Macroinvertebrates	
	Taxa richness (composite)	12–21
	Taxa richness (edge habitat)	23–33
	PET taxa richness (composite)	2–5
	PET taxa richness (edge habitat)	2–5
	SIGNAL index (composite)	3.33–3.85
	SIGNAL index (edge habitat)	3.31–4.20
	% tolerant taxa (composite)	25–50%
	% tolerant taxa (edge habitat)	44–56%
Stock watering	**Water**	
	Total dissolved solids	3000 mg/L
	Aluminium	5 mg/L
	Arsenic	0.5 (up to 5) mg/L
	Beryllium	*no data*
	Boron	5 mg/L
	Cadmium	0.01 mg/L
	Chromium	1 mg/L
	Cobalt	1 mg/L
	Copper	0.4 mg/L (sheep) 1 mg/L (cattle) 5 mg/L (pigs) 5 mg/L (poultry)
	Fluoride	2 mg/L
	Iron	*not sufficiently toxic*
	Lead	0.1 mg/L
	Manganese	*not sufficiently toxic*
	Mercury	0.002 mg/L
	Molybdenum	0.15 mg/L
	Nickel	1 mg/L
	Selenium	0.02 mg/L
	Uranium	0.2 mg/L
	Vanadium	*no data*
	Zinc	20 mg/L

Notes:	EC	electrical conductivity
	PET	Plecoptera, Ephemeroptera, Trichoptera
	NTU	nephelometric turbidity units
	SIGNAL	stream invertebrate grade number - average level

5.0 METHODOLOGY

Industry standard methodologies as described in Section 5.3 through to Section 5.7 were used to survey indicators of aquatic ecological value including:

- surface water quality;
- stream sediment quality;
- creek ecology including:
    - physical assessment;
    - habitat bioassessment;
    - condition assessment;
    - macroinvertebrate populations;
- fauna survey including:
    - aquatic fauna;
    - riparian vertebrate fauna; and
- riparian and aquatic vegetation.

5.1 OVERVIEW OF FIELD SURVEYS

The aquatic environment of the study area is highly ephemeral, with rainfall events sufficient to cause creek-flow occurring irregularly during the wet season and occasionally during the early post-wet season. Even throughout the wet season, creek-flow events are typically short-lived, lasting between a few days to a couple of weeks, at most. Additionally, several methodologies should be undertaken (or avoided) during specific stages of the flow cycle, which leads to narrow windows of opportunity to undertake adequate field sampling.

Consequently, three sampling events were undertaken across three consecutive wet/post-wet seasons, each scheduled following sufficient rainfall to cause creek-flow. Two AARC ecologists undertook aquatic ecology surveys of the study area over the following dates:

- 23rd – 24th February 2018;
- 3rd – 9th April 2019; and
- 17th – 23rd March 2020.

Survey 1: 23rd – 24th February 2018

A small amount of rainfall (2.2 mm) was recorded during the 2018 survey at the Blackdown Tablelands AL weather station (No. 035186) located approximately 14.2 km south-west of the study area (Table 4).

Table 4 Survey rainfall

	February 2018	April 2019	March 2020
During survey (mm)	2.2	0.0	0.0
Preceding 1 week (mm)	73.6	88.6	1.4
Preceding 2 weeks (mm)	73.6	93.4	65.8
Preceding 3 months (mm)	467.4	349.2	585.4

Source: Blackdown Tablelands AL weather station (035186) (BoM 2020b).

In the three months preceding the survey a total of 467.4 mm fell, constrained primarily to four rainfall events, plus a few small showers:

1. a large rainfall event at the beginning of December (188.4 mm over six days);
2. a moderate rainfall event at the beginning of January (72.6 mm over five days);
3. a large rainfall event at the beginning of February (93.0 mm over three days); and
4. a moderate rainfall event in the five days prior to the survey (73.6 mm over five days).

Of the rainfall event immediately preceding the survey, 56.6 mm fell the day before the survey commenced, resulting in sub-optimal survey conditions. Consequently, several survey methodologies were impractical including fauna trapping and macroinvertebrate sampling due to localised flooding and fast creek flow. Water and stream sediment sampling was undertaken where possible, and the survey was cut short after two days.

Survey 2: 3rd – 9th April 2019

Conditions during the 2019 survey were mostly fine, with no rainfall recorded during the survey at the Blackdown Tablelands AL weather station (Table 4).

The three months preceding the survey were drier than the 2018 survey, with a total of 349.2 mm falling across five rainfall events:

1. a large rainfall event in early January (126.2 mm over two days);
2. a small rainfall event in early February (15.8 mm over ten days);
3. a small rainfall event in late February (15.2 mm over four days);
4. a moderate rainfall event in mid-March (101.4 mm over nine days); and
5. a moderate rainfall event in the week prior to the survey (88.6 mm over five days).

Of the rainfall event preceding the survey, the rainfall was more spread out over the five-day event compared with the rainfall event preceding the 2018 survey. The single largest day of rainfall (45.8 mm) occurred six days prior to the 2019 survey commencing, with the two days immediately prior to the survey recording no rainfall. This resulted in more optimal conditions during the 2019 survey, allowing for the full suite of survey methodologies to be undertaken. However, all methodologies could not be undertaken at all sites, due to smaller creeks already having dried out.

Survey 3: **17th – 23rd March 2020**

A final survey was undertaken in 2020 to supplement the two prior surveys, focussing on the aquatic methodologies, improving robustness in the datasets, and adding several new survey sites to expand the study area. Conditions during the 2020 survey were fine, with no rainfall recorded during the survey at the Blackdown Tablelands AL weather station (Table 4).

The three months preceding the survey were the wettest of the three surveys, with a total of 585.4 mm falling across three rainfall events, one prolonged period of rainfall and a few small showers:

1. a small rainfall event in mid-January (49.6 mm over three days);
2. a large rainfall event in late-January (133 mm over six days);
3. a prolonged period of rainfall throughout February with only four dry days recorded during the month (319.4 mm month total); and
4. a moderate rainfall event in early-March (65.8 mm over six days).

No rainfall occurred during the six days preceding the 2020 survey, resulting in moderate survey conditions. Due to the prolonged period of rainfall throughout February and moderate rainfall event two weeks prior to the survey, the larger waterways retained pools of varying sizes, whilst the smaller creeks had dried out. Consequently, survey methodologies appropriate to the level of water remaining were undertaken at each site.

5.2 SAMPLING SITES

The selection of sampling site locations was designed to achieve spatial distribution across the study area and the three creek catchments, as well as capturing 'entry' and 'exit' points of waterways traversing the Project, to initiate collection of baseline data for 'reference' and 'impact' sites that could be used in long-term monitoring.

Table 5 describes each sampling site and sampling location, whilst Figure 5 illustrates the location of each site. Due to the number of sampling sites, size of the study area, frequent access issues during/following rainfall events, and level of water present at each site; not all sampling methodologies were undertaken at every sampling site. Table 6 and Table 7 detail the survey methods used at each sampling site. Detailed descriptions of each methodology are provided in the following sub-sections.

Assessments undertaken at all sites included stream sediment sampling, creek ecology values including physical assessment, habitat bioassessment, and condition assessment, and vegetation sampling. Additional assessments undertaken at all sites with water present included surface water sampling and macroinvertebrate sampling[2].

Aquatic fauna trapping was prioritised along the major watercourses (Springton Creek and Charlevue Creek) that offered the greatest potential of suitable habitat for aquatic macro-fauna, including the retention of water for the longest period of time. Site scoping identified the potential for aquatic fauna trapping to be undertaken along Stanley Creek, however due to the ephemeral nature of this waterway and its low stream order; Stanley Creek and many waterways throughout the study area did not contain sufficient water to undertake aquatic fauna trapping.

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[2] Except for site DWR1; where water was present at this site only during the initial 2018 survey when localised flooding and fast creek flow resulted in unsuitable conditions for sampling of macroinvertebrate populations.

Riparian fauna surveys were undertaken at selective sites during the 2018 survey, designed to complement the terrestrial ecology assessment (AARC 2019). Most aquatics sites throughout the study area had little to no riparian habitat due to prior clearing practices. The sites where riparian fauna survey was undertaken were those which contained riparian habitat of value.

During the 2020 survey, site DWI1 was inaccessible, however three new sites were added to expand the study area further upstream and downstream of the Project:

- **DAR2:** upstream of the Project on Springton Creek;
- **DAI7:** downstream of the Project on Charlevue Creek; and
- **DAI8:** downstream of the Project on Duckworth Creek.

Table 5 Sampling site locations

Site Code	Locality	Easting	Northing
Stanley Creek and Duckworth Creek			
DWR1	Located on a stream order (SO) 1 tributary of Stanley Creek originating within study area. Upstream of Capricorn Highway, DWI1 and DAI8.	726539	7385851
DWI1	Located along Stanley Creek (SO2) as creek exits through the northern EPC boundary. Downstream of Capricorn Highway and DWR1, upstream of DAI8.	728495	7388452
DAI8	Located on Duckworth Creek (SO5) as creek crosses under the Fitzroy Development Road. Downstream of study area, DWR1 and DWI1.	735277	7391193
Charlevue Creek and unnamed tributaries			
DAR1	Located on Charlevue Creek (SO5) as creek enters through the western EPC boundary. Furthest upstream site on the Charlevue Creek catchment along with DWR5.	726343	7382890
DWR5	Located on SO2 tributary of Charlevue Creek where it enters through the south-western boundary of the EPC. Furthest upstream site on the Charlevue Creek catchment along with DAR1.	727637	7381175
DAI1	Located on Charlevue Creek (SO5) downstream of DAR1, at confluence with DWR5 tributary.	728041	7382229
DAI2	Located on Charlevue Creek (SO5), downstream of DAR1, DWR5 and DAI1.	729777	7382855
DWR4	Located on depression in SO2 tributary of Charlevue Creek.	729148	7383186
DAI3	Located on Charlevue Creek (SO5), downstream of DAI2 and confluence of DWR4 tributary. Upstream of DAI4 and Capricorn Highway.	730965	7384404
DAI4	Located on Charlevue Creek (SO5), downstream of DAI3 and Capricorn Highway.	732562	7385666
DWI3	Located on SO1 tributary of Charlevue Creek originating within study area. Located where tributary exits through the north-eastern boundary of EPC.	731371	7387530
DAI7	Located on Charlevue Creek (SO5) as creek crosses under the Fitzroy Development Road. Downstream of study area, DAI4 and confluence of DWI3 tributary. Slightly upstream of highway.	735906	7387047
Springton Creek and unnamed tributaries			
DWR6	Located on SO2 tributary of Springton Creek, slightly downstream of confluence of three smaller tributaries originating outside of the south-western boundary of the EPC. Upstream of proposed developments.	728560	7378606
DAR2	Located on Springton Creek (SO5), upstream of study area and proposed developments.	731871	7377771
DWI8	Located on SO1 tributary of Springton Creek originating within study area. Located where tributary exits through the south-eastern boundary of EPC. Downstream of proposed developments.	731226	7378412
DWI9	Located on SO1 tributary of Springton Creek originating within study area. Located where tributary exits through the south-eastern boundary of EPC. Downstream of proposed developments.	731242	7377634
DAI5	Located on Springton Creek (SO5) where it briefly crosses into the EPC. Downstream of DWR6, DWI8 and DWI9 tributaries.	732910	7381153
DWI6	Located on Springton Creek (SO5) as creek crosses under the Capricorn Highway. Downstream of study area, slightly upstream of highway. Furthest downstream site on the Springton Creek catchment.	736129	7383390

Coordinate System: Geocentric Datum of Australia (GDA) 1994 (Zone 55K).

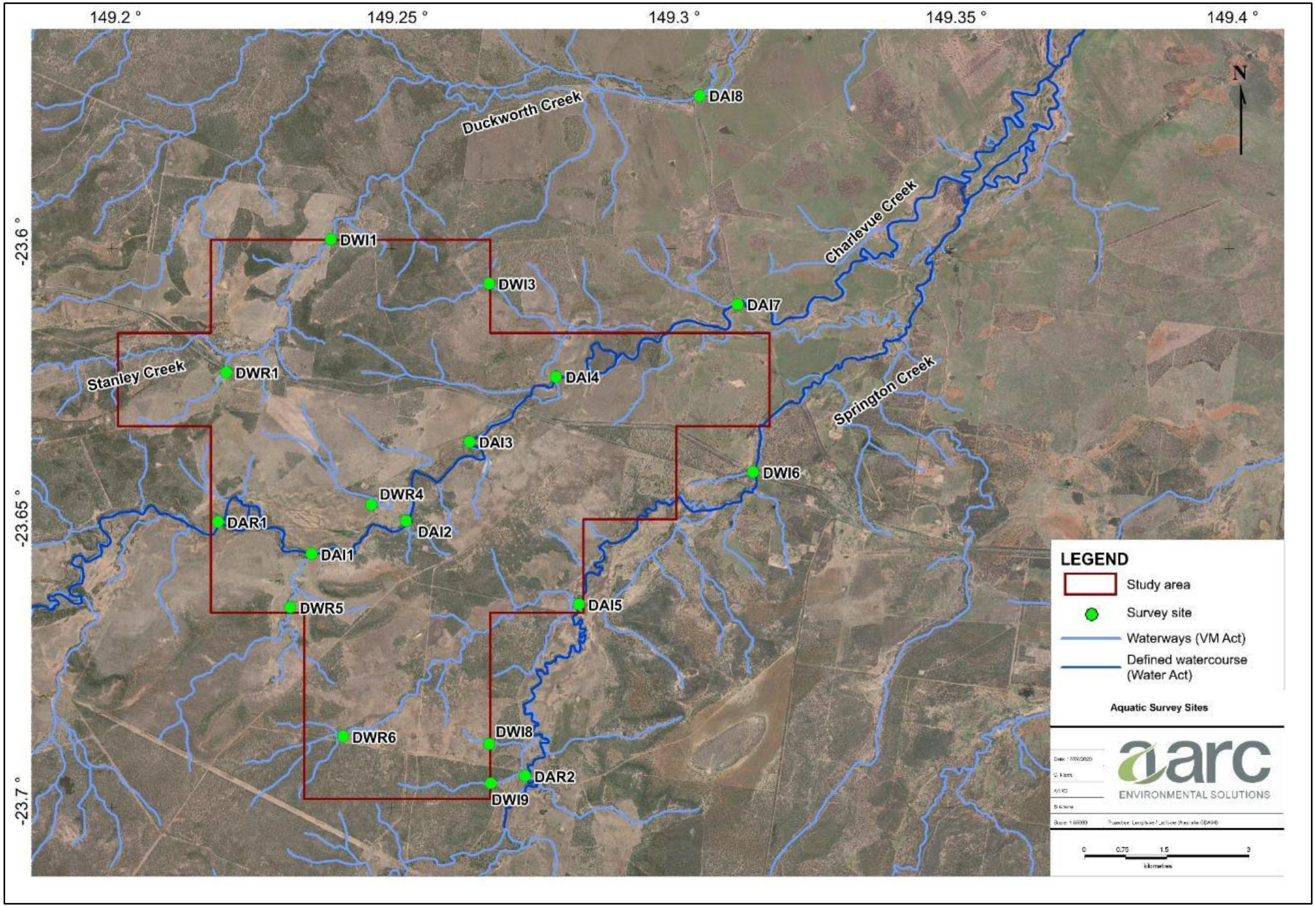


Figure 5 Location of survey sites

Table 6 Survey methods (Stanley Creek and Duckworth Creek, Springton Creek)

Survey Method		Stanley Creek and Duckworth Creek									Springton Creek and unnamed tributaries																	
		DWR1			DWI1			DAI8			DWR6			DAR2			DWI8			DWI9			DAI5			DWI6		
		2018	2019	2020	2018	2019	2020	2018	2019	2020	2018	2019	2020	2018	2019	2020	2018	2019	2020	2018	2019	2020	2018	2019	2020	2018	2019	2020
Surface water sampling		✓								✓						✓					✓		✓	✓	✓	✓	✓	✓
Stream sediment sampling		✓	✓	✓	✓	✓				✓	✓	✓	✓			✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Creek ecology	Physical assessment		✓	✓		✓				✓		✓	✓			✓		✓	✓		✓	✓		✓	✓		✓	✓
	Habitat bioassessment		✓	✓		✓				✓		✓	✓			✓		✓	✓		✓	✓		✓	✓		✓	✓
	Condition assessment		✓			✓				✓		✓				✓		✓			✓			✓	✓		✓	✓
Aquatic fauna	Macroinvertebrate sampling									✓						✓					✓			✓	✓		✓	✓
	Fish and crustacean trapping									✓						✓								✓	✓			✓
Riparian fauna	Bird survey																							✓				
	Spotlight																							✓				
	Call playback																							✓				
	Habitat search																							✓				
Vegetation			✓			✓				✓		✓				✓		✓			✓			✓	✓		✓	✓

Notes: Blue survey years denote the site was wet. Orange survey years denotes the site was dry.
DWI1 was inaccessible in 2020. DAI8 and DAR2 were new sites added in 2020.

Table 7 Survey methods (Charlevue Creek)

Survey Method		Charlevue Creek and unnamed tributaries																										
		DAR1			DWR5			DAI1			DAI2			DWR4			DAI3			DAI4			DWI3			DAI7		
		2018	2019	2020	2018	2019	2020	2018	2019	2020	2018	2019	2020	2018	2019	2020	2018	2019	2020	2018	2019	2020	2018	2019	2020	2018	2019	2020
Surface water sampling		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓			✓	✓	✓	✓	✓	✓	✓						✓
Stream sediment sampling		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓			✓
Creek ecology	Physical assessment		✓	✓		✓	✓		✓	✓		✓	✓		✓	✓		✓	✓		✓	✓		✓	✓			✓
	Habitat bioassessment		✓	✓		✓	✓		✓	✓		✓	✓		✓	✓		✓	✓		✓	✓		✓	✓			✓
	Condition assessment		✓	✓		✓			✓			✓	✓		✓			✓	✓		✓	✓		✓				✓
Aquatic fauna	Macroinvertebrate sampling		✓	✓		✓	✓		✓	✓		✓	✓			✓		✓	✓		✓	✓						✓
	Fish and crustacean trapping		✓	✓					✓			✓	✓						✓		✓	✓						✓
Riparian fauna	Bird survey		✓						✓			✓						✓			✓							
	Spotlight		✓						✓			✓						✓			✓							
	Call playback		✓						✓			✓						✓			✓							
	Habitat search		✓						✓			✓						✓			✓							
Vegetation			✓	✓		✓			✓	✓		✓	✓		✓			✓	✓		✓	✓		✓				✓

Notes: Blue survey years denote the site was wet. Orange survey years denotes the site was dry.
DAI7 was a new site added in 2020.

5.3 SURFACE WATER SAMPLING

Water quality sampling was carried out in accordance with the *Monitoring and Sampling Manual: Environmental Protection (Water) Policy 2009* (DES 2018b) methodology. Field readings of pH, dissolved oxygen (DO), turbidity, electrical conductivity (EC) and temperature were also recorded. In-situ measurements were collected using a multi-parameter water quality meter that was laboratory calibrated to the manufacturers' specifications.

Grab samples were collected at a depth of 10-20 cm where sufficient water was available. Several water samples were collected at each site (where possible) in analyte specific sterilised collection bottles and a suite of parameters tested. All water samples were kept on ice or refrigerated during storage and transport to a National Association of Testing Authorities (NATA) accredited laboratory for analysis.

Surface water sampling was undertaken at all sites where water was present during each survey.

5.4 STREAM SEDIMENT SAMPLING

Stream sediment quality sampling was undertaken in accordance with the *Monitoring and Sampling Manual: Environmental Protection (Water) Policy 2009* (DES 2018b). Five sub-samples (approximately 500 g each) of stream-bed substrate was taken at 10 m intervals along a 50 m transect in the river bed. Sub-samples were collected using a non-metallic shovel and mixed in a plastic bucket to obtain a composite sample. A representative 500 g sample was taken from the sub-sample composite and sent to a NATA accredited laboratory for analysis of trace metals and particle size.

Stream sediment sampling was undertaken at all sites during each survey.

5.5 CREEK ECOLOGY

5.5.1 Physical Assessment

The monitoring methodologies utilised in the physical assessment is presented in Table 8. This assessment utilises monitoring techniques adapted from the following environmental sampling manuals:

- *AusRivAS Physical Assessment Protocol* (Parsons, Thoms & Norris 2002); and
- *Queensland AusRivAS Sampling and Processing Manual* (DNRM 2001).

The physical assessment was undertaken at all sampling sites.

5.5.2 Habitat Bioassessment

A habitat bioassessment has been undertaken at all sites using monitoring techniques adapted from *Queensland AusRivAS Sampling and Processing Manual* (DNRM 2001). AusRivAS is a nationally standardised method for undertaking an assessment of the biological health of inland rivers within Australia.

The assessment considers morphological characteristics of waterways only; including the broad habitat type, channel pattern, water level and flow, substrate character and cover, bed and bank stability, and riparian cover at each site. Each assessment criteria is assigned a numerical value, which totals to a maximum site score of 135. Higher scores indicate favourable habitats normally associated with healthy waterways. Table 9 provides a framework for interpreting habitat assessment scores.

Table 8 Physical assessment methodology

Characteristic	Assessment
Bank shape	Categorise the predominant shape of the left and right banks along the length of the sampling site in accordance with the AusRivAS physical assessment categories for bank shape (i.e. concave, convex, stepped, wide lower bench, or undercut).
Bank slope	Categorise the predominant slope of the left and right banks along the length of the sampling site in accordance with the AusRivAS physical assessment categories for bank slope (i.e. vertical, steep, moderate, low, or flat).
Factors affecting bank stability	Identify disturbance factors present that may negatively influence bank stability of either the left or right bank.
Artificial bank stability features	Note the presence of any artificial bank protection measures.
Large woody debris	Visually estimate the percent cover of large woody debris within the lower embankment and channel area, along a length of stream that is equal to the length of the sampling site. Large woody debris includes logs and branches greater than 10 cm in diameter.
Turbidity, water and sediment oils and odours	Visually assess and categorise the presence of oily residues or odours in surface water and stream sediments at the aquatic sites.
Bare ground	Note the extent of bare ground including eroded areas or those not supporting vegetation, due to some form of disturbance that would otherwise be expected to be vegetated.
Exposed tree roots	Note whether tree roots are exposed due to any disturbances.
Gully erosion	Record any visible gully erosion adjacent to the waterway.
Bank slumping	Record any evidence of slumping banks along the waterway.
Local catchment erosion	Note the erosion in the surrounding catchment on the approach to the site.

Table 9 Key to AusRivAS habitat bioassessment scores

Site Score	Interpretation
0 – 35	**Poor:** There is limited habitat availability for in-stream fauna. There is little variation in velocity and depth of water, and the creek bed consists of a single sediment type. The water body typically consists of a small, shallow pool. Streamside vegetation, if present, consists of grasses and sedges. There is moderate to significant erosion on the banks.
36 – 70	**Moderate:** This could be due to leaf litter and other vegetation or detritus in the water, or the presence of boulders and rocks. The streamside vegetation consists mainly of grasses and sedges. There is moderate evidence of bank erosion, and the percentage of vegetative cover on the banks is less than 50%.
71 – 100	**Good:** The bank is stable, there is variety in depth and velocity within the water body and substrate type is variable and tending towards boulders and rocks. Streamside vegetation is of trees and shrubs, adding to the bank stability. The percentage of streamside cover by vegetation is relatively high.
101 – 135	**Excellent:** A pristine and favourable habitat. There is no bank erosion and the dominant vegetation is trees. There is great variety in depth and velocity, and the habitat is quite complex, offering many types of protection for fauna. This is usually afforded by logs and branches, leaf litter, variety in substrate type, variety in water depth, and presence of vegetation living within the water body.

5.5.3 Condition Assessment

The condition assessment is an evaluation of the possible impacts to aquatic environmental values caused by major disturbances within the waterway. Each category is scored from one to five, one indicating a 'very major' disturbance, and five indicating an 'indiscernible' disturbance. This assessment evaluates the influence of criteria described in Table 10.

Table 10 Condition assessment methodology

Criteria	Description
Upstream influence of agriculture.	That which involves irrigation, widespread soil disturbance, use of agrochemicals and pine plantations. Dry-land grazing does not fail into this category.
Upstream influence of major extractive industry (historical/current).	Including mines, quarries, and sand/gravel extraction.
Upstream influence of major urban area.	Relative to population size, river size and distance between the site and the impact.
Upstream influence of significant point-source waste water discharge.	Exceptions can be made for small discharges into large rivers.
Upstream influence of dam/major weir.	Sites within the ponded area of impoundments also fail.
Influence of alteration to seasonal flow regime.	This may be due to abstraction or regulation further upstream than the coverage by the above criterion. Includes either an increase or decrease in seasonal flow.
Influence of alteration to riparian zone.	Riparian vegetation should be intact and dominant by native species.
Influence of erosion and damage on riparian zone and banks.	Includes stock damage to the stream bed.
Influence of major geomorphological change on stream channel.	Includes bank slumping, shallowing, braiding and unnatural aggradation or degradation.
Influence of alteration to instream conditions and habitats.	This may be due to excessive algal and macrophyte growth, sedimentation and siltation, reduction in habitat diversity by drowning or drying out of habitats (e.g. riffles) or direct access of stock into the river.

5.6 FAUNA SURVEY

The aquatic fauna surveys were conducted in accordance with the following guidelines:

- *Monitoring and Sampling Manual: Environmental Protection (Water) Policy 2009* (DES 2018b);
- *Survey guidelines for Australia's threatened birds* (DEWHA 2010b);
- *Survey guidelines for Australia's threatened reptiles* (DEWHA 2011b); and
- *Terrestrial Vertebrate Fauna Survey Guidelines for Queensland (V 3.0)* (Eyre *et al.* 2018).

5.6.1 Macroinvertebrate Sampling

Macroinvertebrate sampling was conducted in accordance with the AusRivAS sampling and assessment methodology as outlined by the *Monitoring and Sampling Manual: Environmental Protection (Water) Policy 2009* (DES 2018b).

When sufficient water was available at a site to sample the macroinvertebrate population, a 250 µm dip net on a D-frame was used to sample along a 10 m stretch of the waterbody. The nets were checked thoroughly for damage before use and washed between sites to ensure no cross contamination of samples. Macroinvertebrates were live picked on-site, samples preserved, and sent for taxonomic identification to an AusRivAS accredited laboratory.

When possible, the sampling procedure is replicated to target each micro-habitat; including riffles, runs, pools and edge/backwaters. Due to the ephemeral nature of the creeks, micro-habitats available for sampling were limited to the edge habitats of pools. Ideally site sampling should include sampling in shallow and deep sections to target the various micro-habitats, however this was not possible due to the limited water levels within the study area.

Macroinvertebrate sampling has been undertaken at each sample site except DWR1 (refer to footnote in Section 5.2). Data collected was assessed using a range of indices including total abundance, taxa richness, PET taxa richness, SIGNAL index, community composition, and percent tolerant taxa.

5.6.2 Aquatic Fauna

Aquatic fauna trapping to sample fish and crustaceans has been conducted at several sites along the major waterways. Due to the ephemeral nature of the waterways within the study area, several sites did not contain sufficient water to undertake aquatic fauna trapping.

Three opera house traps and three box traps (0.5 mm mesh) were baited and deployed at each site where trapping was undertaken (refer Table 6 and Table 7) to sample small bodied fish and crustaceans. A total of 282 trap nights were undertaken throughout the study area across the 2019 (120 total trap nights) and 2020 surveys (162 total trap nights). Traps were deployed within the range of microhabitat types present within the sites (i.e. littoral margin, among snags, open water) for four nights across the sites.

All captured aquatic fauna was identified and counted. Any exotic species captured were euthanized in accordance with permit conditions, and all native species were released at the site of capture. No wounds, lesions, or deformities on captured aquatic fauna were recorded.

5.6.3 Riparian Fauna

The *Gemini Project: Terrestrial Ecology Assessment* (AARC 2019) describes the terrestrial vertebrate fauna values of the study area. The aquatic ecology assessment utilised several fauna surveying methodologies in the riparian zone of six sites that presented suitable riparian habitat, with the following methodologies employed consistently across the six sites.

Bird Survey

A minimum of one hour of dedicated searches for birds were conducted visually and aurally during the early morning peak avian activity period. 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 bird species of conservation significance.

Spotlight

Spotlight surveys were carried out in the early evenings (before midnight) to maximise encounter rate of nocturnal wildlife such as night birds and arboreal mammals primarily active at night. Two spotlighting techniques were employed:

Foot traverses:	Dedicated spotlighting events were undertaken on foot, 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.
Vehicle searches:	During any driving on the study area after dark, spotlighting was conducted by the passenger 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 & Peake 1993; Debus 1995). Detectability of numerous small nocturnal bird species and arboreal marsupials also increase with playback of large owl calls. In addition, call playbacks can be utilised for the identification of cryptic amphibian species such as *Adelotus brevis* (tusked frog). Many species that will respond to call playback inhabit riparian and/or aquatic environments.

Call playback was 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. Species played included:

- *Adelotus brevis* (tusked frog)*;*
- *Ninox strenua* (powerful owl)*;*
- *Aegotheles cristatus* (Australian owlet nightjar)*;*
- *Ninox novaeseelandiae* (southern boobook); and
- *Petaurus volans* (greater glider)*.*

Habitat Searching

To enhance the likelihood of detecting small cryptic species, dedicated diurnal searches were conducted over two events per site. Additional habitat searches were carried out during aquatic trap checks and while conducting vegetation transects. 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 specifically targeted damp areas, bank overhangs, and included visual inspections of water. Searching for tracks, scats, and other signs of wildlife occupation (e.g. tree trunk scratches) also occurred during these habitat searches.

Incidental Recordings

Throughout the surveys, ecologists were traversing the study area on foot and by vehicle every day for numerous hours whilst conducting routine survey activities (e.g. driving between sites, checking traps, vegetation transects, sampling 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.

5.7 FLORA SURVEY

The *Gemini Project: Terrestrial Ecology Assessment* (AARC 2019) describes the flora values and mapped the vegetation communities of the entire study area including riparian and aquatic areas. For the aquatic ecology assessment, a meandering 100 m bankside transect was undertaken at each sampling site, recording the riparian vegetation species and any aquatic vegetation in the waterway.

6.0 RESULTS AND DISCUSSION

6.1 SURFACE WATER QUALITY

The results from the three sampling periods were compared to the WQOs (EHP 2013b) discussed in Section 4.1.2 (Water Quality Objectives).

No exceedances of the WQOs for dissolved metals were detected at any site, across all sampling periods (Table 11 and Table 12). Most site results were below the laboratory limit of reporting, with those sites that did have detectable levels of metals, were trace amounts well below the designated WQOs.

6.1.1 Charlevue Creek

Charlevue Creek is the main watercourse running through the centre of the Project. Eight sites were sampled throughout the Project catchment, with several exceedances of WQOs detected. Physico-chemical sampling results are presented in Table 13, whilst hydrocarbons are presented in Table 14.

Salinity (at baseflow) and fluoride levels were within WQOs at all sites during all sampling periods, whilst one exceedance of the sulphate WQO was detected at DWR5 in 2019 (of 15 mg/L) (all sites downstream were within WQOs). Dissolved oxygen was generally below the WQO range at most sites across all survey periods (≤ 81%), suggesting a relatively anoxic environment. However, these low levels of dissolved oxygen were recorded in stagnant pools along ephemeral waterways. Stagnant pools in intermittent streams naturally experience values of dissolved oxygen below 50% saturation (EHP 2013b).

Levels of pH were mostly within WQOs (pH 6.5-8.5), with three sites showing slightly acidic results during the 2019 sampling period. DWR5 (pH 6.27) is located on an upper tributary, as it crosses into the Project lease, whilst DAI1 (pH 6.24) is located at the downstream confluence of this tributary with Charlevue Creek. DAI2 (pH 6.37) is the next downstream site on Charlevue Creek. The furthest upstream site located on the main Charlevue Creek channel (DAR1 – also located on the EPC boundary) was within the WQOs, suggesting that the acidic influence is isolated to outside the southwest boundary of the Project. The acidic influence appears to have been minor, with the creek system having returned to within the WQOs from DAI4 onwards, and an event isolated to the 2019 sampling period, with no exceedances detected during either the 2018 or 2020 sampling periods.

Exceedances of WQOs for turbidity across all sites and all years were observed, with exceedances ranging from 112 to 23,199 NTU. Likewise, several exceedances of the aquatic ecosystem WQO for suspended solids were detected during the 2018 and 2019 sampling periods (concentrations ranging from 131 to 8,660 mg/L), however no exceedances of the stock watering WQO for total dissolved solids occurred throughout all sampling years. Turbidity is an indicator of water quality, where clear water is typically considered part of a healthy system. Exceedances of this parameter can indicate soil erosion, runoff, pollution, and algal blooms; however, some waterways can have naturally high levels of suspended solids and turbidity (Fondriest Environmental Inc. 2014). The study area has historically been used for pastoral purposes and has been heavily cleared, likely leading to increased local sediment loads from soil erosion and cattle access to creeks. Regional agricultural and pastoral land uses, including direct stock access to waterways, is also the likely influencer of elevated nutrient levels (ammonia and nitrogen) across most sites and sampling years.

Elevated nutrient levels across most sites and sampling years were recorded, ammonia levels ranging from 0.02 to 1.35 mg/L, total nitrogen ≥ 1.1 mg/L for all sites and years sampled, and phosphorus generally exceeding WQO with concentrations ≥ 0.17 mg/L.

Petroleum hydrocarbons were detected at two sites in 2018, with total recoverable hydrocarbons detected at the same sites, plus an additional three sites, in 2018 only. Petroleum hydrocarbons were detected at DWR5 (upper tributary entry point into the study area) and DAI1 (downstream confluence of tributary and Charlevue Creek). No other sites detected petroleum hydrocarbons in 2018, and no petroleum hydrocarbons were detected at any site in the 2019 or 2020 sampling periods. Similarly, to pH results; the influence appears to have come from outside of the study area (to the south-west), and was a minor and isolated influence with the creek system affected in 2018 only, and no petroleum hydrocarbons detected from DAI2 or further downstream.

6.1.2 Stanley Creek and Duckworth Creek

Stanley Creek is a small waterway crossing the northwest portion of the study and flowing into Duckworth Creek, downstream of the study area. Physico-chemical sampling results are presented in Table 15, whilst hydrocarbons are presented in Table 16.

Salinity (at baseflow), pH, fluoride, and sulphate levels were within WQOs at all sites during all sampling periods. Similar to the Charlevue Creek catchment; dissolved oxygen was generally below the WQO range (< 39%) and turbidity levels generally exceeded the WQO, with levels > 155 NTU. The WQO for suspended solid was only exceeded at one site (DWR1 [N]) in 2018, with 145 mg/L. Total nitrogen and total phosphorus levels also exceeded WQOs, for all sites and years sampled, with concentrations ≥ 1.3 and 0.28 mg/L respectively. Moreover, the ammonia WQO was exceeded for both sites in 2018, with 0.12 and 0.13 mg/L. However, waters were still within the stock watering WQO for total dissolved solids.

Petroleum hydrocarbons were detected at the two sites located north and south of the Capricorn Highway (DWR1 south and DWR1 north) in 2018. Run-off from the highway is the likely influence, given the higher carbon chain fractions being reported, possible hydrocarbon sources include; crude oil, heavy fuel oils, lubricating oils, asphalts, and pitch.

6.1.3 Springton Creek

Springton Creek is a major watercourse primarily running close to the eastern boundary of the Project and crossing into the Project for a small stretch. Both the Charlevue Creek and Stanley/Duckworth Creek catchments flow into Springton Creek some distance downstream on the study area. Four sites were sampled from upstream, within, and downstream of the Project, with several exceedances of WQOs detected. Physico-chemical sampling results are presented in Table 15, whilst hydrocarbons are presented in Table 16.

The Springton Creek catchment followed the same trends as the previously discussed sampling areas, with salinity (at baseflow), fluoride, and sulphate levels all within WQOs at all sites during all sampling periods. Dissolved oxygen was also generally below the WQO range at most sites across all survey periods (≤ 53% for most sites), suggesting all local catchments have a relatively anoxic environment, likely due to ephemeral waterways and stagnant pools.

Levels of pH were within WQOs in 2018 and 2020, however showed some acidity at three sites in 2019. DWI9 (pH 6.11) is located on a tributary originating within the study area, as it crosses out of the Project lease, whilst DAI5 (pH 6.28) is located downstream on Springton Creek where it crosses back into the Project boundary. DWI6 (pH 5.95) is located on Springton Creek, downstream of the Project on the Capricorn Highway. The 2019 acidic influence may have originated within the study area, although further influence appears to have been present downstream (possibly runoff from the Capricorn Highway) indicated by the further drop in pH, downstream of the Project. The influence was isolated to the 2019 sampling period, with no exceedances during the 2018 or 2020 sampling periods. Alternatively, an error may have occurred during the laboratory calibration of the pH meter used in the 2019 sampling event, resulting in the isolated occurrences of slightly acidic readings.

Exceedances of WQOs for turbidity were frequently observed throughout the sampling periods, ranging from 146 to 44,098.4 NTU in most sites. Similar to the previously discussed catchments, several exceedances of the aquatic ecosystem WQO for suspended solids was detected during the 2018 and 2019 sampling periods (ranging from 215 to 852 mg/L), as well as elevated nutrient levels across most sites and sampling years. Total nitrogen concentration was ≥ 1.1 mg/L for all sites and total phosphorus was ≥ 0.24 mg/L for most sites. Ammonia levels were also higher than the WQO for most sites and years sampled (≥ 0.02 mg/L). Petroleum hydrocarbons were detected at the two sites in 2018 only. Similar to Stanley Creek, run-off from the highway was a likely influence at DWI6.

Table 11 Water quality: Dissolved metals (Charlevue Creek)

Metal	WQO	Charlevue Creek																			
		DAR1			DWR5			DAI1			DAI2			DWR4	DAI3			DAI4			DAI7
		2018	2019	2020	2018	2019	2020	2018	2019	2020	2018	2019	2020	2020	2018	2019	2020	2018	2019	2020	2020
As	0.5[b]	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.001	<0.001	<0.001	0.001	0.001	0.001	<0.001	0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Be	ND	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
B	5[b]	0.08	0.06	0.07	0.26	0.1	0.09	0.13	<0.05	0.06	0.07	<0.05	<0.05	<0.05	0.1	<0.05	<0.05	0.1	<0.05	<0.05	0.07
Cd	0.01[a]	0.0001	<0.0001	<0.0001	0.0001	<0.0001	<0.0001	0.0001	<0.0001	<0.0001	0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Cr	1[b]	<0.001	<0.001	<0.001	0.002	0.001	<0.001	<0.001	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.001	<0.001	<0.001
Co	1[b]	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Cu	0.4[b]	0.004	0.003	0.001	0.003	0.003	0.002	0.004	0.003	0.002	0.004	0.003	0.001	0.001	0.004	0.003	0.002	0.004	0.003	0.003	0.002
Fe	-	0.09	0.45	<0.05	<0.05	0.16	<0.05	<0.05	0.47	0.07	0.12	1.21	0.12	0.12	0.08	0.48	<0.05	0.07	0.44	<0.05	<0.05
Pb	0.1[a]	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Mn	-	0.003	0.005	<0.001	0.002	0.002	<0.001	0.002	0.007	0.004	0.002	0.004	0.055	0.007	0.004	0.006	<0.001	0.002	0.006	0.001	0.001
Hg	0.002[b]	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Ni	1[b]	0.001	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.001	0.002	0.002	0.002
Se	0.02[b]	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
V	ND	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Zn	20[b]	<0.005	<0.005	<0.005	0.018	<0.005	<0.005	0.082	0.005	<0.005	0.053	<0.005	<0.005	<0.005	0.028	0.006	<0.005	0.056	<0.005	<0.005	<0.005

Notes: [a] Aquatic ecosystem (moderately disturbed) (EHP 2013b)
[b] Stock watering (EHP 2013b)
Units: mg/L
No exceedances of WQOs detected

As	Arsenic	Pb	Lead
Be	Beryllium	Mn	Manganese
B	Boron	Hg	Mercury
Cd	Cadmium	Ni	Nickel
Cr	Chromium	Se	Selenium
Co	Cobalt	V	Vanadium
Cu	Copper	Zn	Zinc
Fe	Iron		

Table 12 Water quality: Dissolved metals (Stanley and Duckworth Creeks; Springton Creek)

Metal	WQO	Stanley & Duckworth Creeks			Springton Creek							
		DWR1 (S)	DWR1 (N)	DAI8	DAR2	DWI9	DAI5			DWI6		
		2018	2018	2020	2020	2019	2018	2019	2020	2018	2019	2020
As	0.5^b	0.001	<0.001	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.002	<0.001	<0.001
Be	ND	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
B	5^b	0.06	0.13	0.07	0.05	0.07	0.21	0.07	0.06	0.06	<0.05	0.05
Cd	0.01^b	0.0001	0.0001	<0.0001	<0.0001	<0.0001	0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Cr	1^b	0.002	0.002	<0.001	<0.001	<0.001	<0.001	0.003	<0.001	0.002	<0.001	<0.001
Co	1^b	0.001	<0.001	<0.001	<0.001	0.001	<0.001	<0.001	<0.001	0.005	<0.001	<0.001
Cu	0.4^b	0.006	0.005	0.003	0.001	0.002	0.004	0.003	0.002	0.008	0.001	0.002
Fe	-	0.61	0.17	<0.05	0.05	2.2	0.18	0.94	0.05	0.34	0.4	<0.05
Pb	0.1^b	0.002	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.004	<0.001	<0.001
Mn	-	0.055	0.003	<0.001	0.291	0.041	0.021	0.009	0.248	0.562	0.037	0.002
Hg	0.002^b	<0.00004	<0.00004	<0.0001	<0.0001	<0.0001	<0.00004	<0.0001	<0.0001	<0.00004	<0.0001	<0.0001
Ni	1^b	0.005	0.004	0.002	0.002	0.002	0.002	0.004	0.002	0.005	0.002	0.002
Se	0.02^b	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
V	ND	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Zn	20^b	0.044	<0.005	<0.005	0.005	<0.005	0.056	0.005	<0.005	0.039	<0.005	<0.005

Notes: [a] Aquatic ecosystem (moderately disturbed) (EHP 2013b)

[b] Stock watering (EHP 2013b)

Units: mg/L

No exceedances of WQOs detected

As	Arsenic	Pb	Lead
Be	Beryllium	Mn	Manganese
B	Boron	Hg	Mercury
Cd	Cadmium	Ni	Nickel
Cr	Chromium	Se	Selenium
Co	Cobalt	V	Vanadium
Cu	Copper	Zn	Zinc
Fe	Iron		

Table 13 Water quality: Physico-chemical parameters (Charlevue Creek)

Parameter	Units	WQO	Charlevue Creek																			
			DAR1			DWR5			DAI1			DAI2			DWR4	DAI3			DAI4			DAI7
			2018	2019	2020	2018	2019	2020	2018	2019	2020	2018	2019	2020	2020	2018	2019	2020	2018	2019	2020	2020
Temperature	°C	n/a	27.1	20.5	23.5	29.5	21.2	23.9	30.8	20.7	24.8	26	21	21.6	28.5	26.8	20.1	22.5	26.3	21.2	22.8	23.7
pH	pH unit	6.5 - 8.5[a]	7.27	7.12	7.36	7.28	6.27	7.26	6.63	6.24	7.57	6.91	6.37	7.12	7.04	6.92	6.78	7.55	6.87	6.58	7.38	7.20
EC (baseflow)	µS/cm	<310[a]	73.1	120.6	205.7	209.5	211.2	195.2	74.1	113.9	203.4	67	128.1	197.8	98.5	83.6	124.4	181.3	70.3	105.4	181.8	164.1
DO	%	85-110[a]	87	28	85.7	88	61	25.8	67	58	65.0	80	15	19.2	80.7	80	46	40.0	81	56	33.4	15.7
ORP	mV	n/a	140.5	179.8	124.5	205.4	203.8	151.3	228.7	197.8	134.5	269.3	160.6	101.4	43.5	198.3	184	119.6	137.4	210.8	106.8	130.7
SS	mg/L	<110[a]	58	172	36.0	8660	43	28	2080	131	18.0	880	228	22.0	166	6170	103	31.0	168	152	50.0	31.0
TDS	mg/L	3000[b]	45.6	85.8	122.0	125.3	147.9	114	43.5	80.6	120.0	42.8	90.1	125.0	55	51.9	89.3	111.0	44.6	73.8	110.0	98.0
Turbidity	NTU	<50[a]	387	12154.4	112	1231.6	23199	657	2050.3	13046.2	450	831.2	13896.6	128	330	2582.6	16031.5	184	506.3	13455.6	130	247
Ammonia	mg/L	<0.02[a]	0.02	0.1	0.04	0.28	0.43	1.35	0.04	0.23	0.02	0.09	0.07	<0.01	0.02	0.08	0.14	0.03	0.14	0.13	0.02	0.07
N (total)	mg/L	<0.007[a]	1.3	1.5	1.1	9.5	4.5	3.2	5.8	1.8	1.2	2.3	2.1	1.6	2.3	8.2	2	1.4	2.3	1.8	1.5	2
P (total)	mg/L	0.16[a]	0.31	0.6	0.18	3.94	0.72	0.16	1.91	0.66	0.17	0.87	0.84	0.3	0.79	2.92	0.84	0.27	0.4	0.75	0.22	0.25
P (reactive)	mg/L	<0.02[a]	0.07	0.03	<0.01	<0.01	0.03	<0.01	0.11	0.07	<0.01	0.06	0.04	0.02	0.03	0.01	0.04	0.01	0.05	0.06	<0.01	<0.01
Fluoride	mg/L	2[a]	0.1	0.2	0.2	0.1	0.1	0.2	0.1	0.3	0.2	0.1	0.3	0.2	<0.1	0.2	0.2	0.2	0.1	0.2	0.2	0.2
SO^{4-}	mg/L	<10[a]	2	<1	<1	5	15	3	2	<1	<1	<1	<1	<1	<1	2	<1	<1	<1	1	<1	<1

Notes: [a] Aquatic ecosystem (moderately disturbed) (EHP 2013b)
[b] Stock watering (EHP 2013b)
Yellow cells denote an exceedance of the WQO

DO	dissolved oxygen
ORP	oxygen reduction potential
SS	suspended solids
TDS	total dissolved solids
N	nitrogen
P	phosphorus
SO^{4-}	sulphate (turbidimetric)

Table 14 Water quality: Hydrocarbons (Charlevue Creek)

Parameter	Units	LOR^{c}	Charlevue Creek																			
			DAR1			DWR5			DAI1			DAI2			DWR4	DAI3			DAI4			DAI7
			2018	2019	2020	2018	2019	2020	2018	2019	2020	2018	2019	2020	2020	2018	2019	2020	2018	2019	2020	2020
Total petroleum hydrocarbons																						
C6 - C9 fraction	µg/L	20	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20
C10 - C14 fraction	µg/L	50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50
C15 - C28 fraction	µg/L	100	<100	<100	<100	120	<100	<100	120	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100
C29 - C36 fraction	µg/L	50	<50	<50	<50	90	<50	<50	60	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50
C10 - C36 fraction (sum)	**µg/L**	**50**	**<50**	**<50**	**<50**	**210**	**<50**	**<50**	**180**	**<50**	**<50**	**<50**	**<50**	**<50**	**<50**	**<50**	**<50**	**<50**	**<50**	**<50**	**<50**	**<50**
Total recoverable hydrocarbons - NEPM 2013 fractions																						
C6 - C10 fraction	µg/L	20	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20
C6 - C10 fraction minus BTEX (F1)	µg/L	20	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20
>C10 - C16 fraction	µg/L	100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100
>C10 - C16 fraction minus naphthalene (F2)	µg/L	100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100
>C16 - C34 fraction	µg/L	100	<100	<100	<100	180	<100	<100	140	<100	<100	110	<100	<100	<100	120	<100	<100	120	<100	<100	<100
>C34 - C40 fraction	µg/L	100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100
>C10 - C40 fraction (sum)	**µg/L**	**100**	**<100**	**<100**	**<100**	**180**	**<100**	**<100**	**140**	**<100**	**<100**	**110**	**<100**	**<100**	**<100**	**120**	**<100**	**<100**	**120**	**<100**	**<100**	**<100**

Notes: ^{c} ALS limit of reporting

Yellow cells denote hydrocarbons detected in sample

Table 15 Water quality: Physico-chemical parameters (Stanley and Duckworth Creeks; Springton Creek)

Parameter	Units	WQO	Stanley & Duckworth Creeks			Springton Creek							
			DWR1 (S)	DWR1 (N)	DAI8	DAR2	DWI9	DAI5			DWI6		
			2018	2018	2020	2020	2019	2018	2019	2020	2018	2019	2020
Temperature	°C	n/a	28.1	31.4	23.9	25.6	22.9	27.8	21	26.2	24.6	23.2	23.5
pH	pH unit	6.5 - 8.5[a]	6.61	7.61	7.30	7.00	6.11	6.84	6.28	7.07	7.34	5.95	7.35
EC (baseflow)	µS/cm	<310[a]	113.8	0.4	212.3	246.6	140.7	121.2	137.2	259.1	0.3	65	201.9
DO	%	85-110[a]	4	98	38.9	17.9	17.1	53	46	29	95.0	50	21.3
ORP	mV	n/a	98.2	147.1	138.9	146.8	116.5	242.5	220.9	97.4	158.6	222.8	80.2
SS	mg/L	<110[a]	106	145	65.0	22	238	852	68	40	215.0	86	41
TDS	mg/L	3000[b]	69.9	0.25	127.0	139	95.4	74.8	96.6	144	0.2	43.8	122
Turbidity	NTU	<50[a]	155.3	4.1	537	146	44098.4	3734.08	30580.5	311	21	10730.4	392
Ammonia	mg/L	<0.02[a]	0.12	0.13	0.008	0.04	0.9	<0.01	0.2	0.14	0.02	0.12	0.06
N (total)	mg/L	<0.007	1.4	2.2	1.3	1.1	4.9	3.5	4.1	1.8	1.4	1.6	1.6
P (total)	mg/L	0.16	0.32	0.43	0.28	0.14	1.11	1.5	2.15	0.25	0.27	0.47	0.24
P (reactive)	mg/L	<0.02	<0.01	<0.01	<0.01	<0.01	0.01	<0.01	0.02	<0.01	<0.01	<0.01	<0.01
Fluoride	mg/L	2[a]	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.1	0.2
SO^{4-}	mg/L	<10[a]	10	2	3	<1	4	7	4	<1	<1	2	<1

Notes: [a] Aquatic ecosystem (moderately disturbed) (EHP 2013b)
[b] Stock watering (EHP 2013b)
Yellow cells denote an exceedance of the WQO

DO	dissolved oxygen
ORP	oxygen reduction potential
SS	suspended solids
TDS	total dissolved solids
N	nitrogen
P	phosphorus
SO^{4-}	sulphate (turbidimetric)

Table 16 Water quality: Hydrocarbons (Stanley and Duckworth Creeks; Springton Creek)

Parameter	Units	LOR[c]	Stanley & Duckworth Creeks			Springton Creek							
			DWR1 (S)	DWR1 (N)	DAI8	DAR2	DWI9	DAI5			DWI6		
			2018	2018	2020	2020	2019	2018	2019	2020	2018	2019	2020
Total petroleum hydrocarbons													
C6 - C9 fraction	µg/L	20	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20
C10 - C14 fraction	µg/L	50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50
C15 - C28 fraction	µg/L	100	140	190	<100	<100	<100	180	<100	<100	230	<100	<100
C29 - C36 fraction	µg/L	50	60	70	<50	<50	<50	70	<50	<50	90	<50	<50
C10 - C36 fraction (sum)	**µg/L**	**50**	**200**	**260**	**<50**	**<50**	**<50**	**250**	**<50**	**<50**	**320**	**<50**	**<50**
Total Recoverable Hydrocarbons - NEPM 2013 Fractions													
C6 - C10 fraction	µg/L	20	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20
C6 - C10 fraction minus BTEX (F1)	µg/L	20	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20
>C10 - C16 fraction	µg/L	100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100
>C10 - C16 fraction minus naphthalene (F2)	µg/L	100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100
>C16 - C34 fraction	µg/L	100	170	230	<100	<100	<100	220	<100	<100	280	<100	<100
>C34 - C40 fraction	µg/L	100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100
>C10 - C40 fraction (sum)	**µg/L**	**100**	**170**	**230**	**<100**	**<100**	**<100**	**220**	**<100**	**<100**	**280**	**<100**	**<100**

Notes: [c] ALS limit of reporting

Yellow cells denote hydrocarbons detected in sample

6.2 STREAM SEDIMENT QUALITY

The results from the three sampling periods were compared to the default sediment quality guideline (SQG) values (ANZECC & ARMCANZ 2000) discussed in Section 4.1.1 (Stream Sediment Quality Objectives).

6.2.1 Metals

No exceedances of the SQG high trigger values for total metals were detected at any site, across all sampling periods (Table 17). Cadmium levels were below the laboratory limit of reporting in every sample, whilst traces of arsenic, chromium, copper, lead, mercury, and zinc were detected in most samples, however well below the designated SQG low trigger values.

Nickel was the only metal to exceed the SQG low trigger value (21.0 mg/kg) at one site (DWR6) on upper tributary of Springton Creek, upstream of the Project. The 2018 sample was the highest (28.1 mg/kg), with a continued reduction in nickel levels present over the following two surveys to levels barely exceeding the low trigger value (21.9 mg/kg in 2019 and 21.3 mg/kg in 2020). The exceedance at a single site suggests a localised contaminant upstream of the Project, whilst the continued yearly reduction in nickel levels suggests the contamination may no longer be occurring, with subsequent surveys possibly yielding nickel levels below the low trigger value as residual traces are continually diluted.

Table 17 Stream sediment quality: Total metals

Site		Total Metals (mg/kg)							
		Arsenic	Cadmium	Chromium	Copper	Lead	Mercury	Nickel	Zinc
SQGV trigger	Low	20.00	1.5	80.0	65.0	50.0	0.15	21.0	200.0
	High	70.00	10.0	370.0	270.0	220.0	1.00	52.0	410.0
Springton Creek									
DWR6	2018	2.51	<0.1	23.5	12.2	8.0	0.02	28.1	23.5
	2019	2.33	<0.1	19.7	10.4	7.9	0.01	21.9	16.8
	2020	2.22	<0.1	15.5	10.1	9.1	0.02	21.3	15.6
DAR2	2020	2.18	<0.1	10.9	10.0	7.3	0.01	7.6	15.4
DWI8	2018	3.20	<0.1	11.8	3.1	6.2	<0.01	1.5	2.0
	2019	1.06	<0.1	7.9	1.6	2.3	<0.01	1.1	<1.0
	2020	1.01	<0.1	6.0	1.4	2.1	<0.01	<1.0	<1.0
DWI9	2018	4.70	<0.1	25.2	2.8	8.8	<0.01	1.8	2.3
	2019	2.06	<0.1	13.6	3.4	7.4	<0.01	1.8	2.3
	2020	<1.00	<0.1	5.8	1.5	2.2	<0.01	1.4	1.3
DAI5	2018	3.56	<0.1	15.8	10.8	11.7	0.01	9.2	15.8
	2019	2.92	<0.1	13.1	11.2	9.8	0.01	9.4	15.2
	2020	2.67	<0.1	13.3	9.9	9.6	0.01	9.5	14.0
DWI6	2018	2.54	<0.1	15.7	10.8	8.8	0.01	10.3	17.9
	2019	2.53	<0.1	13.4	10.9	9.3	0.01	9.2	14.2
	2020	1.80	<0.1	9.8	8.0	6.6	<0.01	7.0	9.2

Site		Total Metals (mg/kg)							
		Arsenic	Cadmium	Chromium	Copper	Lead	Mercury	Nickel	Zinc
SQGV trigger	Low	20.00	1.5	80.0	65.0	50.0	0.15	21.0	200.0
	High	70.00	10.0	370.0	270.0	220.0	1.00	52.0	410.0
Stanley Creek & Duckworth Creek									
DWR1 (S)	2018	2.64	<0.1	16.8	11.4	7.3	0.01	15.9	18.3
DWR1 (N)	2018	2.14	<0.1	19.2	8.9	4.8	0.01	15.5	17.4
DWR1	2019	2.02	<0.1	9.1	4.8	4.3	<0.01	5.3	9.4
	2020	2.50	<0.1	13.6	6.6	5.1	<0.01	7.0	6.1
DWI1	2018	1.23	<0.1	7.3	1.1	1.7	<0.01	1.3	1.7
	2019	4.71	<0.1	10.2	5.4	4.8	<0.01	2.5	4.1
DAI8	2020	4.56	<0.1	15.1	17.7	10.9	0.01	15.1	31.4
Charlevue Creek									
DAR1	2018	1.23	<0.1	4.2	1.4	2.4	<0.01	1.4	3.1
	2019	1.00	<0.1	4.4	2.4	3.5	<0.01	2.8	4.6
	2020	3.31	<0.1	8.5	3.2	3.5	<0.01	2.7	5.4
DWR5	2018	6.73	<0.1	35.2	4.9	11.7	<0.01	4.7	5.3
	2019	2.84	<0.1	18.4	5.5	5.3	<0.01	5.0	4.9
	2020	5.43	<0.1	71.0	5.5	15.5	<0.01	5.4	6.0
DAI1	2018	3.08	<0.1	15.3	12.1	8.8	0.01	11.3	22.2
	2019	3.00	<0.1	12.1	15.2	10.0	0.02	11.7	23.5
	2020	2.15	<0.1	7.6	2.8	3.2	<0.01	2.8	4.9
DAI2	2018	3.42	<0.1	14.3	17.6	11.4	0.02	15.8	33.9
	2019	1.03	<0.1	4.9	5.0	3.4	<0.01	4.0	9.6
	2020	1.32	<0.1	5.8	6.4	5.3	<0.01	4.7	13.2
DWR4	2018	1.63	<0.1	12.9	12.3	11.1	0.02	8.0	31.5
	2019	1.37	<0.1	11.7	13.9	11.7	0.02	7.4	30.5
	2020	3.08	<0.1	11.4	15.3	11.4	0.02	11.0	30.5
DAI3	2018	2.33	<0.1	7.0	4.0	7.9	<0.01	4.8	6.1
	2019	2.07	<0.1	8.4	6.6	11.8	<0.01	6.6	9.3
	2020	2.27	<0.1	3.6	1.7	2.1	<0.01	1.8	3.4
DAI4	2018	3.70	<0.1	14.0	15.1	10.6	0.02	13.7	28.0
	2019	2.39	<0.1	7.6	6.9	5.3	<0.01	6.2	11.4
	2020	1.54	<0.1	6.8	5.1	6.8	<0.01	5.1	8.9
DWI3	2018	<1.00	<0.1	3.3	<1.0	1.2	<0.01	<1.0	<1.0
	2019	2.26	<0.1	7.0	1.5	9.7	<0.01	1.6	<1.0
	2020	1.12	<0.1	6.3	1.2	1.3	<0.01	1.4	1.8
DAI7	2020	4.40	<0.1	10.3	13.8	24.6	0.02	13.8	23.2

Yellow cells denote an exceedance of the SQG

6.2.2 Particle Size Distribution

Stream sediment was collected at all sites across each sampling period for particle size analysis. Particle size distribution for sites on the Stanley Creek and Duckworth Creek catchment are presented in Figure 6, with no particles large enough to be classified as cobbles (>6 cm) present in this catchment. The upper tributary (DWR1) of Stanley Creek predominates a mix of sand and silt, with an average of 22% clay, and a maximum of 3% gravel. Further downstream on Stanley Creek (DWI1) the distribution of sediment particles is almost completely sand, with 2-3% silt and clay, and up to 6% gravel. After Stanley Creek joins with Duckworth Creek (DAI8), sediment is a fairly even mix of sand, silt, and clay, with a small portion (7%) of gravel.

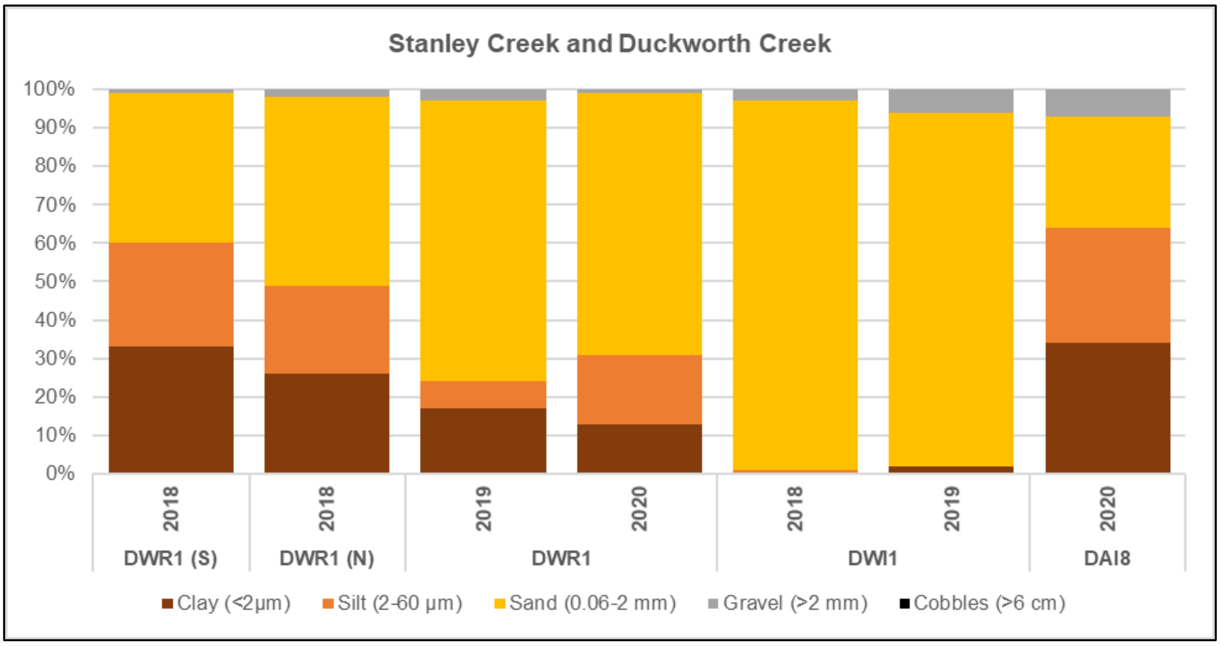


Figure 6 Stream sediment quality: Particle size distribution (Stanley Creek and Duckworth Creek)

Particle size distribution for sites in the Charlevue Creek catchment are presented in Figure 7, with no particles large enough to be classified as cobbles (>6 cm) present in this catchment. Approximately half of the sites (DAR1, DWR5, DAI3, and DWI3) have stream sediment characterised by high percent sand (63-94%) with low levels of clay (1-15%), silt (1-17%), and gravel (1-15%). Two of these sites are located on Charlevue Creek, whilst two are on upper tributaries. Three sites (DAI1, DWR4, and DAI7) located on Charlevue Creek and a lower tributary, had lower levels of sand (29-78%) and gravel (1-5%), and higher levels of clay (5-41%) and silt (15-51%). Two sites (DAI2 and DAI4) located on Charlevue Creek, showed much higher levels of silt (41-66%) and clay (25-26%) in 2018, compared to the 2019 and 2020 sampling periods (silt: 5-19%; clay: 4-12%).

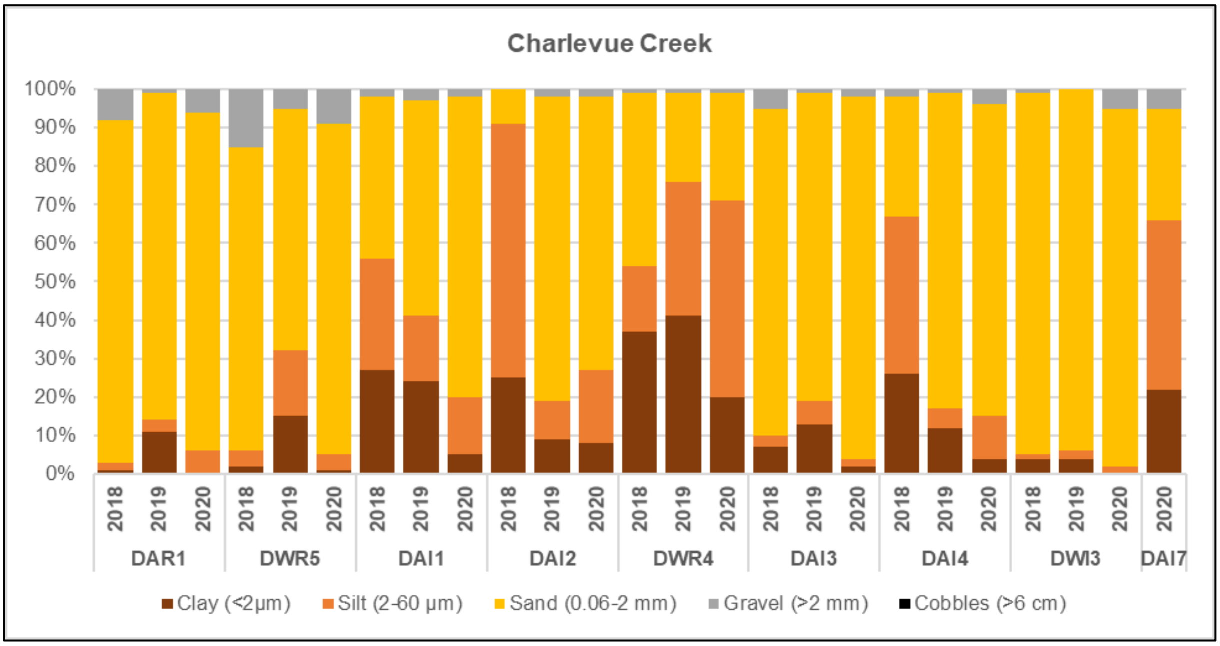


Figure 7 Stream sediment quality: Particle size distribution (Charlevue Creek)

Particle size distribution for sites in the Springton Creek catchment are presented in Figure 8, with no particles large enough to be classified as cobbles (>6 cm) present in this catchment. Two sites on the mid-lower reaches of Springton Creek (DAI5 and DWI6), along with one site (DWR6) on a tributary feeding into the mid-reaches of the Creek, were characterised by moderate to high compositions of silt (19-55%) and clay (22-38%), moderate presence of sand (20-51%), and low presence of gravel (1-2%). Whilst three sites in the upstream reach of Springton Creek (DAR2, DWI8, and DWI9) were characterised by comparatively higher compositions of sand (57-92%) and gravel (1-13%), and lower presence of silt (1-29%) and clay (1-19%).

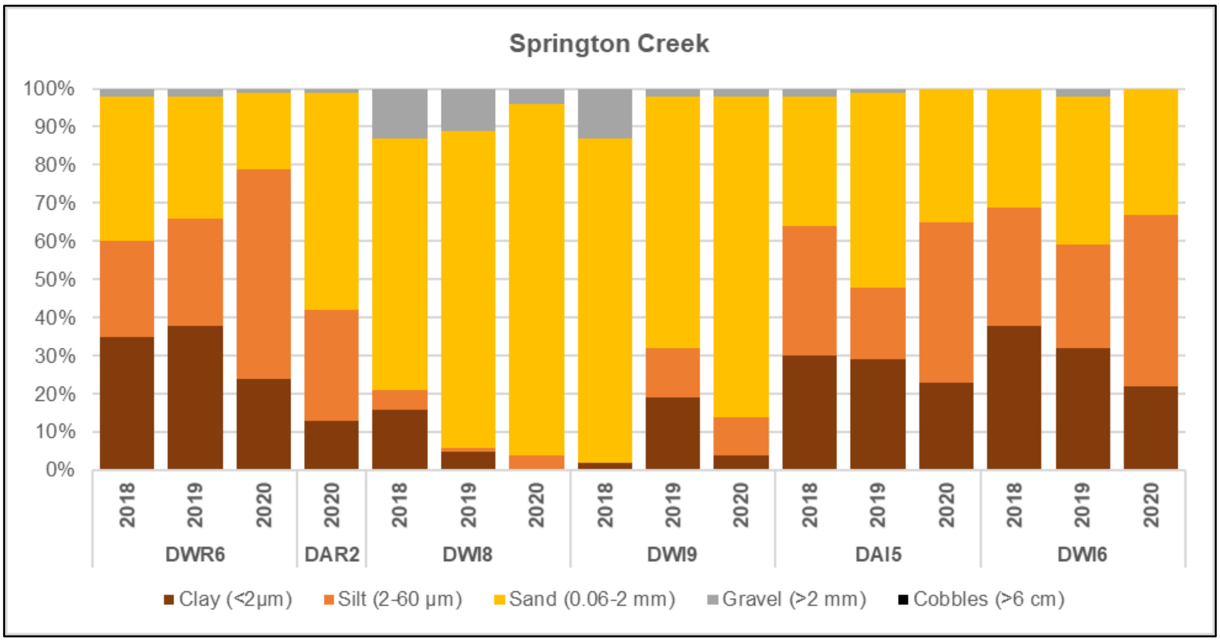


Figure 8 Stream sediment quality: Particle size distribution (Springton Creek)

6.3 CREEK ECOLOGY

6.3.1 Physical Assessment

The *AusRivAS Physical Assessment Protocol* (Parsons, Thoms & Norris 2002) was undertaken at all sites. Site descriptions composed of the data collected and a representative photo of each site is provided in Appendix B (Site Descriptions and Physical Assessment).

Erosion specific observations at each site are provided in Table 18. The effects of erosion on the banks of the receiving waters was evident across all survey sites, with greater erosion characteristics recorded in the Charlevue Creek and Springton Creek catchments. The leading cause of local erosion appeared to be stock access, with runoff and the influence of edge effects from historic clearing also promoting degradation. Large rainfall events each year causes increased runoff, potentially washing sediment away from the bank and depositing it into the creeks. Cattle can compact soil structures and trample vegetation; both leading to increased erosion. Most sites had minimal large woody debris or other stabilising factors.

Table 18 Erosion observations (2020)

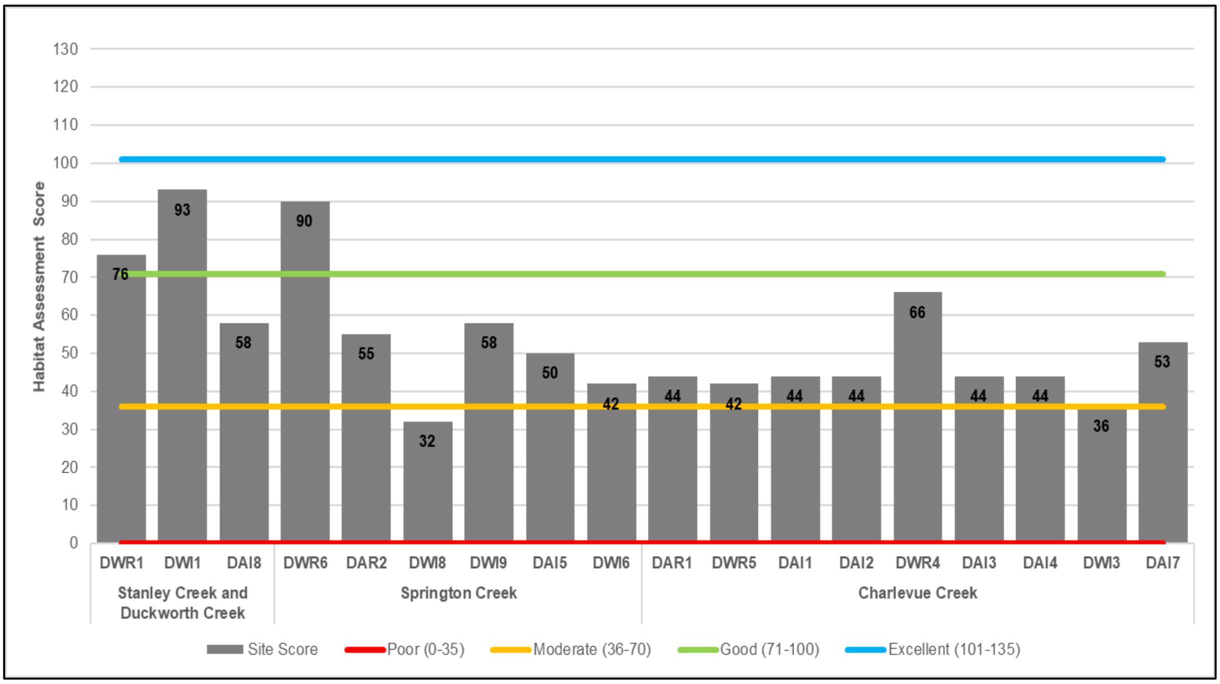
Site	Bare ground	Exposed tree roots	Gully erosion	Bank slumping	Local catchment erosion
	Extent of bare ground due to some form of disturbance.	*Tree roots are exposed due to any disturbances.*	*Visible gully erosion adjacent to the waterway.*	*Evidence of slumping banks along the waterway.*	*Erosion in the surrounding catchment on the approach to the site.*
Stanley Creek and Duckworth Creek					
DWR1	little (1-10%)	little (1-10%)	little (1-10%)	none (0%)	none (0%)
DWI1	none (0%)	none (0%)	none (0%)	none (0%)	some (10-50%)
DAI8	little (1-10%)	little (1-10%)	little (1-10%)	little (1-10%)	moderate (50-75%)
Springton Creek					
DWR6	none (0%)	none (0%)	little (1-10%)	none (0%)	little (1-10%)
DAR2	little (1-10%)	moderate (50-75%)	some (10-50%)	some (10-50%)	moderate (50-75%)
DWI8	moderate (50-75%)	moderate (50-75%)	extensive (>75%)	moderate (50-75%)	some (10-50%)
DWI9	little (1-10%)	none (0%)	little (1-10%)	little (1-10%)	some (10-50%)
DAI5	little (1-10%)	moderate (50-75%)	some (10-50%)	some (10-50%)	moderate (50-75%)
DWI6	little (1-10%)	little (1-10%)	little (1-10%)	little (1-10%)	moderate (50-75%)
Charlevue Creek					
DAR1	little (1-10%)	little (1-10%)	little (1-10%)	some (10-50%)	moderate (50-75%)
DWR5	little (1-10%)	little (1-10%)	little (1-10%)	some (10-50%)	moderate (50-75%)
DAI1	moderate (50-75%)	little (1-10%)	little (1-10%)	little (1-10%)	moderate (50-75%)
DAI2	little (1-10%)	little (1-10%)	little (1-10%)	some (10-50%)	moderate (50-75%)
DWR4	little (1-10%)	none (0%)	none (0%)	none (0%)	moderate (50-75%)
DAI3	little (1-10%)	little (1-10%)	little (1-10%)	some (10-50%)	moderate (50-75%)
DAI4	little (1-10%)	little (1-10%)	little (1-10%)	some (10-50%)	moderate (50-75%)
DWI3	little (1-10%)	little (1-10%)	some (10-50%)	moderate (50-75%)	moderate (50-75%)
DAI7	little (1-10%)	little (1-10%)	little (1-10%)	little (1-10%)	moderate (50-75%)

Note: DAI8 observations are from 2019 (no access in 2020).

6.3.2 Habitat Bioassessment

This assessment considered the morphological characteristics of waterways specified in Section 5.5.2 (Habitat Bioassessment). Sites are classified based on a total score out of 135 as previously outlined in Table 9. These results are indicative of the general health of the river and the surrounding systems, it does not consider the quality of the water present. The following broad habitat types were recorded in and adjacent to the study area; non-riverine wetlands, ephemeral streams, and farm dams.

The habitat bioassessment scores (Figure 9) from the aquatic sites within the sampling environment primarily fell into the moderate classification (total score between 36 to 70), with moderate evidence of bank erosion, and sparse vegetative cover on the banks. Three sites achieved a good classification (total score between 71 to 100), exhibiting stable banks, substrates of variable types and increased stability, and relatively high streamside vegetation cover. One site fell into the poor classification (total score between 0 to 35), which exhibited limited habitat availability for in-stream fauna, little variation or stability in substrates, sparse streamside vegetation and moderate to significant erosion on the banks.



Note: DAI8 observations are from 2019 (no access in 2020).

Figure 9 Habitat bioassessment (2020)

6.3.3 Condition Assessment

The condition assessment considered the impact/influence of ten different upstream activities on the waterways specified in Section 5.5.3 (Condition Assessment). Each criterion previously set out in Table 10, was assigned a score between one (very major impact) and five (indiscernible impact). Condition assessments were completed at all sites and assessment scores are presented in Table 19.

All sites had an indiscernible or minor influence from local or regional upstream major industries (i.e. mining, agriculture, water extraction etc.) or urbanisation, with the exception of DAI3 and DAI4, which both had farmer dams slightly upstream. Most sites had a moderate to major impact from localised influences such as clearing practices disturbing or removing the riparian zone, erosion from cattle access and increased run-off (due to clearing practices), and ephemeral waterways being vulnerable to frequent instream and geomorphological changes.

Table 19 Condition assessment

Criteria	Stanley and Duckworth Creeks			Springton Creek						Charlevue Creek								
	DWR1	DWI1	DAI8	DWR6	DAR2	DWI8	DWI9	DAI5	DWI6	DAR1	DWR5	DAI1	DAI2	DWR4	DAI3	DAI4	DWI3	DAI7
Upstream influence of agriculture.	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
Upstream influence of major extractive industry (historical/current).	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
Upstream influence of major urban area.	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
Upstream influence of significant point-source waste water discharge.	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
Upstream influence of dam/major weir.	4	5	5	5	5	4	5	5	5	5	5	5	5	5	3	3	5	5
Influence of alteration to seasonal flow regime.	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
Influence of alteration to riparian zone.	3	3	2	3	2	1	5	2	3	2	2	3	4	1	2	2	5	1
Influence of erosion and damage on riparian zone and banks.	4	4	3	5	2	1	4	2	4	2	2	3	3	2	2	1	3	1
Influence of major geomorphological change on stream channel.	3	5	2	5	2	1	3	2	2	2	2	3	3	4	2	2	2	1
Influence of alteration to instream conditions and habitats.	2	2	2	4	2	1	2	3	2	2	3	2	3	3	2	2	2	1

Notes:
1 Very major impact
2 Major impact
3 Moderate impact
4 Minor impact
5 Indiscernible impact

6.4 FAUNA

6.4.1 Macroinvertebrate Populations

A complete list of all identified macroinvertebrates is available in Appendix C (Macroinvertebrate Taxonomic List). Macroinvertebrate results have been summarised by calculating total abundance, taxonomic richness, PET taxa richness, SIGNAL index, community composition and percent tolerant taxa. Where applicable, these indices have been compared to relevant WQO for macroinvertebrates in the Mackenzie River sub-basin.

All sites with sufficient water present during the 2019 and 2020 surveys were sampled for macroinvertebrates. Due to the ephemeral nature of the waterways being sampled, habitats for macroinvertebrate sampling were limited to edge habitats (with the exception of the DWR4 wetland). During sampling, baseline flow was present at one site (DWI6) in 2019, and one site (DAR2) in 2020, with the remaining sites having only standing pools of water with no flow; conditions which can impact the abundance and richness of macroinvertebrate taxa found.

Macroinvertebrate sampling provides a good indication of aquatic ecosystem health due to their sensitivity to a variety of factors such as turbidity, dissolved oxygen, pollutants, and salinity. Water quality at the study area was characterised by high turbidity and low levels of dissolved oxygen; which supports the low taxonomic richness, low PET taxa abundance, low SIGNAL indexes, and high percent tolerant taxa recorded across the study area, indicating a degraded system.

6.4.1.1 Total Abundance

Total abundance of macroinvertebrates varied significantly between sites; ranging from three (DAI3) to 625 (DWR5) (Figure 10). Fluctuation in total abundance is expected due to habitat availability for macroinvertebrates and the varying nature of the waterways sampled. Sites associated with Charlevue Creek typically had the highest abundance of macroinvertebrates present. The two sites with the highest abundance (DWR5 and DWR4) were both located on Charlevue Creek tributaries, and shared the common characteristics of low banks and grassy edges resulting in slow creek velocity, even when high volumes of water are present.

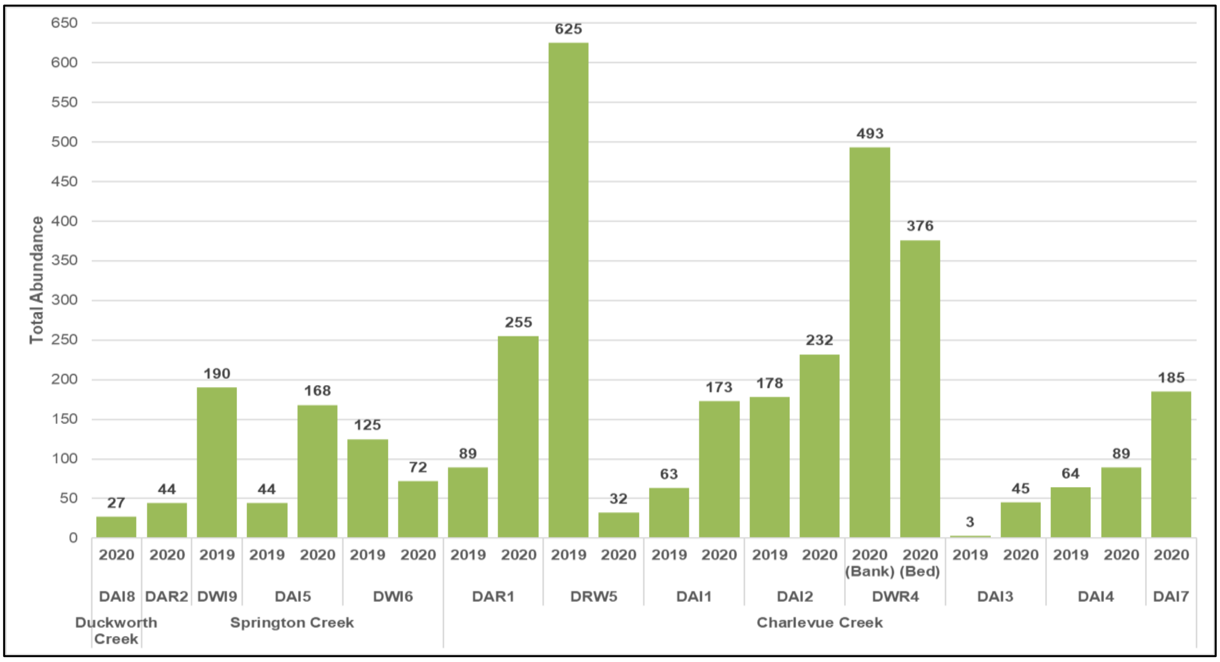


Figure 10 Macroinvertebrate total abundance

6.4.1.2 Taxonomic Richness

Taxonomic richness recorded at the sites is shown in Figure 11; none of the sites sampled reached the lower WQO for taxonomic richness. One site (DAI5) on Springton Creek, fell one taxa short of reaching the low WQO. This is an indicator of poor habitat quality and only a small number of macroinvertebrate taxa were recorded in the available habitat. Two sites had comparatively low taxonomic richness in 2019, with only three (DAI3) and four (DAI5) taxa recorded, however much higher richness in 2020. This was characteristic of most sites that were able to be sampled in both surveys, exhibiting higher richness in 2020. This is likely a result of survey timing with regards to preceding rainfall.

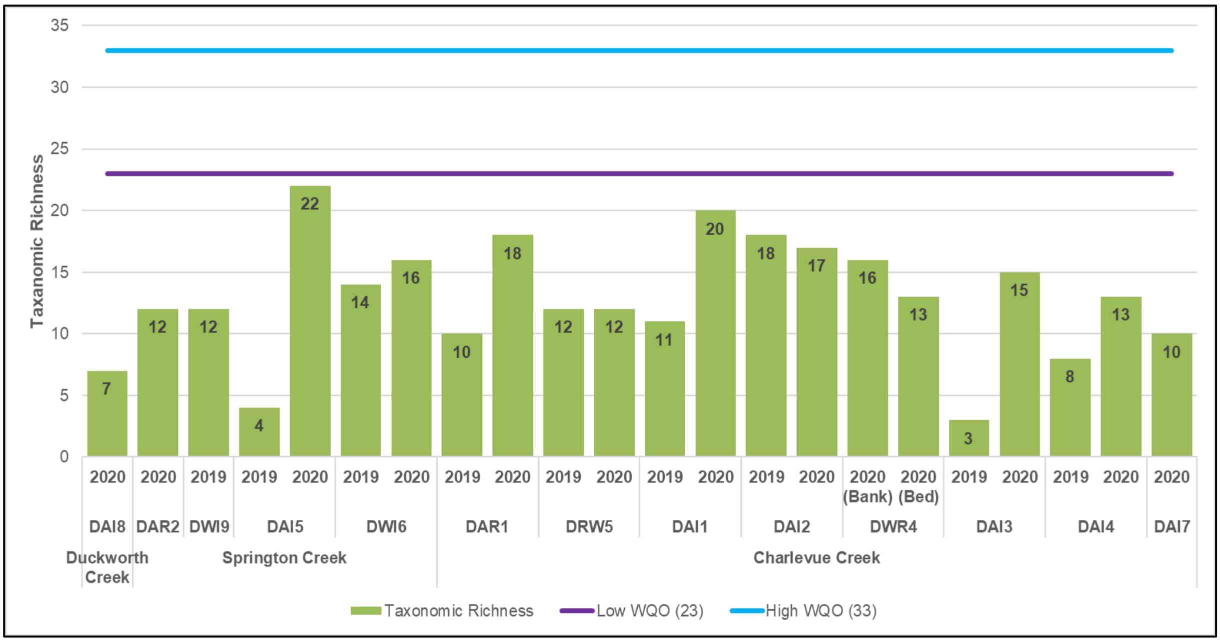


Figure 11 Macroinvertebrate taxonomic richness

6.4.1.3 PET Taxa Richness

The PET taxa are three orders of macroinvertebrate that are particularly sensitive to disturbance. They require favourable water quality conditions and diverse habitat to survive. PET taxa richness in ephemeral waterbodies tends to be low, due to the naturally harsh conditions in these waterways (i.e. poor water quality and low habitat diversity). However, trending declines in the number of PET taxa at a site may be an indication of pollution or poor water quality.

PET taxa were present at nine out of thirteen sampled sites, however richness at each site was typically low (Figure 12). Similarly to total taxonomic richness, greater diversity was observed in 2020, with only four of the nine sites supporting PET taxa in 2019.

The majority of taxa were from the Ephemeroptera order, with a small representation from the Trichoptera order, and no representation from the Plecoptera order.

Of the nine sites with PET taxa present, four met the lower WQO (two taxa), and no sites met the higher WQO (five taxa).

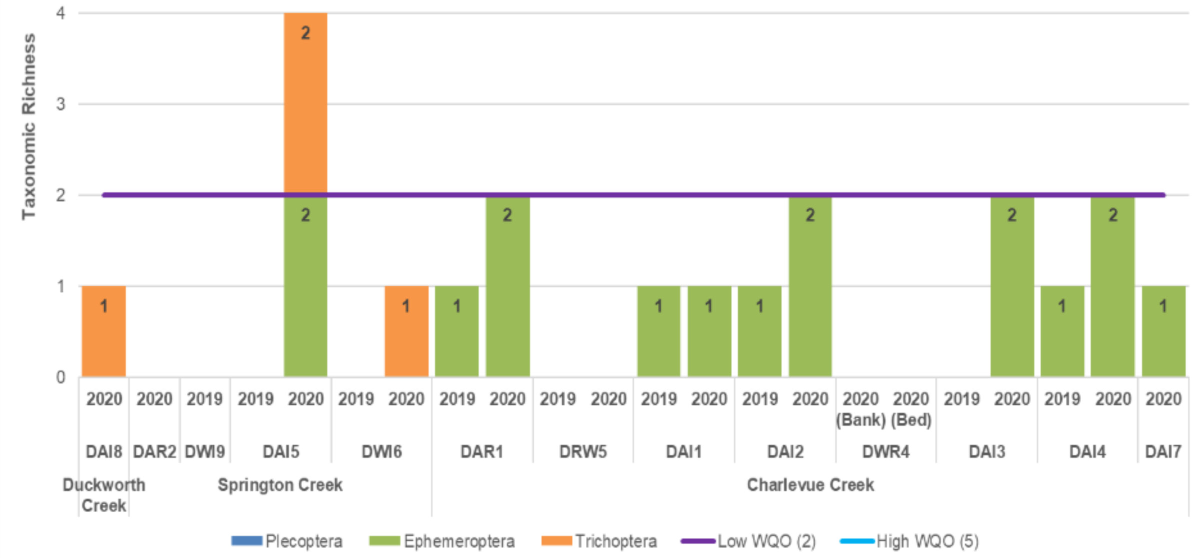


Figure 12 Macroinvertebrate PET taxonomic richness

6.4.1.4 SIGNAL Index

The SIGNAL index was developed for the bioassessment of water quality in Australia. A sensitivity grade number (between one and ten) is allocated to each macroinvertebrate taxon; based on how sensitive each taxon is to various pollutants. The higher the SIGNAL value, the better the condition of the water quality at a site. The site SIGNAL index is calculated as the average grade of each taxon present within the sample.

Site SIGNAL indexes indicated typically poor habitat availability and environmental conditions. Only three sites achieved the lower WQO (Figure 13); DAI8 (2020), DAI3 (2019), and DAI4 (2020). Factors that would have influenced these results include the flow conditions at the site and the ephemeral nature of the waterways. Taxa found in ephemeral waters vary largely with rainfall events and as flow conditions change. Low abundance of sensitive macroinvertebrate taxa is likely to result from the environmental conditions.

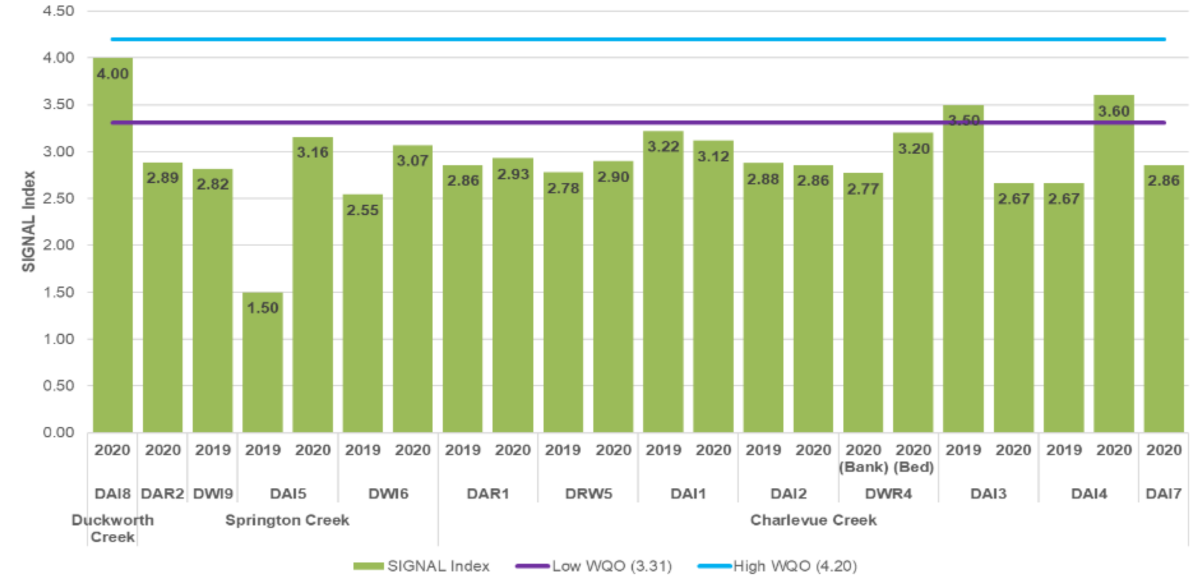


Figure 13 Macroinvertebrate SIGNAL site indexes

6.4.1.5 Percent Tolerant Taxa

This index is based on the proportion of taxa that are rated as having a tolerant SIGNAL sensitivity grade (three or less). Typically, high proportions of tolerant taxa are reflective of poor health in the waterway. This is typical of ephemeral creeks; as the more resilient macroinvertebrate taxa survive. Figure 14 compares the percentage of tolerant taxa found at each site.

All samples (with the exception of DAI8) exceeded the lower trigger value, whilst most sites also exceeded the high trigger values, indicating that populations are comprised primarily of taxa resilient to higher levels of disturbance and poor environmental conditions.

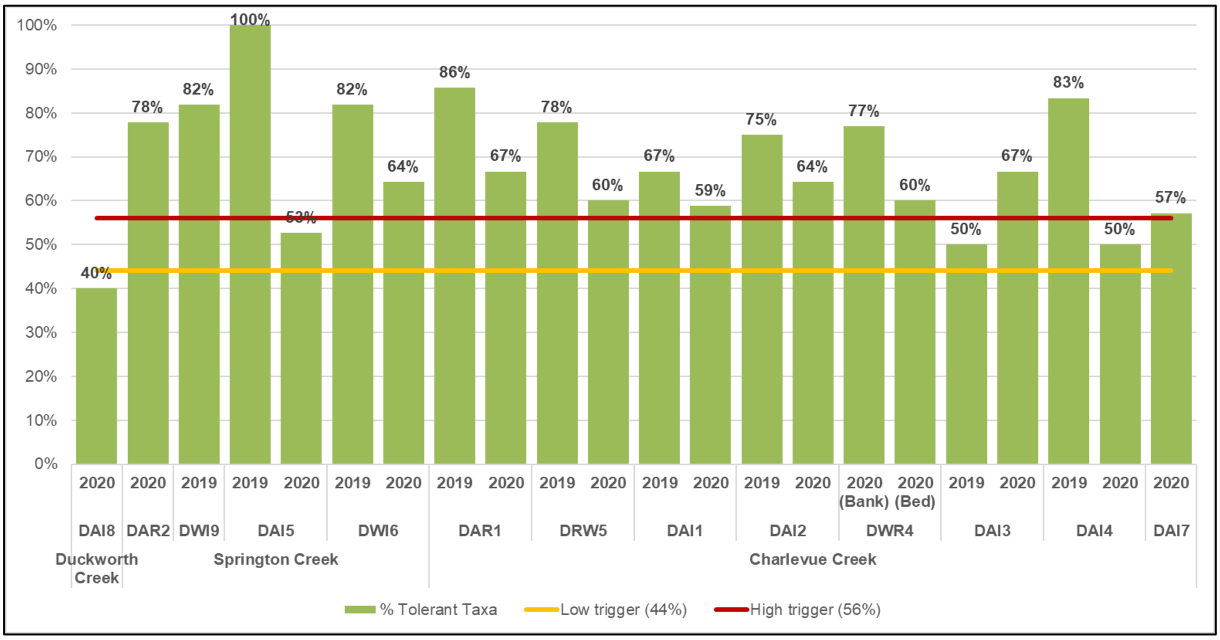


Figure 14 Macroinvertebrate percent tolerant taxa

6.4.1.6 SIGNAL 2 Bi-Plot

A SIGNAL 2 bi-plot was created for the aquatic sites to demonstrate the level of pollution and suitability of the site for macroinvertebrate habitation (Figure 15). Each quadrant is reflective of a specific type of environment:

Quadrant 1: Sites are indicative of favourable water quality and minimal levels of disturbance.

Quadrant 2: Sites reflect waters which are high in nutrients or salinity.

Quadrant 3: Sites indicate the presence of harsh physical environments or toxic pollution.

Quadrant 4: Sites exhibit levels of pollutants that reflect urban, industrial, or agricultural pollution.

All sites fell within quadrant 4; with sites exposed to various anthropogenic pollutions from agricultural and pastoral activities, as well as urban influences from highway and railway infrastructure, and local dwellings. Additionally, all sites were accessible by humans and livestock.

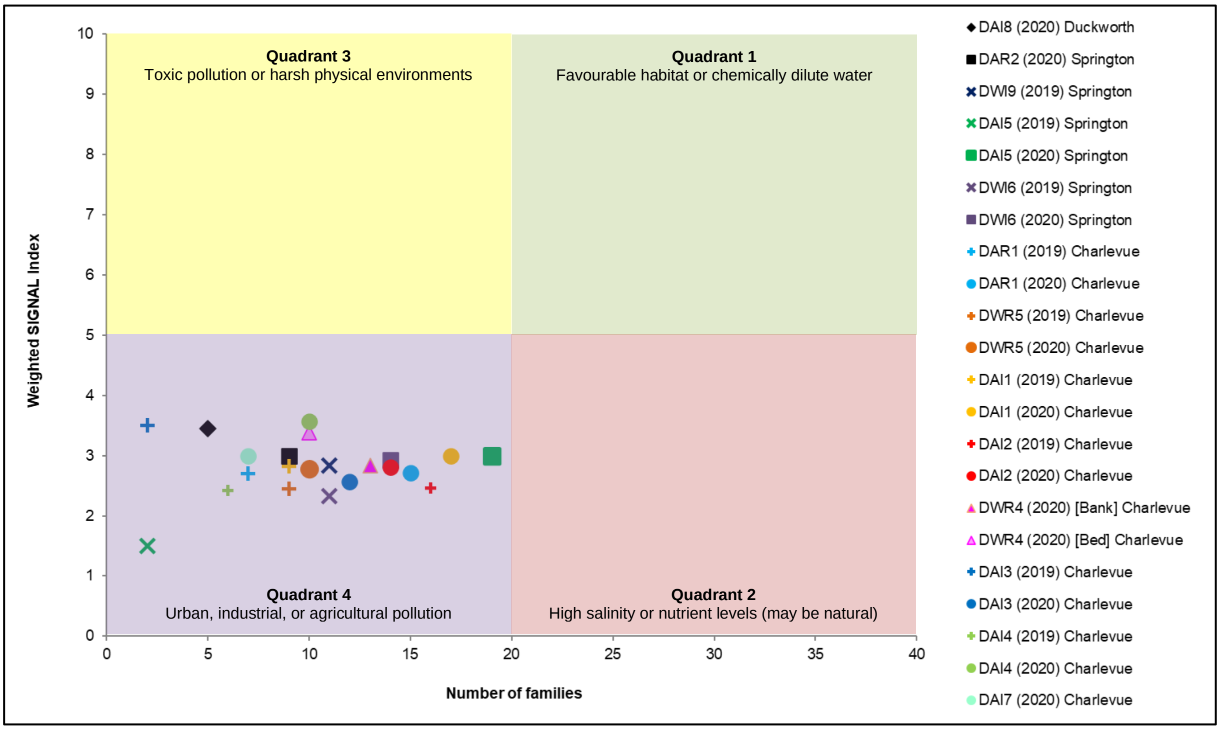


Figure 15 Macroinvertebrate weighted SIGNAL 2 index biplot

6.4.1.7 Community Composition – AusRivAS Predictive Modelling

Macroinvertebrate community composition was interpreted by running data through an AusRivAS predictive modelling program. This model is used to predict macroinvertebrate assemblages that are expected to occur within a site in the absence of impact. This model is then used to compare the expected macroinvertebrate assemblage to that of the assemblage of macroinvertebrates collected during site sampling.

Observed versus expected (O/E) taxa score is a ratio of the number of macroinvertebrate families observed onsite to that of the number of families expected; this provides a measure of biological impairment at the sample site. Five bands are used to categorise O/E taxa scores based on their biological condition as described in Table 20.

The results of the AusRivAS predictive modelling assessment is shown in Table 21. All samples, except for two, fell within or below Band B, with fewer families than expected. This indicates that most of the study area is significantly to extremely impaired; potentially impacted by poor water quality and/or the reduced availability of macroinvertebrate habitats.

However, the eight sites where sampling was able to be undertaken in both 2019 and 2020, showed consistent improvement of O/E taxa score, with each sites' (except for DAI1) O/E taxa score increasing enough to progress to the next overall assessment band, indicating that seasonal variability of water quality and/or habitat availability occurs. Of these sites, both DAI5 on Springton Creek and DAI2 on Charlevue Creek improved sufficiently to achieve a Band A (reference condition) score, indicating that aquatic conditions in some parts of the study area have the potential to be sufficiently improved to support the expected diversity of macroinvertebrate families.

Site DAI3 on Charlevue Creek received the lowest O/E taxa score (0.00 in 2019) falling within Band D, indicating that it was highly degraded at the time with extremely poor water and/or habitat quality. However, the site improved significantly in 2020, achieving a 0.6 O/E taxa score, increasing two levels to Band B.

Table 20 AusRivAS predictive modelling: Bands for Queensland (western) model

Band	Band Name	Upper Limit	Description
X	More biologically diverse than reference sites.	Infinite	More taxa found than expected. Potential biodiversity hotspot. Possible mild organic enrichment.
A	Reference condition.	1.20	Most/all of expected families found. Water quality and/or habitat condition roughly equivalent to reference sites. Impact on water quality and habitat condition does not result in a loss of macroinvertebrate diversity.
B	Significantly impaired.	0.79	Fewer families than expected. Potential impact either on water quality or habitat quality or both resulting in loss of taxa.
C	Severely impaired.	0.37	Many fewer families than expected. Loss of macroinvertebrate biodiversity due to substantial impacts on water and/or habitat quality.
D	Extremely impaired.	0.00	Few of the expected families remain. Extremely poor water and/or habitat quality. Highly degraded.

Table 21 AusRivAS predictive modelling: Results

Site	Year	O/E Taxa Score (OE50)	Overall Sample Assessment Band	Upper Bandwidth Limit	Overall Sample Assessment Habitat
Stanley Creek and Duckworth Creek					
DAI8	2020	0.28	C	0.37	Edge
Springton Creek					
DAR2	2020	0.50	B	0.79	Edge
DWI9	2019	0.40	B	0.79	Edge
DAI5	2019	0.50	B	0.79	Edge
	2020	0.80	A	1.20	Edge
DWI6	2019	0.30	C	0.37	Edge
	2020	0.60	B	0.79	Edge
Charlevue Creek					
DAR1	2019	0.29	C	0.37	Edge
	2020	0.76	B	0.79	Edge
DWR5	2019	0.30	C	0.37	Edge
	2020	0.40	B	0.79	Edge
DAI1	2019	0.40	B	0.79	Edge
	2020	0.70	B	0.79	Edge
DAI2	2019	0.70	B	0.79	Edge
	2020	0.80	A	1.20	Edge
DWR4	2020	0.40	B	0.79	Edge
DAI3	2019	0.00	D	0.00	Edge
	2020	0.60	B	0.79	Edge
DAI4	2019	0.10	C	0.37	Edge
	2020	0.70	B	0.79	Edge
DAI7	2020	0.40	B	0.79	Edge

6.4.2 Crustaceans

Crustacean species living in highly ephemeral waterways display their own unique adaptation to cope with the harsh environment. Many crustaceans can survive long periods outside of a waterbody by extracting oxygen from air with their gills. This can only occur if the gills are kept moist; so many species dig burrows to avoid desiccation and remain underground in estivation until water returns to the system. Mechanisms for desiccation resistance are observed in many species, including those that were identified during field surveys.

A total of five crustacean species were identified in the study area, all of least concern under the NC Act. A complete list of crustaceans detected at each site is presented in Appendix D (Aquatic and Semi-aquatic Fauna Species List).

Austrothelphusa transversa (freshwater crab) was the most abundant species, with 589 individuals captured over the 2019 and 2020 survey periods. *Cherax destructor* (blue claw crayfish) and *Macrobrachium australiense* (freshwater prawn) were also commonly captured in the study area. Two additional freshwater shrimp species from the Atyidae family were also caught on occasion.

6.4.3 Fish

Australia yields a low diversity of freshwater fish species, predominantly due to large areas of arid and semi-arid land, as well as the ephemeral nature of large areas of catchments (Allen, Midgely & Allen 2002). Due to the ephemeral nature of the waterways present within the study area, the overall habitat available to freshwater species is relatively low. For most of the year, the waterways onsite are vastly unconnected with other aquatic habitats, or completely dry. This results in limited refuge, breeding or feeding areas in shallow, still pools of water when available.

A total of seven fish species were identified in the study area, six of least concern under the NC Act, and one listed as introduced under the Biosecurity Act. A complete list of fish detected at each site is presented in Appendix D (Aquatic and Semi-aquatic Fauna Species List).

All fish species recorded in the study area are considered to be common or widespread species in the Mackenzie River Sub-basin. Most of the fish species recorded in the study have adaptations that allow rapid colonization and/or exploitation of ephemeral pool habitats; such as being generalist species (i.e. flexible dietary and habitat requirements) and/or are able to move rapidly to newly created pools. Such adaptations are necessary for exploiting the temporary habitat resources within the study area.

Leiopotherapon unicolor (spangled perch) and *Ambassis agassizii* (Agassiz's glassfish) were the most abundant species, with respectively 48 and 25 individuals captured over the survey periods. *Hypseleotris sp.* (Midgley's carp gudgeon) and *Neosilurus hyrtlii* (Hyrtl's catfish) were also commonly captured in the study area. *Oxyeleotris lineolata* (sleepy cod) and *Melanotaenia splendida* (eastern rainbowfish) were also caught on occasion. Two individuals of *Gambusia holbrooki* (eastern mosquitofish), an introduced species, were captured at one upstream site (DAR2) on Springton Creek.

6.4.4 Semi-aquatic Fauna

A total of four amphibian species were identified in the study area, three of least concern under the NC Act, and one listed as introduced under the Biosecurity Act. A complete list of amphibians detected at each site is presented in Appendix D (Aquatic and Semi-aquatic Fauna Species List).

Limnodynastes terraereginae (scarlet-sided pobblebonk) was the most abundant species, with eight individuals captured over the survey periods. *Litoria inermis* (bumpy rocket frog) (Photo Plate 1) and *Cyclorana novaehollandiae* (New Holland frog) were also caught once each. Four individuals of *Rhinella marina* (cane toad), an introduced species, were captured at two sites (DAI1 and DAI4) on Charlevue Creek.

Photo Plate 1 Bumpy rocket frog

One semi-aquatic reptile species was observed in the study area, which is least concern under the NC Act. A single *Tropidonophis mairii* (keelback snake) (Photo Plate 2) was identified at site DAI1 on Charlevue Creek in 2019.

Photo Plate 2 Keelback snake at DAI2

6.4.5 Riparian Fauna

A total of 63 species were identified in the riparian zone of the study area, including two mammals, seven reptiles, and 54 birds; which includes one vulnerable species under the NC Act. A complete list of riparian fauna detected at each site is presented in Appendix E (Riparian Fauna Species List). Riparian fauna is discussed in greater detail incorporated into the *Gemini Project: Terrestrial Ecology Assessment* (AARC 2019), including impact analysis of conservation significant species.

Petauroides volans volans (greater glider) is a vulnerable species and was detected six times at two sites (DAI1 and DAI2) on Charlevue Creek. *Trichosurus vulpecula* (common brushtail possum) was also detected at two sites (DAI2 and DAI4) on Charlevue Creek.

A total of seven common lizard species were identified across the study area, including one dragon (*Diporiphora australis*), one gecko (*Gehyra dubia*), and five skinks, with lizard presence detected at all sites.

A total of 54 bird species, representing 32 families were identified in the study area, all of least concern under the NC Act. The most common species; *Cracticus tibicen* (Australian magpie), *Struthidea cinereal* (apostlebird), *Corvus orru* (Torresian crow), and *Manorina melanocephala* (noisy miner) are habitat generalists, extremely common throughout Queensland, and not reliant on riparian or aquatic habitat. Two species commonly associated with wetted habitats were detected; *Grus rubicunda* (brolga) and *Threskiornis spinicollis* (straw-necked ibis).

6.5 FLORA

Riparian zone condition was assessed at each aquatic site including a flora species list generated over a 100 m transect, recording instream aquatic species and riparian zone species. The full list of flora species is provided in Appendix F (Flora Species List), and herbarium identification results presented in Appendix G (Queensland Herbarium Identification Results).

No flora species of conservation significance were observed within the aquatic or riparian zones. A total of 186 flora species were sampled throughout the aquatic surveys. This includes 50 introduced species, which incorporates introduced pasture grasses, naturalised species, general weeds, and weeds of management concern.

Ten introduced grass species were identified in the riparian zone, including *Megathyrsus maximus* (guinea grass); an environmental weed known to invade waterways, frequently choking out other vegetation due to easy seed dispersal by water, tall height (up to 3 m), and thick, clumping growth habits.

Numerous other invasive herbaceous species were detected including *Xanthium occidentale* (Noogoora burr), another environmental weed heavily associated with waterways and easily spread due to lightweight prickly seeds, easily caught in fur and clothing, or transported downstream during water flows. Other introduced species of note identified in the riparian zone include *Ricinus communis* (castor oil plant) and *Vachellia farnesiana* (mimosa bush).

Seven weeds of management concern were identified, all of which are listed as restricted invasive species under the Biosecurity Act, and four of which are also declared as a weed of national significance (WoNS). Available government fact sheets for weeds of management concern are attached as Appendix H (Weed Fact Sheets). Weeds of management concern identified in the riparian zone of the study area include:

- *Bryophyllum delagoense* (mother of millions);
- *Cardiospermum grandiflorum* (balloon vine);
- *Cryptostegia grandiflora* (rubber vine) (WoNS);
- *Harrisia martinii* (harrisia cactus);
- *Lantana camara* (lantana) (WoNS);
- *Opuntia tomentosa* (velvety tree pear) (WoNS); and
- *Parthenium hysterophorus* (parthenium weed) (WoNS).

Species richness at each aquatic site varied between 11 species at DWR4 (wetland on Charlevue Creek tributary) to 57 species at DAI5 (Springton Creek), incorporating between four (DWI3) and 16 (DAR2) introduced (and restricted) species at each site (Figure 16).

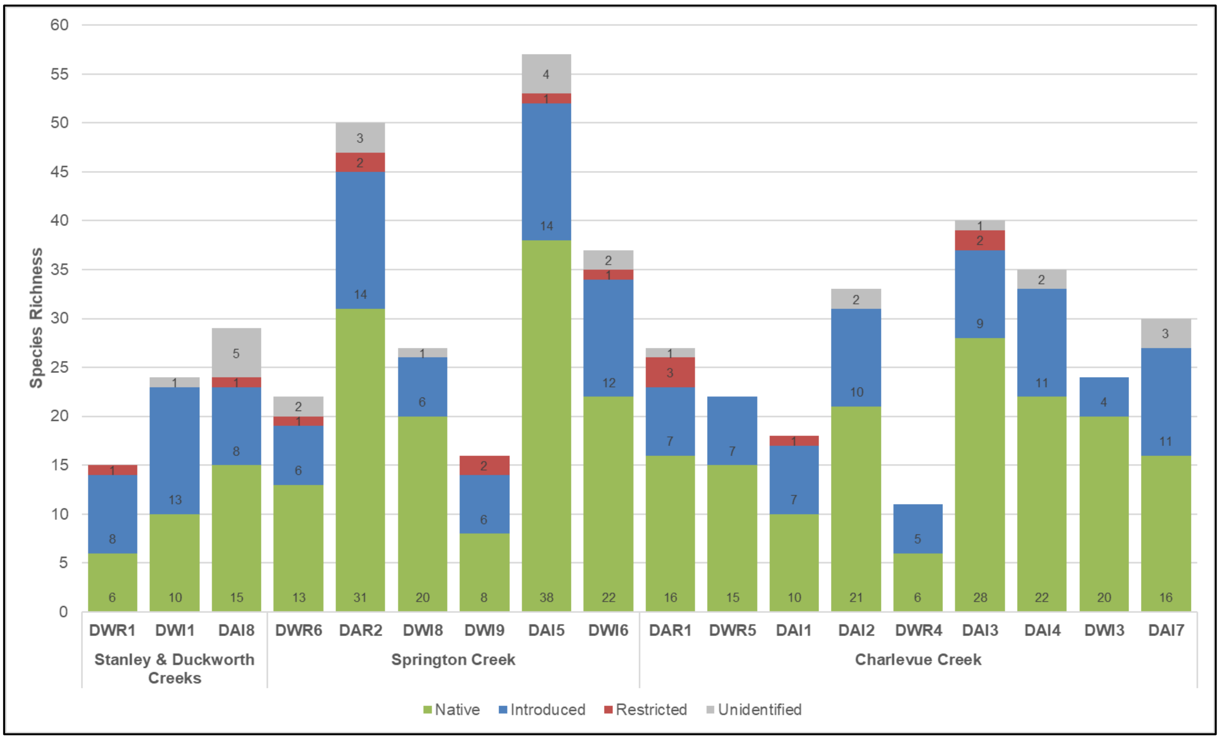


Figure 16 Flora species richness

Species composition consisted of a consistent presence of grasses and forbs at all sites, with almost all sites represented by at least one sedge or water plant. The grassy wetland on a Charlevue Creek tributary (DWR4), was the only site to lack any tree or shrub species (Figure 17). No in-stream aquatic macrophytes were recorded within the study area.

Riparian zone condition (Table 22) varied across the study area. No evidence of dieback was identified with the exception of the ephemeral grassy wetland (DWR4), where scattered dead stags were apparent (refer to photograph in site description of Appendix B). Many sites lacked species characteristic of a riparian environment, whilst broadscale clearing has reduced many waterways within the study area to a narrow corridor of creek side vegetation. Disturbance was evident at all sites, with approximately half of all sites exhibiting moderate or higher levels of various types of disturbance including invasive species, broadscale clearing or thinning practices, pastoral or anthropogenic related impacts, and direct access by livestock.

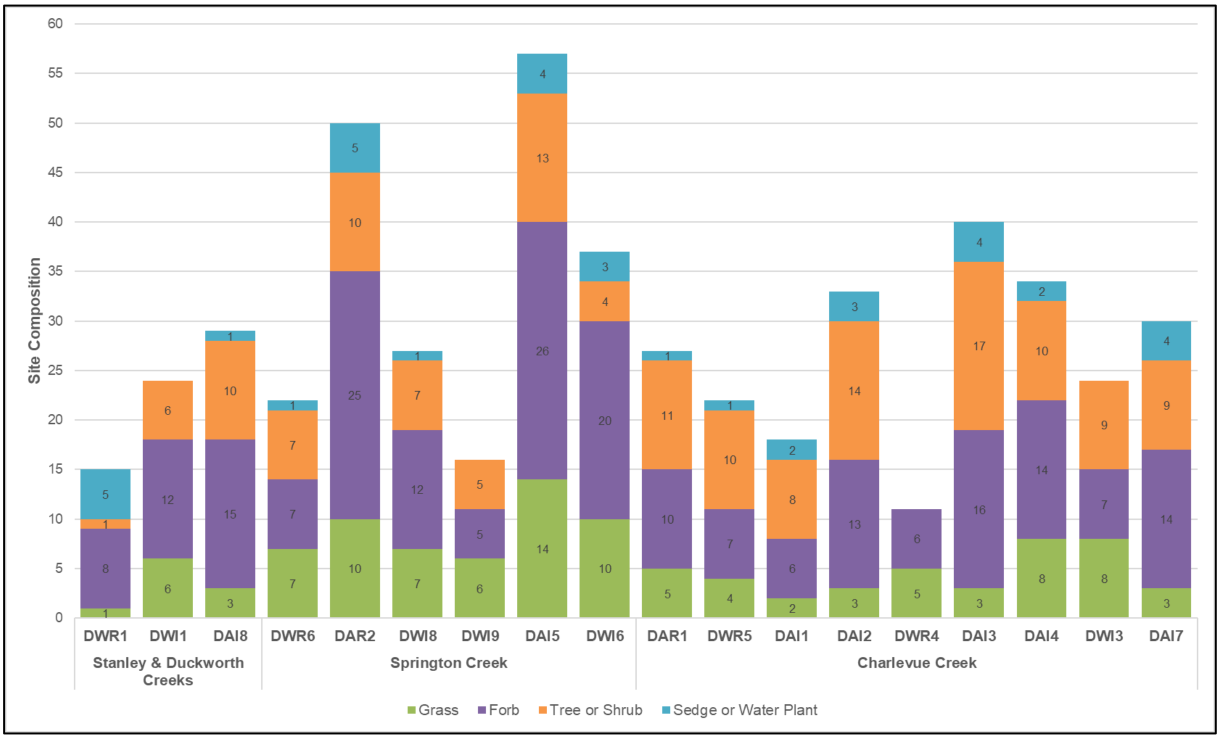


Figure 17 Site flora composition

Table 22 Riparian zone condition

Site Name	Width of Riparian Zone	Width of continued Tree Zone *(from edge of riparian zone)*	Level of Disturbance	Presence of Dieback
Stanley Creek and Duckworth Creek				
DWR1	Low (1 - 20 m)	Nil	Moderate	No
DWI1	Moderate (20 - 40 m)	High (>100 m)	Low	No
DAI8	Low (1 - 20 m)	Moderate (50 - 100 m)	High	No
Springton Creek				
DWR6	Nil	High (>100 m)	Low	No
DAR2	Low (1 - 20 m)	Nil	High	No
DWI8	Nil	Nil	Moderate	No
DWI9	Nil	High (>100 m)	Low	No
DAI5	Low (1 - 20 m)	Nil	Low	No
DWI6	Low (1 - 20 m)	Nil	High	No
Charlevue Creek				
DAR1	Low (1 - 20 m)	Low (1 - 50 m)	Moderate	No
DWR5	Nil	Low (1 - 50 m)	Moderate	No
DAI1	Low (1 - 20 m)	Moderate (50 - 100 m)	Moderate	No
DAI2	Low (1 - 20 m)	Low (1 - 50 m)	Moderate	No
DWR4	Nil	Nil	Moderate	Yes
DAI3	Moderate (20 - 40 m)	Nil	Low	No
DAI4	Moderate (20 - 40 m)	Nil	Moderate	No
DWI3	Nil	High (>100 m)	Low	No
DAI7	Moderate (20 - 40 m)	Nil	Moderate	No

Note: Level of disturbance was based on observed levels of human impact (including land clearing), domestic and feral animal impacts, disturbance from pastoral/agricultural activities, and alteration of riparian vegetation (including the presence of introduced species). Categories included low, moderate, and high.

6.6 WETLANDS

There are several small non-riverine wetlands of medium conservation significance mapped by DES within the study area. These all occur in close association with Charlevue Creek, are highly ephemeral and do not hold water throughout the year. The grassy wetland (DWR4) on a tributary to Charlevue Creek, is characteristic of these small ephemeral wetlands, only having water present during one (2020) out of the three sampling periods. All other mapped wetlands had no water present during the three-year sampling period, and therefore no aquatic assessment was able to be completed. The HES wetland to the south-east of the study area is discussed in the *Gemini Project: Terrestrial Ecology Assessment* (AARC 2019).

6.7 SUMMARY OF AQUATIC VALUES

Numerous industry standard aquatic sampling techniques were undertaken over three years of surveys, timed to occur following sufficient rainfall to allow flow and pooling in the waterways. A total of 18 sites were sampled across the three creek catchments of the study area, including upstream, mid-stream, and downstream sites within each catchment. Whilst aquatic fauna trapping and macroinvertebrate sampling was restricted to sites that contained sufficient levels of water, other assessments such as creek ecology assessments and flora assessments were undertaken at all sites. These assessments took into consideration long term impacts and assessed the overall condition of the survey sites.

The aquatic ecological biodiversity values identified for the study area are typically below average to low value, frequently failing to meet regional objectives or reference conditions. The systems within the study area are ephemeral and are only able to provide aquatic habitat for short periods of time; and throughout the rest of the year the systems are dry and provide no specific aquatic ecology values.

Stream sediments were typically fine grained; containing a high proportion of sand particles and varying levels of silt and clay. Quality of surface waters varied; whilst no dissolved metals were detected within waterways, sites had consistently low levels of dissolved oxygen, high turbidity and suspended solids, and high levels of nutrients such as ammonia and nitrogen.

Macroinvertebrates are a strong bio-indicator of a system's health and its biodiversity value. Macroinvertebrate sampling results correlated with surface water quality results; with low taxonomic richness, low PET taxa abundance, low SIGNAL indexes, and high percent tolerant taxa recorded across the study area, indicating a degraded system. The AusRivAS predictive modelling illustrated that the aquatic environment at sampling sites typically ranged from significantly impaired to extremely impaired, indicating poor water quality and low availability of macroinvertebrate habitats.

The habitat bioassessment ranked most sampling sites as moderate, one as low, three as good, and none as excellent, indicating primarily low to moderate quality of habitat available. This correlated with the generally low diversity and abundance of aquatic fauna.

The aquatic ecology environment of the study area can be summarised as highly ephemeral, and subject to extensive disturbance, leading to low ecological value. Broadscale clearing for agricultural and pastoral purposes has been undertaken across much of the study area, including the removal of riparian vegetation. Clearing, combined with direct livestock access to the waterways has resulted in bank instability, erosion, and high occurrence of invasive flora species, including several weeds of management concern. Local and regional erosion has led to increased runoff, resulting in high fine sediment loads entering the waterways; increasing turbidity. Increased runoff and direct stock access to waterways results in degraded water quality, including high nutrient loads such as ammonia and nitrogen. Low water quality, extensive physical disturbance, and invasive flora species in the aquatic environments throughout the study area, coupled with a highly ephemeral system; results in significantly reduced habitat for macroinvertebrate populations and aquatic fauna.

7.0 POTENTIAL IMPACTS

The aquatic environment within the study area is highly ephemeral, experiencing periodic flows only following large rainfall events. Past clearing for agricultural and pastoral purposes has been undertaken across much of the study area including the removal of riparian zones. The removal of riparian vegetation and direct stock access to the waterways has resulted in bank instability, erosion, and high occurrence of weeds.

The Project (Figure 18) has potential to impact on aquatic ecology values through:

- the release of mine affected water to the receiving waterways and associated impacts to ecosystem health;
- potential for spills and leaks from the mining operation to cause contamination in the receiving waterways;
- direct impacts to aquatic ecosystems via land disturbance for vehicle crossings or diversions of drainage features;
- risk of increased erosion from cleared lands or mine infrastructure such as spoil dumps, resulting in increased sediment loads entering the aquatic ecosystems; and
- impediments to fish or other aquatic fauna movements due to the construction of crossings or other infrastructure.

Climatic Variation

During the life of the Project, climatic variability may be experienced resulting in floods or periods of drought. The study area is already highly ephemeral, resulting in long dry periods and intense wet periods. In drought conditions; the proposed Project is unlikely to impact on the existing aquatic ecological values; as the Project will not release mine affected water into the waterways. The Project water requirements will largely be sourced from water collected within the site water management system, and as such the Project is not expected to exacerbate impacts resulting from drought.

The flood impact assessment (WRM 2019) conducted for the proposed Project concluded that flooding impacts will be contained within the mine lease area (1% annual exceedance probability flood), and no impacts would occur downstream of the Project. The study indicated that water runoff would not result in contaminants entering the system during peak flooding events. During flood events, the clean water drains along Springton Creek tributary will not result in a significant increase to flood depths or velocities. The clean water drains, designed to mimic the existing aquatic values of the diverted waterway, will suitably contain the water preventing flood waters extending out into areas previously unaffected by flood events. The Project is not expected to further lower the quality of the water in the already degraded systems, nor will it cause significant changes during flood events.

As such, Project related potential impacts due to flooding are not likely to negatively impact the aquatic ecology values within or downstream of the study area, and would resemble the potential impacts that would currently occur during a flood event in the undeveloped study area.

Additionally, the Project has a short life and following the decommissioning of the mine; the final voids will not affect the water quality, habitat availability or flow of the waterways within the study area, with minimal loss of stream catchments to occur.

Figure 18 Conceptual project layout

8.0 MITIGATION STRATEGIES

Aquatic ecology values are primarily attributed to Charlevue Creek and Springton Creek within the MLA. The following mitigation measures should be implemented to protect existing values:

- sediment and erosion control structures would be installed and maintained near all at risk areas to prevent sediment release to wetlands;
- waterway crossing designs would provide for fish passage during low and high flow events;
- the release of mine affected water would be in accordance with the quality controls provided by the model mining conditions;
- fuel and hazardous liquids would be stored in a bunded facility, in accordance with Australian Standards;
- a spill and emergency management plan would be implemented during construction and operation to minimise the risk of contaminant release to aquatic ecosystems;
- open-cut pits would be appropriately bunded or located in a manner that prevents surface water from entering the open pits during a 1:1000 year flood event and Project dams would be appropriately bunded or located in a manner that prevents surface water from entering or damaging the dams during a 1:1000 year flood event (consistent with the particular manner decision EPBC 2010/5775 [refer Section 2.1]); and
- a receiving environment monitoring program (REMP) has been designed by AARC Environmental Solutions (AARC 2020) and would be implemented and would include monitoring of water, sediments, riparian/riverine vegetation health and biological indicators in aquatic environments.

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* (EHP 2014) is used to determine whether residual impacts are considered to be significant.

The following prescribed matters were mapped or identified within the aquatic ecological environment of the study area:

- waterways providing for fish passage (under the Fisheries Act); and
- habitat for the vulnerable *Rheodytes leukops* (Fitzroy River turtle).

One HES wetland, that also lies within a wetland protection area, occurs approximately 4 km east of the study area (refer to Figure 4). This wetland has been assessed in the *Gemini Project: Terrestrial Ecology Assessment* (AARC 2019) and has not been duplicated in this report.

9.1 IMPACT ASSESSMENT: WATERWAYS PROVIDING FOR FISH PASSAGE

The Project will require some modifications to, or infrastructure on, waterways. 'Queensland waterways for waterway barrier works' mapping has been consulted to identify the risk of adverse impact from proposed infrastructure to waterways of concern:

- Charlevue Creek crossing (mapped as major risk);
- Stanley Creek crossing (mapped as moderate risk);
- development of clean water drains along a tributary of Springton Creek (and/or its tributaries) (mapped as low to moderate risk); and
- disturbance of first and second order waterways (mapped as low to moderate risk).

The *QEOP: Significant Residual Impact Guideline* (EHP 2014) was used to determine whether or not the impacts of the Project will, or is likely to, have a significant residual impact on waterways providing for fish passage, which is defined as:

> ***Passage** for fish, means the natural movement patterns of fish species required to maintain the biological integrity of the species.*

When assessed against the MSES significant residual impact guidelines (Table 23), the Project is considered unlikely to result in a significant residual impact on waterways providing for fish passage. Based on the assessment, no offsets under the EO Regulation for waterways providing for fish passage are considered to be required for the Project.

Table 23 Significant residual impact assessment: Waterways providing for fish passage

Criteria	Assessment
Will the action result in the mortality or injury of fish?	**No**, the Project would not result in the mortality or injury of fish. The habitat within the study area offers limited habitat for fish species as the water systems are ephemeral and only flow during high rainfall events. All waterway crossings (Charlevue Creek and Stanley Creek) would be constructed in consideration of the *Accepted development requirements for operational work that is constructing or raising waterway barrier works* (DAF 2018), so as not to create a barrier to fish movement. The development of the clean water drains along the Springton Creek tributary would be designed to replicate natural features where possible with the aim of providing similar conditions to the original waterway, so as to provide habitat and refuge for fish inhabiting or passing through the diversion.
Will the action result in conditions that substantially increase risks to the health, wellbeing, and productivity of fish seeking passage such as through the depletion of fishes energy reserves, stranding, increased predation risks, entrapment, or confined schooling behaviour in fish?	**No**, the Project will not result in conditions that substantially increase risks to the health, wellbeing and productivity of fish seeking passage within/through the site. Given the intended design of the waterway crossings and the design of the Springton Creek tributary clean water drains that will be implemented, the Project is unlikely to result in the depletion of fishes' energy reserves, stranding fish, increase the risk of predation, entrapment or confined schooling behaviour in fish.
Will the action reduce the extent, frequency or duration of fish passage previously found at a site?	**No**, the Project will not reduce the extent, frequency, or duration of fish passage within the site. The habitat within the study area offers limited habitat for fish species as the water systems are ephemeral and only flow during high rainfall events. All waterway crossings (Charlevue Creek and Stanley Creek) would be constructed in consideration of the *Accepted development requirements for operational work that is constructing or raising waterway barrier works* (DAF 2018), so as not to create a barrier to fish movement. The development of the clean water drains along the Springton Creek tributary would be designed to replicate natural features where possible with the aim of providing similar conditions to the original waterway, so as to provide habitat and refuge for fish inhabiting or passing through the diversion.
Will the action substantially modify, destroy, or fragment areas of fish habitat (including, but not limited to in-stream vegetation, snags and woody debris, substrate, bank or riffle formations) necessary for the breeding and/or survival of fish?	**No**, the Project will not substantially modify, destroy, or fragment areas of fish habitat necessary for breeding and/or the survival of fish. All waterway crossings (Charlevue Creek and Stanley Creek) would be constructed in consideration of the *Accepted development requirements for operational work that is constructing or raising waterway barrier works* (DAF 2018), so as not to create a barrier to fish movement. The development of the clean water drains along the Springton Creek tributary would be designed to replicate natural features where possible with the aim of providing similar conditions to the original waterway, so as to provide habitat and refuge for fish inhabiting or passing through the diversion. Several unnamed tributaries of the Springton Creek and Charlevue Creek are expected to be removed or otherwise impacted by mining activities. These waterways have been mapped as low to moderate risk of impact of fish passage. These waterways are of low stream orders (1 or 2) and are ephemeral. These waterways are not considered to provide fish habitat necessary for the breeding and/or the survival of fish.

Criteria	Assessment
Will the action result in a substantial and measurable change in the hydrological regime of the waterway, for example, a substantial change to the volume, depth, timing, duration, and frequency of flows?	**No**, the Project is unlikely to result in substantial and measurable changes in the hydrological regime of the waterways within and around the study area. The volume, depth, timing, duration, and frequency of flows are anticipated continue to reflect the ephemeral and variable flow nature of the waterways around the study area.
Will the action lead to significant changes in water quality parameters such as temperature, dissolved oxygen, pH, and conductivity that provide cues for movement in local fish species?	**No**, given the water management measures that will be implemented (Section 8.0), the Project is unlikely to decrease the quality of habitat for fish utilising the study area or lead to a significant change in water quality parameters. The Project will ensure that any water releases will be managed in accordance with the EA conditions (once developed).

9.2 IMPACT ASSESSMENT: FITZROY RIVER TURTLE

The *QEOP: Significant Residual Impact Guideline* (EHP 2014) was used to determine whether or not the impacts of the Project will, or is likely, to have a significant residual impact on habitat for the vulnerable *Rheodytes leukops* (Fitzroy River turtle).

When assessed against the MSES significant residual impact guidelines (Table 24), the Project is considered unlikely to result in a significant residual impact on Fitzroy River turtle. Based on the assessment, no offsets under the EO Regulation for the Fitzroy River turtle are considered to be required for the Project.

Table 24 Significant residual impact assessment: Fitzroy River turtle

Criteria	Assessment
Will the action lead to a long-term decrease in the size of local population of a species?	**No**, there is no local population of the species. No records of this species occur within 10 km of the Project, and only one record occurs between 10 and 50 km of the Project. The closest population is associated with the waters of the Mackenzie River and Fitzroy River. No suitable riffle or large pool habitat occurs within the study area, as the waterways are ephemeral and only flow during high rainfall events. The Project includes measures to prevent downstream impacts to the Fitzroy River turtle, specifically: • appropriately bunding or locating open-cut pits in a manner that prevents surface water from entering the pit during a 1:1000-year flood event; and • appropriately bunding or locating dams in a manner that prevents surface water from entering or damaging the dams during a during a 1:1000-year flood event.
Will the action reduce the extent of occurrence of the species?	**No**, the Project will not reduce the extent or occurrence of the species. The proposed disturbance and downstream water releases are unlikely to reduce the potential area of occupancy for the Fitzroy River turtle.
Will the action fragment an existing population into two or more populations?	**No**, the Project would not fragment 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**, given the water management measures to prevent downstream impacts to the Fitzroy River turtle; the Project is unlikely to result in genetically distinct populations forming.

Criteria	Assessment
Will the action disrupt ecologically significant locations (breeding, feeding, nesting, migration, or resting sites) of a species?	**No**, given the water management measures to prevent downstream impacts to the Fitzroy River turtle; the Project is unlikely to disrupt an ecologically significant location of this species.
Will the action result in invasive species that are harmful to the species becoming established in the species habitat?	**No**, while the Fitzroy River turtle is vulnerable to predation on nests from introduced pest species (such as feral pigs); pest management strategies will be implemented to minimise the risk of contributing to population increases of introduced pest species that may predate on downstream nests of the Fitzroy River turtle.
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.

9.3 OFFSETS REQUIREMENTS

There are no aquatic MSES environmental offset requirements to be delivered under the Queensland environmental offsets framework as part of this Project.

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Appendix A Database Searches

Queensland Government

Department of Environment and Science

Environmental Reports

Biodiversity and Conservation Values

Biodiversity Planning Assessments and Aquatic Conservation Assessments

For the selected area of interest
epc: 881

Environmental Reports - General Information

The Environmental Reports portal provides for the assessment of selected matters of interest relevant to a user specified location, or Area of Interest (AOI). All area and derivative figures are relevant to the extent of matters of interest contained within the AOI unless otherwise stated. Please note, if a user selects an AOI via the "Central co-ordinates" option, the resulting assessment area encompasses an area extending from 2km radius from the point of interest.

All area and area derived figures included in this report have been calculated via reprojecting relevant spatial features to Albers equal-area conic projection (central meridian = 146, datum Geocentric Datum of Australia 1994). As a result, area figures may differ slightly if calculated for the same features using a different co-ordinate system.

Figures in tables may be affected by rounding.

The matters of interest reported on in this document are based upon available state mapped datasets. Where the report indicates that a matter of interest is not present within the AOI (e.g. where area related calculations are equal to zero, or no values are listed), this may be due either to the fact that state mapping has not been undertaken for the AOI, that state mapping is incomplete for the AOI, or that no values have been identified within the site.

The information presented in this report should be considered as a guide only and field survey may be required to validate values on the ground.

Please direct queries about these reports to: biodiversity.planning@des.qld.gov.au

Disclaimer

Whilst every care is taken to ensure the accuracy of the information provided in this report, the Queensland Government makes no representations or warranties about its accuracy, reliability, completeness, or suitability, for any particular purpose and disclaims all responsibility and all liability (including without limitation, liability in negligence) for all expenses, losses, damages (including indirect or consequential damage) and costs which the user may incur as a consequence of the information being inaccurate or incomplete in any way and for any reason.

Table of Contents

Summary Information . . . 4

Biodiversity Planning Assessments . . . 6

- Introduction . . . 6
- Diagnostic Criteria . . . 6
- Other Essential Criteria . . . 8

Aquatic Conservation Assessments . . . 13

- Introduction . . . 13
- Explanation of Criteria . . . 13
- Riverine Wetlands . . . 14
- Non-riverine Wetlands . . . 15

Threatened and Priority Species . . . 18

- Introduction . . . 18
- Threatened Species . . . 18
- BPA Priority Species . . . 18
- ACA Priority Species . . . 19

Maps . . . 20

- Map 1 - Locality Map . . . 20
- Map 2 - Biodiversity Planning Assessment (BPA) . . . 21
- Map 3 - Corridors . . . 22
- Map 4 - Wetlands and waterways . . . 23
- Map 5 - Aquatic Conservation Assessment (ACA) - riverine . . . 24
- Map 6 - Aquatic Conservation Assessment (ACA) - non-riverine . . . 25

References . . . 26

Appendices . . . 27

- Appendix 1 - Source Data . . . 27
- Appendix 2 - Acronyms and Abbreviations . . . 28

Summary Information

Tables 1 to 8 provide an overview of the AOI with respect to selected topographic and environmental values.

Table 1: Area of interest details: epc: 881

Size (ha)	7,219.57
Local Government(s)	Central Highlands Regional
Bioregion(s)	Brigalow Belt
Subregion(s)	Woorabinda
Catchment(s)	Fitzroy

The following table identifies available Biodiversity Planning Assessments (BPAs) and Aquatic Conservation Assessments (ACAs) with respect to the AOI.

Table 2: Available Biodiversity Planning and Aquatic Conservation Assessments

Assessment Type	Assessment Area and Version
Biodiversity Planning Assessment(s)	Brigalow Belt v2.1
Aquatic Conservation Assessment(s) (riverine)	Great Barrier Reef Catchments v1.3
Aquatic Conservation Assessment(s) (non-riverine)	Great Barrier Reef Catchments v1.3

Table 3: Remnant regional ecosystems within the AOI as per the Qld Herbarium's 'biodiversity status'

Biodiversity Status	Area (Ha)	% of AOI
Endangered	6.41	0.09
Of concern	236.35	3.27
No concern at present	1,816.18	25.16

The following table identifies the extent and proportion of the user specified area of interest (AOI) which is mapped as being of "State", "Regional" or "Local" significance via application of the Queensland Department of Environment and Science's *Biodiversity Assessment and Mapping Methodology* (BAMM).

Table 4: Summary table, biodiversity significance

Biodiversity significance	Area (Ha)	% of AOI
State Habitat for EVNT taxa	0.0	0.0
State	887.22	12.29
Regional	325.7	4.51
Local or Other Values	1,126.39	15.6

Table 5: Non-riverine wetlands intersecting the AOI

Non-riverine wetland types intersecting the area of interest	#
Number of Palustrine wetlands	4
Number of Lacustrine wetlands	2

Non-riverine wetland types intersecting the area of interest	#
Total number of non-riverine wetlands	6

NB. The figures presented in the table above are derived from the relevant non-riverine Aquatic Conservation Assessment(s). Later releases of wetland mapping produced via the Queensland Wetland Mapping Program may provide more recent information in regards to wetland extent.

Table 6: Named waterways intersecting the AOI

Name	Permanency
CHARLEVUE CREEK	Non-perennial
SPRINGTON CREEK	Non-perennial
STANLEY CREEK	Non-perennial

Refer to **Map 1** for general locality information.

The following two tables identify the extent and proportion of the user specified AOI which is mapped as being of "Very High", "High", "Medium", "Low", or "Very Low" aquatic conservation value for riverine and non-riverine wetlands via application of the Queensland Department of Environment and Science's *Aquatic Biodiversity Assessment and Mapping Method* (AquaBAMM).

Table 7: Summary table, aquatic conservation significance (riverine)

Aquatic conservation significance (riverine wetlands)	Area (Ha)	% of AOI
Very High	0.0	0.0
High	0.0	0.0
Medium	7,219.57	100.0
Low	0.0	0.0
Very Low	0.0	0.0

Table 8: Summary table, aquatic conservation significance (non-riverine)

Aquatic conservation significance (non-riverine wetlands)	Area (Ha)	% of AOI
Very High	0.0	0.0
High	0.0	0.0
Medium	10.88	0.15
Low	0.0	0.0
Very Low	0.0	0.0

Biodiversity Planning Assessments

Introduction

The Department of Environment and Science (DES) attributes biodiversity significance on a bioregional scale through a Biodiversity Planning Assessment (BPA). A BPA involves the integration of ecological criteria using the *Biodiversity assessment and Mapping Methodology* (BAMM) and is developed in two stages: 1) **diagnostic criteria**, and 2) **expert panel criteria**. The diagnostic criteria are based on existing data which is reliable and uniformly available across a bioregion, while the expert panel criteria allows for the refinement of the mapped information from the diagnostic output by incorporating local knowledge and expert opinion.

The BAMM methodology has application for identifying areas with various levels of significance solely for biodiversity reasons. These include threatened ecosystems or taxa, large tracts of habitat in good condition, ecosystem diversity, landscape context and connection, and buffers to wetlands or other types of habitat important for the maintenance of biodiversity or ecological processes. While natural resource values such as dryland salinity, soil erosion potential or land capability are not dealt with explicitly, they are included to some extent within the biodiversity status of regional ecosystems recognised by the DES.

Biodiversity Planning Assessments (BPAs) assign three levels of overall biodiversity significance.

- **State significance** - areas assessed as being significant for biodiversity at the bioregional or state scales. They also include areas assessed by other studies/processes as being significant at national or international scales. In addition, areas flagged as being of State significance due to the presence of endangered, vulnerable and/or near threatened taxa, are identified as "State Habitat for EVNT taxa".
- **Regional significance** - areas assessed as being significant for biodiversity at the subregional scale. These areas have lower significance for biodiversity than areas assessed as being of State significance.
- **Local significance and/or other values -** areas assessed as not being significant for biodiversity at state or regional scales. Local values are of significance at the local government scale.

For further information on released BPAs and a copy of the underlying methodology, go to:

http://www.qld.gov.au/environment/plants-animals/biodiversity/planning/

The GIS results can be downloaded from the Queensland Spatial Catalogue at:

http://qspatial.information.qld.gov.au/geoportal/

The following table identifies the extent and proportion of the user specified AOI which is mapped as being of "State", "Regional" or "Local" significance via application of the BAMM.

Table 9: Summary table, biodiversity significance

Biodiversity significance	Area (Ha)	% of AOI
State Habitat for EVNT taxa	0.0	0.0
State	887.22	12.29
Regional	325.7	4.51
Local or Other Values	1,126.39	15.6

Refer to **Map 2** for further information.

Diagnostic Criteria

Diagnostic criteria are based on existing data which is reliable and uniformly available across a bioregion. These criteria are diagnostic in that they are used to filter the available data and provide a "first-cut" or initial determination of biodiversity significance. This initial assessment is then combined through a second group of other essential criteria.

A description of the individual diagnostic criteria is provided in the following sections.

Criteria A. Habitat for EVNT taxa: Classifies areas according to their significance based on the presence of endangered, vulnerable and/or rare (EVNT) taxa. EVNT taxa are those scheduled under the *Nature Conservation Act 1992* and/or the

Environment Protection and Biodiversity Conservation Act 1999. It excludes highly mobile fauna taxa which are instead considered in Criterion H and brings together information on EVNT taxa using buffering of recorded sites or habitat suitability models (HSM) where available.

Criteria B. Ecosystem value: Classifies on the basis of biodiversity status of regional ecosystems, their extent in protected areas (presence of poorly conserved regional ecosystems), the presence of significant wetlands; and areas of national importance such as the presence of Threatened Ecological Communities, World Heritage areas and Ramsar sites. Ecosystem value is applied at a bioregional (**B1**) and regional (**B2**) scale.

Criteria C. Tract size: Measures the relative size of tracts of vegetation in the landscape. The size of any tract is a major indicator of ecological significance, and is also strongly correlated with the long-term viability of biodiversity values. Larger tracts are less susceptible to ecological edge effects and are more likely to sustain viable populations of native flora and fauna than smaller tracts.

Criteria D. Relative size of regional ecosystems: Classifies the relative size of each regional ecosystem unit within its bioregion (**D1**) and its subregion (**D2**). Remnant units are compared with all other occurrences with the same regional ecosystem. Large examples of a regional ecosystem are more significant than smaller examples of the same regional ecosystem because they are more representative of the biodiversity values particular to the regional ecosystem, are more resilient to the effects of disturbance, and constitute a significant proportion of the total area of the regional ecosystem.

Criteria F. Ecosystem diversity: Is an indicator of the number of regional ecosystems occurring within an area. An area with high ecosystem diversity will have many regional ecosystems and ecotones relative to other areas within the bioregion.

Criteria G. Context and connection: Represents the extent to which a remnant unit incorporates, borders or buffers areas such as significant wetlands, endangered ecosystems; and the degree to which it is connected to other vegetation.

A summary of the biodiversity status based upon the diagnostic criteria is provided in the following table.

Table 10: Summary of biodiversity significance based upon diagnostic criteria with respect to the AOI

Biodiversity significance	Description	Area (Ha)	% of AOI
State	Remnant contains at least 1 Vulnerable or Near Threatened species (A) & Nat. Threatened Ecol. Community (B1)	49.69	0.69
State	Remnant contains at least one Of Concern RE (B1) & Nat. Threatened Ecol. Community (B1)	170.08	2.36
Regional	Remnant contains at least 1 Vulnerable or Near Threatened species (A)	297.04	4.11
Regional	Remnant contains at least one Of Concern RE (B1)	24.52	0.34
Local or Other Values	Refer to diagnostic data for additional information	1,787.11	24.75

Assessment of diagnostic criteria with respect to the AOI

The following table reflects an assessment of the individual diagnostic criteria noted above in regards to the AOI.

Table 11: Assessment of individual diagnostic criteria with respect to the AOI

Diagnostic Criteria	Very High Rating - Area (Ha)	Very High Rating - % of AOI	High Rating - Area (Ha)	High Rating - % of AOI	Medium Rating - Area (Ha)	Medium Rating - % of AOI	Low Rating - Area (Ha)	Low Rating - % of AOI
A: Habitat for EVNT Taxa			346.7	4.8	1,451.58	20.1	530.12	7.3
B1: Ecosystem Value (Bioregion)	219.75	3.0	24.52	0.3	1,842.09	25.5		
B2: Ecosystem Value (Subregion)					2,086.36	28.9		
C: Tract Size			695.57	9.6	635.1	8.8	755.69	10.5
D1: Relative RE Size (Bioregion)							2,086.36	28.9
D2: Relative RE Size (Subregion)							2,086.36	28.9
F: Ecosystem Diversity	40.49	0.6	770.08	10.7	1,160.05	16.1	115.74	1.6
G: Context and Connection	182.92	2.5	467.75	6.5	1,377.66	19.1	58.03	0.8

Other Essential Criteria

Other essential criteria (also known as expert panel criteria) are based on non-uniform information sources and which may rely more upon expert opinion than on quantitative data. These criteria are used to provide a "second-cut" determination of biodiversity significance, which is then combined with the diagnostic criteria for an overall assessment of relative biodiversity significance. A summary of the biodiversity status based upon the other essential criteria is provided in the following table.

Table 12: Summary of biodiversity significance based upon other essential criteria with respect to the AOI

Biodiversity significance	Description	Area (Ha)	% of AOI
State	Remnant contains Special Biodiversity Values (view Expert Panel data for further information) (I)	709.9	9.83
Regional	Remnant contains Special Biodiversity Values (view Expert Panel data for further information) (I)	0.32	0.0
Regional	Remnant forms part of a bioregional corridor (J)	95.17	1.32
Local	Remnant contains Special Biodiversity Values (view Expert Panel data for further information) (I)	10.56	0.15

A description of each of the other essential criteria and associated assessment in regards to the AOI is provided in the following sections.

Criteria H. Essential and general habitat for priority taxa: Priority taxa are those which are at risk or of management concern, taxa of scientific interest as relictual (ancient or primitive), endemic taxa or locally significant populations (such as a flying fox camp or heronry), highly specialised taxa whose habitat requirements are complex and distributions are not well correlated with any particular regional ecosystem, taxa important for maintaining genetic diversity (such as complex spatial patterns of genetic variation, geographic range limits, highly disjunct populations), taxa critical for management or monitoring of biodiversity (functionally important or ecological indicators), or economic and culturally important taxa.

Criteria I. Special biodiversity values: areas with special biodiversity values are important because they contain multiple taxa in a unique ecological and often highly biodiverse environment. Areas with special biodiversity values can include the following:

- Ia - centres of endemism - areas where concentrations of taxa are endemic to a bioregion or subregion are found.
- Ib - wildlife refugia (Morton *et al*. 1995), for example, islands, mound springs, caves, wetlands, gorges, mountain ranges and topographic isolates, ecological refuges, refuges from exotic animals, and refuges from clearing. The latter may include large areas that are not suitable for clearing because of land suitability/capability.
- Ic - areas with concentrations of disjunct populations.
- Id - areas with concentrations of taxa at the limits of their geographic ranges.
- Ie - areas with high species richness.
- If - areas with concentrations of relictual populations (ancient and primitive taxa).
- Ig - areas containing REs with distinct variation in species composition associated with geomorphology and other environmental variables.
- Ih - an artificial waterbody or managed/manipulated wetland considered by the panel/s to be of ecological significance.
- Ii - areas with a high density of hollow-bearing trees that provide habitat for animals.
- Ij - breeding or roosting sites used by a significant number of individuals.
- Ik - climate change refuge.

The following table identifies the value and extent area of the Other Essential Criteria H and I within the AOI.

Table 13: Relative importance of expert panel criteria (H and I) used to access overall biodiversity significance with respect to the AOI

Expert Panel	Very High Rating - Area (Ha)	Very High Rating - % of AOI	High Rating - Area (Ha)	High Rating - % of AOI	Medium Rating - Area (Ha)	Medium Rating - % of AOI	Low Rating - Area (Ha)	Low Rating - % of AOI
H: Core Habitat Priority Taxa								
Ia: Centres of Endemism								
Ib: Wildlife Refugia	709.92	9.8	0.32		10.55	0.1		
Ic: Disjunct Populations								

Expert Panel	Very High Rating - Area (Ha)	Very High Rating - % of AOI	High Rating - Area (Ha)	High Rating - % of AOI	Medium Rating - Area (Ha)	Medium Rating - % of AOI	Low Rating - Area (Ha)	Low Rating - % of AOI
Id: Limits of Geographic Ranges								
Ie: High Species Richness								
If: Relictual Populations								
Ig: Variation in Species Composition								
Ih: Artificial Wetland								
Ii: Hollow Bearing Trees								
Ij: Breeding or Roosting Site	30.51	0.4						
Ik: Climate Refugia								

NB. Whilst biodiversity values associated with Criteria I may be present within the site (refer to tables 12 and 15), for the New England Tableland and Central Queensland Coast BPAs, area and % area figures associated with Criteria Ia through to Ij cannot be listed in the table above (due to slight variations in data formats between BPAs).

Criteria J. Corridors: areas identified under this criterion qualify either because they are existing vegetated corridors important for contiguity, or cleared areas that could serve this purpose if revegetated. Some examples of corridors include riparian habitats, transport corridors and "stepping stones".

Bioregional and subregional conservation corridors have been identified in the more developed bioregions of Queensland through the BPAs, using an intensive process involving expert panels. Map 3 displays the location of corridors as identified under the Statewide Corridor network. The Statewide Corridor network incorporates BPA derived corridors and for bioregions where no BPA has been assessed yet, corridors derived under other planning processes. *Note: as a result of updating and developing a statewide network, the alignment of corridors may differ slightly in some instances when compared to those used in individual BPAs.*

The functions of these corridors are:

- **Terrestrial** Bioregional corridors, in conjunction with large tracts of remnant vegetation, maintain ecological and evolutionary processes at a landscape scale, by:

    - Maintaining long term evolutionary/genetic processes that allow the natural change in distributions of species and connectivity between populations of species over long periods of time;
    - Maintaining landscape/ecosystems processes associated with geological, altitudinal and climatic gradients, to allow for ecological responses to climate change;
    - Maintaining large scale seasonal/migratory species processes and movement of fauna;
    - Maximising connectivity between large tracts/patches of remnant vegetation;
    - Identifying key areas for rehabilitation and offsets; and

- **Riparian** Bioregional Corridors also maintain and encourage connectivity of riparian and associated ecosystems.

The location of the corridors is determined by the following principles:

- Terrestrial
    - Complement riparian landscape corridors (i.e. minimise overlap and maximise connectivity);
    - Follow major watershed/catchment and/or coastal boundaries;
    - Incorporate major altitudinal/geological/climatic gradients;
    - Include and maximise connectivity between large tracts/patches of remnant vegetation;

- Include and maximise connectivity between remnant vegetation in good condition; and

- Riparian
  - Located on the major river or creek systems within the bioregion in question.

The total extent of remnant vegetation triggered as being of "State", "Regional" or "Local" significance due to the presence of an overlying BPA derived terrestrial or riparian corridor within the AOI, is provided in the following table. For further information on how remnant vegetation is triggered due to the presence of an overlying BPA derived corridor, refer to the relevant landscape BPA expert panel report(s).

Table 14: Extent of triggered remnant vegetation due to the presence of BPA derived corridors with respect to the AOI

Biodiversity Significance	Area (Ha)	% of AOI
State	0.0	0.0
Regional	95.17	1.32
Local	0.0	0.0

NB: area figures associated with the extent of corridor triggered remnant vegetation are only available for those bioregions where a BPA has been undertaken.

Refer to **Map 3** for further information.

Threatening process/condition (Criteria K) - areas identified by experts under this criterion may be used to amend (upgrade or downgrade) biodiversity significance arising from the "first-cut" analysis. The condition of remnant vegetation is affected by threatening processes such as weeds, ferals, grazing and burning regime, selective timber harvesting/removal, salinity, soil erosion, and climate change.

Assessment of Criteria K with respect to the AOI is not currently included in the "Biodiversity and Conservation Values" report, as it has not been applied to the majority of Queensland due to data/information limitations and availability.

Special Area Decisions

Expert panel derived "Special Area Decisions" are used to assign values to Other Essential Criteria. The specific decisions which relate to the AOI in question are listed in the table below.

Table 15: Expert panel decisions for assigning levels of biodiversity significance with respect to the AOI

Decision Number	Description	Panel Recommended Significance	Criteria Values
brbn_l_62	Taunton Scientific Reserve	State	Ib (refugia): VH
brbs_l_18b	None	None	None
brbs_l_47	Regionally significant natural palustrine & lacustrine wetlands	Regional	Ib (refugia): H
brbs_l_48	Locally significant natural palustrine & lacustrine wetlands	Local	Ib (refugia): M
brbs_l_49	Gilgai Remnants	State	Ib (refugia): VH; Ij (aggregation site):VH

Expert panel decision descriptions:

brbn_l_62

Taunton National Park (Scientific) acts as a refugia within a heavily modified landscape. The park was established primarily for the purpose of protecting the endangered bridled nailtail wallaby Onychogalea fraenata. Dispersal of individuals in time to suitable habitat to the south will rely on retaining connectivity from the park, particularly along the creeks Five Mile, Duckworth, Walton, Iguana, Stanley, Charlevue, Spectacle, Lagoon and Wild Horse (not captured in the spatial implementation).

Other known conservation significant fauna which occur or have been recorded within the park are golden-tailed gecko Strophurus taenicauda, brigalow scaly-foot Paradelma orientalis, ornamental snake Denisonia maculata, speckled warbler Chthonicola sagittata, koala Phascolarctos cinereus and squatter pigeon Geophaps s. scripta. Representatives from six of the Australian snake families are also found in the reserve.

With respect to flora, 12 regional ecosystems are present including endangered brigalow communities. More than 190 species of flora have been recorded, of which at least 4 are threatened - Solanum elachophyllum, Solanum adenophorum, Dichanthium setosum and Cerbera dumicola.

brbs_l_18b

None

brbs_l_47

The panel considered that relatively natural palustrine and lacustrine wetlands and waterbodies within the Brigalow Belt bioregion act as important refugia, especially during periods of drought.

Whilst State significant wetlands are captured under Criterion B1, the panel agreed that all such natural wetland complexes with a combined area of greater than or equal to 5ha in size should be classed as being of at least Regional significance.

Refer to brbn_l_92 for the northern BRB implementation of this decision.

brbs_l_48

The panel considered that relatively natural palustrine and lacustrine wetlands and waterbodies within the Brigalow Belt bioregion act as important refugia, especially during periods of drought.

Whilst State significant wetlands are captured under Criterion B1, and regionally significant wetlands under the decision brbn_l_47, the panel agreed that all remaining relatively natural wetland complexes of less than 5ha in size be classed as being of at least local significance.

Refer to brbn_l_93 for the northern BRB implementation of this decision.

brbs_l_49

The gilgai wetland systems in the Brigalow Belt tend to be dominated by acacia and casuarina (mostly brigalow Acacia harpophylla and belah Casuarina cristata). Melaleuca, Corymbia and Eucalyptus species are also common along with Astrebla or Dichanthium spp. grassland. Gilgai systems are widespread and some are in good condition while others are largely cleared. The range of threatened wildlife present may use inundated gilgai as a water source at some stage of their life or are closely associated with the cracking clay soil habitat and wetlands.

Gilgai reptiles include the death adder Acanthophis antarcticus, De Vis' banded snake Denisonia devisi and ornamental snake D. maculata. Amphibians that use gilgai include salmon striped frog Limnodynastes salmini, scarlet-sided pobblebonk L. terraereginae and striped burrowing frog Cyclorana alboguttata. Other fauna which may use gilgai habitat at various times include bridled nailtail wallaby Onychogalea fraenata, black-striped wallaby Macropus dorsalis and the glossy black cockatoo Calyptorhynchus lathami.

Refer to brbn_l_75 for the northern BRB implementation of this decision.

Aquatic Conservation Assessments

Introduction

The Aquatic Biodiversity Assessment and Mapping Method or AquaBAMM (Clayton *et al.* 2006), was developed to assess conservation values of wetlands in queensland, and may also have application in broader geographical contexts. It is a comprehensive method that uses available data, including data resulting from expert opinion, to identify relative wetland conservation/ecological values within a specified study area (usually a catchment). The product of applying this method is an Aquatic Conservation Assessment (ACA) for the study area.

An ACA using AquaBAMM is non-social, non-economic and identifies the conservation/ecological values of wetlands at a user-defined scale. It provides a robust and objective conservation assessment using criteria, indicators and measures that are founded upon a large body of national and international literature. The criteria, each of which may have variable numbers of indicators and measures, are naturalness (aquatic), naturalness (catchment), diversity and richness, threatened species and ecosystems, priority species and ecosystems, special features, connectivity and representativeness. An ACA using AquaBAMM is a powerful decision support tool that is easily updated and simply interrogated through a geographic information system (GIS).

Where they have been conducted, ACAs can provide a source of baseline wetland conservation/ecological information to support natural resource management and planning processes. They are useful as an independent product or as an important foundation upon which a variety of additional environmental and socio-economic elements can be added and considered (i.e. an early input to broader 'triple-bottom-line' decision-making processes). An ACA can have application in:

- determining priorities for protection, regulation or rehabilitation of wetlands and other aquatic ecosystems
- on-ground investment in wetlands and other aquatic ecosystems
- contributing to impact assessment of large-scale development (e.g. dams)
- water resource and strategic regional planning prcesses

For a detailed explanation of the methodology please refer to the summary and expert panel reports relevant to the ACA utilised in this assessment. These reports can be accessed at Wetland *Info*:

http://wetlandinfo.des.qld.gov.au/wetlands/assessment/assessment-methods/aca

The GIS results can be downloaded from the Queensland Spatial Catalogue at:

http://qspatial.information.qld.gov.au/geoportal/

Explanation of Criteria

Under the AquaBAMM, eight criteria are assessed to derive an overall conservation value. Similar to the Biodiversity Assessment and Mapping Methodology, the criteria may be primarily diagnostic (quantitative) or primarily expert opinion (qualitative) in nature. The following sections provide a brief description of each of the 8 criteria.

Criteria 1. Naturalness - Aquatic: This attribute reflects the extent to which a wetland's (riverine, non-riverine, estuarine) aquatic state of naturalness is affected through relevant influencing indicators which include: presence of exotic flora and fauna; presence of aquatic communities; degree of habitat modification and degree of hydrological modification.

Criteria 2. Naturalness - Catchment: The naturalness of the terrestrial systems of a catchment can have an influence on many wetland characteristics including: natural ecological processes e.g. nutrient cycling, riparian vegetation, water chemistry, and flow. The indicators utilised to assess this criterion include: presence of exotic flora and/or fauna; riparian, catchment and flow modification.

Criteria 3. Naturalness - Diversity and Richness: This criterion is common to many ecological assessment methods and can include both physical and biological features. It includes such indicators as species richness, riparian ecosystem richness and geomorphological diversity.

Criteria 4. Threatened Species and Ecosystems: This criterion evaluates ecological rarity characteristics of a wetland. This includes both species rarity and rarity of communities / assemblages. The communities and assemblages are best represented by regional ecosystems. Species rarity is determined by NCA and EPBC status with Endangered, Vulnerable or Near-threatened species being included in the evaluation. Ecosystem rarity is determined by regional ecosystem biodiversity status i.e. Endangered, Of Concern, or Not of Concern.

Criteria 5. Priority Species and Ecosystems: Priority flora and fauna species lists are expert panel derived. These are aquatic, semi-aquatic and riparian species which exhibit at least 1 particular trait in order to be eligible for consideration. For flora species the traits included:

- It forms significant macrophyte beds (in shallow or deep water).
- It is an important food source.
- It is important/critical habitat.
- It is implicated in spawning or reproduction for other fauna and/or flora species.
- It is at its distributional limit or is a disjunct population.
- It provides stream bank or bed stabilisation or has soil binding properties.
- It is a small population and subject to threatening processes.

Fauna species are included if they meet at least one of the following traits:

- It is endemic to the study area (>75 per cent of its distribution is in the study area/catchment).
- It has experienced, or is suspected of experiencing, a serious population decline.
- It has experienced a significant reduction in its distribution and has a naturally restricted distribution in the study area/catchment.
- It is currently a small population and threatened by loss of habitat.
- It is a significant disjunct population.
- It is a migratory species (other than birds).
- A significant proportion of the breeding population (>one per cent for waterbirds, >75 per cent other species) occurs in the waterbody (see Ramsar criterion 6 for waterbirds).
- Limit of species range.

See the individual expert panel reports for the priority species traits specific to an ACA.

Criteria 6. Special Features: Special features are areas identified by flora, fauna and ecology expert panels which exhibit characteristics beyond those identified in other criteria and which the expert panels consider to be of the highest ecological importance. Special feature traits can relate to, but are not solely restricted to geomorphic features, unique ecological processes, presence of unique or distinct habitat, presence of unique or special hydrological regimes e.g. spring-fed streams. Special features are rated on a 1 - 4 scale (4 being the highest).

Criteria 7. Connectivity: This criterion is based on the concept that appropriately connected aquatic ecosystems are healthy and resilient, with maximum potential biodiversity and delivery of ecosystem services.

Criteria 8. Representativeness: This criterion applies primarily to non-riverine assessments, evaluates the rarity and uniqueness of a wetland type in relation to specific geographic areas. Rarity is determined by the degree of wetland protection within "protected Areas" estate or within an area subject to the *Fisheries Act 1994*, *Coastal Protection and Management Act 1995*, or *Marine Parks Act 2004*. Wetland uniqueness evaluates the relative abundance and size of a wetland or wetland management group within geographic areas such as catchment and subcatchment.

Riverine Wetlands

Riverine wetlands are all wetlands and deepwater habitats within a channel. The channels are naturally or artificially created, periodically or continuously contain moving water, or connecting two bodies of standing water. AquaBAMM, when applied to riverine wetlands uses a discrete spatial unit termed subsections. A subsection can be considered as an area which encompasses discrete homogeneous stream sections in terms of their natural attributes (i.e. physical, chemical, biological and utilitarian values) and natural resources. Thus in an ACA, an aquatic conservation significance score is calculated for each subsection and applies to all streams within a subsection, rather than individual streams as such.

Please note, the area figures provided in Tables 16 and 17, are derived using the extent of riverine subsections within the AOI. Refer to **Map 5** for further information. A summary of the conservation significance of riverine wetlands within the AOI is provided in the following table.

Table 16: Overall level/s of riverine aquatic conservation significance

Aquatic conservation significance (riverine wetlands)	Area (Ha)	% of AOI
Very High	0.0	0.0

Aquatic conservation significance (riverine wetlands)	Area (Ha)	% of AOI
High	0.0	0.0
Medium	7,219.57	100.0
Low	0.0	0.0
Very Low	0.0	0.0

The individual aquatic conservation criteria ratings for riverine wetlands within the AOI are listed below.

Table 17: Level/s of riverine aquatic conservation significance based on selected criteria

Criteria	Very High Rating - Area (Ha)	Very High Rating - % of AOI	High Rating - Area (Ha)	High Rating - % of AOI	Medium Rating - Area (Ha)	Medium Rating - % of AOI	Low Rating - Area (Ha)	Low Rating - % of AOI
1. Naturalness aquatic					1,273.24	17.6	5,946.33	82.4
2. Naturalness catchment	2.53		7,217.04	100.0				
3. Diversity and richness	1,273.24	17.6	2,074.17	28.7	3,872.16	53.6		
4. Threatened species and ecosystems			7,219.57	100.0				
5. Priority species and ecosystems	7,217.04	100.0						
6. Special features								
7. Connectivity			5,946.33	82.4	1,273.24	17.6		
8. Representative-ness								

The table below lists and describes the relevant expert panel decisions used to assign conservation significance values to riverine wetlands within the AOI.

Table 18: Expert panel decisions for assigning overall levels of riverine aquatic conservation significance

Decision number	Special feature	Catchment	Criteria/Indicator/Measure	Conservation rating (1-4)
(No Records)				

4 is the highest rating/value

Expert panel decision descriptions:

(No Records)

Non-riverine Wetlands

Non-riverine wetlands include both lacustrine and palustrine wetlands, however, do not currently incorporate estuarine, marine or subterranean wetland types. A summary of the conservation significance of non-riverine wetlands within the AOI is provided in the following table. Refer to **Map 6** for further information.

Table 19: Overall level/s of non-riverine aquatic conservation significance

Aquatic conservation significance (non-riverine wetlands)	Area (Ha)	% of AOI
Very High	0.0	0.0
High	0.0	0.0
Medium	10.88	0.15
Low	0.0	0.0
Very Low	0.0	0.0

The following table provides an assessment of non-riverine wetlands within the AOI and associated aquatic conservation criteria values.

Table 20: Level/s of non-riverine aquatic conservation significance based on selected criteria

Criteria	Very High Rating - Area (Ha)	Very High Rating - % of AOI	High Rating - Area (Ha)	High Rating - % of AOI	Medium Rating - Area (Ha)	Medium Rating - % of AOI	Low Rating - Area (Ha)	Low Rating - % of AOI
1. Naturalness aquatic	4.68	0.1			6.19	0.1		
2. Naturalness catchment					10.87	0.2		
3. Diversity and richness			6.8	0.1	3.75	0.1	0.32	
4. Threatened species and ecosystems	2.43		4.37	0.1				
5. Priority species and ecosystems			10.87	0.2				
6. Special features								
7. Connectivity								
8. Representative-ness					6.8	0.1		

The table below lists and describes the relevant expert panel decisions used to assign conservation significance values to non-riverine wetlands within the AOI.

Table 21: Expert panel decisions for assigning overall levels of non-riverine aquatic conservation significance.

Decision number	Special feature	Catchment	Criteria/Indicator/Measure	Conservation rating (1-4)
ma_nr_fl_02	Regional ecosystems 8.3.4 & 11.3.27	Mackenzie	5.2.1	3

4 is the highest rating/value

Expert panel decision descriptions:

ma_nr_fl_02

These regional ecosystems contain significant habitat values that are under threat from threatening processes such as physical alteration/ destruction and invasion by **hymenachne**.

Note: This priority ecosystem decision applies to the following catchments: Calliope, Comet, Dawson, Fitzroy, Isaac, Mackenzie, Misc Other Islands, Nogoa, O'Connell, Pioneer, Plane, Proserpine, Shoalwater, Styx and Waterpark.

Threatened and Priority Species

Introduction

This chapter contains a list of threatened and priority flora and/or fauna species that have been recorded on, or within 4km of the Assessment Area.

The information presented in this chapter with respect to species presence is derived from compiled databases developed primarily for the purpose of BPAs and ACAs. Data is collated from a number of sources and is updated periodically.

It is important to note that the list of species provided in this report, may differ when compared to other reports generated from other sources such as the State government's WildNet, Herbrecs or the federal government's EPBC database for a number of reasons.

Records for threatened and priority species are filtered and checked based on a number of rules including:

- Taxonomic nomenclature - current scientific names and status,
- Location - cross-check co-ordinates with location description,
- Taxon by location - requires good knowledge of the taxon and history of the record,
- Duplicate records - identify and remove,
- Expert panels - check records and provide new records,
- Flora cultivated records excluded,
- Use precise records less than or equal to 2000m,
- Use recent records greater than or equal to 1975 animals, greater than or equal to 1950 plants.

Threatened Species

Threatened species are those species classified as "Endangered" or "Vulnerable" under the *Environment Protection and Biodiversity Conservation Act 1999* or "Endangered", "Vulnerable" or "Near threatened" under the *Nature Conservation Act 1992*.

The following threatened species have been recorded on, or within approximately 4km of the AOI.

Table 22: Threatened species recorded on, or within 4km of the AOI

Species	Common name	NCA status	EPBC status	Back on Track rank	Migratory species*	Wetland species**	Identified flora/fauna
Cerbera dumicola		NT		Low			FL
Geophaps scripta scripta	Squatter Pigeon (southern subsp.)	V	V	Medium			FA
Onychogalea fraenata	Bridled Nailtail Wallaby	E	E	Critical			FA
Solanum elachophyllum		E		Medium			FL

NB. Please note that the threatened species listed in this section are based upon the most recently compiled DES internal state-wide threatened species dataset. This dataset may contain additional records that were not originally available for inclusion in the relevant individual BPAs and ACAs.

**JAMBA - Japan-Australia Migratory Bird Agreement; CAMBA - China-Australia Migratory Bird Agreement; ROKAMBA - Republic of Korea-Australia Migratory Bird Agreement; CMS - Convention on the Conservation of Migratory Species*.

***Y - wetland indicator species*.

BPA Priority Species

A list of BPA priority species that have been recorded on, or within approximately 4km of the AOI is contained in the following table.

Table 23: Priority species recorded on, or within 4km of the AOI

(no results)

NB. Please note that the list of priority species is based on those species identified in the BPAs, however records for these species may be more recent than the originals used. furthermore, the BPA priority species databases are updated from time to time. At each update, the taxonomic details for all species are amended as necessary to reflect current taxonomic name and/or status changes.

ACA Priority Species

A list of ACA priority species used in riverine and non-riverine ACAs that have been recorded on, or within approximately 4km of the AOI are contained in the following tables.

Table 24: Priority species recorded on, or within 4 km of the AOI - riverine

Species	Common name	Back on Track rank	Identified flora/fauna
Eucalyptus camaldulensis			FL
Eucalyptus tereticornis			FL
Lomandra longifolia			FL

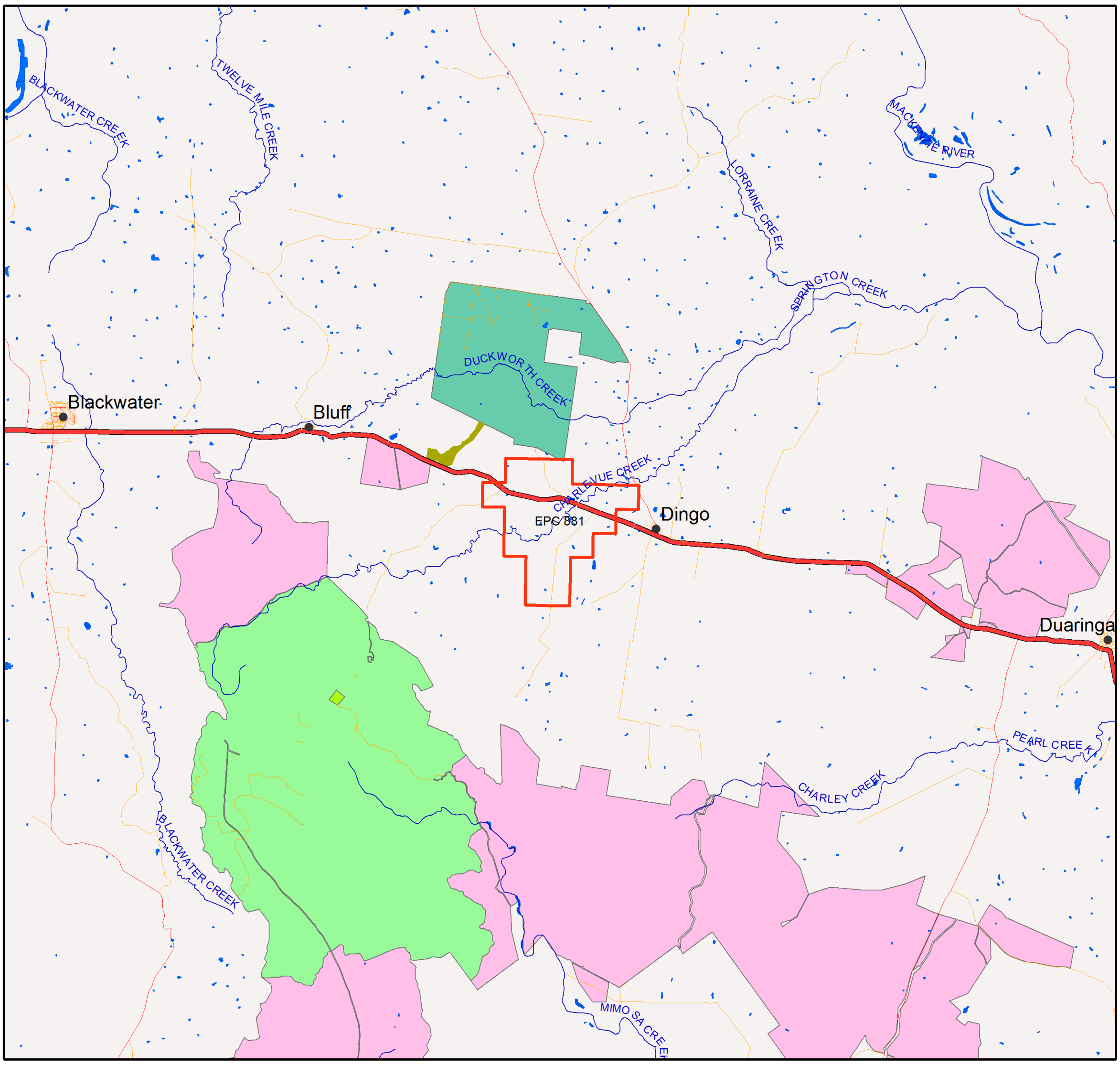
Table 25: Priority species recorded on, or within 4 km of the AOI - non-riverine

Species	Common name	Back on Track rank	Identified flora/fauna
Eucalyptus tereticornis			FL

NB. Please note that the priority species records used in the above two tables are comprised of those adopted for the released individual ACAs. The ACA riverine and non-riverine priority species databases are updated from time to time to reflect new release of ACAs. At each update, the taxonomic details for all ACAs records are amended as necessary to reflect current taxonomic name and/or status changes.

Maps

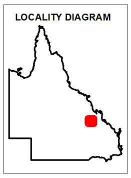
Map 1 - Locality Map



Locality Map

Legend

- 🟥 Selected Exploration Permit Coal (EPC)
- ● Towns
- Highway
- Connector
- Street/Local Road
- ■ Reservoirs
- ■ Lakes
- ■ National Park (Scientific)
- ■ National Park
- ■ National Park (CYPAL)
- ■ Conservation Park
- ■ Resources Reserve
- ■ Forest Reserve
- ■ State Forest
- ■ Timber Reserve
- ■ Nature Refuges
- ■ Coordinated Conservation Areas
- Major rivers/creeks
- ■ Queensland



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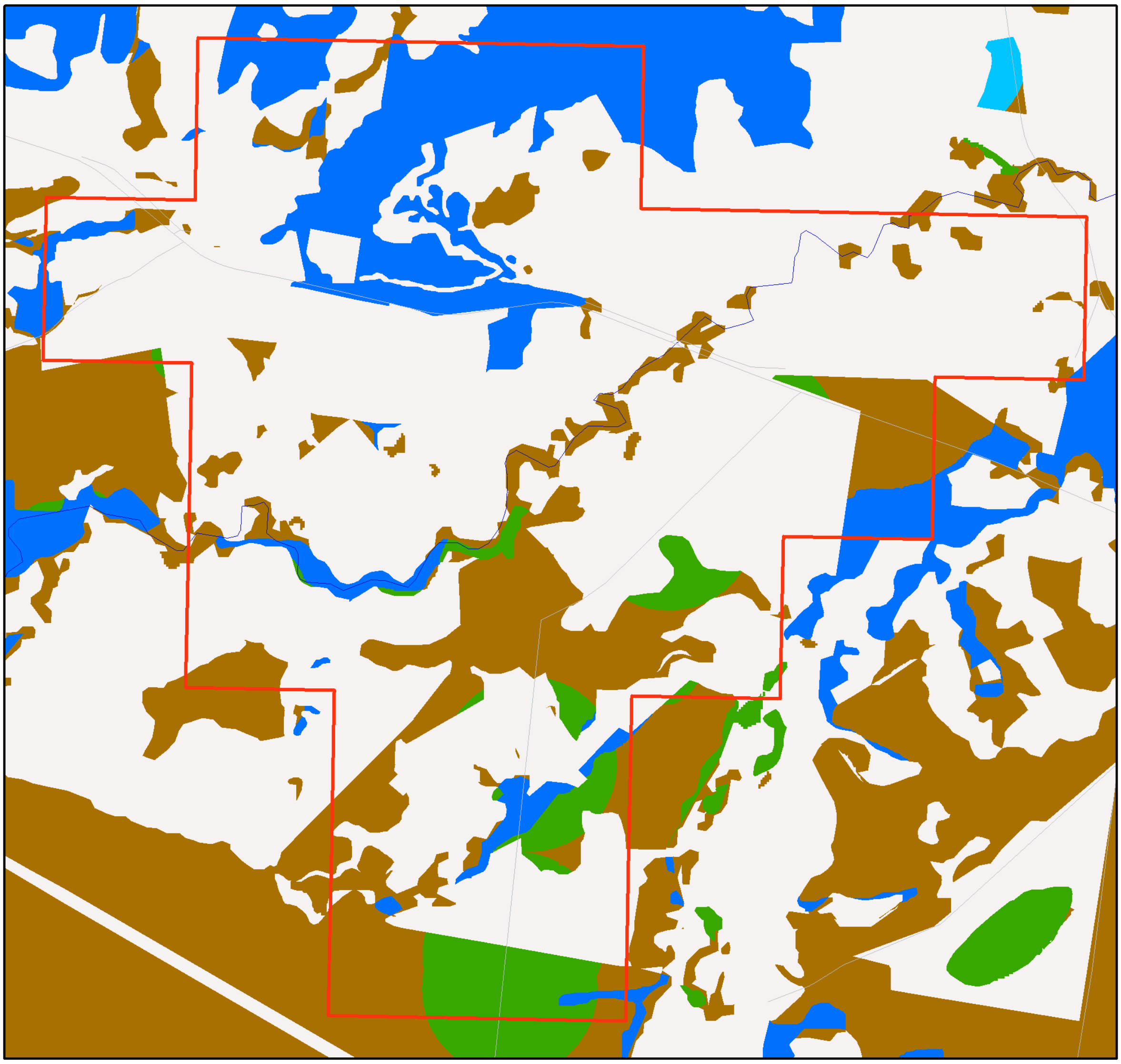
This product is projected into GDA 1994 Queensland Albers

Map 2 - Biodiversity Planning Assessment (BPA)



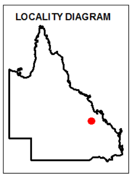
Biodiversity Planning Assessments

Legend

- ▭ Selected Exploration Permit Coal (EPC)
- ● Towns
- — Roads
- — Major rivers/creeks
- ⬜ Queensland

Biodiversity Planning Assessment

- 🟦 State Habitat for EVNT taxa
- 🟦 State
- 🟩 Regional
- 🟫 Local or Other Values
- ⬜ Non Bioregion Ecosystem



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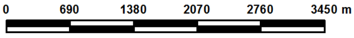
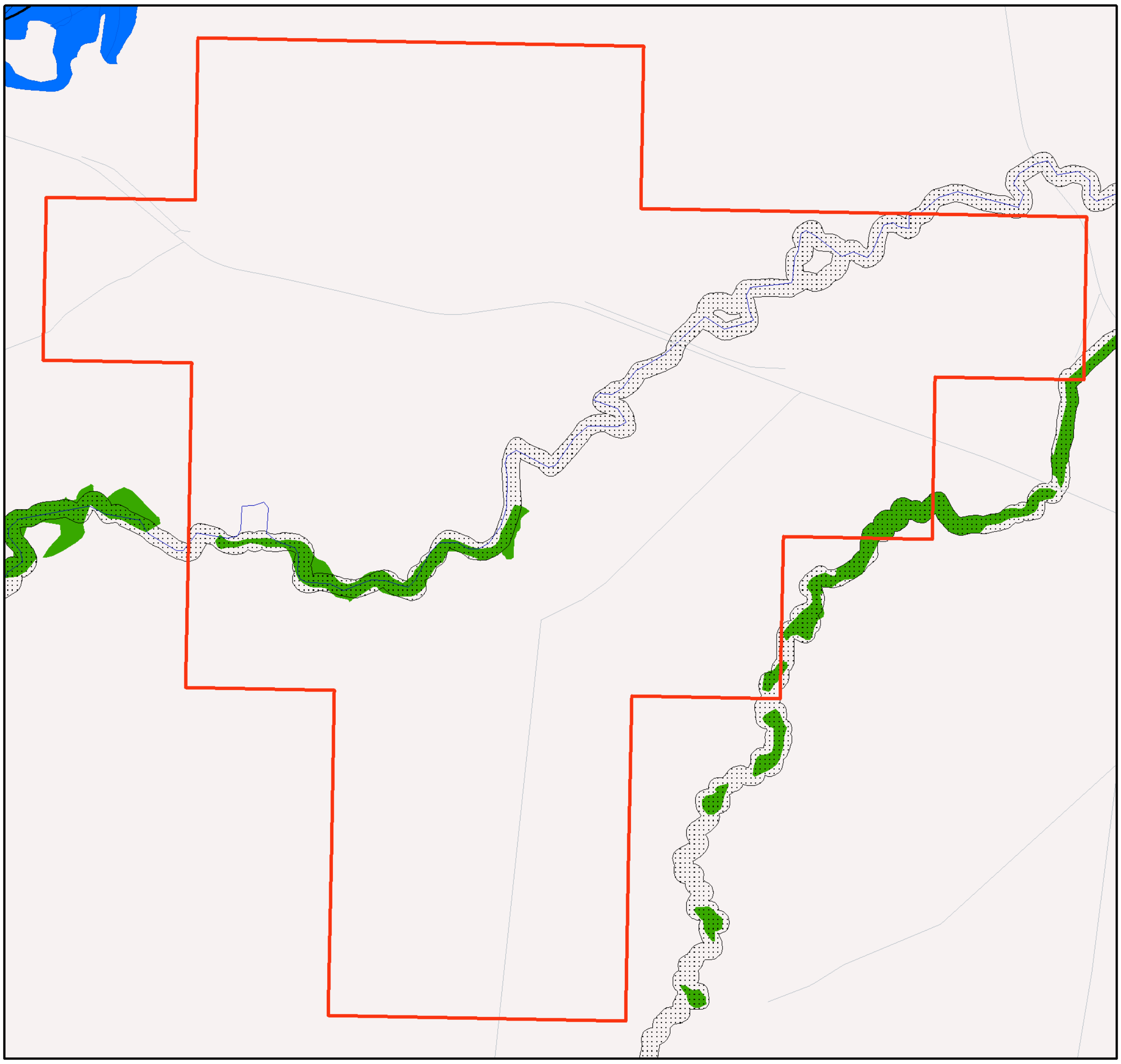


This product is projected into GDA 1994 Queensland Albers

Map 3 - Corridors



Corridors

Legend

☐ Selected Exploration Permit Coal (EPC)
● Towns
— Roads
— Major rivers/creeks
⬜ Queensland

Corridors

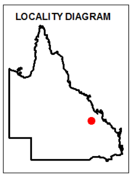
▨ State
░ Regional

Corridor Triggered Vegetation

🟦 State
🟩 Regional
🟫 Local

Core Area Vegetation

🟩 Brigalow Belt only



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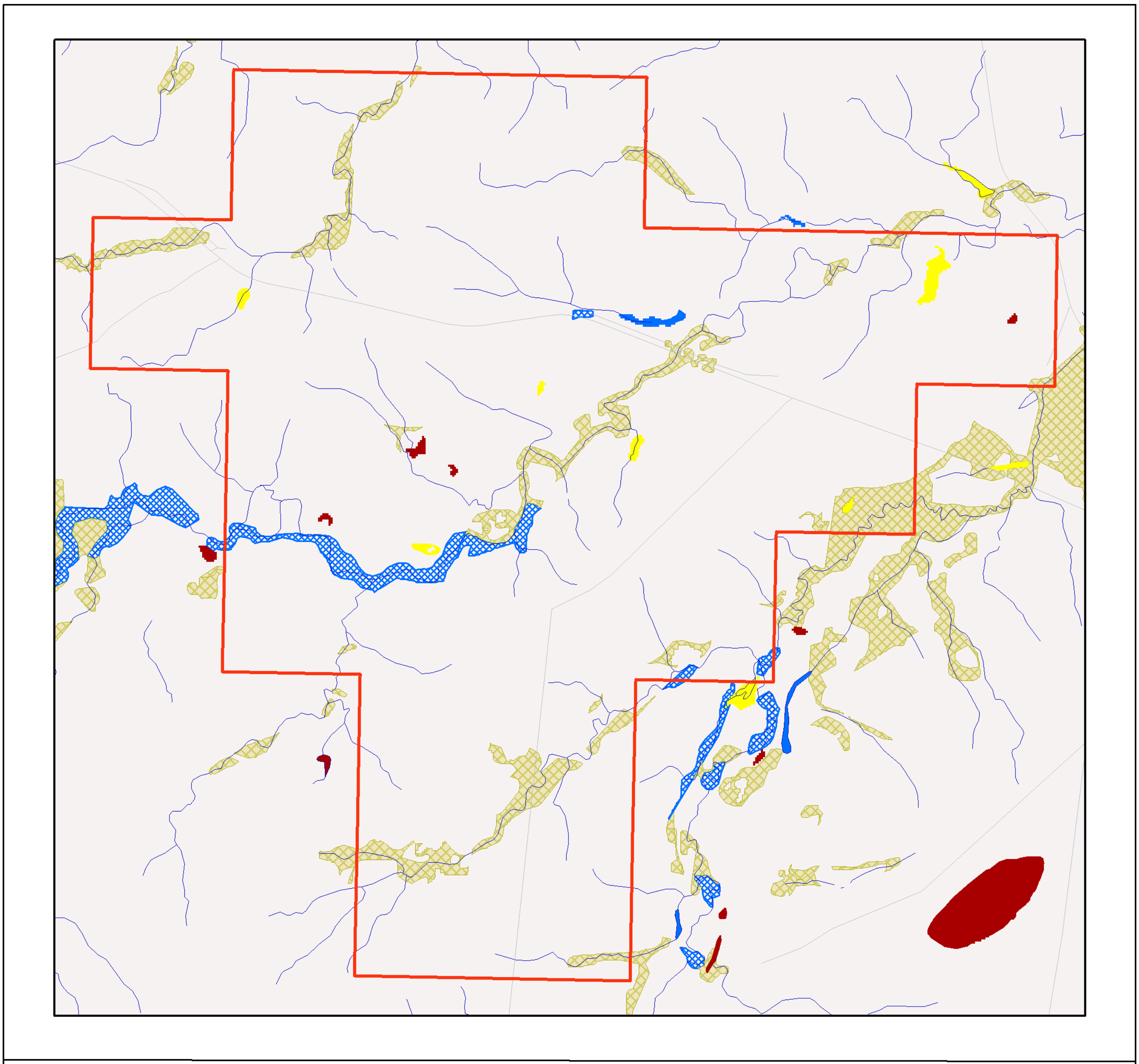
0 690 1380 2070 2760 3450 m

This product is projected into GDA 1994 Queensland Albers

Map 4 - Wetlands and waterways



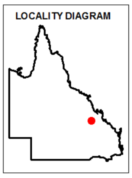
Wetlands and Waterways

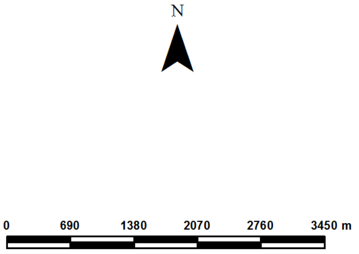
Legend

- ☐ Selected Exploration Permit Coal (EPC)
- ● Towns
- — Roads
- ● Springs
- — Rivers/Creeks
- ▤ Directory of Important Wetlands
- ▥ Ramsar Sites - QLD
- ▢ Queensland

Wetland Type

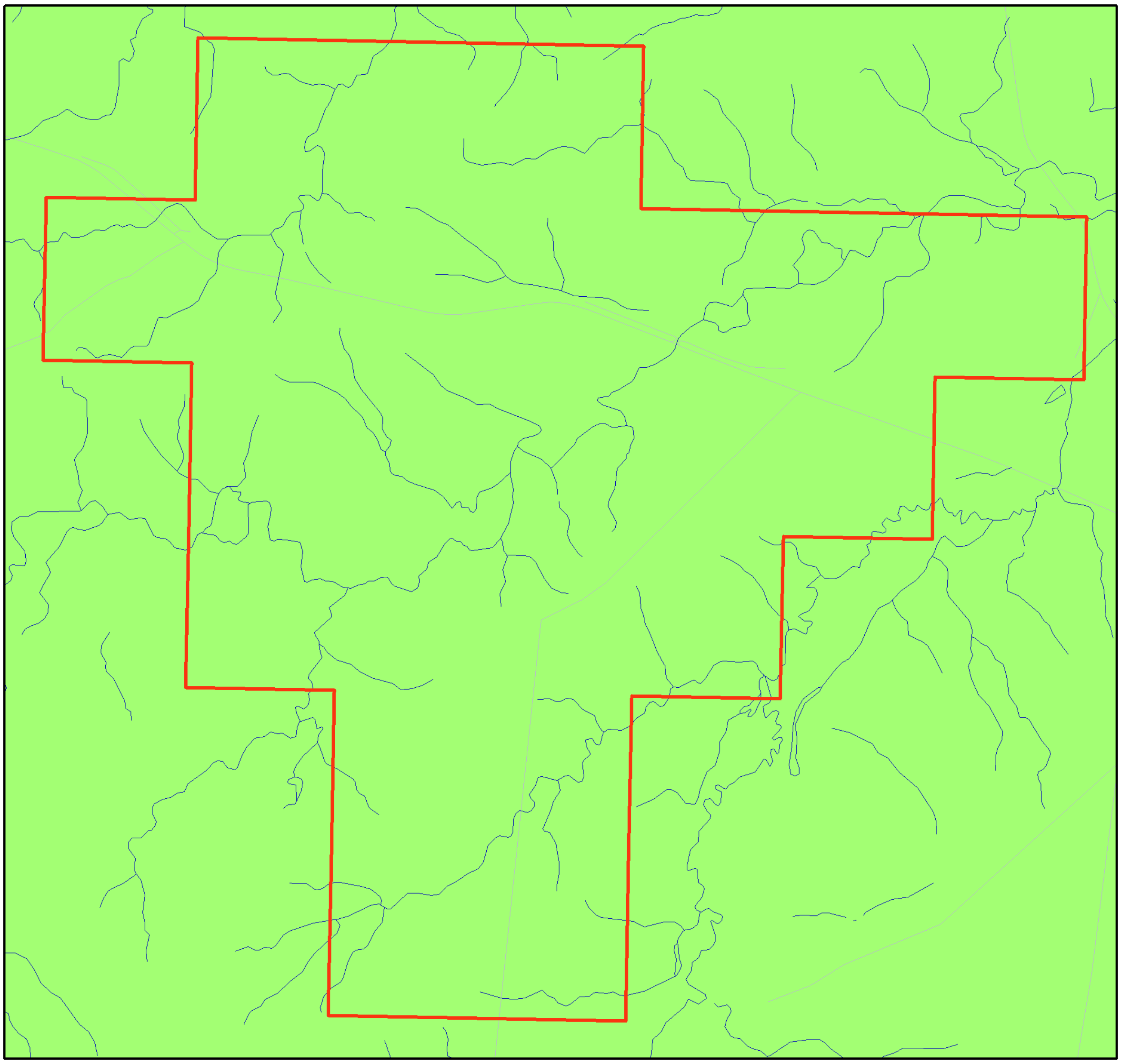
- 🟦 Marine Waterbodies
- 🟧 Estuarine Waterbodies
- 🟦 Riverine Waterbodies
- 🟨 Lacustrine Waterbodies
- 🟥 Palustrine Waterbodies
- ▨ Marine RE
- ▨ Estuarine RE
- ▨ Riverine RE
- ▨ Lacustrine RE
- ▨ Palustrine RE
- ▨ RE 51-80% wetland (mosaic units)
- ▨ RE 1-50% wetland (mosaic units)





This product is projected into GDA 1994 Queensland Albers

Map 5 - Aquatic Conservation Assessment (ACA) - riverine



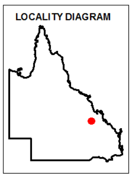
Aquatic Conservation Assessment (ACA) - riverine

Legend

- ▭ Selected Exploration Permit Coal (EPC)
- ● Towns
- — Roads
- — Rivers/Creeks
- ⬜ Queensland

ACA Riverine - Subcatchment Significance

- 🟦 Very High
- 🟦 High
- 🟩 Medium
- 🟨 Low
- 🟧 Very Low



N

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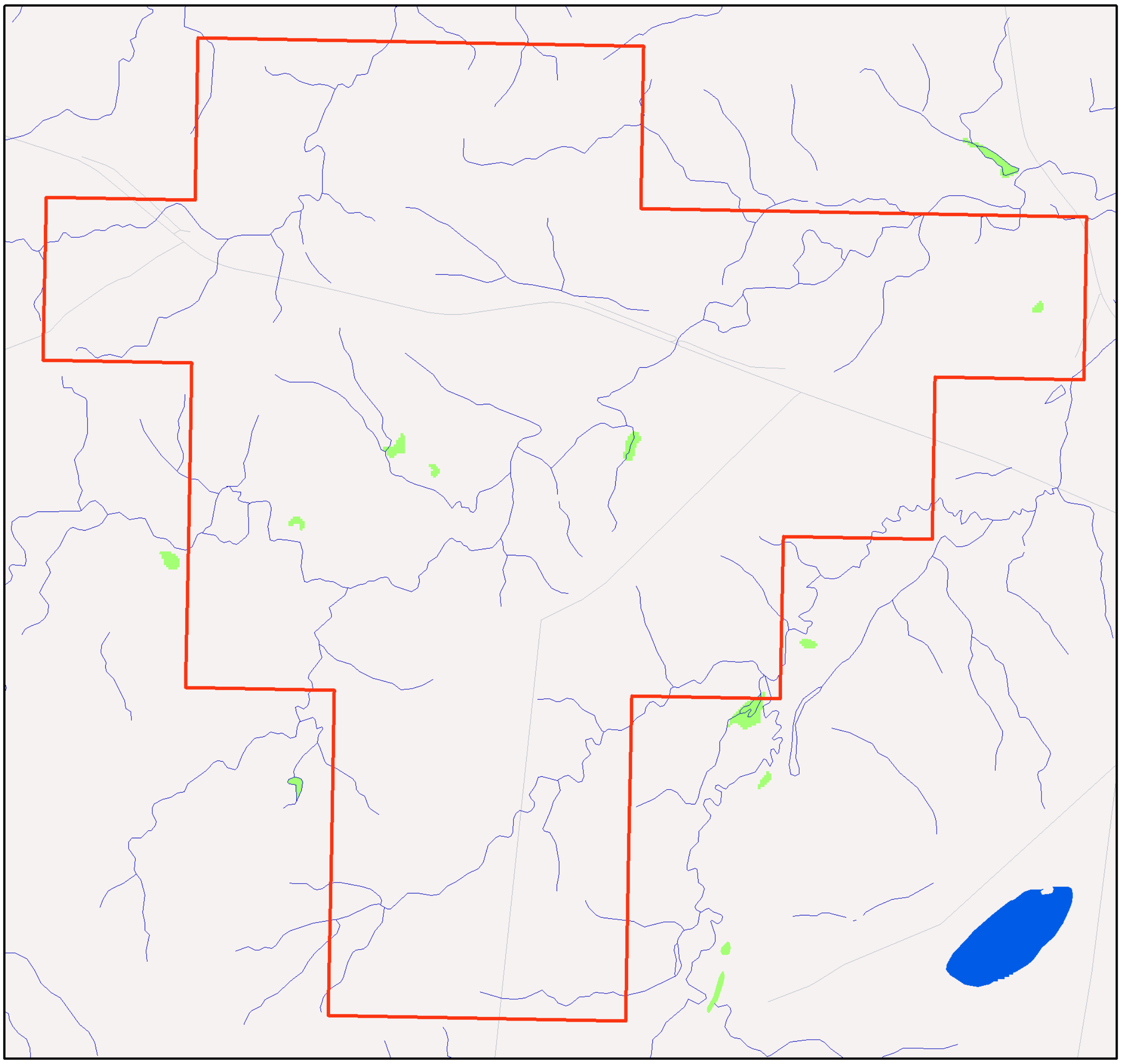
This product is projected into GDA 1994 Queensland Albers

Map 6 - Aquatic Conservation Assessment (ACA) - non-riverine



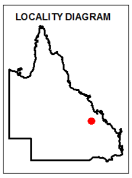
Aquatic Conservation Assessment (ACA) - nonriverine

Legend

🟥	Selected Exploration Permit Coal (EPC)
●	Towns
—	Roads
—	Rivers/Creeks
▭	Queensland

ACA Non-riverine

🟦	Very High
🟦	High
🟩	Medium
🟨	Low
🟧	Very Low



N

0 690 1380 2070 2760 3450 m

This product is projected into GDA 1994 Queensland Albers

References

Clayton, P.D., Fielder, D.F., Howell, S. and Hill, C.J. (2006) *Aquatic biodiversity assessment and mapping method (AquaBAMM): a conservation values assessment tool for wetlands with trial application in the Burnett River catchment.* Published by the Environmental Protection Agency, Brisbane. ISBN 1-90928-07-3. Available at

http://wetlandinfo.des.qld.gov.au/wetlands/assessment/assessment-methods/aca/

Environmental Protection Agency (2002) *Biodiversity Assessment and Mapping Methodology. Version 2.1, July 2002.* (Environmental Protection Agency, Brisbane).

Morton, S. R., Short, J. and Barker, R. D. with an Appendix by G.F. Griffin and G. Pearce (1995). *Refugia for Biological Diversity in Arid and Semi-arid Australia. Biodiversity Series* , Paper No. 4, Biodiversity Unit, Environment Australia.

Sattler, P.S. and Williams, R.D. (eds) (1999). *The Conservation Status of Queensland's Bioregional Ecosystems*. Environmental Protection Agency, Brisbane.

Appendices

Appendix 1 - Source Data

Theme	Datasets
Aquatic Conservation Assessments Non-riverine*	Combination of the following datasets: Cape York Peninsula Non-riverine v1.1 Eastern Gulf of Carpentaria v1.1 Great Barrier Reef Catchment Non-riverine v1.3 Lake Eyre and Bulloo Basins v1.1 QMDB Non-riverine ACA v1.4 Southeast Queensland ACA v1.1 WBB Non-riverine ACA v1.1
Aquatic Conservation Assessments Riverine*	Combination of the following datasets: Cape York Peninsula Riverine v1.1 Eastern Gulf of Carpentaria v1.1 Great Barrier Reef Catchment Riverine v1.1 Lake Eyre and Bulloo Basins v1.1 QMDB Riverine ACA v1.4 Southeast Queensland ACA v1.1 WBB Riverine ACA v1.1
Biodiversity Planning Assessments*	Combination of the following datasets: Brigalow Belt BPA v2.1 Cape York Peninsula BPA v1.1 Central Queensland Coast BPA v1.3 Channel Country BPA v1.1 Desert Uplands BPA v1.3 Einasleigh Uplands BPA v1.1 Gulf Plains BPA v1.1 Mitchell Grass Downs BPA v1.1 Mulga Lands BPA v1.4 New England Tableland v2.3 Southeast Queensland v4.1
Statewide BPA Corridors*	Statewide corridors v1.4
Threatened Species	An internal DES database compiled from Wildnet, Herbrecs, Corveg, the QLD Museum, as well as other incidental sources.
BPA Priority Species	An internal DES database compiled from Wildnet, Herbrecs, Corveg, the QLD Museum, as well as other incidental sources.
ACA Priority Species	An internal DES database compiled from Wildnet, Herbrecs, Corveg, the QLD Museum, as well as other incidental sources.

***These datasets are available at:**

http://dds.information.qld.gov.au/DDS

Appendix 2 - Acronyms and Abbreviations

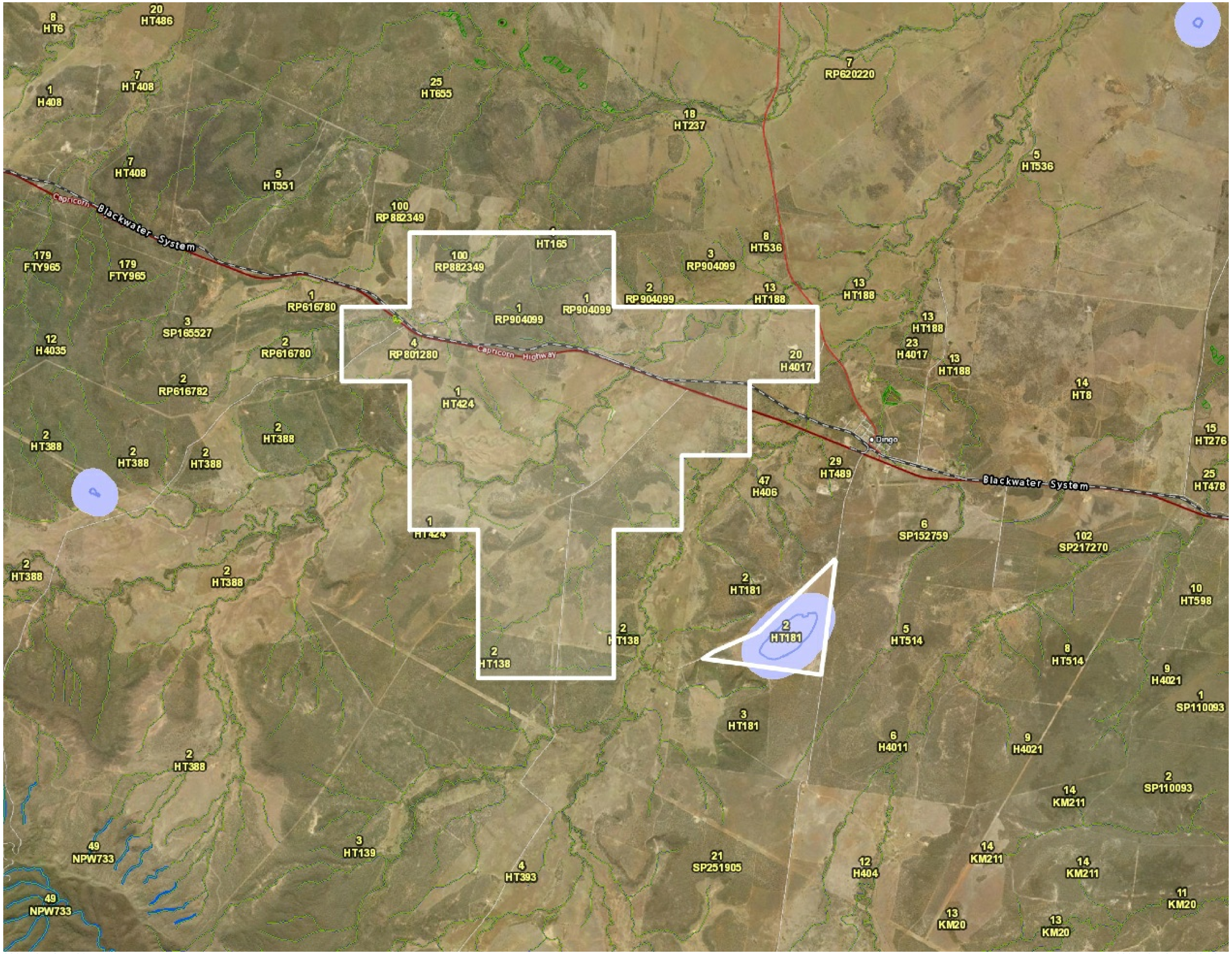
AOI - Area of Interest
ACA - Aquatic Conservation Assessment
AQUABAMM - Aquatic Biodiversity Assessment and Mapping Methodology
BAMM - Biodiversity Assessment and Mapping Methodology
BoT - Back on Track
BPA - Biodiversity Planning Assessment
CAMBA - China-Australia Migratory Bird Agreement
DES - Department of Environment and Science
EPBC - *Environment Protection and Biodiversity Conservation Act 1999*
EVNT - Endangered, Vulnerable, Near Threatened
GDA94 - Geocentric Datum of Australia 1994
GIS - Geographic Information System
JAMBA - Japan-Australia Migratory Bird Agreement
NCA - *Nature Conservation Act 1992*
RE - Regional Ecosystem
REDD - Regional Ecosystem Description Database
ROKAMBA - Republic of Korea-Australia Migratory Bird Agreement

Dingo West

Wetlands of High Ecological Significance with trigger area

23°32'48"S 149°7'4"E

23°32'48"S 149°25'6"E



23°45'34"S 149°7'4"E

23°45'34"S 149°25'6"E

A product of Queensland Globe

N

2.5 km

Print Date: 12/4/2019
Paper Size: A3

Imagery

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Queensland Government

Dingo West

Wetlands of High Ecological Significance with trigger area

Legend

Road

- ━ Highway
- ━ Main
- ═ Local
- ═ Private

Vegetation management wetlands map

- ▨ Wetlands map

VM watercourse/drainage feature - 1:100 000 and 1:250 000

—

Pondage area

- ⬚ Aquaculture
- ⬚ Salt evaporator
- ▦ Settling pond

MSES regulated vegetation [defined watercourse]

—

MSES declared high ecological value waters [watercourse]

—

MSES declared high ecological value waters [wetland]

◫

MSES high ecological significance wetlands

◫

MSES strategic environmental area [designated precinct]

⬚

Wetlands of high ecological significance

☐

Trigger area

■

Railway

—

Land parcel label - gt 10 ha

Cities and Towns

○

Attribution

DigitalGlobe, Earthstar Geographics

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WetlandMaps Report

For selected area of interest

Current as at 06/06/2019

Environmental Reports - General Information

The matters of interest reported on in this document are based upon available state mapped datasets. Where the report indicates that a matter of interest is ot present within the Area of Interest(AOI) (e.g. where area related calculations are equal to zero, or no values are listed), this may be due either to the fact that state mapping has not been undertaken for the AOI, that state mapping is incomplete for the AOI, or that no matters of interest have been identified within the site.

The information presented in this report should be considered as a guide only and field survey may be required to validate values on the ground.

Important Note to User

Information presented in this report is based upon the mapping of water bodies and wetland regional ecosystems across Queensland. The Queensland wetland mapping was produced using existing information including water body mapping derived from Landsat satellite imagery, regional ecosystem mapping, topographic data, and a springs database. The result is a consistent wetland map for the whole of Queensland.

Ancillary data, such as higher resolution imagery (for example SPOT and aerial photographs), other vegetation and wetland mapping, geology, soil and land system mapping was also used in attributing and assessing the derived Queensland Wetlands Program wetland mapping products.

The wetland mapping was done in accordance with a detailed peer reviewed methodology which included quality assurance measures for all steps in the process. For more detailed information on how the Queensland Wetlands Program wetland mapping was produced, please see the Wetland Mapping and Classification Methodology.

Disclaimer

Summary Information

The following table provides an overview of the area of interest.

Table 1. Area of interest details

Size (ha)	133,776.49
Local Government(s)	Central Highlands Regional
Bioregion(s)	Brigalow Belt
Subregion(s)	Woorabinda, Isaac - Comet Downs
Catchment(s)	Fitzroy
Drainage sub-basin	Mackenzie River, Dawson River, Comet River

NRM Regions

The following NRM region(s) are in the area of interest:

Fitzroy Basin Association

Water Resource Plan Boundaries

The following Water Resource Plan(s) are in the area of interest:

Fitzroy Basin

Great Artesian Basin and Other Regional Aquifers

Learn more about how Wetlands are mapped in Queensland:

Queensland Wetlands Mapping Definitions

Wetlands are areas of permanent or periodic/intermittent inundation, with water that is static or flowing fresh, brackish or salt, including areas of marine water the depth of which at low tide does not exceed 6 metres. To be a wetland the area must have one or more of the following attributes:

- at least periodically the land supports plants or animals that are adapted to and dependent on living in wet conditions for at least part of their life cycle, or
- the substratum is predominantly undrained soils that are saturated, flooded or ponded long enough to develop anaerobic conditions in the upper layers, or
- the substratum is not soil and is saturated with water, or covered by water at some time.

Examples under this definition **include**:

- those areas shown as a river, stream, creek, swamp, lake, marsh, waterhole, wetland, billabong, pool or spring on the latest Sunmap 1:25,000, 1:50,000, 1:100,000 or 1:250,000 topographic map
- areas defined as wetlands on local or regional maps prepared with the aim of mapping wetlands
- wetland regional ecosystems (REs) as defined by the Queensland Herbarium (Environmental Protection Agency 2005a)
- areas containing recognised hydrophytes as provided by the Queensland Herbarium
- saturated parts of the riparian zone
- artificial wetlands such as farm dams
- water bodies not connected to rivers or flowing water such as billabongs and rock pools.

Examples under this definition **exclude**:

- areas that may be covered by water but are not wetlands according to the definition
- floodplains that are intermittently covered by flowing water but do not meet the hydrophytes and soil criteria
- riparian zone above the saturation level.

Wetland Systems

Riverine wetlands are all wetlands and deepwater habitats within a channel. The channels are naturally or artificially created, periodically or continuously contain moving water, or connecting two bodies of standing water.

Palustrine wetlands are primarily vegetated non-channel environments of less than 8 hectares. They include billabongs, swamps, bogs, springs, soaks etc, and have more than 30% emergent vegetation.

Lacustrine wetlands are large, open, water-dominated systems (for example, lakes) larger than 8ha. This definition also applies to modified systems (for example, dams), which are similar to lacustrine systems (for example, deep, standing or slow-moving waters).

Marine wetlands include the area of ocean from the coastline or estuary, extending to the jurisdictional limits of Queensland waters (3 nautical mile limit). This definition differs from that in Ramsar, as it includes waters deeper than 6m below the lowest astronomical tide.

Estuarine wetlands are those with oceanic water sometimes diluted with freshwater run-off from the land.

Subterranean wetlands are wetlands occurring below the surface of the ground and that are fed by groundwater i.e. caves and aquifers. These wetlands provide water to groundwater dependent ecosystems.

Methodology and Wetland Classification: https://wetlandinfo.des.qld.gov.au/wetlands/facts-maps/wetland-background/

Links and support

Other sites that deliver wetland related information include:

Wetland*Summary* tool: https://wetlandinfo.des.qld.gov.au/wetlands/facts-maps/

Queensland Spatial Catalogue: http://qldspatial.information.qld.gov.au/catalogue/custom/index.page

Queensland Globe: https://qldglobe.information.qld.gov.au/

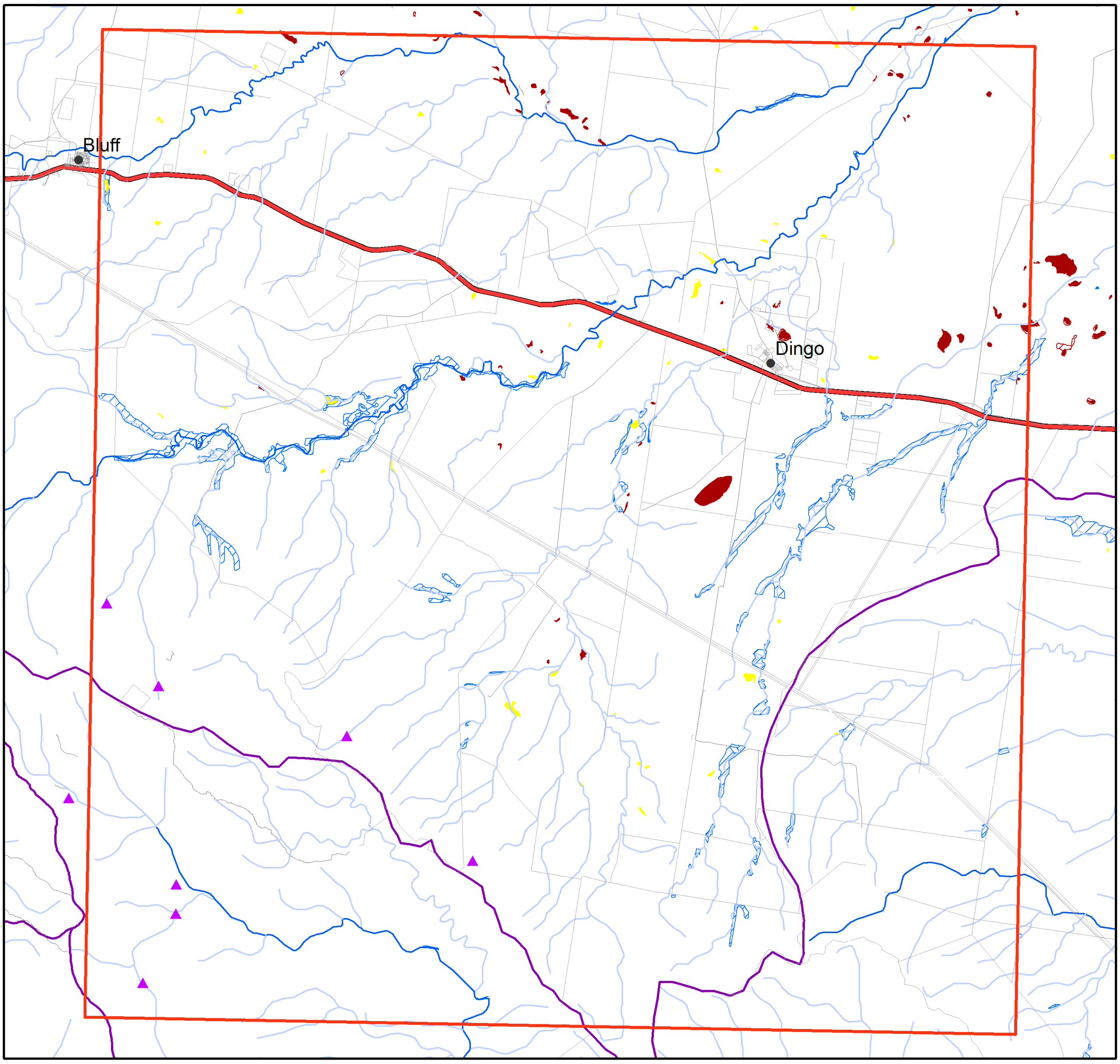
Environmental reports online: https://environment.ehp.qld.gov.au/report-request/environment/

Wetland on-line education modules: https://wetlandinfo.des.qld.gov.au/wetlands/resources/training/

Regional Ecosystem Mapping information: : https://www.qld.gov.au/environment/plants-animals/plants/herbarium/mapping-ecosystems

Aquatic Conservation Assessments: : https://wetlandinfo.des.qld.gov.au/wetlands/assessment/assessment-methods/aca/

Groundwater Dependant Ecosystems information: https://wetlandinfo.des.qld.gov.au/wetlands/ecology/aquatic-ecosystems-natural/groundwater-dependent/



Legend

- ▭ polygon
- ▲ Springs
- ● Dams and weirs
- ● Towns
- ▬ Highways
- — Roads
- — Cadastral boundaries
- ▭ Sub-basin

Wetland Mapping

Wetland System - Water Bodies

- ■ Marine Waterbodies
- ■ Estuarine Waterbodies
- ■ Riverine Waterbodies
- ■ Lacustrine Waterbodies
- ■ Palustrine Waterbodies

Wetland System - Regional Ecosystems

- ▨ Marine RE
- ▨ Estuarine RE
- ▨ Riverine RE
- ▨ Lacustrine RE
- ▨ Palustrine RE
- ■ RE 51_80% wetland (mosaic units)

Riverine System Drainage Lines

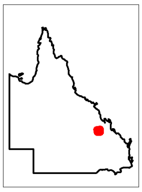
- — Major
- — Minor

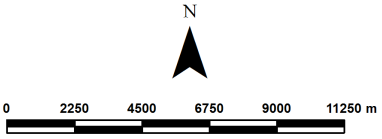
Queensland Wetland Map

Queensland Government

Australian Government

Queensland Wetlands Program

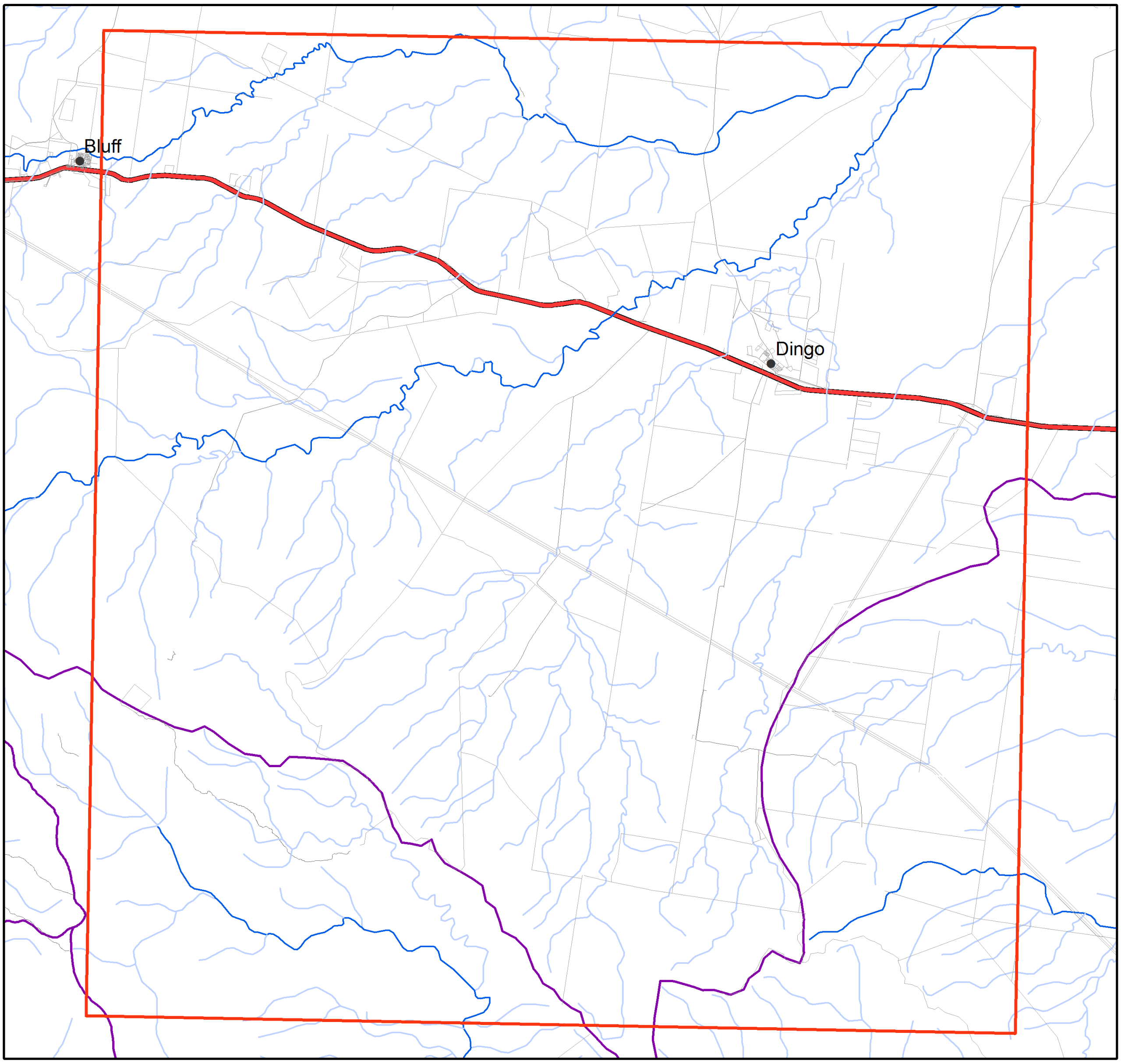




Horizontal Datum: Geographic Datum of Australia 1994 (GDA94)

This map was produced by the Queensland Wetlands Program, Department of Environment and Science, June 2019.

For further information contact: wetlands@des.qld.gov.au



Queensland Wetlands of Importance Map

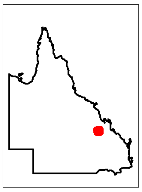
Legend

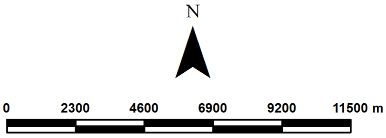
- 🟥 polygon
- ● Towns
- — Cadastral boundaries
- — Highways
- — Roads
- 🟪 Sub-basin
- 🟩 Directory of Important Wetlands
- 🟫 Ramsar Wetlands

Riverine System Drainage Lines

- — Major
- — Minor

Queensland
Wetlands Program





Horizontal Datum: Geographic Datum of Australia 1994 (GDA94)

This map was produced by the Queensland Wetlands Program, Department of Environment and Science, June 2019.

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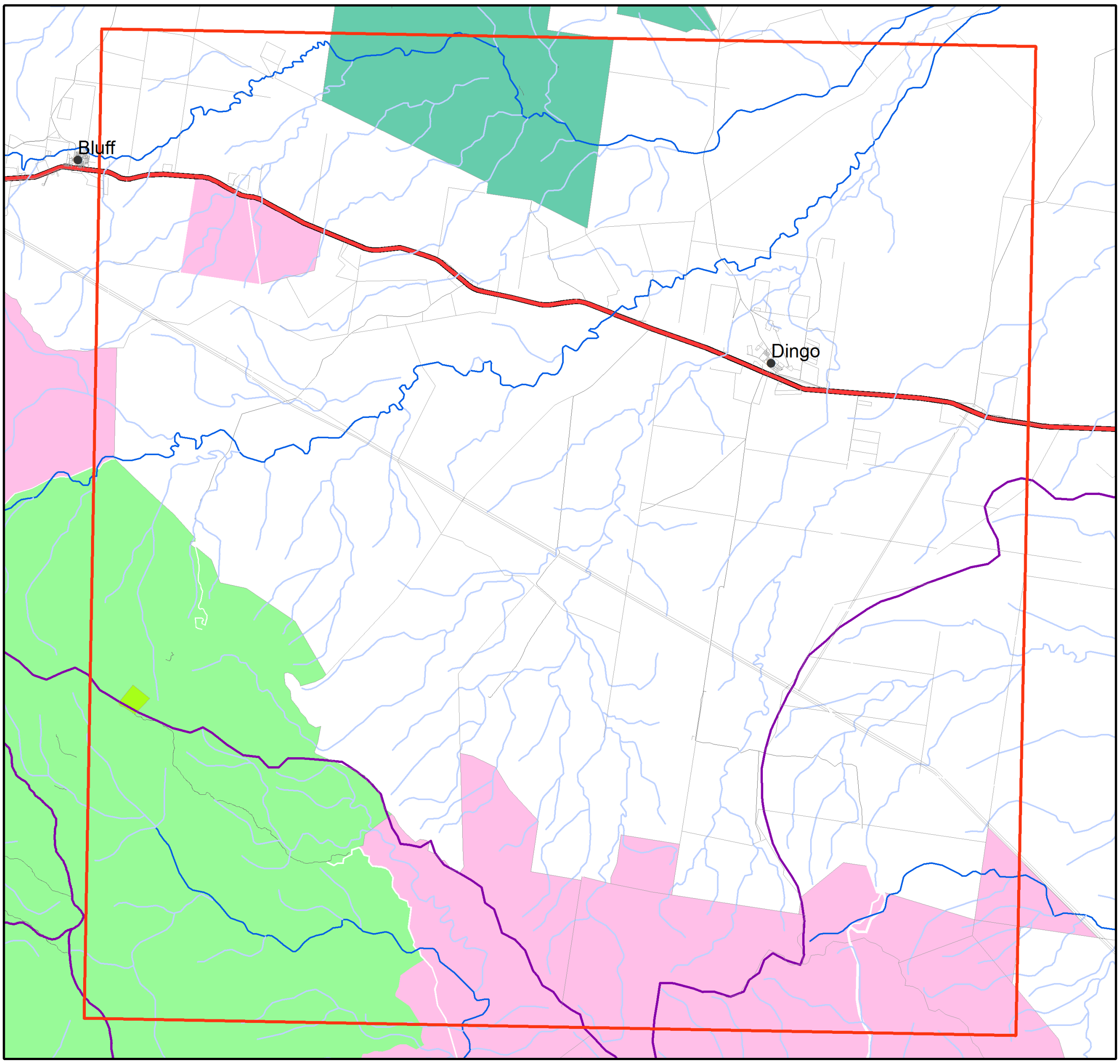


Legend

▭ polygon
● Towns
— Cadastral boundaries
▬ Highways
— Roads
▭ Sub-basin

Riverine System Drainage Lines

— Major
— Minor

Protected Areas

🟩 National Park
🟩 National Park (Scientific)
🟩 National Park (CYPAL)
🟩 Conservation Park
🟨 Resources Reserve
🟧 Forest Reserve
🟪 State Forest
🟫 Timber Reserve

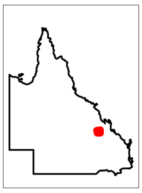
Marine Parks

🟦 General Use Zone
🟦 Habitat Protection Zone
🟧 Estuarine Conservation Zone
🟨 Conservation Park Zone
🟩 Buffer Zone
🟧 Scientific Research Zone
🟩 Marine National Park Zone
🟪 Preservation Zone

Queensland Protected Area Map

Queensland Government
Australian Government

Queensland
Wetlands Program



N

0 2250 4500 6750 9000 11250 m

Horizontal Datum: Geographic Datum of Australia 1994 (GDA94)

This map was produced by the Queensland Wetlands Program, Department of Environment and Science, June 2019.

For further information contact: wetlands@des.qld.gov.au

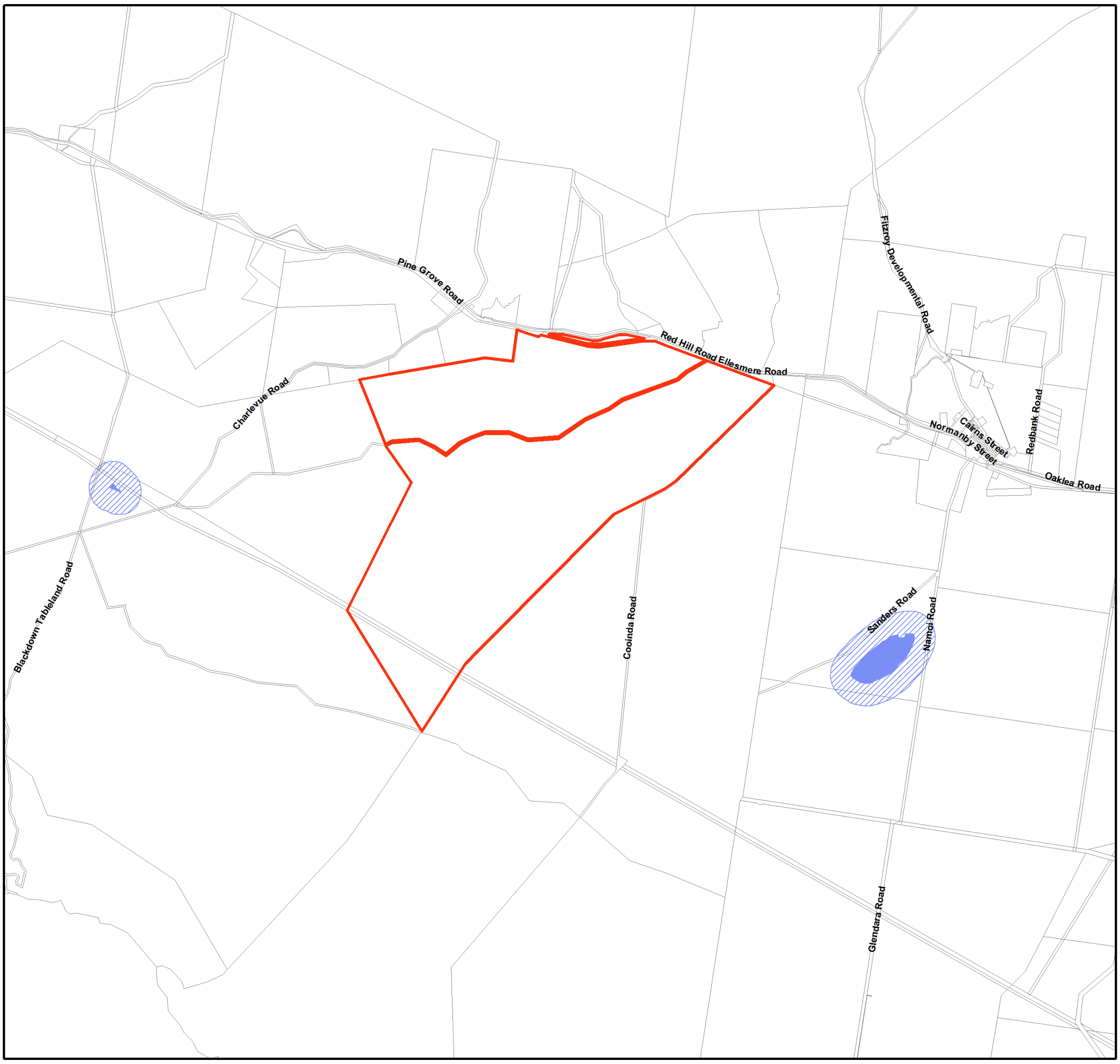
Wetland habitat types in the AOI. Total area: 11468.08ha

Wetland Class	Habitat type	Area (ha)
None	Coastal/ Sub-coastal floodplain tree swamps (Melaleuca and Eucalypt)	8578.24
Riverine	Riverine	1931.53
None	Coastal/ Sub-Coastal non-floodplain tree swamps (Melaleuca and Eucalypt)	530.79
Lacustrine	Artificial/ highly modified wetlands (dams, ring tanks, irrigation channel	149.53
Palustrine	Coastal/ Sub-coastal floodplain tree swamps (Melaleuca and Eucalypt)	121.24
Palustrine	Coastal/ Sub-Coastal non-floodplain tree swamps (Melaleuca and Eucalypt)	110.62
Palustrine	Coastal/ Sub-coastal floodplain grass, sedge and herb swamps	46.13

Queensland wetland habitat typology: Major wetland habitat types for wetland conceptual models and wetland management profiles

Wetland name	Conceptual model	Wetland profile
Mangrove Wetlands	Not developed	Mangrove Wetlands
Saltmarsh Wetlands	Not developed	Saltmarsh Wetlands
Coastal and subcoastal saline swamps of all substrates, water regimes, topographic types and vegetation communities	Coastal and subcoastal saline swamps	Coastal grass-sedge wetlands
Coastal and subcoastal non-floodplain tree swamps (Melaleuca and Eucalypt) of all substrates and water regimes	Coastal and subcoastal non-floodplain tree swamps - melaleuca and eucalypt	Coastal and subcoastal tree swamps
Coastal and subcoastal non-floodplain wet heath swamps of all substrates and water regimes	Coastal and subcoastal non-floodplain wet heath swamps	Coastal and subcoastal wet heath swamps
Coastal and subcoastal non-floodplain grass, sedge and herb swamps of all substrates and water regimes	Coastal and subcoastal non-floodplain grass, sedge and herb swamps	Coastal grass-sedge wetlands
Coastal and subcoastal spring swamps of all substrates, water types, water regimes and vegetation communities	Coastal and subcoastal spring swamps	Great Artesian Basin spring wetlands
Coastal and subcoastal floodplain tree swamps - melaleuca and eucalypt of all substrates and water regimes	Coastal and subcoastal floodplain tree swamps - melaleuca and eucalypt	Coastal and subcoastal tree swamps
Coastal and subcoastal floodplain wet heath swamps of all substrates and water regimes	Coastal and subcoastal floodplain wet heath swamps	Coastal and subcoastal wet heath swamps
Coastal and subcoastal floodplain, grass, sedge herb swamps of all substrates and water regimes	Coastal and subcoastal floodplain grass, sedge, herb swamps	Coastal grass-sedge wetlands
Coastal and subcoastal tree swamps - palm of all substrates, topographic types and water regimes	Coastal and subcoastal floodplain tree swamps - palm	Coastal Palm Swamps
Coastal and subcoastal Floodplain Lakes of all substrates, water types and water regimes	Coastal and subcoastal Floodplain Lakes	Coastal and subcoastal floodplain lakes and non-floodplain soil lakes
Coastal and subcoastal non-floodplain rock lakes of all water types and water regimes	Coastal and subcoastal non-floodplain rock lakes	Coastal and subcoastal non-floodplain rock lakes

Wetland name	Conceptual model	Wetland profile
Coastal and subcoastal non-floodplain sand lakes (window) of all water types and water regimes	Coastal and subcoastal non-floodplain sand lakes - window	Coastal non-floodplain sand lakes
Coastal and subcoastal non-floodplain sand lakes (perched) of all water types and water regimes	Coastal and subcoastal non-floodplain sand lakes - perched	Coastal non-floodplain sand lakes
Coastal and subcoastal non-floodplain soil lakes of all water types and water regimes	Coastal and subcoastal non-floodplain soil lakes	Coastal and subcoastal floodplain lakes and non-floodplain soil lakes
Arid and semi-arid saline swamps of all substrates, water regimes, topographic types and vegetation communities	Arid and semi-arid saline swamps	Semi-arid swamps
Arid and semi-arid fresh tree swamps of all substrates, and water regimes and topographic types	Arid and semi-arid tree swamps	Arid swamps Semi-Arid swamps
Arid and semi-arid lignum swamps of all substrates, and water regimes and topographic types	Arid and semi-arid lignum swamps	Arid swamps Semi-Arid swamps
Arid and semi-arid grass, sedge, herb swamps of all substrates, water regimes and topographic types	Arid and semi-arid grass, sedge, herb swamps	Arid swamps Semi-Arid swamps
Arid and semi-arid fresh non-floodplain tree swamps of all substrates and water regimes	Arid and semi-arid non-floodplain tree swamps	Arid swamps Semi-Arid swamps
Arid and semi-arid fresh non-floodplain lignum swamps of all substrates and water regimes	Arid and semi-arid non-floodplain lignum swamps	Arid swamps Semi-Arid swamps
Arid and semi-arid fresh non-floodplain grass, sedge, herb swamps of all substrates and water regimes	Arid and semi-arid non-floodplain grass, sedge, herb swamps	Arid swamps Semi-Arid swamps
Arid and semi-arid, non-floodplain swamps - springs of all substrates, water regimes and vegetation communities	Arid and semi-arid spring swamps	Great Artesian Basin spring wetlands
Arid and semi-arid, saline lakes of all substrates, topographic types and water regimes	Arid and semi-arid saline lakes	Arid and semi-arid lakes
Arid and semi-arid, floodplain lakes of all, substrates and water regimes	Arid and semi-arid floodplain lakes	Arid and semi-arid lakes
Arid and semi-arid, non-floodplain Lakes of all substrates and water regimes	Arid and semi-arid non-floodplain lakes	Arid and semi-arid lakes
Arid/ semi-arid, non-floodplain (clay pans) lakes of all substrates and water regimes	Arid and semi-arid fresh non-floodplain lakes (clay pans)	Arid and semi-arid lakes
Arid and semi-arid, Permanent Lakes permanently inundated lakes of all substrates, water types, topographic types and vegetation communities	Arid and semi-arid permanent lakes	Arid and semi-arid lakes



Map of Referable Wetlands
Wetland Protection Areas

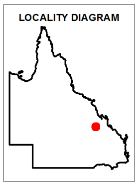
▭ Lot and Plan

▭ Cadastral Boundary

Wetland Protection Areas

🟦 Wetland

▨ Trigger Area



N

Note:
This map shows the location of wetland protection areas which are defined under the Environmental Protection Regulation 2008. Within wetland protection areas, certain types of development involving high impact earthworks are made assessable under Schedule 3 of the Sustainable Planning Regulation 2009.

The Department of State Development, Manufacturing, Infrastructure and Planning is the State Assessment Referral Agency (SARA) under Schedule 7 of the Sustainable Planning Regulation 2009 for assessable development involving high impact earthworks within wetland protection areas. The Department of Environment and Science is a technical agency.

The policy outcome and assessment criteria for assessing these applications are described in the State Development Assessment Provisions (SDAP) *Module 11: Wetlands and wild rivers.*

This map is produced at a scale relevant to the size of the lot on plan identified and should be printed at A4 size in portrait orientation. Consideration of the effects of mapped scale is necessary when interpreting data at a large scale.

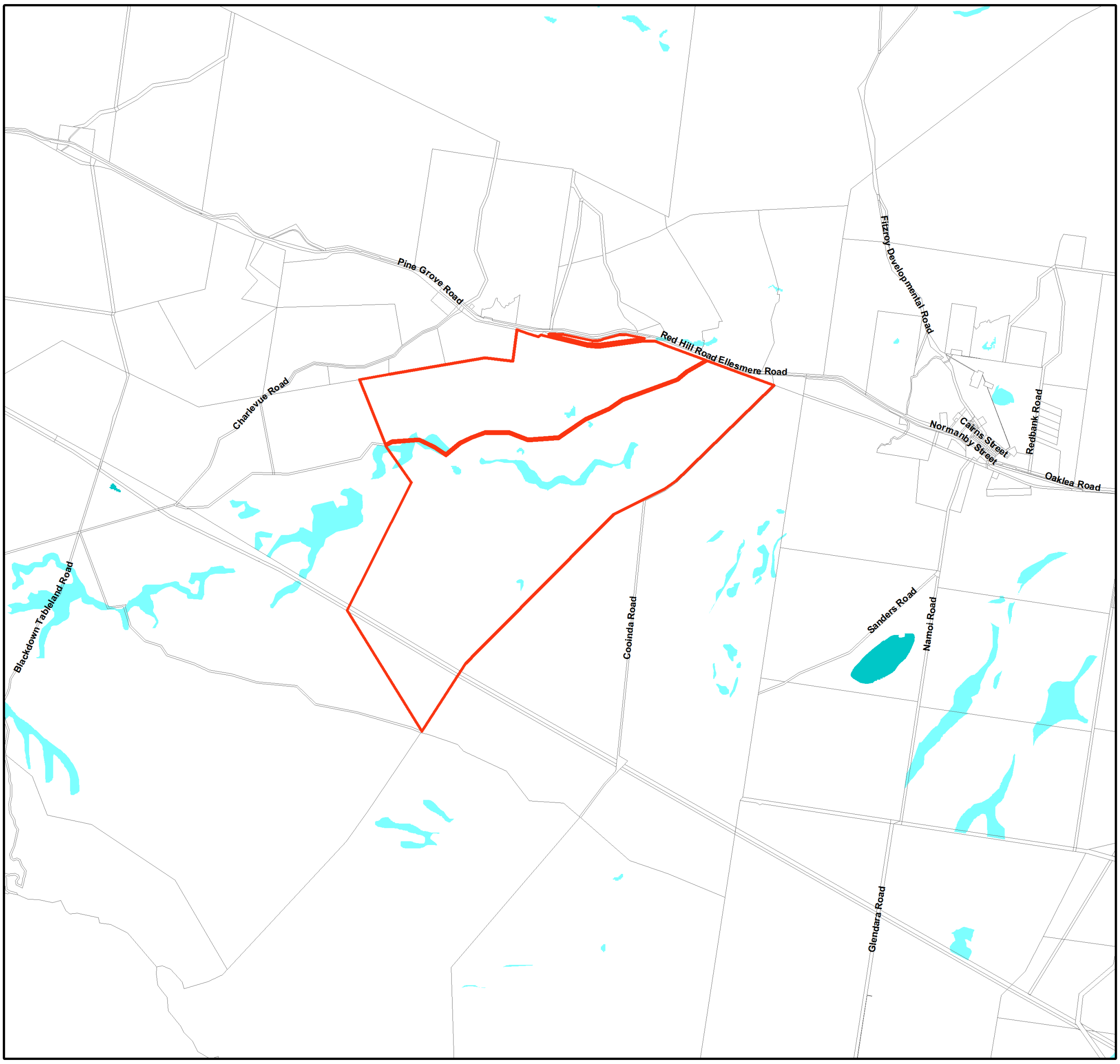
For further information or assistance with interpretation of this product, please contact the Department of Environment and Science, email planning.support@des.qld.gov.au.

0 1300 2600 3900 5200 6500 m

This product is projected into GDA 1994 MGA Zone 55

Map requested: 25/10/2018 16:58:21

Centred on: Lot: 1 Plan: HT424



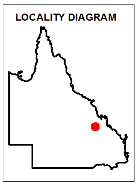
Map of Referable Wetlands for the Environmental Protection Act 1994

▭ Lot and Plan

⬚ Cadastral Boundary

■ HES Wetland

■ GES Wetland



N

Note:
This map shows the location of wetlands on the Map of Referable Wetlands which are defined under the Environmental Protection Regulation 2008.

Wetlands are assessed for ecological significance using the environmental values for wetlands in section 81A of the Environmental Protection Regulation 2008. Wetlands are considered either High Ecological Significance (HES) or of General Ecological Significance (GES) for the purposes of the environmental values.

This map is produced at a scale relevant to the size of the lot on plan identified and should be printed at A4 size in portrait orientation. Consideration of the effects of mapped scale is necessary when interpreting data at a large scale.

For further information or assistance with interpretation of this product, please contact the Department of Environment and Science, email planning.support@des.qld.gov.au.

0 1300 2600 3900 5200 6500 m

This product is projected into GDA 1994 MGA Zone 55

Queensland Government

Department of Environment and Science

Environmental Reports

Regional Ecosystems

Biodiversity Status

For the selected area of interest
epc: 881

Environmental Reports - General Information

The Environmental Reports portal provides for the assessment of selected matters of interest relevant to a user specified location, or area of interest (AOI). All area and derivative figures are relevant to the extent of matters of interest contained within the AOI unless otherwise stated. Please note, if a user selects an AOI via the "central coordinates" option, the resulting assessment area encompasses an area extending for a 2km radius from the input coordinates.

All area and area derived figures included in this report have been calculated via reprojecting relevant spatial features to Albers equal-area conic projection (central meridian = 146, datum Geocentric Datum of Australia 1994). As a result, area figures may differ slightly if calculated for the same features using a different co-ordinate system.

Figures in tables may be affected by rounding.

The matters of interest reported on in this document are based upon available state mapped datasets. Where the report indicates that a matter of interest is not present within the AOI (e.g. where area related calculations are equal to zero, or no values are listed), this may be due either to the fact that state mapping has not been undertaken for the AOI, that state mapping is incomplete for the AOI, or that no matters of interest have been identified within the site.

The information presented in this report should be considered as a guide only and field survey may be required to validate values on the ground.

Important Note to User

Information presented in this report is based upon the Queensland Herbarium's Regional Ecosystem framework. The Biodiversity Status has been used to depict the extent of "Endangered", "Of Concern" and "No Concern at Present" regional ecosystems in all cases, rather than the classes used for the purposes of the *Vegetation Management Act 1999* (VMA). Mapping and figures presented in this document reflect the Queensland Herbarium's Remnant and Pre-clearing Regional Ecosystem Datasets, and not the certified mapping used for the purpose of the VMA.

For matters relevant to vegetation management under the VMA, please refer to the Department of Natural Resources, Mines and Energy website

https://www.dnrme.qld.gov.au/

Please direct queries about these reports to: Queensland.Herbarium@dsiti.qld.gov.au

Disclaimer

Whilst every care is taken to ensure the accuracy of the information provided in this report, the Queensland Government makes no representations or warranties about its accuracy, reliability, completeness, or suitability, for any particular purpose and disclaims all responsibility and all liability (including without limitation, liability in negligence) for all expenses, losses, damages (including indirect or consequential damage) and costs which the user may incur as a consequence of the information being inaccurate or incomplete in any way and for any reason.

Table of Contents

Summary Information 4

Regional Ecosystems 5

- 1. Introduction 5
- 2. Remnant Regional Ecosystems 6
- 3. Remnant Regional Ecosystems by Broad Vegetation Group 7
- 4. Technical and BioCondition Benchmark Descriptions 8

Maps 10

- Map 1 - Location 10
- Map 2 - Remnant 2015 regional ecosystems 11
- Map 3 - Pre-clearing regional ecosystems 12
- Map 4 - Remnant 2015 regional ecosystems by BVG (5M) 13
- Map 5 - Pre-clearing regional ecosystems by BVG (5M) 14
- Map 6 - Wetlands and waterways 15

Links and Other Information Sources 16

References 16

Appendices 17

- Appendix 1 - Source Data 17
- Appendix 2 - Acronyms and Abbreviations 18

Summary Information

The following table provides an overview of the AOI with respect to selected topographic and environmental themes. Refer to **Map 1** for locality information.

Table 1: Area of interest details: epc: 881

Size (ha)	7,219.57
Local Government(s)	Central Highlands Regional
Bioregion(s)	Brigalow Belt
Subregion(s)	Woorabinda
Catchment(s)	Fitzroy

The table below summarizes the extent of remnant vegetation classed as "Endangered", "Of concern" and "No concern at present" regional ecosystems classified by Biodiversity Status within the area of interest (AOI).

Table 2: Summary table, biodiversity status of regional ecosystems within the AOI

Biodiversity Status	Area (Ha)	% of AOI
Endangered	6.41	0.09
Of concern	237.45	3.29
No concern at present	1,842.10	25.52
Total remnant vegetation	2,085.96	28.89

Refer to **Map 2** for further information.

Regional Ecosystems

1. Introduction

Regional ecosystems are vegetation communities in a bioregion that are consistently associated with particular combinations of geology, landform and soil (Sattler and Williams 1999). Descriptions of Queensland's Regional ecosystems are available online from the Regional Ecosystem Description Database (REDD). Descriptions are compiled from a broad range of information sources including vegetation, land system and geology survey and mapping and detailed vegetation site data. The regional ecosystem classification and descriptions are reviewed as new information becomes available. A number of vegetation communities may form a single regional ecosystem and are usually distinguished by differences in dominant species, frequently in the shrub or ground layers and are denoted by a letter following the regional ecosystem code (e.g. a, b, c). Vegetation communities and regional ecosystems are amalgamated into a higher level classification of broad vegetation groups (BVGs).

A published methodology for survey and mapping of regional ecosystems across Queensland (Neldner et al 2017) provides further details on regional ecosystem concepts and terminology.

This report provides information on the type, status, and extent of vegetation communities, regional ecosystems and broad vegetation groups present within a user specified area of interest. Please note, for the purpose of this report, the Biodiversity Status is used. This report has not been developed for application of the *Vegetation Management Act 1999* (VMA). Additionally, information generated in this report has been derived from the Queensland Herbarium's Regional Ecosystem Mapping, and not the regulated mapping certified for the purposes of the VMA. If your interest/matter relates to regional ecosystems and the VMA, users should refer to the Department of Natural Resources, Mines and Energy website.

https://www.dnrme.qld.gov.au/

With respect to the Queensland Biodiversity Status,

"Endangered" regional ecosystems are described as those where:

- remnant vegetation is less than 10 per cent 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 hectares, or
- less than 10 per cent of its pre-clearing extent remains unaffected by severe degradation and/or biodiversity loss*, or
- 10-30 per cent of its pre-clearing extent remains unaffected by severe degradation and/or biodiversity loss and the remnant vegetation is less than 10,000 hectares; or
- it is a rare** regional ecosystem subject to a threatening process.***

"Of concern" regional ecosystems are described as those where:

- the degradation criteria listed above for 'Endangered' regional ecosystems are not met and,
- remnant vegetation is 10-30 per cent of its pre-clearing extent across the bioregion; or more than 20 per cent of its pre-clearing extent remains and the remnant extent is less than 10,000 hectares, or
- 10-30 percent of its pre-clearing extent remains unaffected by moderate degradation and/or biodiversity loss.****

and "No concern at present" regional ecosystems are described as those where:

- remnant vegetation is over 30 per cent of its pre-clearing extent across the bioregion, and the remnant area is greater than 10,000 hectares, and
- the degradation criteria listed above for 'Endangered' or 'Of concern' regional ecosystems are not met.

**Severe degradation and/or biodiversity loss is defined as: floristic and/or faunal diversity is greatly reduced but unlikely to recover within the next 50 years even with the removal of threatening processes; or soil surface is severely degraded, for example, by loss of A horizon, surface expression of salinity; surface compaction, loss of organic matter or sheet erosion.*

***Rare regional ecosystem: pre-clearing extent (1000 ha); or patch size (100 ha and of limited total extent across its range).*

****Threatening processes are those that are reducing or will reduce the biodiversity and ecological integrity of a regional ecosystem. For example, clearing, weed invasion, fragmentation, inappropriate fire regime or grazing pressure, or infrastructure development.*

*****Moderate degradation and/or biodiversity loss is defined as: floristic and/or faunal diversity is greatly reduced but unlikely to recover within the next 20 years even with the removal of threatening processes; or soil surface is moderately degraded.*

2. Remnant Regional Ecosystems

The following table identifies the remnant regional ecosystems and vegetation communities mapped within the AOI and provides their short descriptions, Biodiversity Status, and remnant extent within the selected AOI. Please note, where heterogeneous vegetated patches (mixed patches of remnant vegetation mapped as containing multiple regional ecosystems) occur within the AOI, they have been split and listed as individual regional ecosystems (or vegetation communities where present) for the purposes of the table below. In such instances, associated area figures have been generated based upon the estimated proportion of each regional ecosystem (or vegetation community) predicted to be present within the larger mixed patch.

Table 3: Remnant regional ecosystems, description and status within the AOI

Regional Ecosystem	Short Description	BD Status	Area (Ha)	% of AOI
11.3.1	Acacia harpophylla and/or Casuarina cristata open forest on alluvial plains	Endangered	6.41	0.09
11.3.2	Eucalyptus populnea woodland on alluvial plains	Of concern	125.33	1.74
11.3.25	Eucalyptus tereticornis or E. camaldulensis woodland fringing drainage lines	Of concern	112.12	1.55
11.5.2	Eucalyptus crebra, Corymbia spp., with E. moluccana woodland on lower slopes of Cainozoic sand plains and/or remnant surfaces	No concern at present	1,004.51	13.91
11.5.9b	Eucalyptus crebra and other Eucalyptus spp. and Corymbia spp. woodland on Cainozoic sand plains and/or remnant surfaces	No concern at present	142.87	1.98
11.7.2	Acacia spp. woodland on Cainozoic lateritic duricrust. Scarp retreat zone	No concern at present	694.73	9.62
non-rem	None	None	5,133.61	71.11

Refer to **Map 2** for further information. **Map 3** also provides a visual estimate of the distribution of regional ecosystems present before clearing.

Table 4 provides further information in regards to the remnant regional ecosystems present within the SOI. Specifically, the extent of remnant vegetation remaining within the bioregion, the 1:1,000,000 broad vegetation group (BVG) classification, whether the regional ecosystem is identified as a wetland, and extent of representation in Queensland's Protected Area Estate. For a description of the vegetation communities within the AOI and classified according to the 1:1,000,000 BVG, refer to **Table 6**.

Table 4: Remnant regional ecosystems within the AOI, additional information

Regional Ecosystem	Remnant Extent	BVG (1 Million)	Wetland	Representation in protected estate
11.3.1	Pre-clearing 783000 ha; Remnant 2015 80000 ha	25a	None	High
11.3.2	Pre-clearing 1936000 ha; Remnant 2015 514000 ha	17a	Contains palustrine wetland (e.g. in swales).	Low
11.3.25	Pre-clearing 791000 ha; Remnant 2015 513000 ha	16a	Riverine wetland or fringing riverine wetland.	Low
11.5.2	Pre-clearing 360000 ha; Remnant 2015 190000 ha	18b	None	Low

Regional Ecosystem	Remnant Extent	BVG (1 Million)	Wetland	Representation in protected estate
11.5.9b	Pre-clearing 364000 ha; Remnant 2015 237000 ha	18b	None	Low
11.7.2	Pre-clearing 565000 ha; Remnant 2015 367000 ha	24a	None	Low
non-rem	None	None	None	None

Representation in Protected Area Estate: High greater than 10% of pre-clearing extent is represented; Medium 4 - 10% is represented; Low less than 4% is represented, No representation.

The distribution of mapped wetland systems within the area of interest is displayed in **Map 6**.

The following table lists known special values associated with a regional ecosystem type.

Table 5: Remnant regional ecosystems within the AOI, special values

Regional Ecosystem	Special Values
11.3.1	Habitat for threatened fauna species including painted honeyeater, Grantiella picta particularly in subregion 35 (Oliver et al. 2003).
11.3.2	Habitat for threatened flora species Homopholis belsonii.
11.3.25	Shown to be associated with a high fauna species richness in the Taroom area (Venz et al. 2002). Within parts of the Fitzroy catchment, this RE is known habitat for the threatened freshwater turtle Rheodytes leukops. Known to be important habitat for other riparian freshwater turtle species.
11.5.2	None
11.5.9b	None
11.7.2	Habitat for threatened plant species including Acacia wardellii.
non-rem	None

3. Remnant Regional Ecosystems by Broad Vegetation Group

BVGs are a higher-level grouping of vegetation communities. Queensland encompasses a wide variety of landscapes across temperate, wet and dry tropics and semi-arid climatic zones. BVGs provide an overview of vegetation communities across the state or a bioregion and allow comparison with other states. There are three levels of BVGs which reflect the approximate scale at which they are designed to be used: the 1:5,000,000 (national), 1:2,000,000 (state) and 1:1,000,000 (regional) scales.

A comprehensive description of BVGs is available at:

https://publications.qld.gov.au/dataset/redd/resource/

The following table provides a description of the 1:1,000,000 BVGs present and their associated extent within the AOI.

Table 6: Broad vegetation groups (1 million) within the AOI

BVG (1 Million)	Description	Area (Ha)	% of AOI
None	None	5,133.61	71.11

BVG (1 Million)	Description	Area (Ha)	% of AOI
16a	Open forest and woodlands dominated by Eucalyptus camaldulensis (river red gum) (or E. tereticornis (blue gum)) and/or E. coolabah (coolabah) (or E. microtheca (coolabah)) fringing drainage lines. Associated species may include Melaleuca spp., Corymbia tessellaris (carbeen), Angophora spp., Casuarina cunninghamiana (riveroak). Does not include alluvial areas dominated by herb and grasslands or alluvial plains that are not flooded. (land zone 3) (MGD, BRB, GUP, CHC, MUL, DEU, EIU, NWH, SEQ, [NET, WET]) (All bioregions except CYP and CQC)	112.12	1.55
17a	Woodlands dominated by Eucalyptus populnea (poplar box) (or E. brownii (Reid River box)) on alluvium, sand plains and footslopes of hills and ranges. (land zones 3, 5, 10, 9, 4, 11, 12, [8]) (BRB, MUL, DEU, MUL, EIU)	125.33	1.74
18b	Woodlands dominated Eucalyptus crebra (sens. lat.) (narrow-leaved red ironbark) frequently with Corymbia spp. or Callitris spp. on flat to undulating plains. (land zones 5, 3) (BRB, DEU, EIU, GUP, CYP)	1,147.37	15.89
24a	Low woodlands to tall shrublands dominated by Acacia spp. on residuals. Species include A. shirleyi (lancewood), A. catenulata (bendee), A. microsperma (bowyakka), A. clivicola, A. sibirica, A. rhodoxylon (rosewood) and A. leptostachya (Townsville wattle). (land zones 7, 10, 5, 12, 11, [9, 3]) (MUL, CHC, BRB, GUP, EIU, MGD, DEU, NWH, [CYP])	694.73	9.62
25a	Open forests to woodlands dominated by Acacia harpophylla (brigalow) sometimes with Casuarina cristata (belah) on heavy clay soils. Includes areas co-dominated with A. cambagei (gidgee) and/or emergent eucalypts (land zones 4, 9, 3, 11, 7, 12, [5, 8]) (BRB, MUL, MGD, DEU, [SEQ])	6.41	0.09

Refer to **Map 4** for further information. **Map 5** also provides a representation of the distribution of vegetation communities as per the 1:5,000,000 BVG believed to be present prior to European settlement.

4. Technical and BioCondition Benchmark Descriptions

Technical descriptions provide a detailed description of the full range in structure and floristic composition of regional ecosystems (e.g. 11.3.1) and their component vegetation communities (e.g. 11.3.1a, 11.3.1b). See:

http://www.qld.gov.au/environment/plants-animals/plants/ecosystems/technical-descriptions/

The descriptions are compiled using site survey data from the Queensland Herbarium's CORVEG database. Distribution maps, representative images (if available) and the pre-clearing and remnant extent (hectares) of each vegetation community derived from the regional ecosystem mapping data are included. The technical descriptions should be used in conjunction with the fields from the regional ecosystem description database (REDD) for a full description of the regional ecosystem.

Technical descriptions include data on canopy height, canopy cover and native plant species composition of the predominant layer, which are attributes relevant to assessment of the remnant status of vegetation under the *Vegetation Management Act 1999*. However, as technical descriptions reflect the full range in structure and floristic composition across the climatic, natural disturbance and geographic range of the regional ecosystem, local reference sites should be used for remnant assessment where possible (Neldner et al. 2012 (PDF)* section 3.3.1 of:

https://publications.qld.gov.au/dataset/redd/resource/

The technical descriptions are subject to review and are updated as additional data becomes available.

When conducting a BioCondition assessment, these technical descriptions should be used in conjunction with BioCondition benchmarks for the specific regional ecosystem, or component vegetation community.

http://www.qld.gov.au/environment/plants-animals/biodiversity/benchmarks/

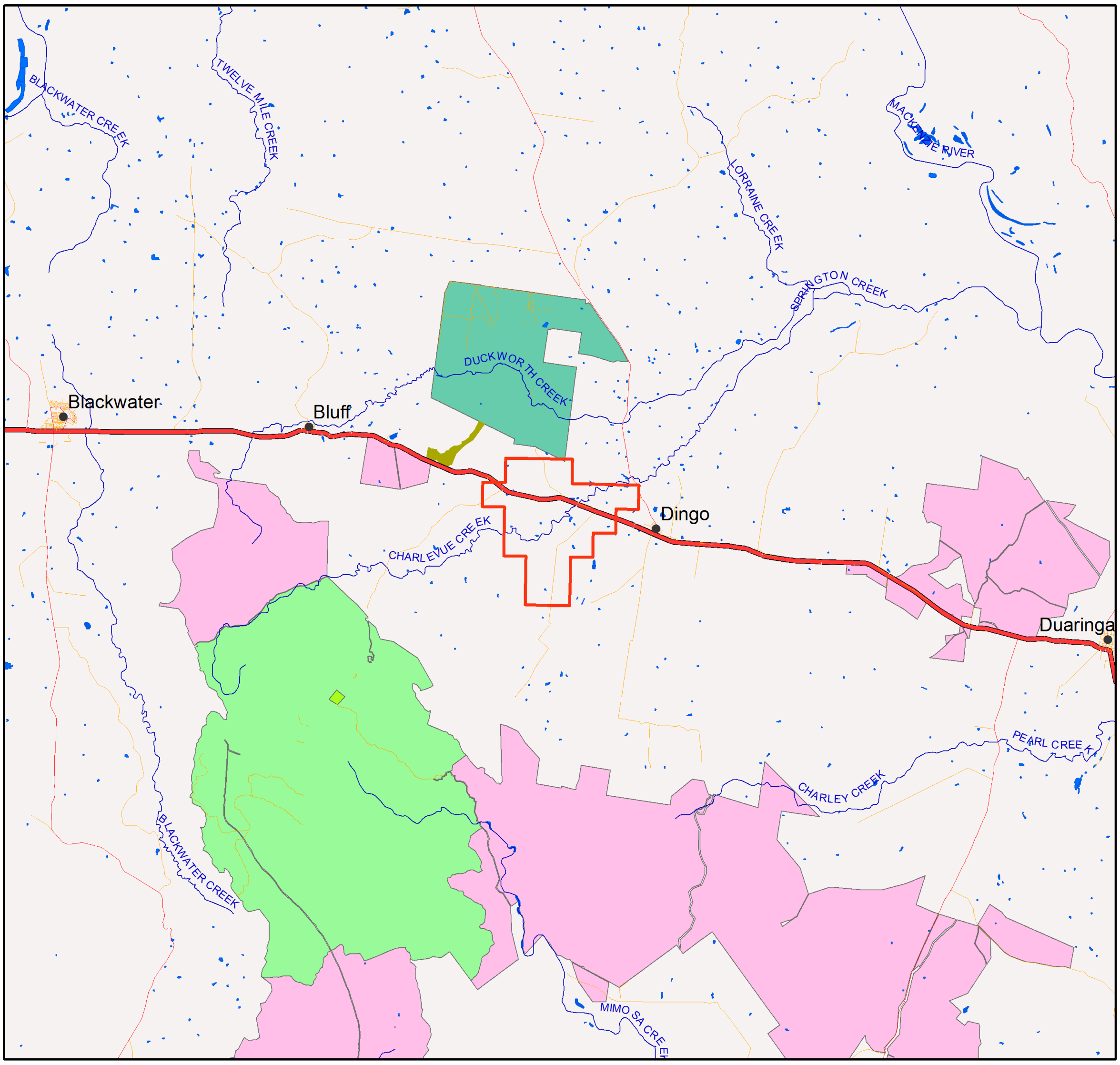
Benchmarks are based on a combination of quantitative and qualitative information and should be used as a guide only. Benchmarks are specific to one regional ecosystem vegetation community, however, the natural variability in structure and floristic composition under a range of climatic and natural disturbance regimes has been considered throughout the geographic extent of the regional ecosystem. Local reference sites should be used for this spatial and temporal (seasonal and annual) variability.

Table 7: List of remnant regional ecosystems within the AOI for which technical and biocondition benchmark descriptions are available

Regional ecosystems mapped as within the AOI	Technical Descriptions	Biocondition Benchmarks
11.3.1	Available	Available
11.3.2	Available	Available
11.3.25	Not currently available	Available
11.5.2	Not currently available	Not currently available
11.5.9b	Not currently available	Not currently available
11.7.2	Not currently available	Available
non-rem	Not currently available	Not currently available

Maps

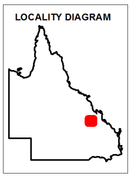
Map 1 - Location



Locality Map

Legend

- ☐ Selected Exploration Permit Coal (EPC)
- ● Towns
- ━ Highway
- — Connector
- — Street/Local Road
- 🟦 Reservoirs
- 🟦 Lakes
- 🟩 National Park (Scientific)
- 🟩 National Park
- 🟩 National Park (CYPAL)
- 🟩 Conservation Park
- 🟨 Resources Reserve
- 🟨 Forest Reserve
- 🟪 State Forest
- ⬜ Timber Reserve
- ▨ Nature Refuges
- ▨ Coordinated Conservation Areas
- — Major rivers/creeks
- ⬜ Queensland



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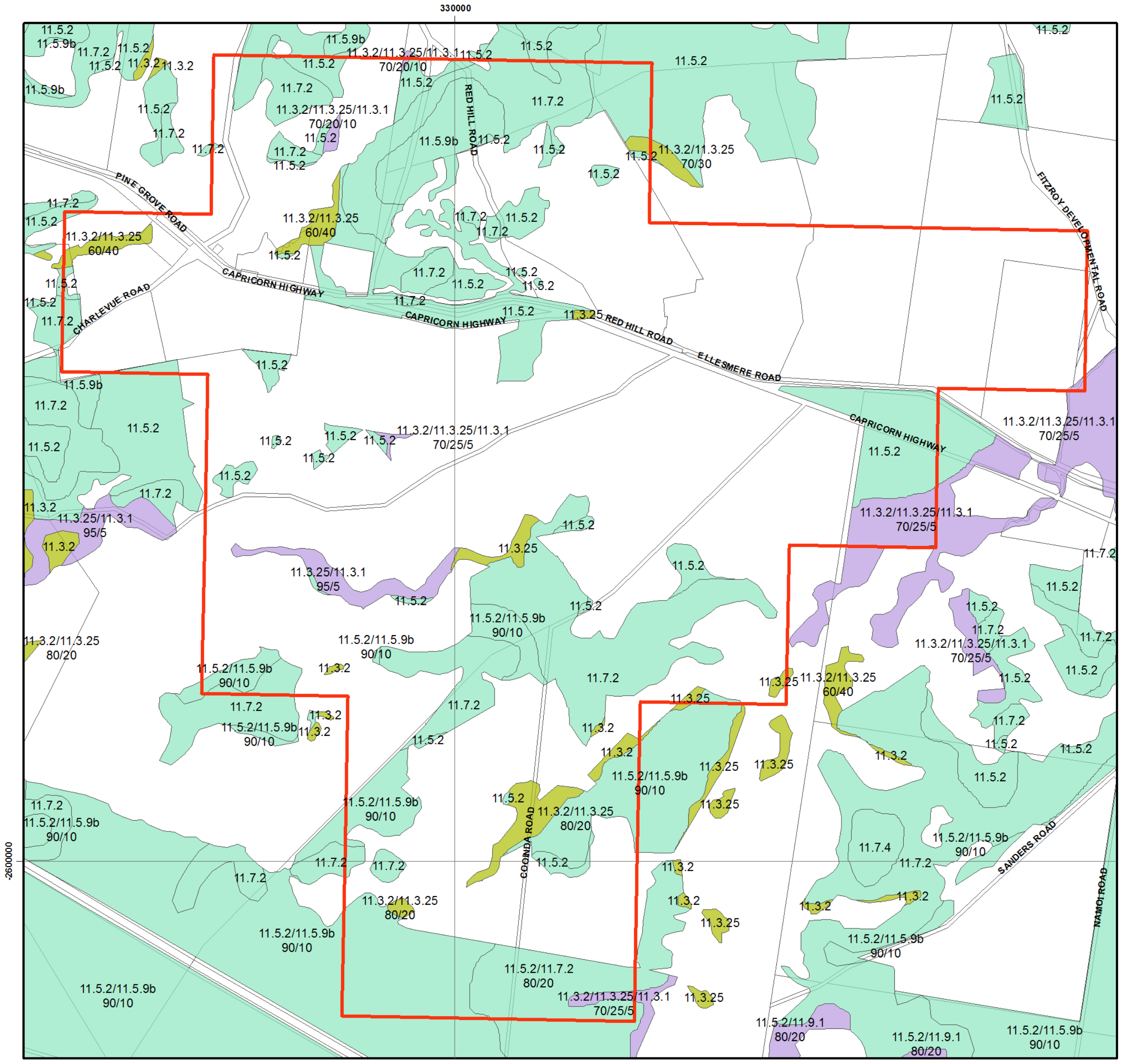
0 4500 9000 13500 18000 22500 m

This product is projected into GDA 1994 Queensland Albers

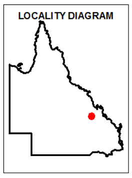
Map 2 - Remnant 2015 regional ecosystems

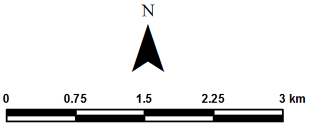


Remnant 2015 Regional Ecosystems

Biodiversity Status

- 🟥 Selected Exploration Permit Coal (EPC)
- 🟪 Endangered - Dominant vegetation
- 🟪 Endangered - Sub-dominant
- 🟩 Of Concern - Dominant
- 🟨 Of Concern - Sub-dominant
- 🟩 No concern at present
- ⬜ Non-remnant vegetation, cultivated or built environment
- 🟨 Plantation
- 🟦 Water
- ⬜ Cadastral Boundaries





Regional ecosystem mapping over the majority of Queensland is produced at a scale of 1:100,000. At this scale, the minimum remnant polygon area is 5 hectares or minimum remnant width of 75 metres. Regional ecosystem linework reproduced at a scale greater than 1:100,000, except in designated areas, should be used as a guide only. The precision of polygon boundaries or positional accuracy of linework is 100 metres.

Regional ecosystems are defined as vegetation communities in a bioregion that are consistently associated with a particular combination of geology, landform and soil. The polygons are labelled by regional ecosystem (RE); where more than one RE occurs, the percentage of each is labelled. The label consists of 3 components: bioregion, land zone, and vegetation community – the dominant canopy species. e.g.: RE 12.3.3. Descriptions of REs are found online. Use the search term "Regional Ecosystem Framework".

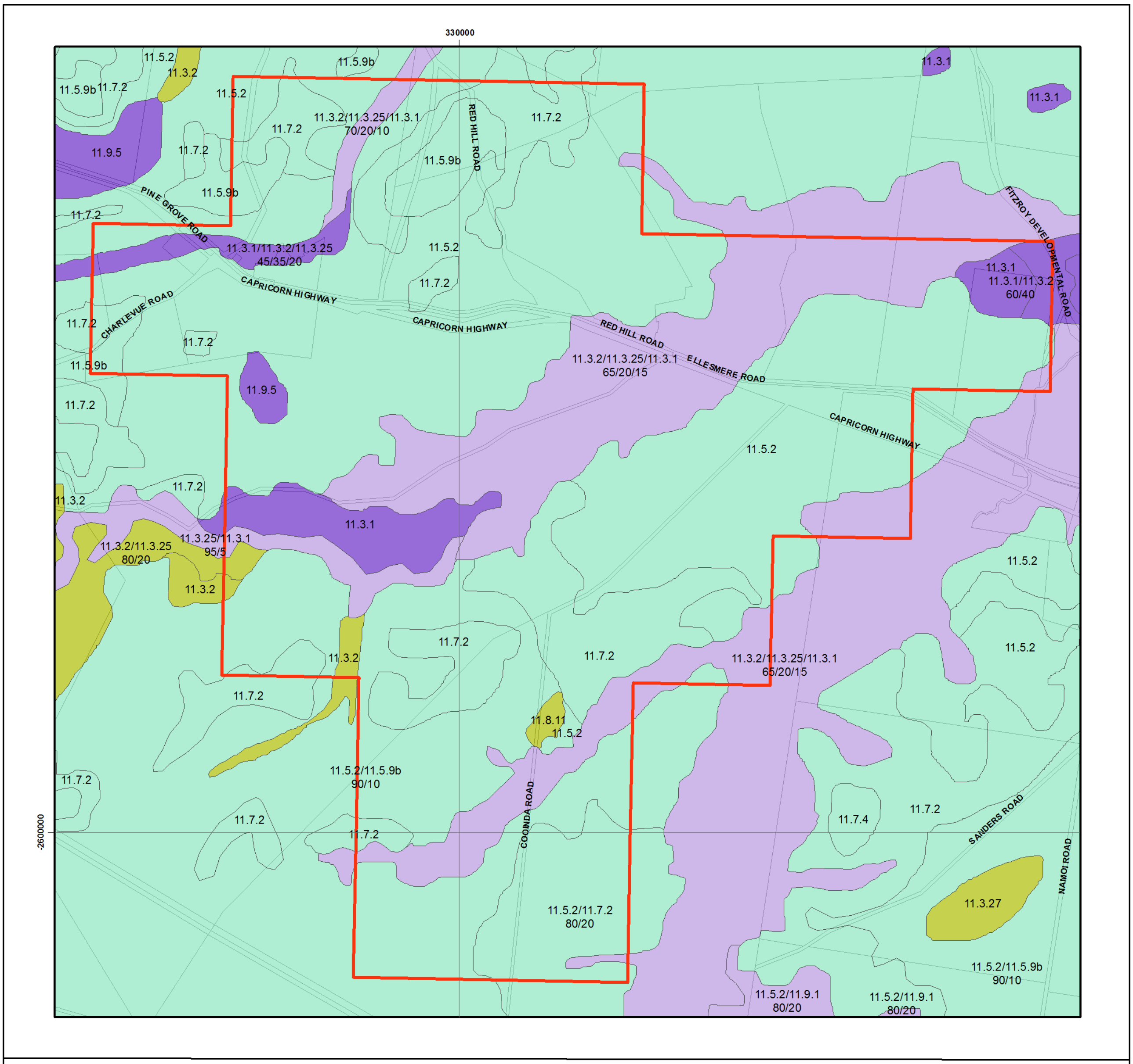
Regional ecosystem mapping at 1:100,000 map scale is derived from the following sources: 1:80,000 B&W 1960's aerial photography, Landsat TM imagery, geology, soils, land systems data, field survey and historical records.

Remnant woody vegetation is defined as vegetation that has not been cleared or vegetation that has been cleared but where the dominant canopy has >70% of the height and >50% of the cover relative to the undisturbed height and cover of that stratum and is dominated by species characteristic of the vegetation's undisturbed canopy.

Non-remnant vegetation includes regrowth and disturbed native vegetation.

This product is projected into GDA 1994 Queensland Albers

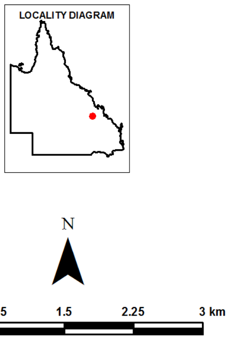
Map 3 - Pre-clearing regional ecosystems



Pre-clearing Regional Ecosystems

Biodiversity Status

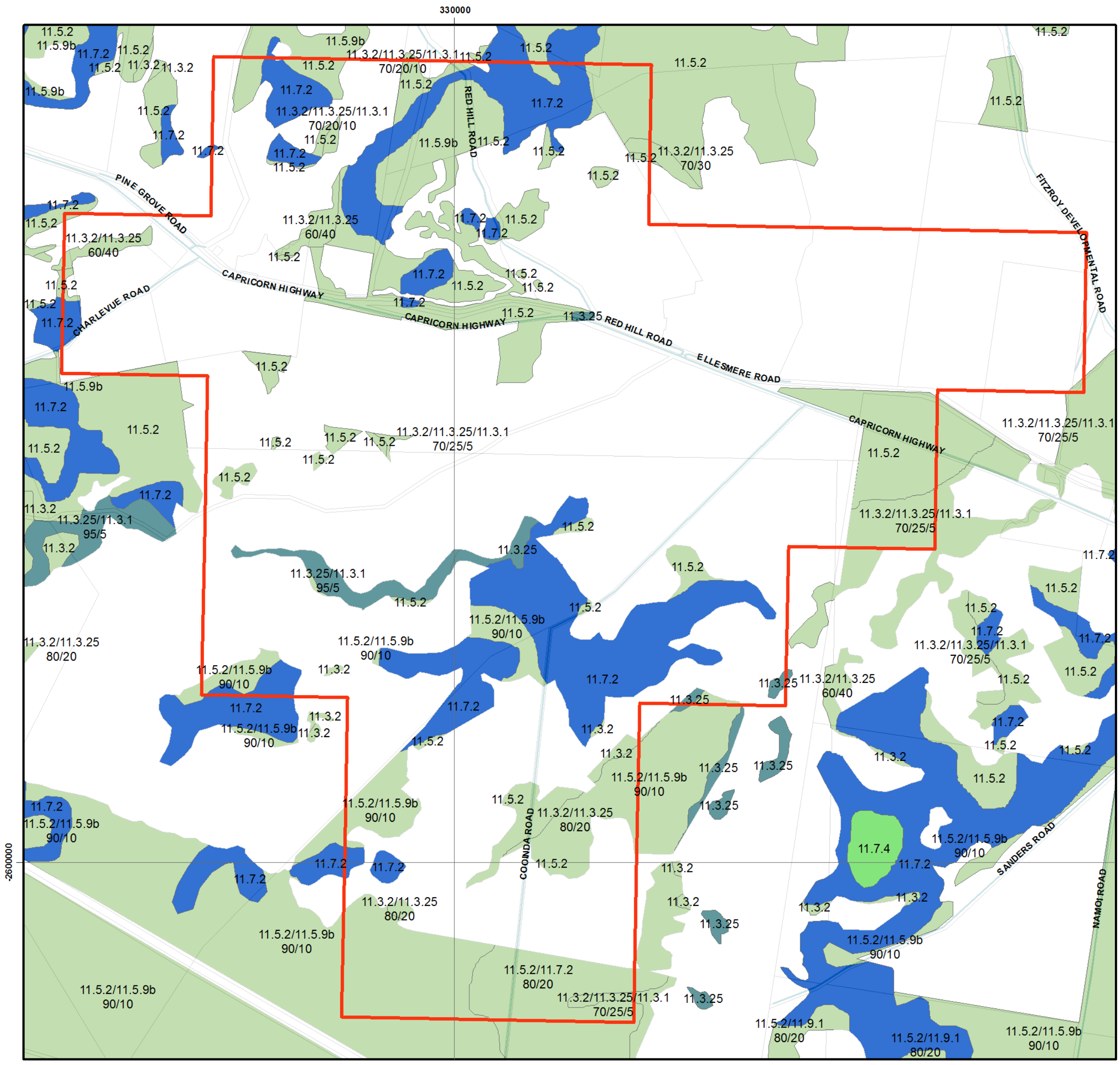
- 🟥 Selected Exploration Permit Coal (EPC)
- 🟪 Endangered - Dominant vegetation
- 🟪 Endangered - Sub-dominant
- 🟩 Of Concern - Dominant
- 🟨 Of Concern - Sub-dominant
- 🟩 No concern at present
- 🟦 Water
- ⬜ Cadastral Boundaries



Regional ecosystem mapping over the majority of Queensland is produced at a scale of 1:100,000. At this scale, the minimum remnant polygon area is 5 hectares or minimum remnant width of 75 metres. Regional ecosystem linework reproduced at a scale greater than 1:100,000, except in designated areas, should be used as a guide only. The precision of polygon boundaries or positional accuracy of linework is 100 metres.
Regional ecosystems are defined as vegetation communities in a bioregion that are consistently associated with a particular combination of geology, landform and soil.
The polygons are labelled by regional ecosystem (RE); where more than one RE occurs, the percentage of each is labelled. The label consists of 3 components: bioregion, land zone, and vegetation community – the dominant canopy species. e.g.: RE 12.3.3. Descriptions of REs are found online. Use the search term "Regional Ecosystem Framework".
Regional ecosystem mapping at 1:100,000 map scale is derived from the following sources: 1:80,000 B&W 1960's aerial photography, Landsat TM imagery, geology, soils, land systems data, field survey and historical records.

This product is projected into GDA 1994 Queensland Albers

Map 4 - Remnant 2015 regional ecosystems by BVG (5M)

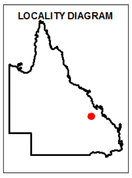


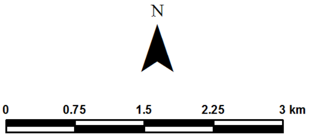
Remnant 2015 Regional Ecosystems coloured by Broad Vegetation Groups

Broad Vegetation Groups

BVG5M Description (BVG1M codes)

- 🟥 Selected Exploration Permit Coal (EPC)
- 🟥 1. Rainforests and scrubs (1-7b)
- 🟩 2. Wet eucalypt open forests (8-8b)
- 🟩 3. Eucalypt woodlands to open forests (mainly eastern Qld) (9-15b)
- ▨ 4. Eucalypt open forests to woodlands on floodplains (16-16d)
- ▨ 5. Eucalypt dry woodlands on inland depositional plains (17-18d)
- 🟨 6. Eucalypt low open woodlands usually with spinifex understorey (19-19d)
- 🟩 7. Callitris woodland - open forests (20a)
- 🟩 8. Melaleuca open woodlands on depositional plains (21-22c)
- 🟦 9. Acacia aneura (mulga) dominated open forests, woodlands and shrublands (23-23b)
- 🟦 10. Other acacia dominated open forests, woodlands and shrublands (24-26a)
- 🟨 11. Mixed species woodlands, open woodland - (inland bioregions) includes wooded downs (27-27c)
- ▨ 12. Other coastal communities or heaths (28-29b)
- 🟧 13. Tussock grasslands, forblands (30-32b)
- 🟨 14. Hummock grasslands (33-33b)
- 🟦 15. Wetlands (swamps and lakes) (34-34g)
- 🟪 16. Mangroves and saltmarshes (35-35b)
- ☐ Non-remnant vegetation, cultivated or built environment
- ☐ Water
- ☐ Cadastral Boundaries





This product is projected into GDA 1994 Queensland Albers

Broad Vegetation Groups (BVG) of Queensland are applied by look up table to the regional ecosystem vegetation communities. Each polygon is coloured by the dominant BVG5M and the component regional ecosystems labelled. Where more than one regional ecosystem occurs, the percentage of each is labelled.

Regional ecosystem mapping over the majority of Queensland is produced at a scale of 1:100,000. At this scale, the minimum remnant polygon area is 5 hectares or minimum remnant width of 75 metres. Regional ecosystem linework reproduced at a scale greater than 1:100,000, except in designated areas, should be used as a guide only. The precision of polygon boundaries or positional accuracy of linework is 100 metres.

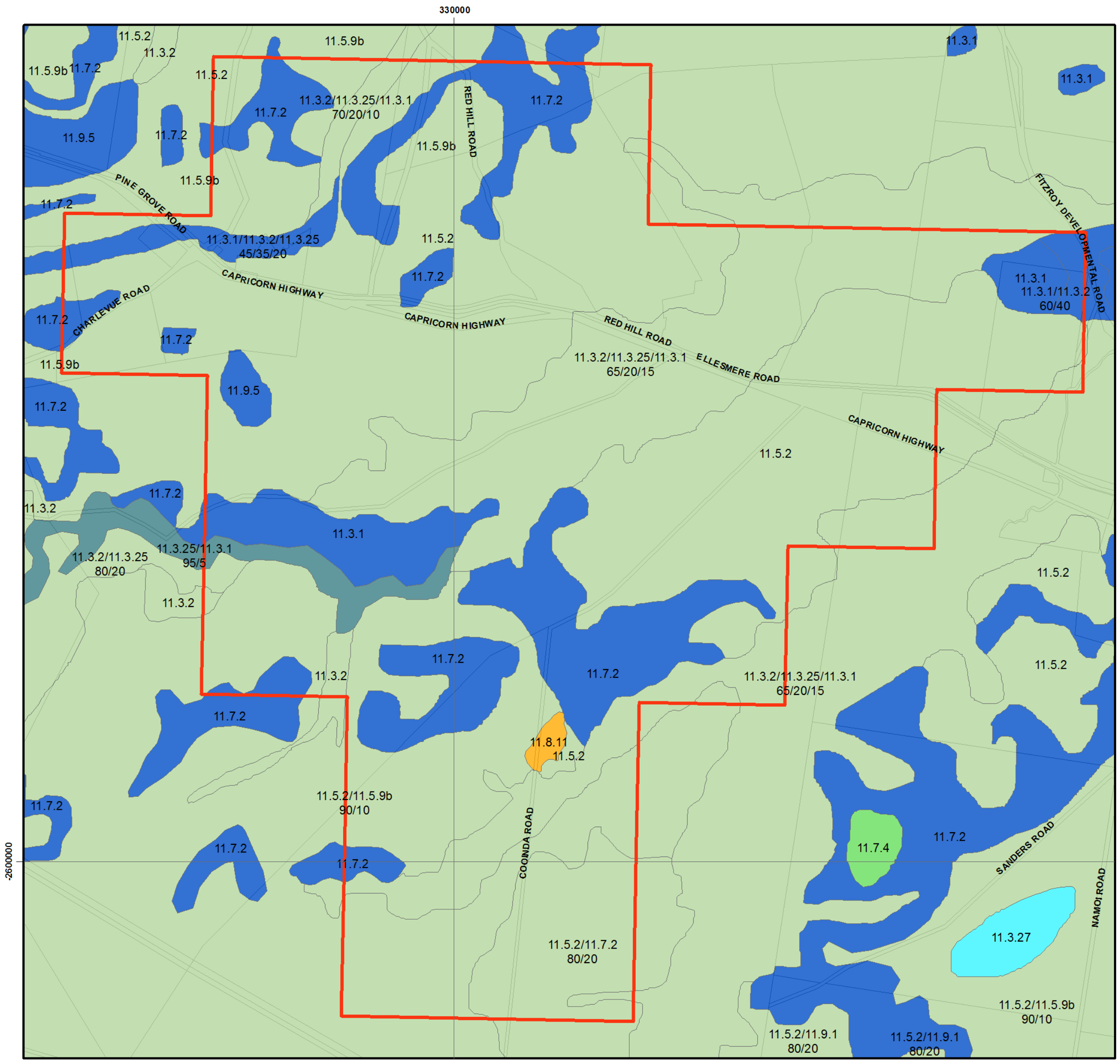
Regional ecosystems are defined as vegetation communities in a bioregion that are consistently associated with a particular combination of geology, landform and soil. The label consists of 3 components: bioregion, land zone, and vegetation community – the dominant canopy species. e.g.: RE 12.3.3. Descriptions of REs are found online. Use the search term "Regional Ecosystem Framework".

Regional ecosystem mapping at 1:100,000 map scale is derived from the following sources: 1:80,000 B&W 1960's aerial photography, Landsat TM imagery, geology, soils, land systems data, field survey and historical records.

Remnant woody vegetation is defined as vegetation that has not been cleared or vegetation that has been cleared but where the dominant canopy has >70% of the height and >50% of the cover relative to the undisturbed height and cover of that stratum and is dominated by species characteristic of the vegetation's undisturbed canopy.

Non-remnant vegetation includes regrowth and disturbed native vegetation.

Map 5 - Pre-clearing regional ecosystems by BVG (5M)

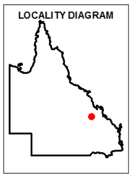


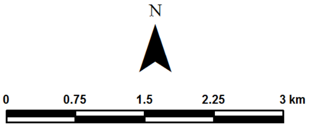
Pre-clearing Regional Ecosystems coloured by Broad Vegetation Groups

Broad Vegetation Groups

BVG5M Description (BVG1M codes)

- ☐ Selected Exploration Permit Coal (EPC)
- 🟥 1. Rainforests and scrubs (1-7b)
- 🟩 2. Wet eucalypt open forests (8-8b)
- 🟩 3. Eucalypt woodlands to open forests (mainly eastern Qld) (9-15b)
- 🟦 4. Eucalypt open forests to woodlands on floodplains (16-16d)
- 🟩 5. Eucalypt dry woodlands on inland depositional plains (17-18d)
- 🟨 6. Eucalypt low open woodlands usually with spinifex understorey (19-19d)
- 🟩 7. Callitris woodland - open forests (20a)
- 🟩 8. Melaleuca open woodlands on depositional plains (21-22c)
- 🟦 9. Acacia aneura (mulga) dominated open forests, woodlands and shrublands (23-23b)
- 🟦 10. Other acacia dominated open forests, woodlands and shrublands (24-26a)
- 🟨 11. Mixed species woodlands, open woodland - (inland bioregions) includes wooded downs (27-27c)
- 🟫 12. Other coastal communities or heaths (28-29b)
- 🟧 13. Tussock grasslands, forblands (30-32b)
- 🟨 14. Hummock grasslands (33-33b)
- 🟦 15. Wetlands (swamps and lakes) (34-34g)
- 🟪 16. Mangroves and saltmarshes (35-35b)
- ⬜ Water
- ⬜ Cadastral Boundaries

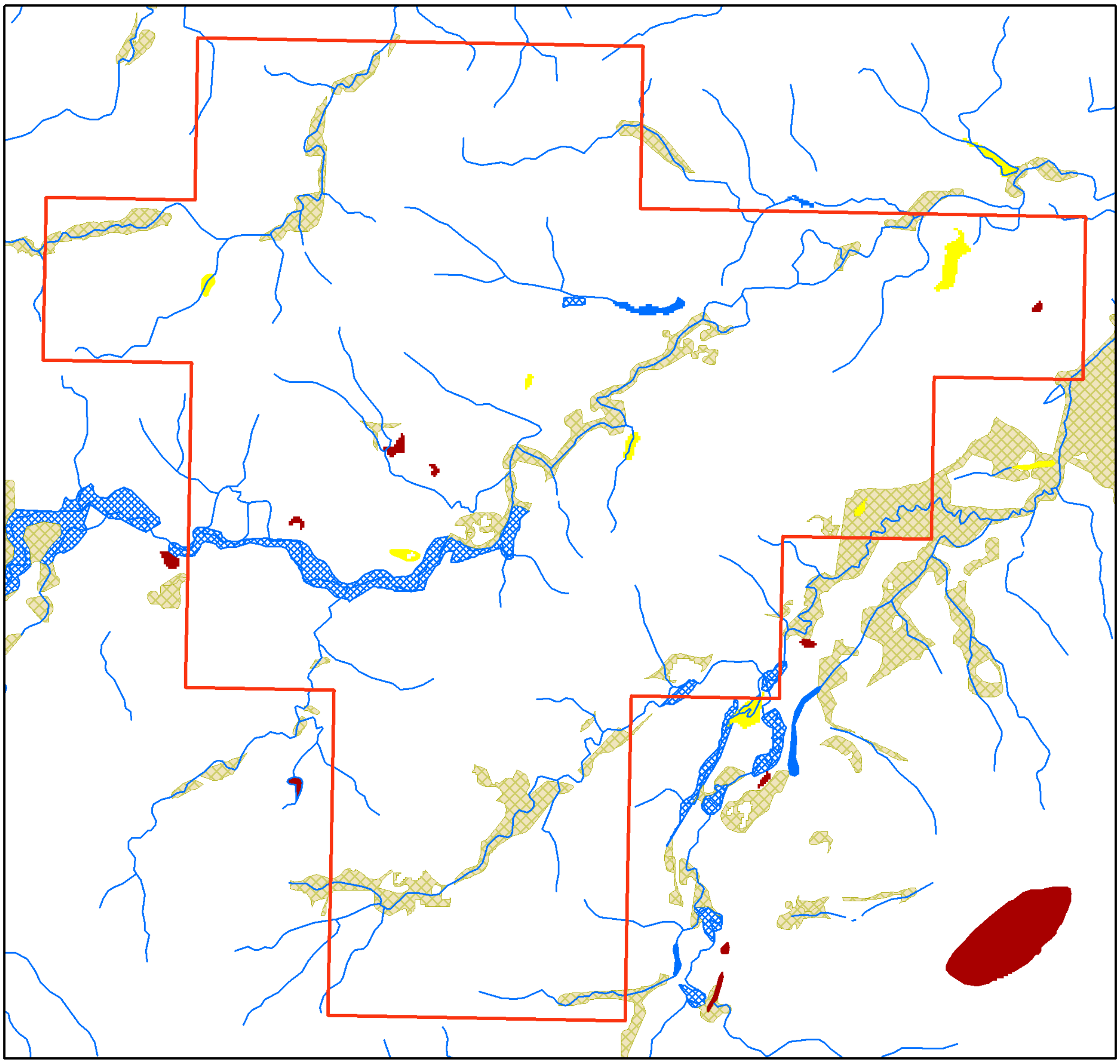




This product is projected into GDA 1994 Queensland Albers

Broad Vegetation Groups (BVG) of Queensland are applied by look up table to the regional ecosystem vegetation communities. Each polygon is coloured by the dominant BVG5M and the component regional ecosystems labelled. Where more than one regional ecosystem occurs, the percentage of each is labelled.
Regional ecosystem mapping over the majority of Queensland is produced at a scale of 1:100,000. At this scale, the minimum remnant polygon area is 5 hectares or minimum remnant width of 75 metres. Regional ecosystem linework reproduced at a scale greater than 1:100,000, except in designated areas, should be used as a guide only. The precision of polygon boundaries or positional accuracy of linework is 100 metres.
Regional ecosystems are defined as vegetation communities in a bioregion that are consistently associated with a particular combination of geology, landform and soil. The label consists of 3 components: bioregion, land zone, and vegetation community – the dominant canopy species. e.g.: RE 12.3.3. Descriptions of REs are found online. Use the search term "Regional Ecosystem Framework".
Regional ecosystem mapping at 1:100,000 map scale is derived from the following sources: 1:80,000 B&W 1960's aerial photography, Landsat TM imagery, geology, soils, land systems data, field survey and historical records.

Map 6 - Wetlands and waterways



Queensland Wetland Data

Legend

- ▭ Selected Exploration Permit Coal (EPC)
- ▲ Towns

Queensland Wetland Data

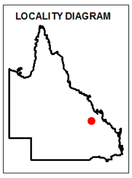
- — Riverine Drainage Lines
- ▲ Springs

Wetland System - Water Bodies

- ■ Marine Waterbodies
- ■ Estuarine Waterbodies
- ■ Riverine Waterbodies
- ■ Lacustrine Waterbodies
- ■ Palustrine Waterbodies

Wetland System - Regional Ecosystems

- ▨ Marine RE
- ▨ Estuarine RE
- ▨ Riverine RE
- ▨ Lacustrine RE
- ▨ Palustrine RE
- ■ RE 51-80% wetland (mosaic units)
- ▨ RE 1-50% wetland (mosaic units)



N

0 690 1380 2070 2760 3450 m

Accuracy information: The positional accuracy of wetland data mapped at a scale of 1:100,000 is +/-100m with a minimum polygon size of 5ha or 75m wide for linear features, except for areas along the east coa st which are mapped at the 1:50,000 scale with a positional accuracy of +/-50m, with a minimum polygon size of 1ha or 35m wide for linear features. Wetlands smaller than 1ha are not delineated on the wetland data. Consideration of the effects of mapped scale is necessary when interpret ing data at a larger scale, e.g. 1:25,000. For property assessment, digital linework should be used as a guide only. The extent of wetlands depicted on this map is based on rectified 2013 Landsat ETM+ imagery supplied by Statewide Landcover and Trees Study (SLATS), Department of Environment and Science. The extent of water bodies is based on the maximum extent of inundation derived from available Landsat imagery up to and including the 2013 imagery.

This product is projected into GDA 1994 Queensland Albers

Links and Other Information Sources

The Department of Environment and Science's Website -

http://www.qld.gov.au/environment/plants-animals/plants/ecosystems/

provides further information on the regional ecosystem framework, including access to links to the Regional Ecosystem Database, Broad Vegetation Group Definitions, Regional Ecosystem and Land zone descriptions.

Descriptions of the broad vegetation groups of Queensland can be downloaded from:

https://publications.qld.gov.au/dataset/redd/resource/

The methodology for mapping regional ecosystems can be downloaded from:

https://publications.qld.gov.au/dataset/redd/resource/

Technical descriptions for regional ecosystems can be obtained from:

http://www.qld.gov.au/environment/plants-animals/plants/ecosystems/technical-descriptions/

Benchmarks can be obtained from:

http://www.qld.gov.au/environment/plants-animals/biodiversity/benchmarks/

For further information associated with the remnant regional ecosystem dataset used by this report, refer to the metadata associated with the Biodiversity status of pre-clearing and Remnant Regional Ecosystems of Queensland dataset (version listed in **Appendix 1**) which is available through the Queensland Government Information System portal,

http://dds.information.qld.gov.au/dds/

The Queensland Globe is a mapping and data application. As an interactive online tool, Queensland Globe allows you to view and explore Queensland maps, imagery (including up-to-date satellite images) and other spatial data, including regional ecosystem mapping. To further view and explore regional ecosystems over an area of interest, access the Biota Globe (a component of the Queensland Globe). The Queensland Globe can be accessed via the following link:

http://www.dnrm.qld.gov.au/mapping-data/queensland-globe

References

Neldner, V.J., Niehus R.E., Wilson, B.A. McDonald, W.J.F., Ford, A.J. and Accad, A. (2017) The Vegetation of Queensland. Descriptions of Broad Vegetation Groups. Version 3.0. Queensland Herbarium, Department of Science, Information Technology, Innovation and the Arts.

(https://publications.qld.gov.au/dataset/redd/resource/78209e74-c7f2-4589-90c1-c33188359086)

Neldner, V.J., Wilson, B.A., Dillewaard, H.A., Ryan, T.S. and Butler, D.W. (2017) *Methodology for Survey and Mapping of Regional Ecosystems and Vegetation Communities in Queensland*. Version 4.0. Queensland Herbarium, Department of Science, Information Technology, Innovation and the Arts.

(https://publications.qld.gov.au/dataset/redd/resource/6dee78ab-c12c-4692-9842-b7257c2511e4)

Sattler, P.S. and Williams, R.D. (eds) (1999). *The Conservation Status of Queensland's Bioregional Ecosystems*. Environmental Protection Agency, Brisbane.

Appendices

Appendix 1 - Source Data

The dataset listed below is available for download from:

http://www.qld.gov.au/environment/plants-animals/plants/ecosystems/download/

- Regional Ecosystem Description Database

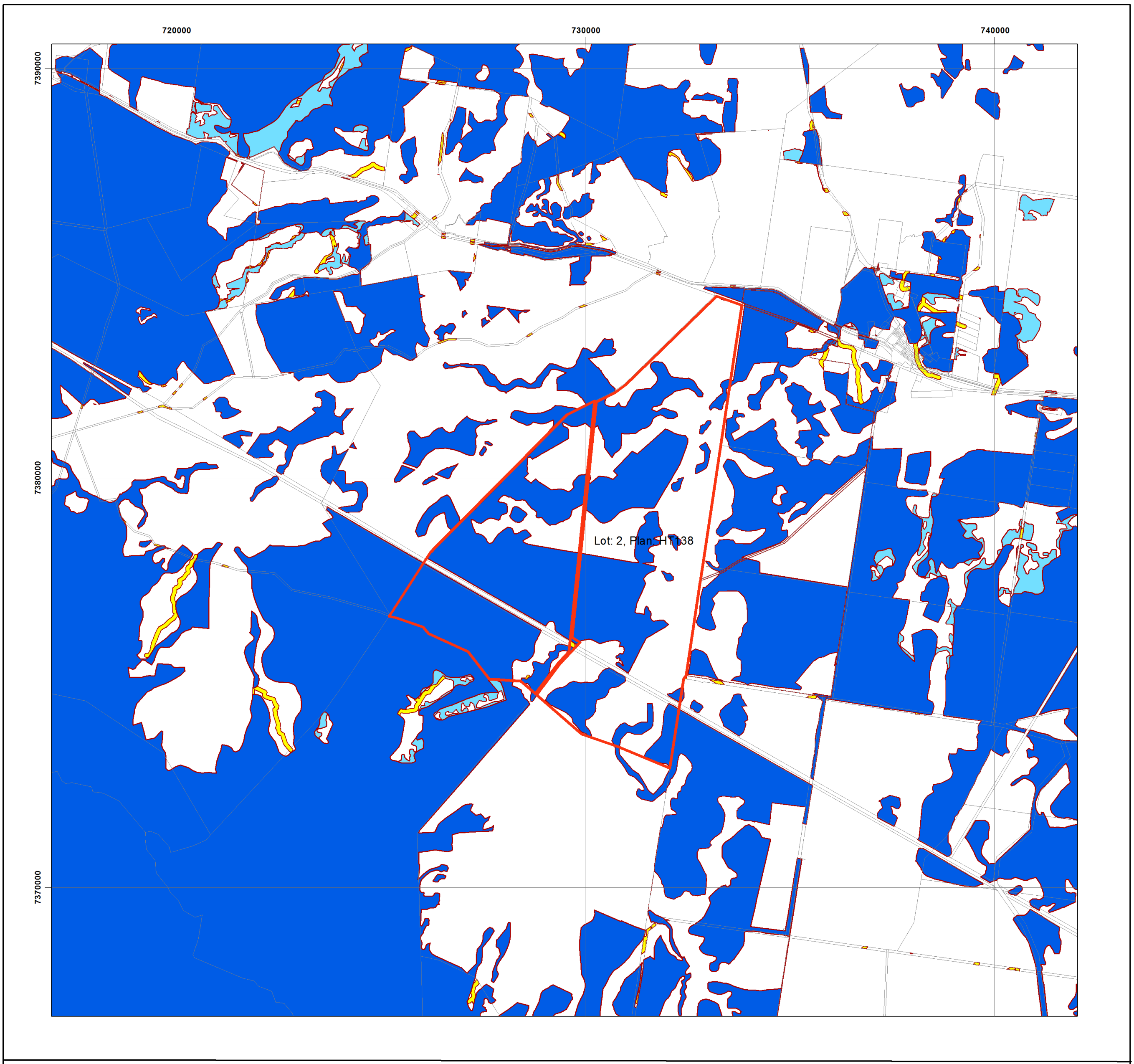
The datasets listed below are available for download from:

http://dds.information.qld.gov.au/dds/

- Biodiversity status of pre-clearing and 2015 remnant regional ecosystems of Queensland
- Pre-clearing Vegetation Communities and Regional Ecosystems of Queensland
- Queensland Wetland Data Version - Wetland lines
- Queensland Wetland Data Version - Wetland points
- Queensland Wetland Data Version - Wetland areas

Appendix 2 - Acronyms and Abbreviations

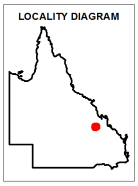
AOI	- Area of Interest
GDA94	- Geocentric Datum of Australia 1994
GIS	- Geographic Information System
RE	- Regional Ecosystem
REDD	- Regional Ecosystem Description Database
VMA	- *Vegetation Management Act 1999*



Regulated Vegetation Management Map

Legend

▭	Lot and Plan
🟥	Category A area (Vegetation offsets/compliance notices/VDecs)
🟦	Category B area (Remnant vegetation)
🟦	Category C area (High-value regrowth vegetation)
🟨	Category R area (Reef regrowth watercourse vegetation)
☐	Category X area (Exempt clearing work on Freehold, Indigenous and Leasehold land)
☐	Water
⬜	Area not categorised
	Cadastral line
	Property boundaries shown are provided as a locational aid only



N

0 1,300 2,600 3,900 5,200 6,500 m

Disclaimer:
While every care is taken to ensure the accuracy of this product, the Department of Natural Resources, Mines and Energy makes no representations or warranties about its accuracy, reliability, completeness or suitability for any particular purpose and disclaims all responsibility and all liability (including without limitation, liability in negligence) for all expenses, losses, damages (including indirect or consequential damage) and costs which you might incur as a result of the product being inaccurate or incomplete in any way and for any reason.

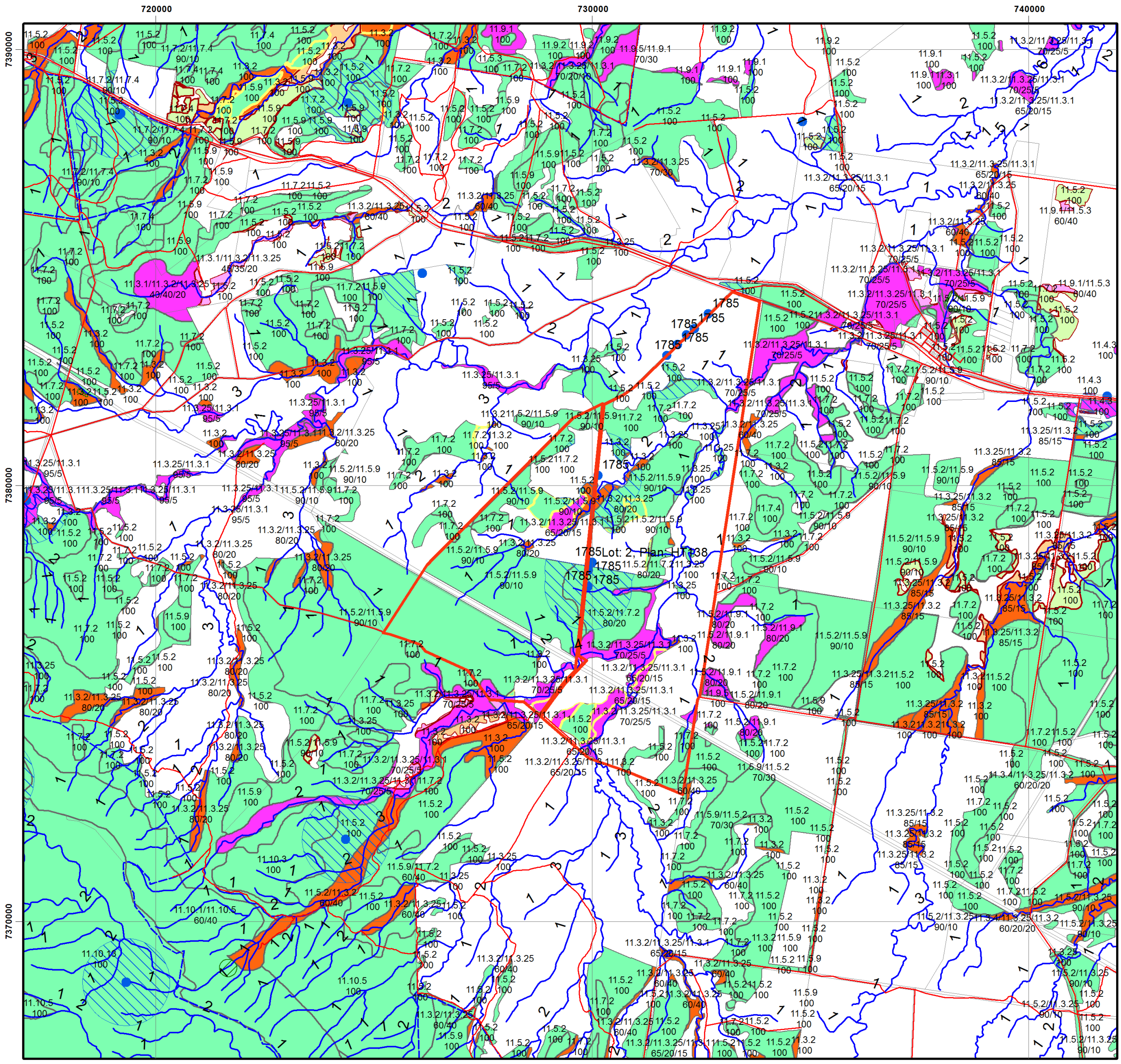
Additional information required for the assessment of vegetation values is provided in the accompanying "Vegetation Management Supporting map". For further information go to the web site: www.dnrme.qld.gov.au or contact the Department of Natural Resources, Mines and Energy.

Digital data for the regulated vegetation management map is available from the Queensland Spatial Portal at http://www.information.qld.gov.au/

This map is updated on a monthly basis to ensure new PMAVs are included as they are approved.

Queensland Government

This product is projected into:
GDA 1994 MGA Zone 55



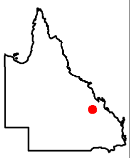
Vegetation Management Supporting Map

Legend

- 🟥 Lot and Plan
- 🟪 Category A or B area containing endangered regional ecosystems
- 🟧 Category A or B area containing of concern regional ecosystems
- 🟩 Category A or B area that is a least concern regional ecosystem
- ☐ Category A or B area under Section 20AH
  These areas are edged in yellow and filled with the remnant RE Status
- 🟪 Category C area containing endangered regional ecosystems
- 🟧 Category C area containing of concern regional ecosystems
- 🟩 Category C area that is a least concern regional ecosystem
- ☐ Category C area under Section 20AI
  These areas are edged in purple and filled with the remnant RE Status
- ☐ Non Remnant
- ☐ Water
- ▨ Wetland on the vegetation management wetlands map
- ▨ Essential habitat on the essential habitat map
- ● Essential habitat species record
- Watercourses and drainage features on the vegetation management watercourse and drainage features map
  (Stream order shown as black number against stream where available)
- Roads
- National Parks, State Forest and other reserves
- Cadastral line
  Property boundaries shown are
  provided as a locational aid only

Queensland
Government

LOCALITY DIAGRAM



N

0 975 1,950 2,925 3,900 4,875 m

This product is projected into:
GDA 1994 MGA Zone 55

Labels for Essential Habitat are centred on the area of enquiry.

Regional ecosystem linework has been compiled at a scale of 1:100 000, except in designated areas where a compilation scale of 1:50 000 is available. Linework should be used as a guide only. The positional accuracy of RE data mapped at a scale of 1:100 000 is +/- 100 metres.

Additional information may be required for the purposes of land clearing or assessment of a regional ecosystem map or PMAV applications. For further information go to the web site: www.dnrme.qld.gov.au or contact the Department of Natural Resources, Mines and Energy.

Digital data for the vegetation management watercourse and drainage feature map, vegetation management wetlands map, essential habitat map and the vegetation management remnant and regional ecosystem map are available from the Queensland Spatial Portal at http://www.information.qld.gov.au/

Vegetation Management Act 1999 - Extract from the essential habitat database

Essential habitat is required for assessment under the:

- State Development Assessment Provisions - State Code 16: Native vegetation clearing which sets out the matters of interest to the state for development assessment under the *Planning Act 2016*; and
- Accepted development vegetation clearing codes made under the *Vegetation Management Act 1999*

Essential habitat for one or more of the following species is found on and within 1.1 km of the identified subject lot/s on the accompanying essential habitat map.

This report identifies essential habitat in Category A, B and Category C areas.

The numeric labels on the essential habitat map can be cross referenced with the database below to determine which essential habitat factors might exist for a particular species.

Essential habitat is compiled from a combination of species habitat models and buffered species records.

The Department of Natural Resources, Mines and Energy website (http://www.dnrme.qld.gov.au) has more information on how the layer is applied under the State Development Assessment Provisions - State Code 16: Native vegetation clearing and the *Vegetation Management Act 1999*.

Regional ecosystem is a mandatory essential habitat factor, unless otherwise stated.

Essential habitat, for protected wildlife, means a category A area, a category B area or category C area shown on the regulated vegetation management map-

1) that has at least 3 essential habitat factors for the protected wildlife that must include any essential habitat factors that are stated as mandatory for the protected wildlife in the essential habitat database; or
2) in which the protected wildlife, at any stage of its life cycle, is located.

Protected wildlife includes endangered, vulnerable or near-threatened native wildlife prescribed under the *Nature Conservation Act 1992*.

Essential habitat in Category A and/or Category B and/or Category C

Label	Scientific Name	Common Name	NCA Status	Vegetation Community	Altitude	Soils	Position in Landscape
1785	Geophaps scripta scripta	squatter pigeon (southern subsp.)	V	Dry eucalypt woodland (including poplar box, spotted gum, yellow box, acacia and callitris), with sparse short grass, often on sandy areas near to permanent water; grassy eucalypt woodlands. Nest on ground near or under grass tussock, log or low bush.	None	None	Gravelly ridges, traprock and river flats.

Label	Regional Ecosystem (mandatory unless otherwise specified)
1785	8.2.1, 8.2.7, 8.2.8, 8.2.12, 8.3.2, 8.3.3, 8.3.5, 8.3.6, 8.3.13, 8.5.2, 8.5.3, 8.5.5, 8.5.6, 8.9.1, 8.11.1, 8.11.3, 8.11.4, 8.11.5, 8.11.6, 8.11.8, 8.12.6, 8.12.7, 8.12.9, 8.12.12, 8.12.14, 8.12.20, 8.12.22, 8.12.23, 8.12.25, 9.3.1, 9.3.2, 9.3.3, 9.3.4, 9.3.5, 9.3.6, 9.3.7, 9.3.8, 9.3.9, 9.3.11, 9.3.13, 9.3.14, 9.3.15, 9.3.16, 9.3.17, 9.3.18, 9.3.19, 9.3.20, 9.3.21, 9.3.22, 9.3.23, 9.4.1, 9.4.2, 9.4.3, 9.5.3, 9.5.4, 9.5.5, 9.5.6, 9.5.7, 9.5.8, 9.5.9, 9.5.10, 9.5.11, 9.5.12, 9.5.16, 9.7.1, 9.7.2, 9.7.3, 9.7.5, 9.7.6, 9.8.1, 9.8.2, 9.8.4, 9.8.5, 9.8.6, 9.8.9, 9.8.10, 9.8.11, 9.10.1, 9.10.3, 9.10.6, 9.10.7, 9.10.8, 9.11.1, 9.11.2, 9.11.3, 9.11.4, 9.11.5, 9.11.7, 9.11.10, 9.11.11, 9.11.12, 9.11.13, 9.11.15, 9.11.16, 9.11.17, 9.11.18, 9.11.19, 9.11.23, 9.11.26, 9.11.28, 9.11.29, 9.11.31, 9.11.32, 9.12.1, 9.12.3, 9.12.4, 9.12.5, 9.12.6, 9.12.7, 9.12.10, 9.12.11, 9.12.12, 9.12.13, 9.12.16, 9.12.17, 9.12.18, 9.12.19, 9.12.20, 9.12.21, 9.12.22, 9.12.23, 9.12.24, 9.12.26, 9.12.28, 9.12.30, 9.12.31, 9.12.33, 9.12.35, 9.12.37, 9.12.39, 10.3.1, 10.3.2, 10.3.3, 10.3.4, 10.3.5, 10.3.6, 10.3.9, 10.3.10, 10.3.11, 10.3.12, 10.3.13, 10.3.14, 10.3.15, 10.3.19, 10.3.20, 10.3.27, 10.3.28, 10.3.30, 10.3.31, 10.4.3, 10.5.1, 10.5.2, 10.5.4, 10.5.5, 10.5.7, 10.5.9, 10.5.10, 10.5.11, 10.5.12, 10.7.2, 10.7.3, 10.7.5, 10.7.11, 10.7.12, 10.9.1, 10.9.2, 10.9.3, 10.9.5, 10.10.1, 10.10.3, 10.10.4, 10.10.5, 10.10.7, 11.2.1, 11.2.5, 11.3.1, 11.3.2, 11.3.3, 11.3.4, 11.3.6, 11.3.7, 11.3.8, 11.3.9, 11.3.10, 11.3.12, 11.3.13, 11.3.14, 11.3.15, 11.3.16, 11.3.17, 11.3.18, 11.3.19, 11.3.23, 11.3.25, 11.3.27, 11.3.28, 11.3.29, 11.3.30, 11.3.35, 11.3.36, 11.3.37, 11.3.38, 11.3.39, 11.4.2, 11.4.3, 11.4.5, 11.4.8, 11.4.10, 11.4.12, 11.4.13, 11.5.1, 11.5.2, 11.5.3, 11.5.4, 11.5.5, 11.5.8, 11.5.9, 11.5.12, 11.5.13, 11.5.14, 11.5.17, 11.5.20, 11.5.21, 11.7.1, 11.7.2, 11.7.4, 11.7.6, 11.8.2, 11.8.4, 11.8.5, 11.8.8, 11.8.9, 11.8.11, 11.8.12, 11.8.14, 11.8.15, 11.9.2, 11.9.3, 11.9.7, 11.9.9, 11.9.14, 11.10.1, 11.10.4, 11.10.6, 11.10.7, 11.10.11, 11.10.12, 11.10.13, 11.11.1, 11.11.3, 11.11.4, 11.11.6, 11.11.7, 11.11.8, 11.11.9, 11.11.10, 11.11.11, 11.11.15, 11.11.16, 11.11.19, 11.11.20, 11.12.1, 11.12.2, 11.12.3, 11.12.5, 11.12.6, 11.12.7, 11.12.8, 11.12.9, 11.12.10, 11.12.11, 11.12.12, 11.12.13, 11.12.14, 11.12.17, 11.12.20, 12.2.5, 12.2.6, 12.2.7, 12.2.10, 12.2.11, 12.3.3, 12.3.6, 12.3.10, 12.3.12, 12.3.14, 12.3.18, 12.3.19, 12.5.1, 12.5.2, 12.5.4, 12.5.5, 12.5.7, 12.5.8, 12.5.11, 12.5.12, 12.7.1, 12.7.2, 12.8.14, 12.8.16, 12.8.17, 12.8.19, 12.9-10.5, 12.9-10.7, 12.9-10.8, 12.9-10.12, 12.9-10.13, 12.9-10.25, 12.9-10.26, 12.9-10.28, 12.11.5, 12.11.7, 12.11.8, 12.11.14, 12.11.15, 12.11.20, 12.11.21, 12.11.22, 12.11.24, 12.11.25, 12.11.26, 12.11.27, 12.11.28, 12.12.7, 12.12.8, 12.12.9, 12.12.12, 12.12.14, 12.12.21, 12.12.22, 12.12.23, 12.12.24, 12.12.25, 12.12.27, 13.3.1, 13.3.4, 13.3.7, 13.11.1, 13.11.3, 13.11.4, 13.11.8, 13.12.2, 13.12.3, 13.12.5, 13.12.8, 13.12.9, 13.12.10

Centred on tenure: epc: 881

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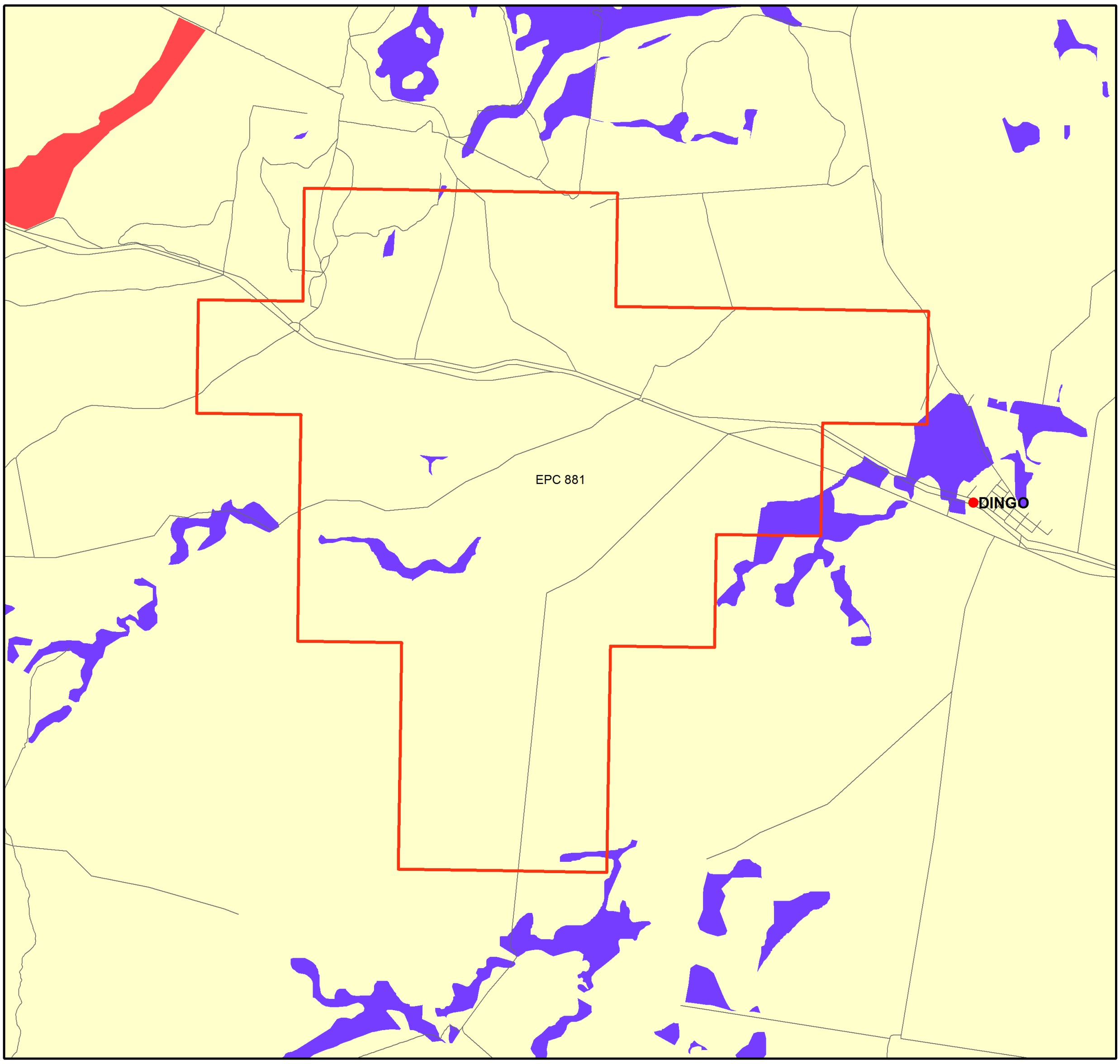


ENVIRONMENTALLY SENSITIVE AREAS - Mining Activities

- ▭ Selected Exploration Permit Coal (EPC)

CATEGORY A

- 🟩 National Parks
- 🟩 Conservation Parks
- 🟧 Forest Reserves
- 🟪 Wet Tropics World Heritage Area
- ▨ Great Barrier Reef Marine Park Area
- ⬜ Marine Parks other than General Use Zones

CATEGORY B

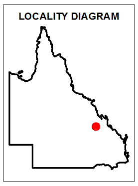
- ☰ World Heritage Areas
- 🟧 Queensland Heritage Register Places
- ▥ Ramsar Sites
- ▨ Cultural Heritage Registered Areas and DLA's other than Stanbroke
- ▩ Special Forestry Areas
- ▨ Fish Habitat Areas
- ▨ Koala Plan
- 🟥 Coordinated Conservation Areas
- 🟪 Endangered Regional Ecosystems (Biodiversity Status)
- ⬜ General Use Zones of Marine Parks
- 🟩 Marine Plants

CATEGORY C

- 🟥 Nature Refuges
- 🟨 Resources Reserve
- 🟪 State Forests
- 🟫 Timber Reserves
- ▩ Declared Catchment Areas
- ▩ Declared Irrigation Areas
- ▩ Drainage Areas
- ▩ River Improvement Areas
- 🟩 Stanbroke DLA
- ▩ Coastal Management District
- ▼ Dams and Weirs

OTHERS

- ● Towns
- — Roads
- — Repealed Wild River Nominated Waterways
- 🟫 Repealed Wild River Preservation Areas
- 🟫 Repealed Wild River High Preservation Areas
- 🟪 Mahogany Glider Habitat
- ▥ Directory of Important Wetlands
- 🟨 Queensland



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0 975 1,950 2,925 3,900 4,875 m

This product is projected into GDA 1994 MGA Zone 55

External contributors (non-government parties) of the data for this product are: Great Barrier Reef Marine Park Authority

Regional ecosystem mapping (remnant biodiversity status) may incorporate amendments, resulting from property level assessments, to the release version of the mapping available on QSpatial.

NOTE TO USER: Themes presented in this map are indicative only. Field survey may be required to verify the 'true' spatial extent and value. Not all environmentally sensitive areas are presented in this map. A user should refer to the particular circumstances relevant to their situation to assess the 'completeness' of themes provided.

The user should note that some boundaries and indicated values are ambient and may change over time (e.g. regional ecosystem boundaries and conservation status, watercourse mapping etc).

The user should be aware that due to multiple overlapping themes/ layers present, some themes/layers may be obscured by others. Ordering in the Legend does not accurately reflect the order by which themes/layers are displayed.

Queensland Government

Department of Environment and Science

Environmental Reports

Matters of State Environmental Significance

For the selected area of interest
epc: 881

Environmental Reports - General Information

The Environmental Reports portal provides for the assessment of selected matters of interest relevant to a user specified location, or area of interest (AOI). All area and derivative figures are relevant to the extent of matters of interest contained within the AOI unless otherwise stated. Please note, if a user selects an AOI via the "central coordinates" option, the resulting assessment area encompasses an area extending for a 2km radius from the point of interest.

All area and area derived figures included in this report have been calculated via reprojecting relevant spatial features to Albers equal-area conic projection (central meridian = 146, datum Geocentric Datum of Australia 1994). As a result, area figures may differ slightly if calculated for the same features using a different co-ordinate system.

Figures in tables may be affected by rounding.

The matters of interest reported on in this document are based upon available state mapped datasets. Where the report indicates that a matter of interest is not present within the AOI (e.g. where area related calculations are equal to zero, or no values are listed), this may be due either to the fact that state mapping has not been undertaken for the AOI, that state mapping is incomplete for the AOI, or that no values have been identified within the site.

The information presented in this report should be considered as a guide only and field survey may be required to validate values on the ground.

Please direct queries about these reports to: Planning.Support@des.qld.gov.au

Disclaimer

Whilst every care is taken to ensure the accuracy of the information provided in this report, the Queensland Government makes no representations or warranties about its accuracy, reliability, completeness, or suitability, for any particular purpose and disclaims all responsibility and all liability (including without limitation, liability in negligence) for all expenses, losses, damages (including indirect or consequential damage) and costs which the user may incur as a consequence of the information being inaccurate or incomplete in any way and for any reason.

Table of Contents

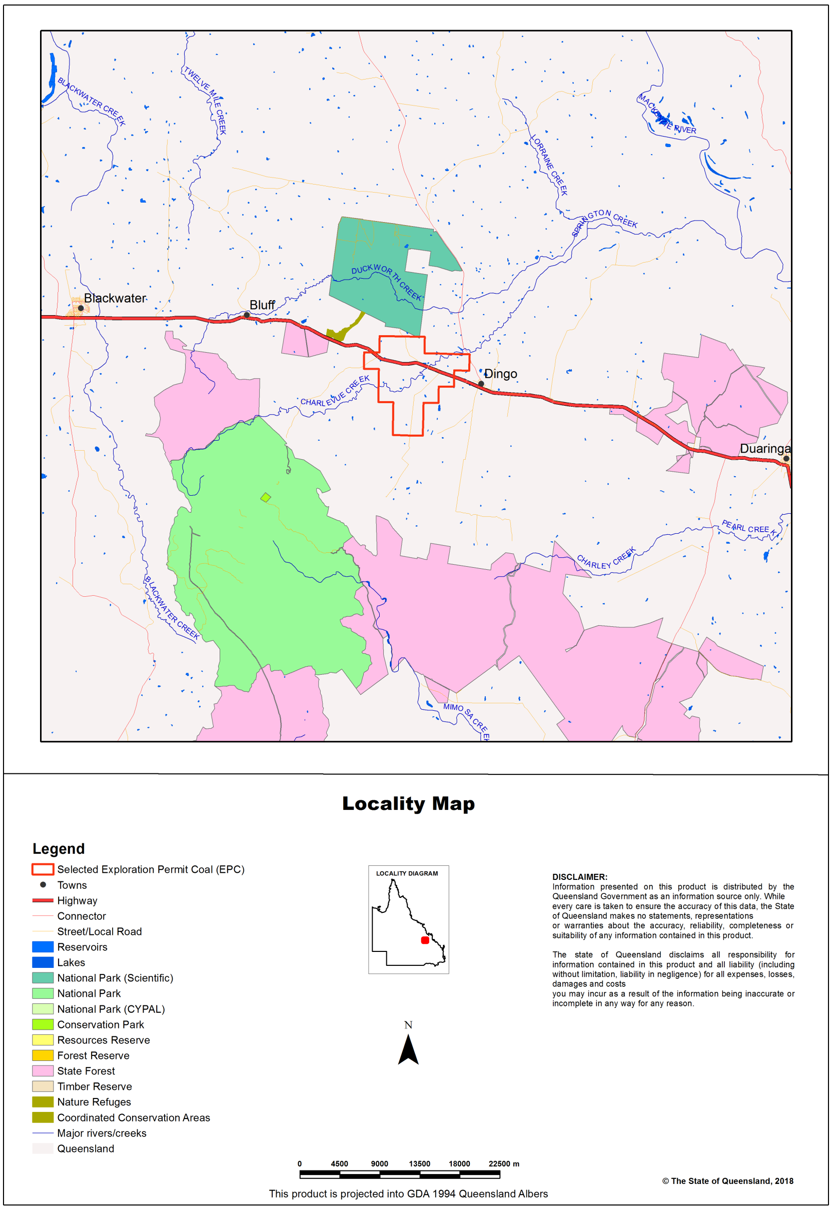
Assessment Area Details . . . 4
Matters of State Environmental Significance (MSES) . . . 5
  MSES Categories . . . 5
  MSES Values Present . . . 6
  Additional Information with Respect to MSES Values Present . . . 7
    MSES - State Conservation Areas . . . 7
    MSES - Wetlands and Waterways . . . 7
    MSES - Species . . . 7
    MSES - Regulated Vegetation . . . 8
  Map 1 - MSES - State Conservation Areas . . . 10
  Map 2 - MSES - Wetlands and Waterways . . . 11
  Map 3 - MSES - Species . . . 12
  Map 4 - MSES - Regulated Vegetation . . . 13
  Map 5 - MSES - Offset Areas . . . 14
Appendices . . . 15
  Appendix 1 - Matters of State Environmental Significance (MSES) methodology . . . 15
  Appendix 2 - Source Data . . . 16
  Appendix 3 - Acronyms and Abbreviations . . . 17

Assessment Area Details

The following table provides an overview of the area of interest (AOI) with respect to selected topographic and environmental values.

Table 1: Summary table, details for AOI epc: 881

Size (ha)	7,219.57
Local Government(s)	Central Highlands Regional
Bioregion(s)	Brigalow Belt
Subregion(s)	Woorabinda
Catchment(s)	Fitzroy



Locality Map

DISCLAIMER:
Information presented on this product is distributed by the Queensland Government as an information source only. While every care is taken to ensure the accuracy of this data, the State of Queensland makes no statements, representations or warranties about the accuracy, reliability, completeness or suitability of any information contained in this product.

The state of Queensland disclaims all responsibility for information contained in this product and all liability (including without limitation, liability in negligence) for all expenses, losses, damages and costs you may incur as a result of the information being inaccurate or incomplete in any way for any reason.

This product is projected into GDA 1994 Queensland Albers

Matters of State Environmental Significance (MSES)

MSES Categories

Queensland's State Planning Policy (SPP) includes a biodiversity State interest that states:

'The sustainable, long-term conservation of biodiversity is supported. Significant impacts on matters of national or state environmental significance are avoided, or where this cannot be reasonably achieved; impacts are minimised and residual impacts offset.'

The MSES mapping product is a guide to assist planning and development assessment decision-making. Its primary purpose is to support implementation of the SPP biodiversity policy. While it supports the SPP, the mapping does not replace the regulatory mapping or environmental values specifically called up under other laws or regulations. Similarly, the SPP biodiversity policy does not override or replace specific requirements of other Acts or regulations.

The SPP defines matters of state environmental significance as:

- Protected areas (including all classes of protected area except coordinated conservation areas) under the *Nature Conservation Act 1992* ;
- Marine parks and land within a 'marine national park', 'conservation park', 'scientific research', 'preservation' or 'buffer' zone under the *Marine Parks Act 2004* ;
- Areas within declared fish habitat areas that are management A areas or management B areas under the Fisheries Regulation 2008;
- Threatened wildlife under the *Nature Conservation Act 1992* and special least concern animals under the Nature Conservation (Wildlife) Regulation 2006;
- Regulated vegetation under the *Vegetation Management Act 1999* that is:
    - Category B areas on the regulated vegetation management map, that are 'endangered' or 'of concern' regional ecosystems;
    - Category C areas on the regulated vegetation management map that are 'endangered' or 'of concern' regional ecosystems;
    - Category R areas on the regulated vegetation management map;
    - Regional ecosystems that intersect with watercourses identified on the vegetation management watercourse and drainage feature map;
    - Regional ecosystems that intersect with wetlands identified on the vegetation management wetlands map;

- Strategic Environmental Areas under the *Regional Planning Interests Act 2014* ;
- Wetlands in a wetland protection area of wetlands of high ecological significance shown on the Map of Referable Wetlands under the Environmental Protection Regulation 2008;
- Wetlands and watercourses in high ecological value waters defined in the Environmental Protection (Water) Policy 2009, schedule 2;
- Legally secured offset areas.

MSES Values Present

The MSES values that are present in the area of interest are summarised in the table below:

Table 2: Summary of MSES present within the AOI

1a Protected Areas- estates	2.94 ha	0.0%
1b Protected Areas- nature refuges	0.0 ha	0.0 %
2 State Marine Parks- highly protected zones	0.0 ha	0.0 %
3 Fish habitat areas (A and B areas)	0.0 ha	0.0 %
4 Strategic Environmental Areas (SEA)	0.0 ha	0.0 %
5 High Ecological Significance wetlands on the map of Referable Wetlands	0.0 ha	0.0 %
6a High Ecological Value (HEV) wetlands	0.0 ha	0.0 %
6b High Ecological Value (HEV) waterways **	0.0 km	Not applicable
7 Threatened species and Iconic species	0.0 ha	0.0 %
8a Regulated Vegetation - Endangered/Of concern in Category B (remnant)	248.85 ha	3.4%
8b Regulated Vegetation - Endangered/Of concern in Category C (regrowth)	3.69 ha	0.1%
8c Regulated Vegetation - Category R (GBR riverine regrowth)	19.17 ha	0.3%
8d Regulated Vegetation - Essential habitat	384.78 ha	5.3%
8e Regulated Vegetation - intersecting a watercourse **	81.4 km	Not applicable
8f Regulated Vegetation - within 100m of a Vegetation Management Wetland	0.0 ha	0.0 %
9a Legally secured offset areas- offset register areas	0.0 ha	0.0 %
9b Legally secured offset areas- vegetation offsets through a Property Map of Assessable Vegetation	0.0 ha	0.0 %

Additional Information with Respect to MSES Values Present

MSES - State Conservation Areas

1a. Protected Areas - estates

LOTPLAN	Estate name
25HT655	Taunton National Park (Scientific)

1b. Protected Areas - nature refuges

(no results)

2. State Marine Parks - highly protected zones

(no results)

3. Fish habitat areas (A and B areas)

(no results)

Refer to **Map 1 - MSES - State Conservation Areas** for an overview of the relevant MSES.

MSES - Wetlands and Waterways

4. Strategic Environmental Areas (SEA)

(no results)

5. High Ecological Significance wetlands on the Map of Referable Wetlands

(no results)

6a. High Ecological Value (HEV) waters - wetlands

(no results)

6b. High Ecological Value (HEV) waters - waterways

(no results)

Refer to **Map 2 - MSES - Wetlands and Waterways** for an overview of the relevant MSES.

MSES - Species

7. Threatened wildlife and special least concern animal

(no results)

Threatened and special least concern species records

(no results)

Note: The Threatened and Special Least Concern Animal (7) layer originates from the previous MSES version (4.1, dated at 2014). The layer does not represent all currently listed species and is subject to review.

**Nature Conservation Act 1992 (NCA) Status- Endangered (E), Vulnerable (V) or Special Least Concern Animal (SL). Environment Protection and Biodiversity Conservation Act 1999 (EPBC) status: Critically Endangered (CE) Endangered (E), Vulnerable (V)*

To request a species list for an area, or search for a species profile, access Wildlife Online at:
https://www.qld.gov.au/environment/plants-animals/species-list/

Refer to **Map 3 - MSES - Species** for an overview of the relevant MSES.

MSES - Regulated Vegetation

8a. Regulated Vegetation - Endangered/Of concern in Category B (remnant)

Regional ecosystem	Vegetation management polygon	Vegetation management status
11.3.2/11.3.25	O-dom	rem_oc
11.3.2/11.3.25/11.3.1	E-subdom	rem_end
11.3.2	O-dom	rem_oc
11.3.25/11.3.1	E-subdom	rem_end

8b. Regulated Vegetation - Endangered/Of concern in Category C (regrowth)

Regional ecosystem	Vegetation management polygon	Vegetation management status
11.3.2/11.3.25	O-dom	hvr_oc
11.3.1/11.3.2/11.3.25	E-dom	hvr_end

For further information relating to regional ecosystems in general, go to:
https://www.qld.gov.au/environment/plants-animals/plants/ecosystems/
For a more detailed description of a particular regional ecosystem, access the regional ecosystem search page at:
https://environment.ehp.qld.gov.au/regional-ecosystems/

8c. Regulated Vegetation - Category R (GBR riverine regrowth)

Regulated vegetation map category	Map number	RVM rule
R	8750	4

8d. Regulated Vegetation - Essential habitat

Values are present

8e. Regulated Vegetation - intersecting a watercourse**

A vegetation management watercourse is mapped as present

8f. Regulated Vegetation - within 100m of a Vegetation Management wetland

Not applicable

Refer to **Map 4 - MSES - Regulated Vegetation** for an overview of the relevant MSES.

MSES - Offsets

9a. Legally secured offset areas - offset register areas

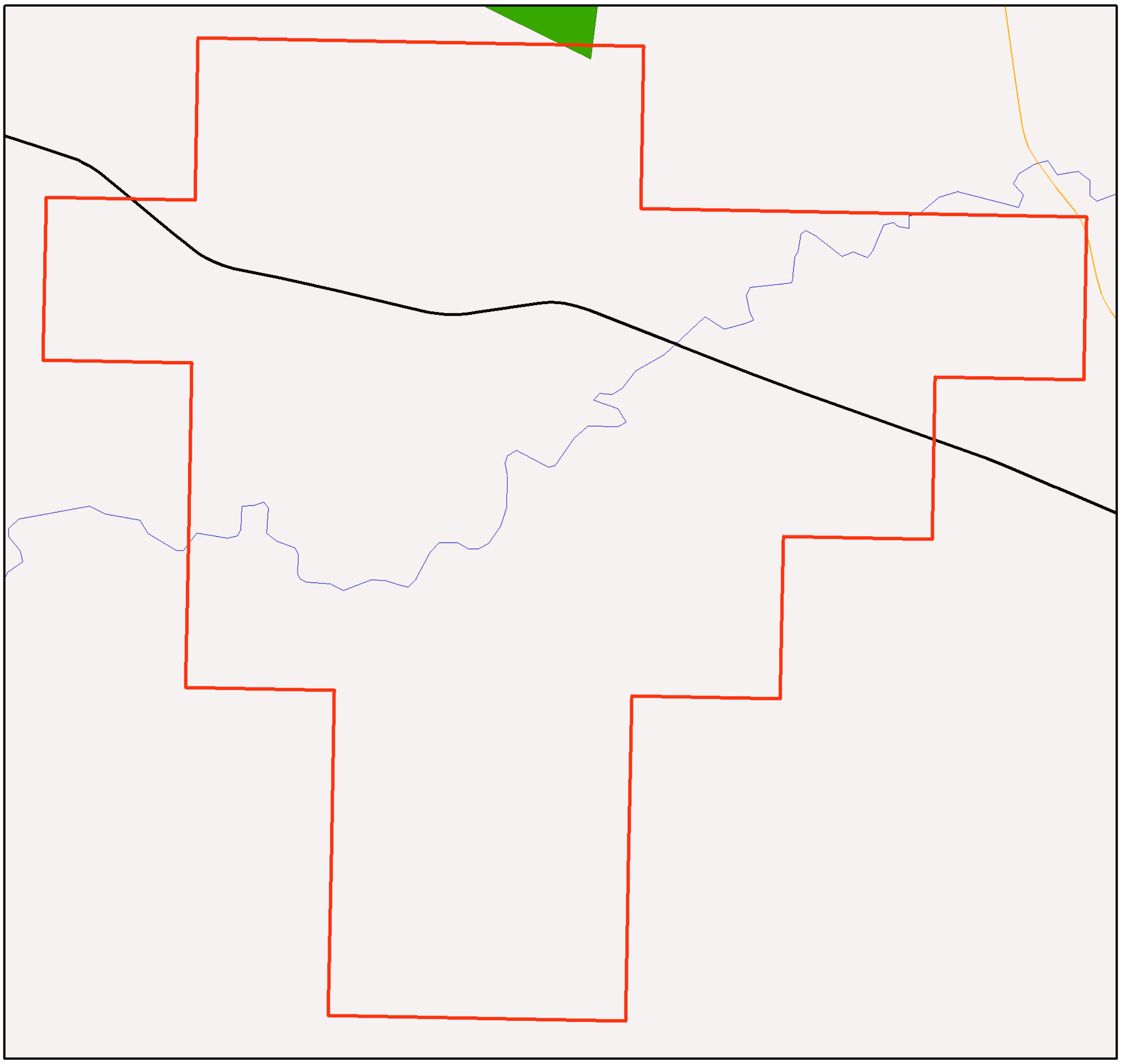
(no results)

9b. Legally secured offset areas - vegetation offsets through a Property Map of Assessable Vegetation

(no results)

Refer to **Map 5 - MSES - Offset Areas** for an overview of the relevant MSES.

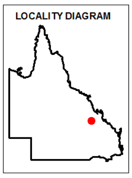
Map 1 - MSES - State Conservation Areas



MSES - State Conservation Areas

Area of Interest

- 🟥 Selected Exploration Permit Coal (EPC)
- ▲ Towns
- — Freeways/Highways
- — Secondary roads
- — Major rivers/creeks
- 🟩 Protected area (estates)
- 🟦 Declared fish habitat area (A and B areas)
- 🟪 Marine park (highly protected)



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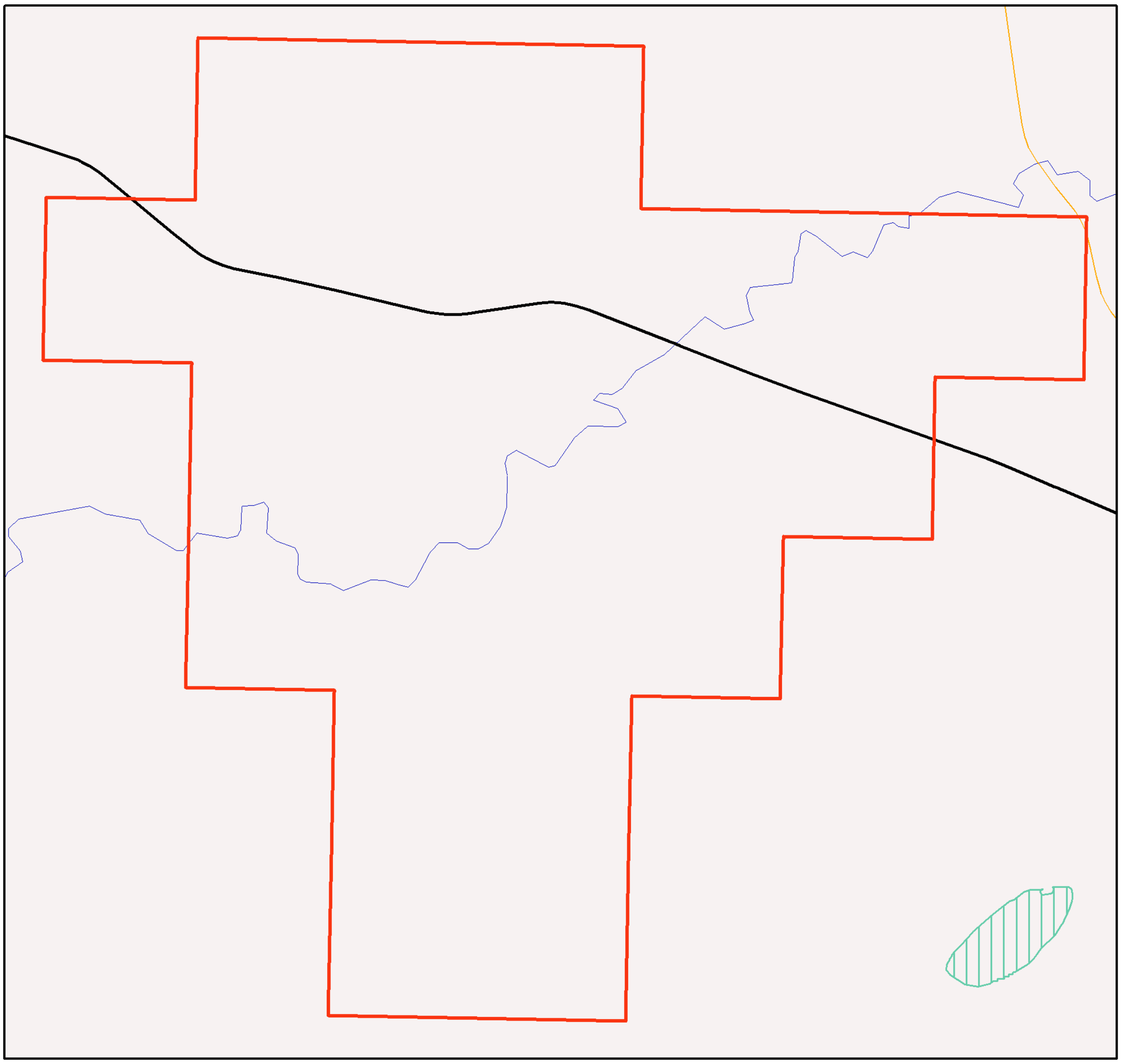
This product is projected into GDA 1994 Queensland Albers

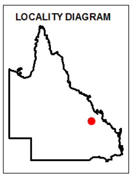
Map 2 - MSES - Wetlands and Waterways



MSES - Wetlands and Waterways

Area of Interest

- 🟥 Selected Exploration Permit Coal (EPC)
- ▲ Towns
- — Freeways/Highways
- — Secondary roads
- — Major rivers/creeks
- — Declared high ecological value waters (watercourse)
- ▨ Strategic environmental area (designated precinct)
- ▥ Declared high ecological value waters (wetland)
- ▥ High ecological significance wetlands



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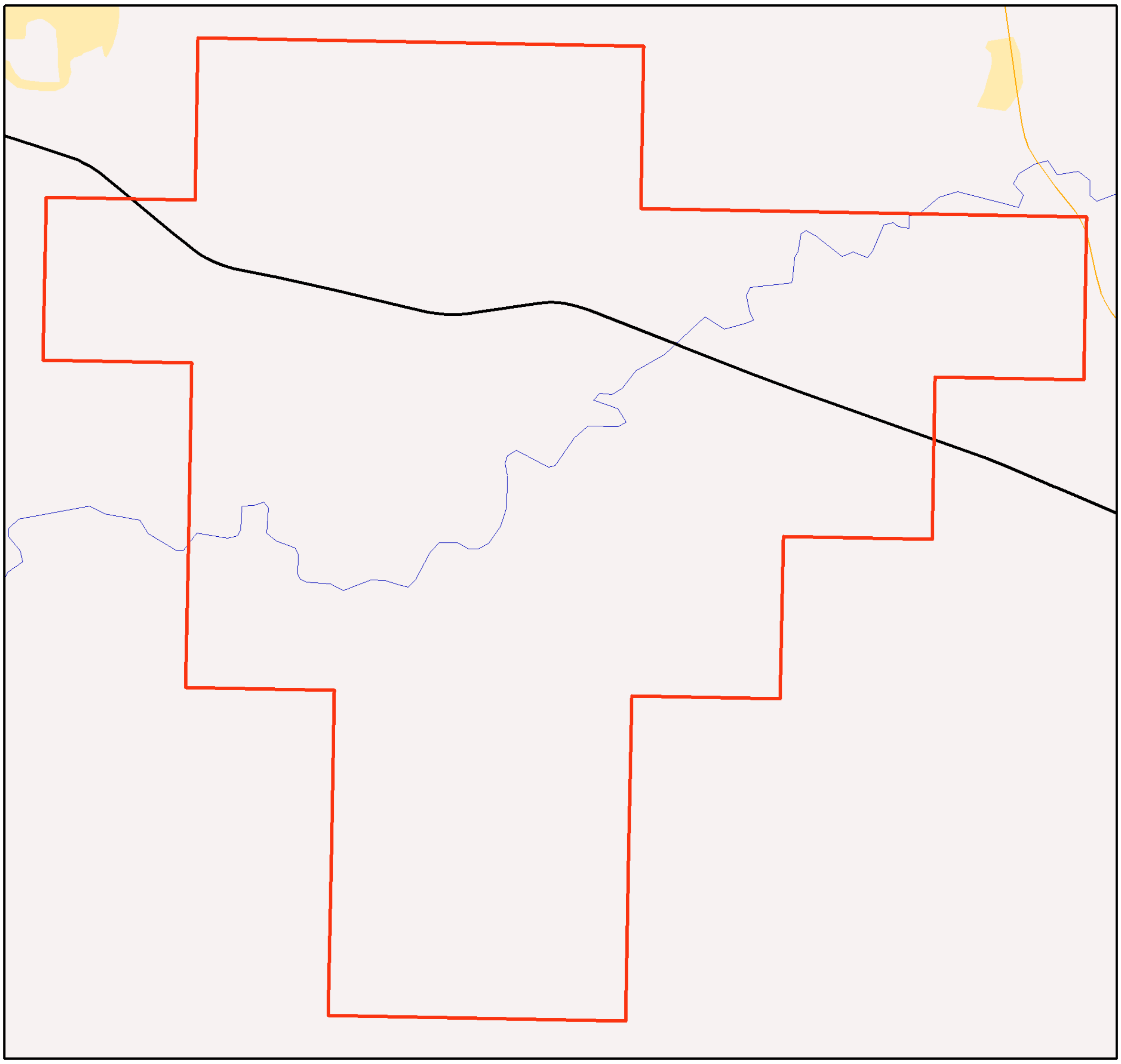
This product is projected into GDA 1994 Queensland Albers

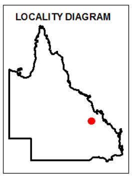
Map 3 - MSES - Species



MSES - Species

Area of Interest

- 🟥 Selected Exploration Permit Coal (EPC)
- ▲ Towns
- — Freeways/Highways
- — Secondary roads
- — Major rivers/creeks
- 🟨 Threatened wildlife and special least concern animal



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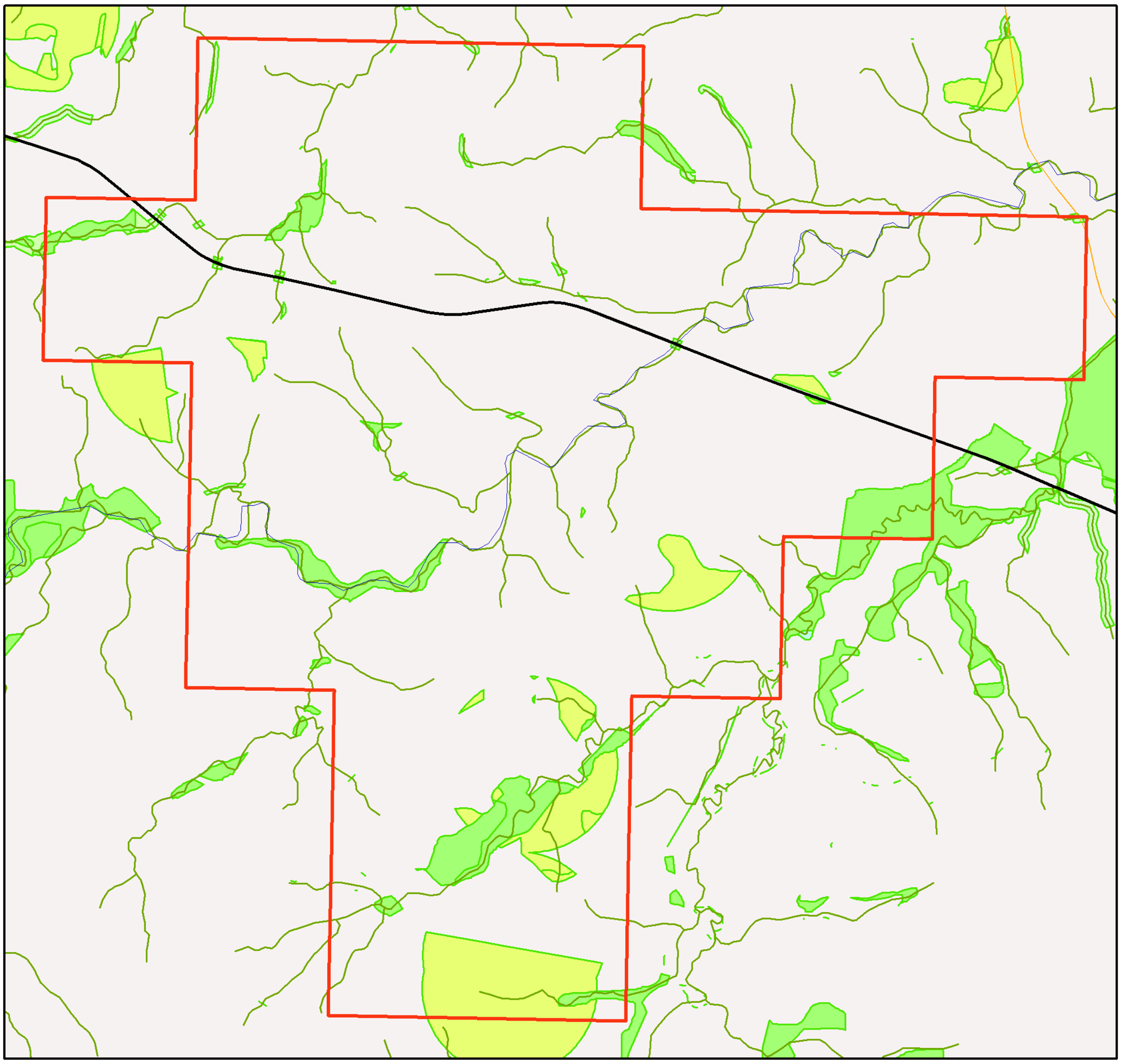
This product is projected into GDA 1994 Queensland Albers

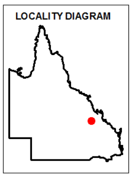
Map 4 - MSES - Regulated Vegetation



MSES - Regulated Vegetation

Area of Interest

- 🟥 Selected Exploration Permit Coal (EPC)
- ▲ Towns
- — Freeways/Highways
- — Secondary roads
- — Major rivers/creeks
- — Regulated vegetation (intersecting a watercourse)
- 🟦 Regulated vegetation (100m from wetland)
- 🟩 Regulated vegetation (category B - endangered or of concern)
- 🟩 Regulated vegetation (category C - endangered or of concern)
- 🟩 Regulated vegetation (category R - GBR riverine)
- 🟨 Regulated vegetation (essential habitat)



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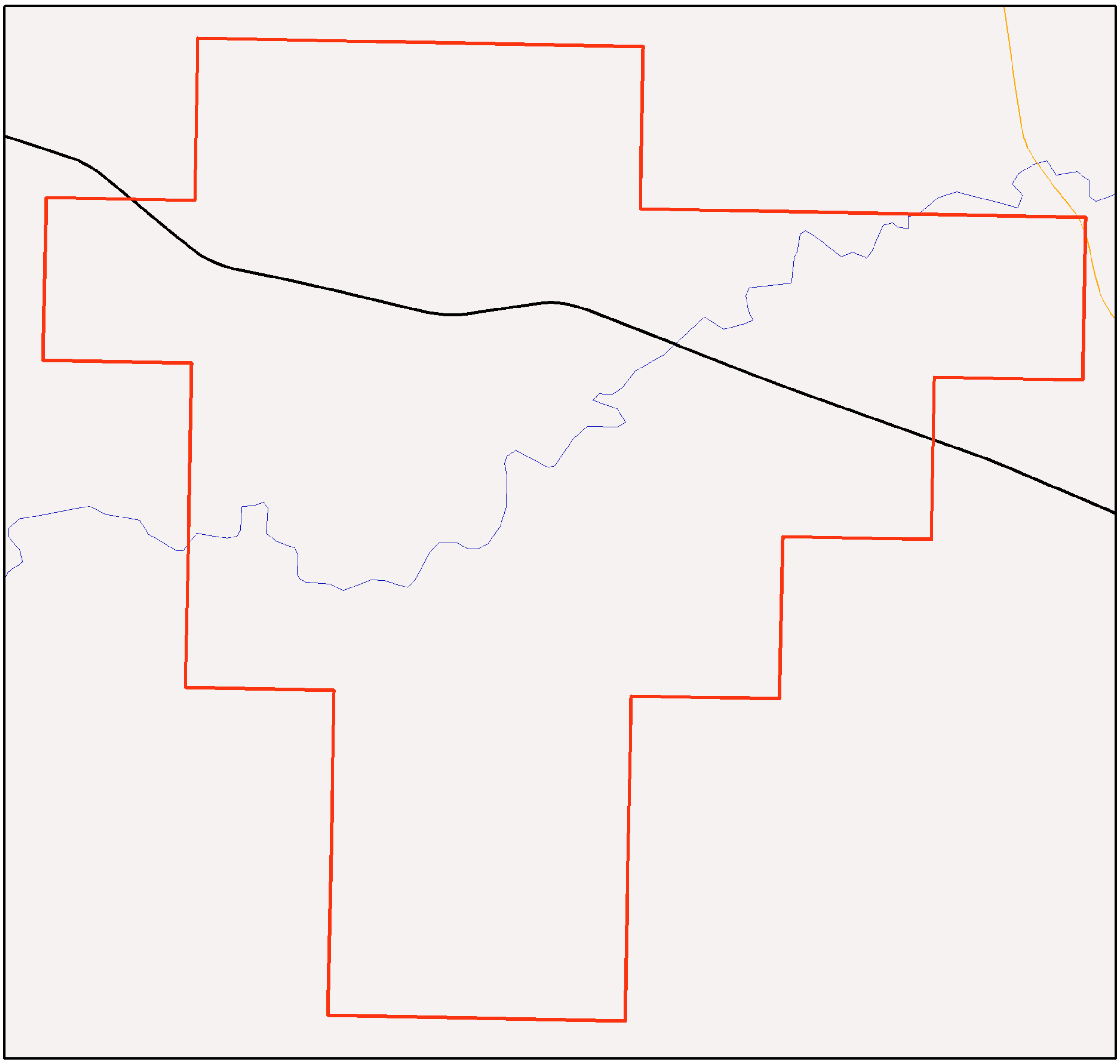
This product is projected into GDA 1994 Queensland Albers

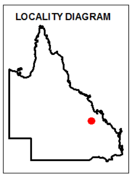
Map 5 - MSES - Offset Areas

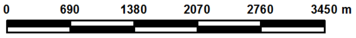


MSES - Offsets

Area of Interest

- ▭ Selected Exploration Permit Coal (EPC)
- ▲ Towns
- — Freeways/Highways
- — Secondary roads
- — Major rivers/creeks
- 🟥 Legally secured offset area (offset register)
- 🟧 Legally secured offset area (vegetation offsets)





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Appendices

Appendix 1 - Matters of State Environmental Significance (MSES) methodology

MSES mapping is a regional-scale representation of the definition for MSES under the State Planning Policy (SPP). The compiled MSES mapping product is a guide to assist planning and development assessment decision-making. Its primary purpose is to support implementation of the SPP biodiversity policy. While it supports the SPP, the mapping does not replace the regulatory mapping or environmental values specifically called up under other laws or regulations. Similarly, the SPP biodiversity policy does not override or replace specific requirements of other Acts or regulations.

The Queensland Government's "Method for mapping - matters of state environmental significance for use in land use planning and development assessment" can be downloaded from:

http://www.ehp.qld.gov.au/land/natural-resource/method-mapping-mses.html .

Appendix 2 - Source Data

The datasets listed below are available on request from:

http://qldspatial.information.qld.gov.au/catalogue/custom/index.page

- Matters of State environmental significance

Note: MSES mapping is not based on new or unique data. The primary mapping product draws data from a number of underlying environment databases and geo-referenced information sources. MSES mapping is a versioned product that is updated generally on a twice-yearly basis to incorporate the changes to underlying data sources. Several components of MSES mapping made for the current version may differ from the current underlying data sources. To ensure accuracy, or proper representation of MSES values, it is strongly recommended that users refer to the underlying data sources and review the current definition of MSES in the State Planning Policy, before applying the MSES mapping.

Individual MSES layers can be attributed to the following source data available at QSpatial:

MSES layers	**current QSpatial data (http://qspatial.ingormation.qld.gov.au)**
Protected Areas-Estates and Nature Refuges	- Protected areas of Queensland - Nature Refuges - Queensland
Marine Park-Highly Protected Zones	Moreton Bay marine park zoning 2008
Fish Habitat Areas	Queensland fish habitat areas
Strategic Environmental Areas-designated	Regional Planning Interests Act - Strategic Environmental Areas
HES wetlands	Map of Referable Wetland - wetland layers: - Wetland management area wetlands - Wetland protection area wetlands
wetlands in HEV waters	HEV waters: - EPP Water (multiple locations) intent for waters Source Wetlands: - Queensland Wetland Mapping (Current version 4, 2015) Source Watercourses: - Vegetation management watercourse and drainage feature map (1:100000 and 1:250000) - latest version 1.4
Wildlife habitat (threatened and special least concern)	-WildNet database species records - habitat suitability models (various)
VMA regulated regional ecosystems	Vegetation management regional ecosystem and remnant map - latest version 8.0
VMA Essential Habitat	Vegetation management - essential habitat map - latest version 4.41
VMA Wetlands	Vegetation management wetlands map - latest version 2.41
Legally secured offsets	Vegetation Management Act property maps of assessable vegetation. For offset register data-contact DES
Regulated Vegetation Map	Vegetation management - regulated vegetation management map - latest version 1.41

Appendix 3 - Acronyms and Abbreviations

AOI	- Area of Interest
DES	- Department of Environment and Science
EP Act	- *Environmental Protection Act 1994*
EPP	- Environmental Protection Policy
GDA94	- Geocentric Datum of Australia 1994
GEM	- General Environmental Matters
GIS	- Geographic Information System
MSES	- Matters of State Environmental Significance
NCA	- *Nature Conservation Act 1992*
RE	- Regional Ecosystem
SPP	- State Planning Policy
VMA	- *Vegetation Management Act 1999*

Australian Government
Department of the Environment and Energy

EPBC Act Protected Matters Report

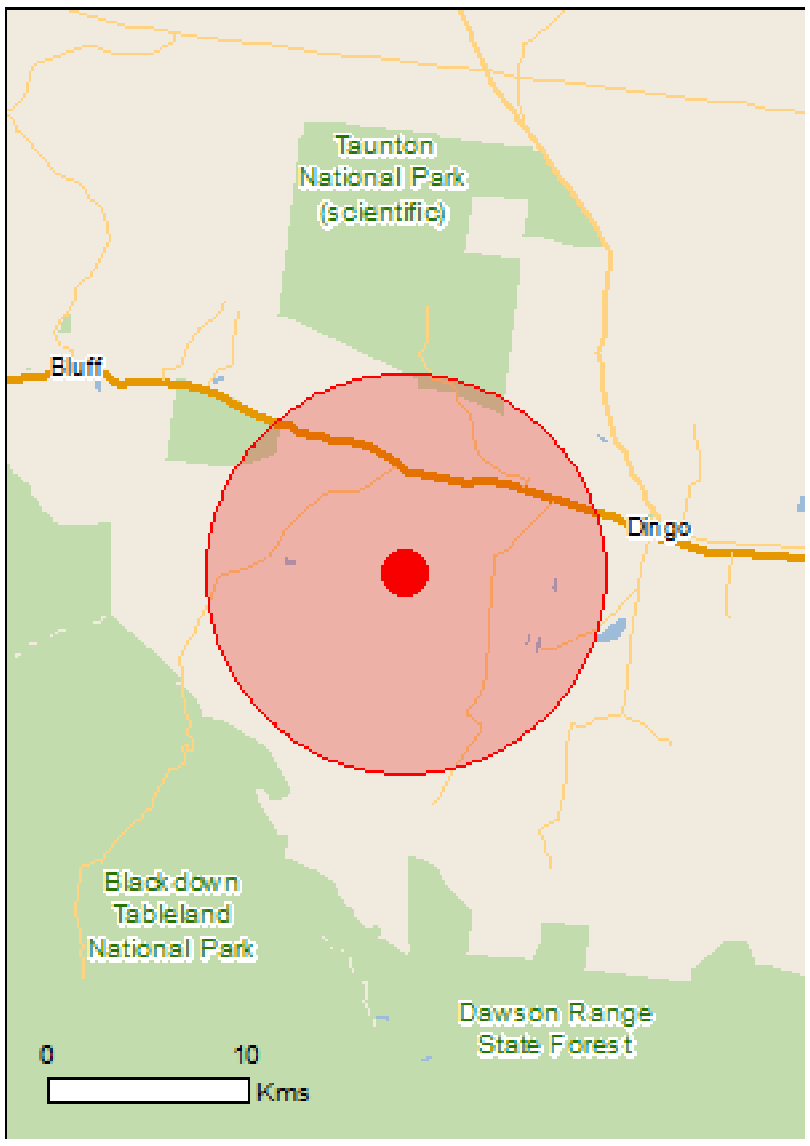
This report provides general guidance on matters of national environmental significance and other matters protected by the EPBC Act in the area you have selected.

Information on the coverage of this report and qualifications on data supporting this report are contained in the caveat at the end of the report.

Information is available about Environment Assessments and the EPBC Act including significance guidelines, forms and application process details.

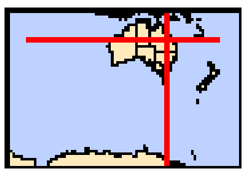
Report created: 03/06/19 10:44:27

- Summary
- Details
  - Matters of NES
  - Other Matters Protected by the EPBC Act
  - Extra Information
- Caveat
- Acknowledgements



This map may contain data which are ©Commonwealth of Australia (Geoscience Australia), ©PSMA 2010

Coordinates
Buffer: 10.0Km



Summary

Matters of National Environmental Significance

This part of the report summarises the matters of national environmental significance that may occur in, or may relate to, the area you nominated. Further information is available in the detail part of the report, which can be accessed by scrolling or following the links below. If you are proposing to undertake an activity that may have a significant impact on one or more matters of national environmental significance then you should consider the Administrative Guidelines on Significance.

World Heritage Properties:	None
National Heritage Places:	None
Wetlands of International Importance:	None
Great Barrier Reef Marine Park:	None
Commonwealth Marine Area:	None
Listed Threatened Ecological Communities:	3
Listed Threatened Species:	25
Listed Migratory Species:	12

Other Matters Protected by the EPBC Act

This part of the report summarises other matters protected under the Act that may relate to the area you nominated. Approval may be required for a proposed activity that significantly affects the environment on Commonwealth land, when the action is outside the Commonwealth land, or the environment anywhere when the action is taken on Commonwealth land. Approval may also be required for the Commonwealth or Commonwealth agencies proposing to take an action that is likely to have a significant impact on the environment anywhere.

The EPBC Act protects the environment on Commonwealth land, the environment from the actions taken on Commonwealth land, and the environment from actions taken by Commonwealth agencies. As heritage values of a place are part of the 'environment', these aspects of the EPBC Act protect the Commonwealth Heritage values of a Commonwealth Heritage place. Information on the new heritage laws can be found at http://www.environment.gov.au/heritage

A permit may be required for activities in or on a Commonwealth area that may affect a member of a listed threatened species or ecological community, a member of a listed migratory species, whales and other cetaceans, or a member of a listed marine species.

Commonwealth Land:	None
Commonwealth Heritage Places:	None
Listed Marine Species:	18
Whales and Other Cetaceans:	None
Critical Habitats:	None
Commonwealth Reserves Terrestrial:	None
Australian Marine Parks:	None

Extra Information

This part of the report provides information that may also be relevant to the area you have nominated.

State and Territory Reserves:	2
Regional Forest Agreements:	None
Invasive Species:	21
Nationally Important Wetlands:	None
Key Ecological Features (Marine)	None

Details

Matters of National Environmental Significance

Listed Threatened Ecological Communities [Resource Information]

For threatened ecological communities where the distribution is well known, maps are derived from recovery plans, State vegetation maps, remote sensing imagery and other sources. Where threatened ecological community distributions are less well known, existing vegetation maps and point location data are used to produce indicative distribution maps.

Name	Status	Type of Presence
Brigalow (Acacia harpophylla dominant and co-dominant)	Endangered	Community known to occur within area
Coolibah - Black Box Woodlands of the Darling Riverine Plains and the Brigalow Belt South Bioregions	Endangered	Community may occur within area
Weeping Myall Woodlands	Endangered	Community likely to occur within area

Listed Threatened Species [Resource Information]

Name	Status	Type of Presence
Birds		
Calidris ferruginea Curlew Sandpiper [856]	Critically Endangered	Species or species habitat may occur within area
Erythrotriorchis radiatus Red Goshawk [942]	Vulnerable	Species or species habitat known to occur within area
Geophaps scripta scripta Squatter Pigeon (southern) [64440]	Vulnerable	Species or species habitat known to occur within area
Grantiella picta Painted Honeyeater [470]	Vulnerable	Species or species habitat may occur within area
Neochmia ruficauda ruficauda Star Finch (eastern), Star Finch (southern) [26027]	Endangered	Species or species habitat likely to occur within area
Poephila cincta cincta Southern Black-throated Finch [64447]	Endangered	Species or species habitat may occur within area
Rostratula australis Australian Painted-snipe, Australian Painted Snipe [77037]	Endangered	Species or species habitat may occur within area
Turnix melanogaster Black-breasted Button-quail [923]	Vulnerable	Species or species habitat may occur within area
Fish		
Maccullochella peelii Murray Cod [66633]	Vulnerable	Species or species habitat may occur within area
Mammals		

Name	Status	Type of Presence
Chalinolobus dwyeri Large-eared Pied Bat, Large Pied Bat [183]	Vulnerable	Species or species habitat may occur within area
Dasyurus hallucatus Northern Quoll, Digul [Gogo-Yimidir], Wijingadda [Dambimangari], Wiminji [Martu] [331]	Endangered	Species or species habitat likely to occur within area
Macroderma gigas Ghost Bat [174]	Vulnerable	Species or species habitat likely to occur within area
Nyctophilus corbeni Corben's Long-eared Bat, South-eastern Long-eared Bat [83395]	Vulnerable	Species or species habitat may occur within area
Onychogalea fraenata Bridled Nail-tail Wallaby, Bridled Nailtail Wallaby [239]	Endangered	Species or species habitat known to occur within area
Petauroides volans Greater Glider [254]	Vulnerable	Species or species habitat likely to occur within area
Phascolarctos cinereus (combined populations of Qld, NSW and the ACT) Koala (combined populations of Queensland, New South Wales and the Australian Capital Territory) [85104]	Vulnerable	Species or species habitat likely to occur within area
Plants		
Cadellia pentastylis Ooline [9828]	Vulnerable	Species or species habitat likely to occur within area
Dichanthium setosum bluegrass [14159]	Vulnerable	Species or species habitat likely to occur within area
Logania diffusa [24159]	Vulnerable	Species or species habitat likely to occur within area
Reptiles		
Delma torquata Adorned Delma, Collared Delma [1656]	Vulnerable	Species or species habitat likely to occur within area
Denisonia maculata Ornamental Snake [1193]	Vulnerable	Species or species habitat may occur within area
Egernia rugosa Yakka Skink [1420]	Vulnerable	Species or species habitat may occur within area
Elseya albagula Southern Snapping Turtle, White-throated Snapping Turtle [81648]	Critically Endangered	Species or species habitat likely to occur within area
Furina dunmalli Dunmall's Snake [59254]	Vulnerable	Species or species habitat may occur within area
Rheodytes leukops Fitzroy River Turtle, Fitzroy Tortoise, Fitzroy Turtle, White-eyed River Diver [1761]	Vulnerable	Species or species habitat likely to occur within area

Listed Migratory Species [Resource Information]

* Species is listed under a different scientific name on the EPBC Act - Threatened Species list.

Name	Threatened	Type of Presence
Migratory Marine Birds		

Name	Threatened	Type of Presence
Apus pacificus Fork-tailed Swift [678]		Species or species habitat likely to occur within area
Migratory Terrestrial Species		
Cuculus optatus Oriental Cuckoo, Horsfield's Cuckoo [86651]		Species or species habitat may occur within area
Monarcha melanopsis Black-faced Monarch [609]		Species or species habitat likely to occur within area
Motacilla flava Yellow Wagtail [644]		Species or species habitat may occur within area
Myiagra cyanoleuca Satin Flycatcher [612]		Species or species habitat may occur within area
Rhipidura rufifrons Rufous Fantail [592]		Species or species habitat may occur within area
Migratory Wetlands Species		
Actitis hypoleucos Common Sandpiper [59309]		Species or species habitat may occur within area
Calidris acuminata Sharp-tailed Sandpiper [874]		Species or species habitat may occur within area
Calidris ferruginea Curlew Sandpiper [856]	Critically Endangered	Species or species habitat may occur within area
Calidris melanotos Pectoral Sandpiper [858]		Species or species habitat may occur within area
Gallinago hardwickii Latham's Snipe, Japanese Snipe [863]		Species or species habitat may occur within area
Pandion haliaetus Osprey [952]		Species or species habitat likely to occur within area

Other Matters Protected by the EPBC Act

Listed Marine Species

[Resource Information]

* Species is listed under a different scientific name on the EPBC Act - Threatened Species list.

Name	Threatened	Type of Presence
Birds		
Actitis hypoleucos Common Sandpiper [59309]		Species or species habitat may occur within area
Anseranas semipalmata Magpie Goose [978]		Species or species habitat may occur within area
Apus pacificus Fork-tailed Swift [678]		Species or species habitat likely to occur

Name	Threatened	Type of Presence
		within area
Ardea alba Great Egret, White Egret [59541]		Species or species habitat likely to occur within area
Ardea ibis Cattle Egret [59542]		Species or species habitat may occur within area
Calidris acuminata Sharp-tailed Sandpiper [874]		Species or species habitat may occur within area
Calidris ferruginea Curlew Sandpiper [856]	Critically Endangered	Species or species habitat may occur within area
Calidris melanotos Pectoral Sandpiper [858]		Species or species habitat may occur within area
Chrysococcyx osculans Black-eared Cuckoo [705]		Species or species habitat likely to occur within area
Gallinago hardwickii Latham's Snipe, Japanese Snipe [863]		Species or species habitat may occur within area
Haliaeetus leucogaster White-bellied Sea-Eagle [943]		Species or species habitat likely to occur within area
Merops ornatus Rainbow Bee-eater [670]		Species or species habitat may occur within area
Monarcha melanopsis Black-faced Monarch [609]		Species or species habitat likely to occur within area
Motacilla flava Yellow Wagtail [644]		Species or species habitat may occur within area
Myiagra cyanoleuca Satin Flycatcher [612]		Species or species habitat may occur within area
Pandion haliaetus Osprey [952]		Species or species habitat likely to occur within area
Rhipidura rufifrons Rufous Fantail [592]		Species or species habitat may occur within area
Rostratula benghalensis (sensu lato) Painted Snipe [889]	Endangered*	Species or species habitat may occur within area

Extra Information

State and Territory Reserves [Resource Information]

Name	State
Taunton	QLD
Wallaby Lane	QLD

Invasive Species [Resource Information]

Weeds reported here are the 20 species of national significance (WoNS), along with other introduced plants that are considered by the States and Territories to pose a particularly significant threat to biodiversity. The following feral animals are reported: Goat, Red Fox, Cat, Rabbit, Pig, Water Buffalo and Cane Toad. Maps from Landscape Health Project, National Land and Water Resouces Audit, 2001.

Name	Status	Type of Presence
Birds		
Columba livia Rock Pigeon, Rock Dove, Domestic Pigeon [803]		Species or species habitat likely to occur within area
Passer domesticus House Sparrow [405]		Species or species habitat likely to occur within area
Streptopelia chinensis Spotted Turtle-Dove [780]		Species or species habitat likely to occur within area
Sturnus vulgaris Common Starling [389]		Species or species habitat likely to occur within area
Frogs		
Rhinella marina Cane Toad [83218]		Species or species habitat known to occur within area
Mammals		
Bos taurus Domestic Cattle [16]		Species or species habitat likely to occur within area
Canis lupus familiaris Domestic Dog [82654]		Species or species habitat likely to occur within area
Felis catus Cat, House Cat, Domestic Cat [19]		Species or species habitat likely to occur within area
Lepus capensis Brown Hare [127]		Species or species habitat likely to occur within area
Mus musculus House Mouse [120]		Species or species habitat likely to occur within area
Oryctolagus cuniculus Rabbit, European Rabbit [128]		Species or species habitat likely to occur within area
Rattus rattus Black Rat, Ship Rat [84]		Species or species habitat likely to occur within area
Sus scrofa Pig [6]		Species or species habitat likely to occur within area

Name	Status	Type of Presence
Vulpes vulpes Red Fox, Fox [18]		Species or species habitat likely to occur within area
Plants		
Acacia nilotica subsp. indica Prickly Acacia [6196]		Species or species habitat may occur within area
Cryptostegia grandiflora Rubber Vine, Rubbervine, India Rubber Vine, India Rubbervine, Palay Rubbervine, Purple Allamanda [18913]		Species or species habitat likely to occur within area
Jatropha gossypifolia Cotton-leaved Physic-Nut, Bellyache Bush, Cotton-leaf Physic Nut, Cotton-leaf Jatropha, Black Physic Nut [7507]		Species or species habitat likely to occur within area
Opuntia spp. Prickly Pears [82753]		Species or species habitat likely to occur within area
Parkinsonia aculeata Parkinsonia, Jerusalem Thorn, Jelly Bean Tree, Horse Bean [12301]		Species or species habitat likely to occur within area
Parthenium hysterophorus Parthenium Weed, Bitter Weed, Carrot Grass, False Ragweed [19566]		Species or species habitat likely to occur within area
Vachellia nilotica Prickly Acacia, Blackthorn, Prickly Mimosa, Black Piquant, Babul [84351]		Species or species habitat likely to occur within area

Caveat

The information presented in this report has been provided by a range of data sources as acknowledged at the end of the report.

This report is designed to assist in identifying the locations of places which may be relevant in determining obligations under the Environment Protection and Biodiversity Conservation Act 1999. It holds mapped locations of World and National Heritage properties, Wetlands of International and National Importance, Commonwealth and State/Territory reserves, listed threatened, migratory and marine species and listed threatened ecological communities. Mapping of Commonwealth land is not complete at this stage. Maps have been collated from a range of sources at various resolutions.

Not all species listed under the EPBC Act have been mapped (see below) and therefore a report is a general guide only. Where available data supports mapping, the type of presence that can be determined from the data is indicated in general terms. People using this information in making a referral may need to consider the qualifications below and may need to seek and consider other information sources.

For threatened ecological communities where the distribution is well known, maps are derived from recovery plans, State vegetation maps, remote sensing imagery and other sources. Where threatened ecological community distributions are less well known, existing vegetation maps and point location data are used to produce indicative distribution maps.

Threatened, migratory and marine species distributions have been derived through a variety of methods. Where distributions are well known and if time permits, maps are derived using either thematic spatial data (i.e. vegetation, soils, geology, elevation, aspect, terrain, etc) together with point locations and described habitat; or environmental modelling (MAXENT or BIOCLIM habitat modelling) using point locations and environmental data layers.

Where very little information is available for species or large number of maps are required in a short time-frame, maps are derived either from 0.04 or 0.02 decimal degree cells; by an automated process using polygon capture techniques (static two kilometre grid cells, alpha-hull and convex hull); or captured manually or by using topographic features (national park boundaries, islands, etc). In the early stages of the distribution mapping process (1999-early 2000s) distributions were defined by degree blocks, 100K or 250K map sheets to rapidly create distribution maps. More reliable distribution mapping methods are used to update these distributions as time permits.

Only selected species covered by the following provisions of the EPBC Act have been mapped:

- migratory and
- marine

The following species and ecological communities have not been mapped and do not appear in reports produced from this database:

- threatened species listed as extinct or considered as vagrants
- some species and ecological communities that have only recently been listed
- some terrestrial species that overfly the Commonwealth marine area
- migratory species that are very widespread, vagrant, or only occur in small numbers

The following groups have been mapped, but may not cover the complete distribution of the species:

- non-threatened seabirds which have only been mapped for recorded breeding sites
- seals which have only been mapped for breeding sites near the Australian continent

Such breeding sites may be important for the protection of the Commonwealth Marine environment.

Coordinates

-23.66512 149.21782

Acknowledgements

This database has been compiled from a range of data sources. The department acknowledges the following custodians who have contributed valuable data and advice:

-Office of Environment and Heritage, New South Wales
-Department of Environment and Primary Industries, Victoria
-Department of Primary Industries, Parks, Water and Environment, Tasmania
-Department of Environment, Water and Natural Resources, South Australia
-Department of Land and Resource Management, Northern Territory
-Department of Environmental and Heritage Protection, Queensland
-Department of Parks and Wildlife, Western Australia
-Environment and Planning Directorate, ACT
-Birdlife Australia
-Australian Bird and Bat Banding Scheme
-Australian National Wildlife Collection
-Natural history museums of Australia
-Museum Victoria
-Australian Museum
-South Australian Museum
-Queensland Museum
-Online Zoological Collections of Australian Museums
-Queensland Herbarium
-National Herbarium of NSW
-Royal Botanic Gardens and National Herbarium of Victoria
-Tasmanian Herbarium
-State Herbarium of South Australia
-Northern Territory Herbarium
-Western Australian Herbarium
-Australian National Herbarium, Canberra
-University of New England
-Ocean Biogeographic Information System
-Australian Government, Department of Defence
Forestry Corporation, NSW
-Geoscience Australia
-CSIRO
-Australian Tropical Herbarium, Cairns
-eBird Australia
-Australian Government – Australian Antarctic Data Centre
-Museum and Art Gallery of the Northern Territory
-Australian Government National Environmental Science Program
-Australian Institute of Marine Science
-Reef Life Survey Australia
-American Museum of Natural History
-Queen Victoria Museum and Art Gallery, Inveresk, Tasmania
-Tasmanian Museum and Art Gallery, Hobart, Tasmania
-Other groups and individuals

The Department is extremely grateful to the many organisations and individuals who provided expert advice and information on numerous draft distributions.

Please feel free to provide feedback via the Contact Us page.

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Australian Government

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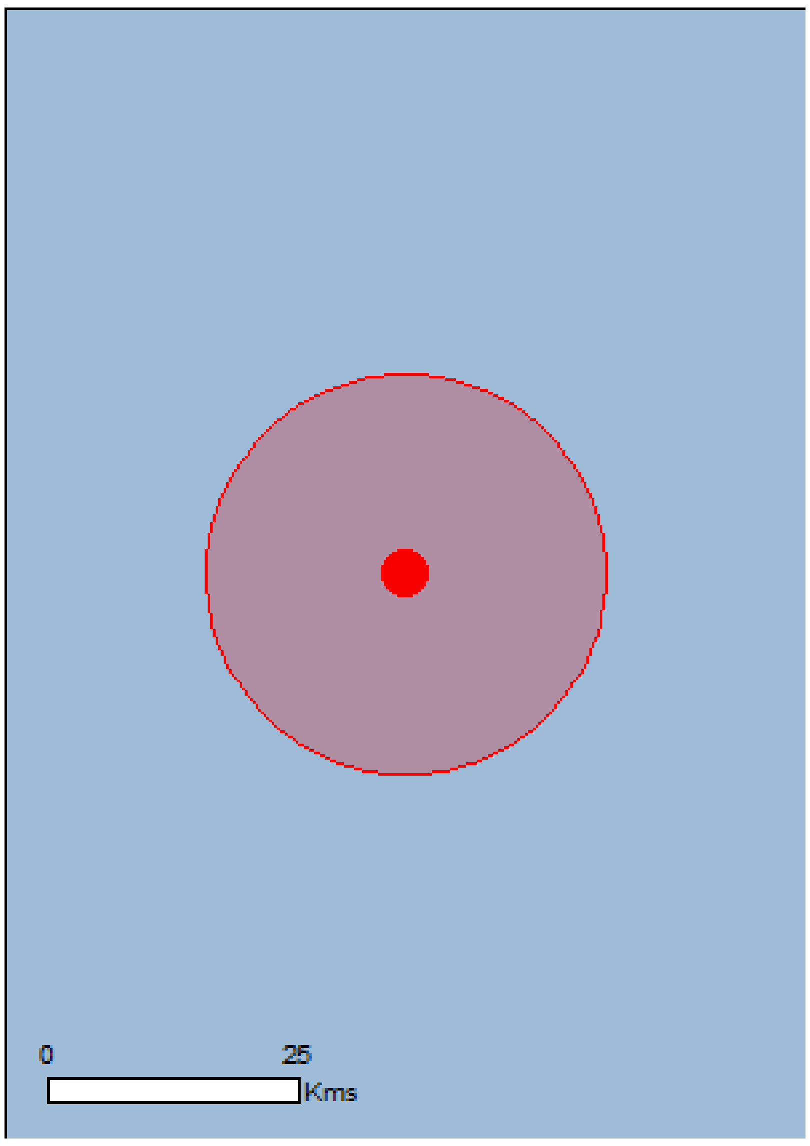

Coordinates

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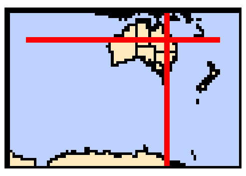

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World Heritage Properties:	None
National Heritage Places:	None
Wetlands of International Importance:	None
Great Barrier Reef Marine Park:	None
Commonwealth Marine Area:	None
Listed Threatened Ecological Communities:	4
Listed Threatened Species:	28
Listed Migratory Species:	15

Other Matters Protected by the EPBC Act

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A permit may be required for activities in or on a Commonwealth area that may affect a member of a listed threatened species or ecological community, a member of a listed migratory species, whales and other cetaceans, or a member of a listed marine species.

Commonwealth Land:	None
Commonwealth Heritage Places:	None
Listed Marine Species:	21
Whales and Other Cetaceans:	None
Critical Habitats:	None
Commonwealth Reserves Terrestrial:	None
Australian Marine Parks:	None

Extra Information

This part of the report provides information that may also be relevant to the area you have nominated.

State and Territory Reserves:	4
Regional Forest Agreements:	None
Invasive Species:	21
Nationally Important Wetlands:	None
Key Ecological Features (Marine)	None

Details

Matters of National Environmental Significance

Listed Threatened Ecological Communities [Resource Information]

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Name	Status	Type of Presence
Brigalow (Acacia harpophylla dominant and co-dominant)	Endangered	Community known to occur within area
Coolibah - Black Box Woodlands of the Darling Riverine Plains and the Brigalow Belt South Bioregions	Endangered	Community may occur within area
Natural Grasslands of the Queensland Central Highlands and northern Fitzroy Basin	Endangered	Community likely to occur within area
Weeping Myall Woodlands	Endangered	Community likely to occur within area

Listed Threatened Species [Resource Information]

Name	Status	Type of Presence
Birds		
Calidris ferruginea Curlew Sandpiper [856]	Critically Endangered	Species or species habitat may occur within area
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Rostratula australis Australian Painted-snipe, Australian Painted Snipe [77037]	Endangered	Species or species habitat may occur within area
Turnix melanogaster Black-breasted Button-quail [923]	Vulnerable	Species or species habitat likely to occur within area
Fish		
Maccullochella peelii Murray Cod [66633]	Vulnerable	Species or species habitat may occur within

Name	Status	Type of Presence
		area
Mammals		
Chalinolobus dwyeri Large-eared Pied Bat, Large Pied Bat [183]	Vulnerable	Species or species habitat likely to occur within area
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Nyctophilus corbeni Corben's Long-eared Bat, South-eastern Long-eared Bat [83395]	Vulnerable	Species or species habitat may occur within area
Onychogalea fraenata Bridled Nail-tail Wallaby, Bridled Nailtail Wallaby [239]	Endangered	Species or species habitat known to occur within area
Petauroides volans Greater Glider [254]	Vulnerable	Species or species habitat known to occur within area
Phascolarctos cinereus (combined populations of Qld, NSW and the ACT) Koala (combined populations of Queensland, New South Wales and the Australian Capital Territory) [85104]	Vulnerable	Species or species habitat known to occur within area
Plants		
Cadellia pentastylis Ooline [9828]	Vulnerable	Species or species habitat likely to occur within area
Daviesia discolor [3567]	Vulnerable	Species or species habitat likely to occur within area
Dichanthium setosum bluegrass [14159]	Vulnerable	Species or species habitat likely to occur within area
Homoranthus decumbens a shrub [55186]	Endangered	Species or species habitat may occur within area
Logania diffusa [24159]	Vulnerable	Species or species habitat likely to occur within area
Macrozamia platyrhachis cycad [3412]	Endangered	Species or species habitat likely to occur within area
Reptiles		
Delma torquata Adorned Delma, Collared Delma [1656]	Vulnerable	Species or species habitat known to occur within area
Denisonia maculata Ornamental Snake [1193]	Vulnerable	Species or species habitat known to occur within area
Egernia rugosa Yakka Skink [1420]	Vulnerable	Species or species habitat known to occur within area
Elseya albagula Southern Snapping Turtle, White-throated Snapping Turtle [81648]	Critically Endangered	Species or species habitat likely to occur within area

Name	Status	Type of Presence
Furina dunmalli Dunmall's Snake [59254]	Vulnerable	Species or species habitat may occur within area
Rheodytes leukops Fitzroy River Turtle, Fitzroy Tortoise, Fitzroy Turtle, White-eyed River Diver [1761]	Vulnerable	Species or species habitat likely to occur within area

Listed Migratory Species [Resource Information]

* Species is listed under a different scientific name on the EPBC Act - Threatened Species list.

Name	Threatened	Type of Presence
Migratory Marine Birds		
Apus pacificus Fork-tailed Swift [678]		Species or species habitat likely to occur within area
Migratory Marine Species		
Crocodylus porosus Salt-water Crocodile, Estuarine Crocodile [1774]		Species or species habitat likely to occur within area
Migratory Terrestrial Species		
Cuculus optatus Oriental Cuckoo, Horsfield's Cuckoo [86651]		Species or species habitat may occur within area
Hirundapus caudacutus White-throated Needletail [682]		Species or species habitat known to occur within area
Monarcha melanopsis Black-faced Monarch [609]		Species or species habitat likely to occur within area
Monarcha trivirgatus Spectacled Monarch [610]		Species or species habitat may occur within area
Motacilla flava Yellow Wagtail [644]		Species or species habitat may occur within area
Myiagra cyanoleuca Satin Flycatcher [612]		Species or species habitat may occur within area
Rhipidura rufifrons Rufous Fantail [592]		Species or species habitat may occur within area
Migratory Wetlands Species		
Actitis hypoleucos Common Sandpiper [59309]		Species or species habitat may occur within area
Calidris acuminata Sharp-tailed Sandpiper [874]		Species or species habitat may occur within area
Calidris ferruginea Curlew Sandpiper [856]	Critically Endangered	Species or species habitat may occur within area
Calidris melanotos Pectoral Sandpiper [858]		Species or species habitat may occur within area
Gallinago hardwickii Latham's Snipe, Japanese Snipe [863]		Species or species habitat may occur within area

Name	Threatened	Type of Presence
Pandion haliaetus Osprey [952]		Species or species habitat likely to occur within area

Other Matters Protected by the EPBC Act

Listed Marine Species [Resource Information]

* Species is listed under a different scientific name on the EPBC Act - Threatened Species list.

Name	Threatened	Type of Presence
Birds		
Actitis hypoleucos Common Sandpiper [59309]		Species or species habitat may occur within area
Anseranas semipalmata Magpie Goose [978]		Species or species habitat may occur within area
Apus pacificus Fork-tailed Swift [678]		Species or species habitat likely to occur within area
Ardea alba Great Egret, White Egret [59541]		Species or species habitat known to occur within area
Ardea ibis Cattle Egret [59542]		Species or species habitat may occur within area
Calidris acuminata Sharp-tailed Sandpiper [874]		Species or species habitat may occur within area
Calidris ferruginea Curlew Sandpiper [856]	Critically Endangered	Species or species habitat may occur within area
Calidris melanotos Pectoral Sandpiper [858]		Species or species habitat may occur within area
Chrysococcyx osculans Black-eared Cuckoo [705]		Species or species habitat likely to occur within area
Gallinago hardwickii Latham's Snipe, Japanese Snipe [863]		Species or species habitat may occur within area

Name	Threatened	Type of Presence
Haliaeetus leucogaster White-bellied Sea-Eagle [943]		Species or species habitat likely to occur within area
Hirundapus caudacutus White-throated Needletail [682]		Species or species habitat known to occur within area
Merops ornatus Rainbow Bee-eater [670]		Species or species habitat may occur within area
Monarcha melanopsis Black-faced Monarch [609]		Species or species habitat likely to occur within area
Monarcha trivirgatus Spectacled Monarch [610]		Species or species habitat may occur within area
Motacilla flava Yellow Wagtail [644]		Species or species habitat may occur within area
Myiagra cyanoleuca Satin Flycatcher [612]		Species or species habitat may occur within area
Pandion haliaetus Osprey [952]		Species or species habitat likely to occur within area
Rhipidura rufifrons Rufous Fantail [592]		Species or species habitat may occur within area
Rostratula benghalensis (sensu lato) Painted Snipe [889]	Endangered*	Species or species habitat may occur within area
Reptiles		
Crocodylus porosus Salt-water Crocodile, Estuarine Crocodile [1774]		Species or species habitat likely to occur within area

Extra Information

State and Territory Reserves [Resource Information]

Name	State
Blackdown Tableland	QLD
Ghungalu	QLD
Taunton	QLD
Wallaby Lane	QLD

Invasive Species [Resource Information]

Weeds reported here are the 20 species of national significance (WoNS), along with other introduced plants that are considered by the States and Territories to pose a particularly significant threat to biodiversity. The following feral animals are reported: Goat, Red Fox, Cat, Rabbit, Pig, Water Buffalo and Cane Toad. Maps from Landscape Health Project, National Land and Water Resouces Audit, 2001.

Name	Status	Type of Presence
Birds		
Columba livia Rock Pigeon, Rock Dove, Domestic Pigeon [803]		Species or species habitat likely to occur within area
Passer domesticus House Sparrow [405]		Species or species

Name	Status	Type of Presence
		habitat likely to occur within area
Streptopelia chinensis Spotted Turtle-Dove [780]		Species or species habitat likely to occur within area
Sturnus vulgaris Common Starling [389]		Species or species habitat likely to occur within area
Frogs		
Rhinella marina Cane Toad [83218]		Species or species habitat known to occur within area
Mammals		
Bos taurus Domestic Cattle [16]		Species or species habitat likely to occur within area
Canis lupus familiaris Domestic Dog [82654]		Species or species habitat likely to occur within area
Felis catus Cat, House Cat, Domestic Cat [19]		Species or species habitat likely to occur within area
Lepus capensis Brown Hare [127]		Species or species habitat likely to occur within area
Mus musculus House Mouse [120]		Species or species habitat likely to occur within area
Oryctolagus cuniculus Rabbit, European Rabbit [128]		Species or species habitat likely to occur within area
Rattus rattus Black Rat, Ship Rat [84]		Species or species habitat likely to occur within area
Sus scrofa Pig [6]		Species or species habitat likely to occur within area
Vulpes vulpes Red Fox, Fox [18]		Species or species habitat likely to occur within area
Plants		
Acacia nilotica subsp. indica Prickly Acacia [6196]		Species or species habitat may occur within area
Cryptostegia grandiflora Rubber Vine, Rubbervine, India Rubber Vine, India Rubbervine, Palay Rubbervine, Purple Allamanda [18913]		Species or species habitat likely to occur within area
Jatropha gossypifolia Cotton-leaved Physic-Nut, Bellyache Bush, Cotton-leaf Physic Nut, Cotton-leaf Jatropha, Black Physic Nut [7507]		Species or species habitat likely to occur within area
Opuntia spp. Prickly Pears [82753]		Species or species habitat likely to occur within area
Parkinsonia aculeata Parkinsonia, Jerusalem Thorn, Jelly Bean Tree, Horse Bean [12301]		Species or species habitat likely to occur within area

Name	Status	Type of Presence
Parthenium hysterophorus		
Parthenium Weed, Bitter Weed, Carrot Grass, False Ragweed [19566]		Species or species habitat likely to occur within area
Vachellia nilotica		
Prickly Acacia, Blackthorn, Prickly Mimosa, Black Piquant, Babul [84351]		Species or species habitat likely to occur within area

Caveat

The information presented in this report has been provided by a range of data sources as acknowledged at the end of the report.

This report is designed to assist in identifying the locations of places which may be relevant in determining obligations under the Environment Protection and Biodiversity Conservation Act 1999. It holds mapped locations of World and National Heritage properties, Wetlands of International and National Importance, Commonwealth and State/Territory reserves, listed threatened, migratory and marine species and listed threatened ecological communities. Mapping of Commonwealth land is not complete at this stage. Maps have been collated from a range of sources at various resolutions.

Not all species listed under the EPBC Act have been mapped (see below) and therefore a report is a general guide only. Where available data supports mapping, the type of presence that can be determined from the data is indicated in general terms. People using this information in making a referral may need to consider the qualifications below and may need to seek and consider other information sources.

For threatened ecological communities where the distribution is well known, maps are derived from recovery plans, State vegetation maps, remote sensing imagery and other sources. Where threatened ecological community distributions are less well known, existing vegetation maps and point location data are used to produce indicative distribution maps.

Threatened, migratory and marine species distributions have been derived through a variety of methods. Where distributions are well known and if time permits, maps are derived using either thematic spatial data (i.e. vegetation, soils, geology, elevation, aspect, terrain, etc) together with point locations and described habitat; or environmental modelling (MAXENT or BIOCLIM habitat modelling) using point locations and environmental data layers.

Where very little information is available for species or large number of maps are required in a short time-frame, maps are derived either from 0.04 or 0.02 decimal degree cells; by an automated process using polygon capture techniques (static two kilometre grid cells, alpha-hull and convex hull); or captured manually or by using topographic features (national park boundaries, islands, etc). In the early stages of the distribution mapping process (1999-early 2000s) distributions were defined by degree blocks, 100K or 250K map sheets to rapidly create distribution maps. More reliable distribution mapping methods are used to update these distributions as time permits.

Only selected species covered by the following provisions of the EPBC Act have been mapped:

- migratory and
- marine

The following species and ecological communities have not been mapped and do not appear in reports produced from this database:

- threatened species listed as extinct or considered as vagrants
- some species and ecological communities that have only recently been listed
- some terrestrial species that overfly the Commonwealth marine area
- migratory species that are very widespread, vagrant, or only occur in small numbers

The following groups have been mapped, but may not cover the complete distribution of the species:

- non-threatened seabirds which have only been mapped for recorded breeding sites
- seals which have only been mapped for breeding sites near the Australian continent

Such breeding sites may be important for the protection of the Commonwealth Marine environment.

Coordinates

-23.66512 149.21782

Acknowledgements

This database has been compiled from a range of data sources. The department acknowledges the following custodians who have contributed valuable data and advice:

-Office of Environment and Heritage, New South Wales
-Department of Environment and Primary Industries, Victoria
-Department of Primary Industries, Parks, Water and Environment, Tasmania
-Department of Environment, Water and Natural Resources, South Australia
-Department of Land and Resource Management, Northern Territory
-Department of Environmental and Heritage Protection, Queensland
-Department of Parks and Wildlife, Western Australia
-Environment and Planning Directorate, ACT
-Birdlife Australia
-Australian Bird and Bat Banding Scheme
-Australian National Wildlife Collection
-Natural history museums of Australia
-Museum Victoria
-Australian Museum
-South Australian Museum
-Queensland Museum
-Online Zoological Collections of Australian Museums
-Queensland Herbarium
-National Herbarium of NSW
-Royal Botanic Gardens and National Herbarium of Victoria
-Tasmanian Herbarium
-State Herbarium of South Australia
-Northern Territory Herbarium
-Western Australian Herbarium
-Australian National Herbarium, Canberra
-University of New England
-Ocean Biogeographic Information System
-Australian Government, Department of Defence
Forestry Corporation, NSW
-Geoscience Australia
-CSIRO
-Australian Tropical Herbarium, Cairns
-eBird Australia
-Australian Government – Australian Antarctic Data Centre
-Museum and Art Gallery of the Northern Territory
-Australian Government National Environmental Science Program
-Australian Institute of Marine Science
-Reef Life Survey Australia
-American Museum of Natural History
-Queen Victoria Museum and Art Gallery, Inveresk, Tasmania
-Tasmanian Museum and Art Gallery, Hobart, Tasmania
-Other groups and individuals

The Department is extremely grateful to the many organisations and individuals who provided expert advice and information on numerous draft distributions.

Please feel free to provide feedback via the Contact Us page.

Australian Government
Department of the Environment and Energy

EPBC Act Protected Matters Report

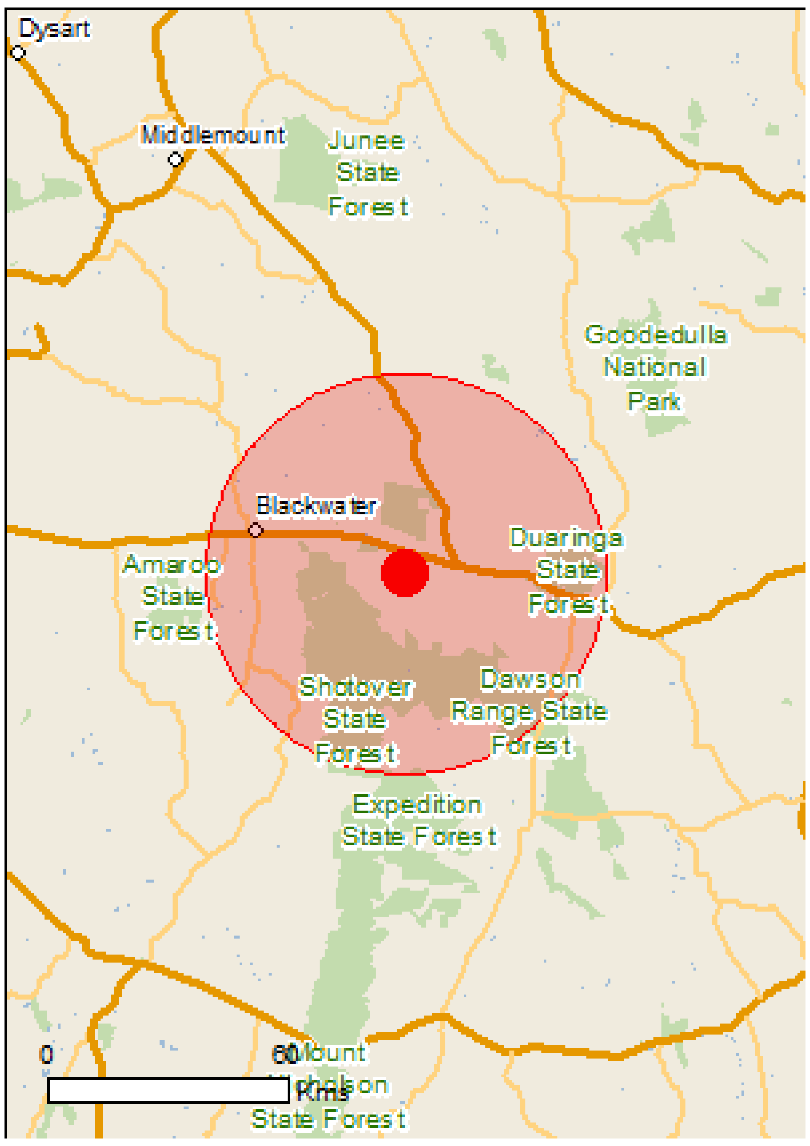
This report provides general guidance on matters of national environmental significance and other matters protected by the EPBC Act in the area you have selected.

Information on the coverage of this report and qualifications on data supporting this report are contained in the caveat at the end of the report.

Information is available about Environment Assessments and the EPBC Act including significance guidelines, forms and application process details.

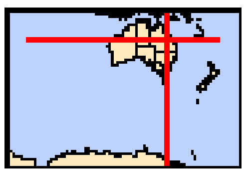
Report created: 03/06/19 09:45:56

- Summary
- Details
  - Matters of NES
  - Other Matters Protected by the EPBC Act
  - Extra Information
- Caveat
- Acknowledgements



This map may contain data which are ©Commonwealth of Australia (Geoscience Australia), ©PSMA 2010

Coordinates
Buffer: 50.0Km



Summary

Matters of National Environmental Significance

This part of the report summarises the matters of national environmental significance that may occur in, or may relate to, the area you nominated. Further information is available in the detail part of the report, which can be accessed by scrolling or following the links below. If you are proposing to undertake an activity that may have a significant impact on one or more matters of national environmental significance then you should consider the Administrative Guidelines on Significance.

World Heritage Properties:	None
National Heritage Places:	None
Wetlands of International Importance:	None
Great Barrier Reef Marine Park:	None
Commonwealth Marine Area:	None
Listed Threatened Ecological Communities:	5
Listed Threatened Species:	39
Listed Migratory Species:	16

Other Matters Protected by the EPBC Act

This part of the report summarises other matters protected under the Act that may relate to the area you nominated. Approval may be required for a proposed activity that significantly affects the environment on Commonwealth land, when the action is outside the Commonwealth land, or the environment anywhere when the action is taken on Commonwealth land. Approval may also be required for the Commonwealth or Commonwealth agencies proposing to take an action that is likely to have a significant impact on the environment anywhere.

The EPBC Act protects the environment on Commonwealth land, the environment from the actions taken on Commonwealth land, and the environment from actions taken by Commonwealth agencies. As heritage values of a place are part of the 'environment', these aspects of the EPBC Act protect the Commonwealth Heritage values of a Commonwealth Heritage place. Information on the new heritage laws can be found at http://www.environment.gov.au/heritage

A permit may be required for activities in or on a Commonwealth area that may affect a member of a listed threatened species or ecological community, a member of a listed migratory species, whales and other cetaceans, or a member of a listed marine species.

Commonwealth Land:	1
Commonwealth Heritage Places:	None
Listed Marine Species:	22
Whales and Other Cetaceans:	None
Critical Habitats:	None
Commonwealth Reserves Terrestrial:	None
Australian Marine Parks:	None

Extra Information

This part of the report provides information that may also be relevant to the area you have nominated.

State and Territory Reserves:	5
Regional Forest Agreements:	None
Invasive Species:	27
Nationally Important Wetlands:	None
Key Ecological Features (Marine)	None

Details

Matters of National Environmental Significance

Listed Threatened Ecological Communities [Resource Information]

For threatened ecological communities where the distribution is well known, maps are derived from recovery plans, State vegetation maps, remote sensing imagery and other sources. Where threatened ecological community distributions are less well known, existing vegetation maps and point location data are used to produce indicative distribution maps.

Name	Status	Type of Presence
Brigalow (Acacia harpophylla dominant and co-dominant)	Endangered	Community known to occur within area
Coolibah - Black Box Woodlands of the Darling Riverine Plains and the Brigalow Belt South Bioregions	Endangered	Community may occur within area
Natural Grasslands of the Queensland Central Highlands and northern Fitzroy Basin	Endangered	Community likely to occur within area
Semi-evergreen vine thickets of the Brigalow Belt (North and South) and Nandewar Bioregions	Endangered	Community likely to occur within area
Weeping Myall Woodlands	Endangered	Community likely to occur within area

Listed Threatened Species [Resource Information]

Name	Status	Type of Presence
Birds		
Calidris ferruginea Curlew Sandpiper [856]	Critically Endangered	Species or species habitat may occur within area
Erythrotriorchis radiatus Red Goshawk [942]	Vulnerable	Species or species habitat known to occur within area
Geophaps scripta scripta Squatter Pigeon (southern) [64440]	Vulnerable	Species or species habitat known to occur within area
Grantiella picta Painted Honeyeater [470]	Vulnerable	Species or species habitat may occur within area
Neochmia ruficauda ruficauda Star Finch (eastern), Star Finch (southern) [26027]	Endangered	Species or species habitat likely to occur within area
Numenius madagascariensis Eastern Curlew, Far Eastern Curlew [847]	Critically Endangered	Species or species habitat may occur within area
Poephila cincta cincta Southern Black-throated Finch [64447]	Endangered	Species or species habitat may occur within area
Rostratula australis Australian Painted-snipe, Australian Painted Snipe [77037]	Endangered	Species or species habitat likely to occur within area
Turnix melanogaster Black-breasted Button-quail [923]	Vulnerable	Species or species

Name	Status	Type of Presence
		habitat likely to occur within area
Fish		
Maccullochella peelii Murray Cod [66633]	Vulnerable	Species or species habitat may occur within area
Mammals		
Chalinolobus dwyeri Large-eared Pied Bat, Large Pied Bat [183]	Vulnerable	Species or species habitat likely to occur within area
Dasyurus hallucatus Northern Quoll, Digul [Gogo-Yimidir], Wijingadda [Dambimangari], Wiminji [Martu] [331]	Endangered	Species or species habitat likely to occur within area
Macroderma gigas Ghost Bat [174]	Vulnerable	Species or species habitat likely to occur within area
Nyctophilus corbeni Corben's Long-eared Bat, South-eastern Long-eared Bat [83395]	Vulnerable	Species or species habitat may occur within area
Onychogalea fraenata Bridled Nail-tail Wallaby, Bridled Nailtail Wallaby [239]	Endangered	Species or species habitat known to occur within area
Petauroides volans Greater Glider [254]	Vulnerable	Species or species habitat known to occur within area
Phascolarctos cinereus (combined populations of Qld, NSW and the ACT) Koala (combined populations of Queensland, New South Wales and the Australian Capital Territory) [85104]	Vulnerable	Species or species habitat known to occur within area
Pteropus poliocephalus Grey-headed Flying-fox [186]	Vulnerable	Foraging, feeding or related behaviour may occur within area
Plants		
Acacia grandifolia [3566]	Vulnerable	Species or species habitat known to occur within area
Aristida annua [17906]	Vulnerable	Species or species habitat likely to occur within area
Bertya opponens [13792]	Vulnerable	Species or species habitat likely to occur within area
Cadellia pentastylis Ooline [9828]	Vulnerable	Species or species habitat likely to occur within area
Cycas ophiolitica [55797]	Endangered	Species or species habitat likely to occur within area
Daviesia discolor [3567]	Vulnerable	Species or species habitat likely to occur within area
Dichanthium queenslandicum King Blue-grass [5481]	Endangered	Species or species habitat may occur within area
Dichanthium setosum bluegrass [14159]	Vulnerable	Species or species habitat likely to occur within area

Name	Status	Type of Presence
Eucalyptus raveretiana Black Ironbox [16344]	Vulnerable	Species or species habitat likely to occur within area
Homoranthus decumbens a shrub [55186]	Endangered	Species or species habitat known to occur within area
Logania diffusa [24159]	Vulnerable	Species or species habitat likely to occur within area
Macrozamia platyrhachis cycad [3412]	Endangered	Species or species habitat likely to occur within area
Phaius australis Lesser Swamp-orchid [5872]	Endangered	Species or species habitat known to occur within area
Solanum dissectum [75720]	Endangered	Species or species habitat known to occur within area
Solanum johnsonianum [84820]	Endangered	Species or species habitat may occur within area
Reptiles		
Delma torquata Adorned Delma, Collared Delma [1656]	Vulnerable	Species or species habitat known to occur within area
Denisonia maculata Ornamental Snake [1193]	Vulnerable	Species or species habitat known to occur within area
Egernia rugosa Yakka Skink [1420]	Vulnerable	Species or species habitat known to occur within area
Elseya albagula Southern Snapping Turtle, White-throated Snapping Turtle [81648]	Critically Endangered	Species or species habitat known to occur within area
Furina dunmalli Dunmall's Snake [59254]	Vulnerable	Species or species habitat may occur within area
Rheodytes leukops Fitzroy River Turtle, Fitzroy Tortoise, Fitzroy Turtle, White-eyed River Diver [1761]	Vulnerable	Species or species habitat likely to occur within area

Listed Migratory Species [Resource Information]

* Species is listed under a different scientific name on the EPBC Act - Threatened Species list.

Name	Threatened	Type of Presence
Migratory Marine Birds		
Apus pacificus Fork-tailed Swift [678]		Species or species habitat likely to occur within area
Migratory Marine Species		
Crocodylus porosus Salt-water Crocodile, Estuarine Crocodile [1774]		Species or species habitat likely to occur within area
Migratory Terrestrial Species		
Cuculus optatus Oriental Cuckoo, Horsfield's Cuckoo [86651]		Species or species habitat may occur within area

Name	Threatened	Type of Presence
Hirundapus caudacutus White-throated Needletail [682]		Species or species habitat known to occur within area
Monarcha melanopsis Black-faced Monarch [609]		Species or species habitat likely to occur within area
Monarcha trivirgatus Spectacled Monarch [610]		Species or species habitat may occur within area
Motacilla flava Yellow Wagtail [644]		Species or species habitat may occur within area
Myiagra cyanoleuca Satin Flycatcher [612]		Species or species habitat may occur within area
Rhipidura rufifrons Rufous Fantail [592]		Species or species habitat may occur within area
Migratory Wetlands Species		
Actitis hypoleucos Common Sandpiper [59309]		Species or species habitat may occur within area
Calidris acuminata Sharp-tailed Sandpiper [874]		Species or species habitat likely to occur within area
Calidris ferruginea Curlew Sandpiper [856]	Critically Endangered	Species or species habitat may occur within area
Calidris melanotos Pectoral Sandpiper [858]		Species or species habitat may occur within area
Gallinago hardwickii Latham's Snipe, Japanese Snipe [863]		Species or species habitat may occur within area
Numenius madagascariensis Eastern Curlew, Far Eastern Curlew [847]	Critically Endangered	Species or species habitat may occur within area
Pandion haliaetus Osprey [952]		Species or species habitat likely to occur within area

Other Matters Protected by the EPBC Act

Commonwealth Land [Resource Information]

The Commonwealth area listed below may indicate the presence of Commonwealth land in this vicinity. Due to the unreliability of the data source, all proposals should be checked as to whether it impacts on a Commonwealth area, before making a definitive decision. Contact the State or Territory government land department for further information.

Name
Defence - BLACKWATER TRAINING DEPOT

Listed Marine Species [Resource Information]

* Species is listed under a different scientific name on the EPBC Act - Threatened Species list.

Name	Threatened	Type of Presence
Birds		

Name	Threatened	Type of Presence
Actitis hypoleucos Common Sandpiper [59309]		Species or species habitat may occur within area
Anseranas semipalmata Magpie Goose [978]		Species or species habitat may occur within area
Apus pacificus Fork-tailed Swift [678]		Species or species habitat likely to occur within area
Ardea alba Great Egret, White Egret [59541]		Breeding known to occur within area
Ardea ibis Cattle Egret [59542]		Species or species habitat may occur within area
Calidris acuminata Sharp-tailed Sandpiper [874]		Species or species habitat likely to occur within area
Calidris ferruginea Curlew Sandpiper [856]	Critically Endangered	Species or species habitat may occur within area
Calidris melanotos Pectoral Sandpiper [858]		Species or species habitat may occur within area
Chrysococcyx osculans Black-eared Cuckoo [705]		Species or species habitat likely to occur within area
Gallinago hardwickii Latham's Snipe, Japanese Snipe [863]		Species or species habitat may occur within area
Haliaeetus leucogaster White-bellied Sea-Eagle [943]		Species or species habitat likely to occur within area
Hirundapus caudacutus White-throated Needletail [682]		Species or species habitat known to occur within area
Merops ornatus Rainbow Bee-eater [670]		Species or species habitat may occur within area
Monarcha melanopsis Black-faced Monarch [609]		Species or species habitat likely to occur within area
Monarcha trivirgatus Spectacled Monarch [610]		Species or species habitat may occur within area
Motacilla flava Yellow Wagtail [644]		Species or species habitat may occur within area
Myiagra cyanoleuca Satin Flycatcher [612]		Species or species habitat may occur within area
Numenius madagascariensis Eastern Curlew, Far Eastern Curlew [847]	Critically Endangered	Species or species habitat may occur within area
Pandion haliaetus Osprey [952]		Species or species

Name	Threatened	Type of Presence
		habitat likely to occur within area
Rhipidura rufifrons Rufous Fantail [592]		Species or species habitat may occur within area
Rostratula benghalensis (sensu lato) Painted Snipe [889]	Endangered*	Species or species habitat likely to occur within area
Reptiles		
Crocodylus porosus Salt-water Crocodile, Estuarine Crocodile [1774]		Species or species habitat likely to occur within area

Extra Information

State and Territory Reserves [Resource Information]

Name	State
Blackdown Tableland	QLD
Blackwater	QLD
Ghungalu	QLD
Taunton	QLD
Wallaby Lane	QLD

Invasive Species [Resource Information]

Weeds reported here are the 20 species of national significance (WoNS), along with other introduced plants that are considered by the States and Territories to pose a particularly significant threat to biodiversity. The following feral animals are reported: Goat, Red Fox, Cat, Rabbit, Pig, Water Buffalo and Cane Toad. Maps from Landscape Health Project, National Land and Water Resouces Audit, 2001.

Name	Status	Type of Presence
Birds		
Anas platyrhynchos Mallard [974]		Species or species habitat likely to occur within area
Columba livia Rock Pigeon, Rock Dove, Domestic Pigeon [803]		Species or species habitat likely to occur within area
Passer domesticus House Sparrow [405]		Species or species habitat likely to occur within area
Streptopelia chinensis Spotted Turtle-Dove [780]		Species or species habitat likely to occur within area
Sturnus vulgaris Common Starling [389]		Species or species habitat likely to occur within area
Frogs		
Rhinella marina Cane Toad [83218]		Species or species habitat known to occur within area
Mammals		
Bos taurus Domestic Cattle [16]		Species or species habitat likely to occur within area
Canis lupus familiaris Domestic Dog [82654]		Species or species habitat likely to occur within area

Name	Status	Type of Presence
Felis catus Cat, House Cat, Domestic Cat [19]		Species or species habitat likely to occur within area
Lepus capensis Brown Hare [127]		Species or species habitat likely to occur within area
Mus musculus House Mouse [120]		Species or species habitat likely to occur within area
Oryctolagus cuniculus Rabbit, European Rabbit [128]		Species or species habitat likely to occur within area
Rattus rattus Black Rat, Ship Rat [84]		Species or species habitat likely to occur within area
Sus scrofa Pig [6]		Species or species habitat likely to occur within area
Vulpes vulpes Red Fox, Fox [18]		Species or species habitat likely to occur within area
Plants		
Acacia nilotica subsp. indica Prickly Acacia [6196]		Species or species habitat may occur within area
Cryptostegia grandiflora Rubber Vine, Rubbervine, India Rubber Vine, India Rubbervine, Palay Rubbervine, Purple Allamanda [18913]		Species or species habitat likely to occur within area
Hymenachne amplexicaulis Hymenachne, Olive Hymenachne, Water Stargrass, West Indian Grass, West Indian Marsh Grass [31754]		Species or species habitat likely to occur within area
Jatropha gossypifolia Cotton-leaved Physic-Nut, Bellyache Bush, Cotton-leaf Physic Nut, Cotton-leaf Jatropha, Black Physic Nut [7507]		Species or species habitat likely to occur within area
Lantana camara Lantana, Common Lantana, Kamara Lantana, Large-leaf Lantana, Pink Flowered Lantana, Red Flowered Lantana, Red-Flowered Sage, White Sage, Wild Sage [10892]		Species or species habitat likely to occur within area
Opuntia spp. Prickly Pears [82753]		Species or species habitat likely to occur within area
Parkinsonia aculeata Parkinsonia, Jerusalem Thorn, Jelly Bean Tree, Horse Bean [12301]		Species or species habitat likely to occur within area
Parthenium hysterophorus Parthenium Weed, Bitter Weed, Carrot Grass, False Ragweed [19566]		Species or species habitat likely to occur within area
Prosopis spp. Mesquite, Algaroba [68407]		Species or species habitat likely to occur within area
Salvinia molesta Salvinia, Giant Salvinia, Aquarium Watermoss, Kariba Weed [13665]		Species or species habitat likely to occur within area
Tamarix aphylla Athel Pine, Athel Tree, Tamarisk, Athel Tamarisk, Athel Tamarix, Desert Tamarisk, Flowering		Species or species habitat likely to occur

Name	Status	Type of Presence
Cypress, Salt Cedar [16018]		within area
Vachellia nilotica		
Prickly Acacia, Blackthorn, Prickly Mimosa, Black Piquant, Babul [84351]		Species or species habitat likely to occur within area

Caveat

The information presented in this report has been provided by a range of data sources as acknowledged at the end of the report.

This report is designed to assist in identifying the locations of places which may be relevant in determining obligations under the Environment Protection and Biodiversity Conservation Act 1999. It holds mapped locations of World and National Heritage properties, Wetlands of International and National Importance, Commonwealth and State/Territory reserves, listed threatened, migratory and marine species and listed threatened ecological communities. Mapping of Commonwealth land is not complete at this stage. Maps have been collated from a range of sources at various resolutions.

Not all species listed under the EPBC Act have been mapped (see below) and therefore a report is a general guide only. Where available data supports mapping, the type of presence that can be determined from the data is indicated in general terms. People using this information in making a referral may need to consider the qualifications below and may need to seek and consider other information sources.

For threatened ecological communities where the distribution is well known, maps are derived from recovery plans, State vegetation maps, remote sensing imagery and other sources. Where threatened ecological community distributions are less well known, existing vegetation maps and point location data are used to produce indicative distribution maps.

Threatened, migratory and marine species distributions have been derived through a variety of methods. Where distributions are well known and if time permits, maps are derived using either thematic spatial data (i.e. vegetation, soils, geology, elevation, aspect, terrain, etc) together with point locations and described habitat; or environmental modelling (MAXENT or BIOCLIM habitat modelling) using point locations and environmental data layers.

Where very little information is available for species or large number of maps are required in a short time-frame, maps are derived either from 0.04 or 0.02 decimal degree cells; by an automated process using polygon capture techniques (static two kilometre grid cells, alpha-hull and convex hull); or captured manually or by using topographic features (national park boundaries, islands, etc). In the early stages of the distribution mapping process (1999-early 2000s) distributions were defined by degree blocks, 100K or 250K map sheets to rapidly create distribution maps. More reliable distribution mapping methods are used to update these distributions as time permits.

Only selected species covered by the following provisions of the EPBC Act have been mapped:

- migratory and
- marine

The following species and ecological communities have not been mapped and do not appear in reports produced from this database:

- threatened species listed as extinct or considered as vagrants
- some species and ecological communities that have only recently been listed
- some terrestrial species that overfly the Commonwealth marine area
- migratory species that are very widespread, vagrant, or only occur in small numbers

The following groups have been mapped, but may not cover the complete distribution of the species:

- non-threatened seabirds which have only been mapped for recorded breeding sites
- seals which have only been mapped for breeding sites near the Australian continent

Such breeding sites may be important for the protection of the Commonwealth Marine environment.

Coordinates

-23.66512 149.21782

Acknowledgements

This database has been compiled from a range of data sources. The department acknowledges the following custodians who have contributed valuable data and advice:

-Office of Environment and Heritage, New South Wales
-Department of Environment and Primary Industries, Victoria
-Department of Primary Industries, Parks, Water and Environment, Tasmania
-Department of Environment, Water and Natural Resources, South Australia
-Department of Land and Resource Management, Northern Territory
-Department of Environmental and Heritage Protection, Queensland
-Department of Parks and Wildlife, Western Australia
-Environment and Planning Directorate, ACT
-Birdlife Australia
-Australian Bird and Bat Banding Scheme
-Australian National Wildlife Collection
-Natural history museums of Australia
-Museum Victoria
-Australian Museum
-South Australian Museum
-Queensland Museum
-Online Zoological Collections of Australian Museums
-Queensland Herbarium
-National Herbarium of NSW
-Royal Botanic Gardens and National Herbarium of Victoria
-Tasmanian Herbarium
-State Herbarium of South Australia
-Northern Territory Herbarium
-Western Australian Herbarium
-Australian National Herbarium, Canberra
-University of New England
-Ocean Biogeographic Information System
-Australian Government, Department of Defence
Forestry Corporation, NSW
-Geoscience Australia
-CSIRO
-Australian Tropical Herbarium, Cairns
-eBird Australia
-Australian Government – Australian Antarctic Data Centre
-Museum and Art Gallery of the Northern Territory
-Australian Government National Environmental Science Program
-Australian Institute of Marine Science
-Reef Life Survey Australia
-American Museum of Natural History
-Queen Victoria Museum and Art Gallery, Inveresk, Tasmania
-Tasmanian Museum and Art Gallery, Hobart, Tasmania
-Other groups and individuals

The Department is extremely grateful to the many organisations and individuals who provided expert advice and information on numerous draft distributions.

Please feel free to provide feedback via the Contact Us page.

Department of the Environment
GPO Box 787
Canberra ACT 2601 Australia
+61 2 6274 1111

Queensland
Government

Wildlife Online Extract

Search Criteria: Species List for a Specified Point
Species: All
Type: Native
Status: Rare and threatened species
Records: All
Date: All
Latitude: -23.6651
Longitude: 149.2178
Distance: 10
Email: ceales@aarc.net.au
Date submitted: Monday 03 Jun 2019 10:43:03
Date extracted: Monday 03 Jun 2019 10:50:02

The number of records retrieved = 9

Disclaimer

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Kingdom	Class	Family	Scientific Name	Common Name	I	Q	A	Records
animals	birds	Columbidae	*Geophaps scripta scripta*	squatter pigeon (southern subspecies)		V	V	15
animals	mammals	Macropodidae	*Onychogalea fraenata*	bridled nailtail wallaby		E	E	6
animals	mammals	Phascolarctidae	*Phascolarctos cinereus*	koala		V	V	1
animals	mammals	Pseudocheiridae	*Petauroides volans*	greater glider		V	V	1
animals	mammals	Pseudocheiridae	*Petauroides volans volans*	southern greater glider		V	V	1
animals	reptiles	Diplodactylidae	*Strophurus taenicauda*	golden-tailed gecko		NT		2
plants	Equisetopsida	Apocynaceae	*Cerbera dumicola*			NT		2/2
plants	Equisetopsida	Orchidaceae	*Corunastylis pedersonii*			V		1/1
plants	Equisetopsida	Solanaceae	*Solanum elachophyllum*			E		1

CODES

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Q - Indicates the Queensland conservation status of each taxon under the *Nature Conservation Act 1992.* The codes are Extinct in the Wild (PE), Endangered (E), Vulnerable (V), Near Threatened (NT), Least Concern (C) or Not Protected ( ).

A - Indicates the Australian conservation status of each taxon under the *Environment Protection and Biodiversity Conservation Act 1999.* The values of EPBC are Conservation Dependent (CD), Critically Endangered (CE), Endangered (E), Extinct (EX), Extinct in the Wild (XW) and Vulnerable (V).

Records – The first number indicates the total number of records of the taxon for the record option selected (i.e. All, Confirmed or Specimens).
This number is output as 99999 if it equals or exceeds this value. The second number located after the / indicates the number of specimen records for the taxon.
This number is output as 999 if it equals or exceeds this value.

Queensland
Government

Wildlife Online Extract

Search Criteria: Species List for a Specified Point
Species: All
Type: Native
Status: Rare and threatened species
Records: All
Date: All
Latitude: -23.6651
Longitude: 149.2178
Distance: 20
Email: ceales@aarc.net.au
Date submitted: Monday 03 Jun 2019 10:01:02
Date extracted: Monday 03 Jun 2019 10:10:11

The number of records retrieved = 32

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Kingdom	Class	Family	Scientific Name	Common Name	I	Q	A	Records
animals	amphibians	Limnodynastidae	*Adelotus brevis*	tusked frog		V		9
animals	birds	Accipitridae	*Erythrotriorchis radiatus*	red goshawk		E	V	1
animals	birds	Cacatuidae	*Calyptorhynchus lathami*	glossy black-cockatoo		V		2
animals	birds	Cacatuidae	*Calyptorhynchus lathami erebus*	glossy black-cockatoo (northern)		V		9/1
animals	birds	Columbidae	*Geophaps scripta scripta*	squatter pigeon (southern subspecies)		V	V	23
animals	mammals	Dasyuridae	*Antechinus argentus*	silver-headed antechinus		V	E	23
animals	mammals	Macropodidae	*Onychogalea fraenata*	bridled nailtail wallaby		E	E	37
animals	mammals	Phascolarctidae	*Phascolarctos cinereus*	koala		V	V	6
animals	mammals	Pseudocheiridae	*Petauroides volans*	greater glider		V	V	3
animals	mammals	Pseudocheiridae	*Petauroides volans volans*	southern greater glider		V	V	40
animals	reptiles	Diplodactylidae	*Strophurus taenicauda*	golden-tailed gecko		NT		10/1
animals	reptiles	Pygopodidae	*Delma torquata*	collared delma		V	V	1
plants	Equisetopsida	Apocynaceae	*Cerbera dumicola*			NT		3/3
plants	Equisetopsida	Arecaceae	*Livistona fulva*			V		9/9
plants	Equisetopsida	Asteraceae	*Rutidosis glandulosa*			NT		7/7
plants	Equisetopsida	Byttneriaceae	*Commersonia pearnii*			E		2/2
plants	Equisetopsida	Euphorbiaceae	*Bertya pedicellata*			NT		2
plants	Equisetopsida	Fabaceae	*Daviesia discolor*			V	V	3/3
plants	Equisetopsida	Fabaceae	*Daviesia quoquoversus*			V		2/2
plants	Equisetopsida	Lamiaceae	*Plectranthus blakei*			NT		9/9
plants	Equisetopsida	Loganiaceae	*Logania diffusa*			V	V	3/2
plants	Equisetopsida	Mimosaceae	*Acacia storyi*			NT		8/6
plants	Equisetopsida	Myrtaceae	*Melaleuca pearsonii*			NT		10/10
plants	Equisetopsida	Myrtaceae	*Baeckea trapeza*			V		7/7
plants	Equisetopsida	Myrtaceae	*Melaleuca groveana*			NT		5/4
plants	Equisetopsida	Orchidaceae	*Corunastylis pedersonii*			V		1/1
plants	Equisetopsida	Orchidaceae	*Gastrodia crebriflora*			V		1/1
plants	Equisetopsida	Orchidaceae	*Corunastylis valida*			V		1/1
plants	Equisetopsida	Picrodendraceae	*Pseudanthus pauciflorus subsp. arenicola*			NT		2/1
plants	Equisetopsida	Solanaceae	*Solanum adenophorum*			E		9/8
plants	Equisetopsida	Solanaceae	*Solanum elachophyllum*			E		7/5
plants	Equisetopsida	Zamiaceae	*Macrozamia platyrhachis*			E	E	19/8

CODES

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This number is output as 999 if it equals or exceeds this value.

Queensland
Government

Wildlife Online Extract

Search Criteria: Species List for a Specified Point
Species: All
Type: Native
Status: Rare and threatened species
Records: All
Date: All
Latitude: -23.6651
Longitude: 149.2178
Distance: 50
Email: ceales@aarc.net.au
Date submitted: Monday 03 Jun 2019 10:00:25
Date extracted: Monday 03 Jun 2019 10:10:03
The number of records retrieved = 49

Disclaimer

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Kingdom	Class	Family	Scientific Name	Common Name	I	Q	A	Records
animals	amphibians	Limnodynastidae	*Adelotus brevis*	tusked frog		V		10
animals	birds	Accipitridae	*Erythrotriorchis radiatus*	red goshawk		E	V	15
animals	birds	Cacatuidae	*Calyptorhynchus lathami*	glossy black-cockatoo		V		4
animals	birds	Cacatuidae	*Calyptorhynchus lathami erebus*	glossy black-cockatoo (northern)		V		19/2
animals	birds	Columbidae	*Geophaps scripta scripta*	squatter pigeon (southern subspecies)		V	V	44
animals	birds	Estrildidae	*Poephila cincta cincta*	black-throated finch (white-rumped subspecies)		E	E	4/1
animals	birds	Meliphagidae	*Grantiella picta*	painted honeyeater		V	V	3
animals	birds	Pedionomidae	*Pedionomus torquatus*	plains-wanderer		V	CE	1
animals	birds	Psittacidae	*Lathamus discolor*	swift parrot		E	CE	1
animals	birds	Psittacidae	*Psephotus pulcherrimus*	paradise parrot		PE	EX	9/2
animals	birds	Strigidae	*Ninox strenua*	powerful owl		V		3
animals	birds	Turnicidae	*Turnix melanogaster*	black-breasted button-quail		V	V	7
animals	insects	Lycaenidae	*Jalmenus eubulus*	pale imperial hairstreak		V		5
animals	mammals	Dasyuridae	*Antechinus argentus*	silver-headed antechinus		V	E	23
animals	mammals	Macropodidae	*Onychogalea fraenata*	bridled nailtail wallaby		E	E	41
animals	mammals	Phascolarctidae	*Phascolarctos cinereus*	koala		V	V	14
animals	mammals	Potoroidae	*Bettongia gaimardi gaimardi*	eastern bettong		PE	EX	4
animals	mammals	Pseudocheiridae	*Petauroides volans volans*	southern greater glider		V	V	71
animals	mammals	Pseudocheiridae	*Petauroides volans*	greater glider		V	V	3
animals	mammals	Vespertilionidae	*Chalinolobus dwyeri*	large-eared pied bat		V	V	2
animals	reptiles	Chelidae	*Elseya albagula*	southern snapping turtle		E	CE	2
animals	reptiles	Chelidae	*Rheodytes leukops*	Fitzroy River turtle		V	V	1
animals	reptiles	Diplodactylidae	*Strophurus taenicauda*	golden-tailed gecko		NT		10/1
animals	reptiles	Elapidae	*Denisonia maculata*	ornamental snake		V	V	2
animals	reptiles	Pygopodidae	*Delma torquata*	collared delma		V	V	1
plants	Equisetopsida	Apocynaceae	*Cerbera dumicola*			NT		6/6
plants	Equisetopsida	Arecaceae	*Livistona fulva*			V		16/12
plants	Equisetopsida	Asteraceae	*Rutidosis glandulosa*			NT		7/7
plants	Equisetopsida	Byttneriaceae	*Commersonia pearnii*			E		2/2
plants	Equisetopsida	Euphorbiaceae	*Bertya pedicellata*			NT		3
plants	Equisetopsida	Fabaceae	*Daviesia quoquoversus*			V		7/2
plants	Equisetopsida	Fabaceae	*Daviesia discolor*			V	V	8/6
plants	Equisetopsida	Lamiaceae	*Plectranthus blakei*			NT		10/10
plants	Equisetopsida	Loganiaceae	*Logania diffusa*			V	V	4/2
plants	Equisetopsida	Mimosaceae	*Acacia storyi*			NT		21/17
plants	Equisetopsida	Myrtaceae	*Melaleuca pearsonii*			NT		13/12
plants	Equisetopsida	Myrtaceae	*Baeckea trapeza*			V		7/7
plants	Equisetopsida	Myrtaceae	*Sannantha brachypoda*			V		1/1
plants	Equisetopsida	Myrtaceae	*Melaleuca groveana*			NT		6/4
plants	Equisetopsida	Orchidaceae	*Phaius australis*			E	E	5/3
plants	Equisetopsida	Orchidaceae	*Corunastylis pedersonii*			V		1/1
plants	Equisetopsida	Orchidaceae	*Gastrodia crebriflora*			V		1/1
plants	Equisetopsida	Orchidaceae	*Corunastylis valida*			V		1/1
plants	Equisetopsida	Picrodendraceae	*Pseudanthus pauciflorus subsp. arenicola*			NT		2/1
plants	Equisetopsida	Solanaceae	*Solanum dissectum*			E	E	3/3

Kingdom	Class	Family	Scientific Name	Common Name	I	Q	A	Records
plants	Equisetopsida	Solanaceae	*Solanum adenophorum*			E		12/ 10
plants	Equisetopsida	Solanaceae	*Solanum elachophyllum*			E		17/ 14
plants	Equisetopsida	Surianaceae	*Cadellia pentastylis*	ooline		V	V	5/ 4
plants	Equisetopsida	Zamiaceae	*Macrozamia platyrhachis*			E	E	55/ 30

CODES

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Records – The first number indicates the total number of records of the taxon for the record option selected (i.e. All, Confirmed or Specimens).
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This number is output as 999 if it equals or exceeds this value.

Appendix B Site Descriptions and Physical Assessment

<table>
<tr><th>Characteristic</th><th colspan="6">DWR1 (2020)</th></tr>
<tr><td rowspan="2">Bank shape</td><td colspan="3">Left bank</td><td colspan="3">Right bank</td></tr>
<tr><td colspan="3">Concave</td><td colspan="3">Concave</td></tr>
<tr><td rowspan="2">Bank slope</td><td colspan="3">Left bank</td><td colspan="3">Right bank</td></tr>
<tr><td colspan="3">30°</td><td colspan="3">35°</td></tr>
<tr><td>Associated watercourse</td><td colspan="6">Stanley Creek (tributary)</td></tr>
<tr><td>Factors affecting bank stability</td><td colspan="6">High presence of weeds, low tree density, cattle access.</td></tr>
<tr><td>Artificial bank stability features</td><td colspan="6">Highway culvert, rocks added to stream bed, fence line.</td></tr>
<tr><td>Large woody debris</td><td colspan="6">1%</td></tr>
<tr><td rowspan="2">Turbidity, water and sediment oils and odours</td><td>Turbidity</td><td>Sediment oils</td><td colspan="2">Water oils</td><td>Sediment odours</td><td>Water odours</td></tr>
<tr><td>-</td><td>None</td><td colspan="2">-</td><td>None</td><td>-</td></tr>
<tr><td>Water level</td><td colspan="6">Dry at time of survey.</td></tr>
<tr><td>Bare ground</td><td colspan="6">Little (1-10%).</td></tr>
<tr><td>Exposed tree roots</td><td colspan="6">Little(1-10%), primarily at the base of trees at fence line.</td></tr>
<tr><td>Gully erosion</td><td colspan="6">Little (1-10%).</td></tr>
<tr><td>Bank slumping</td><td colspan="6">None (0%).</td></tr>
<tr><td>Local catchment erosion</td><td colspan="6">None (0%).</td></tr>
</table>

<table>
<tr><th>Characteristic</th><th colspan="10">DWI1 (2019)</th></tr>
<tr><td rowspan="2">Bank shape</td><td colspan="5">Left bank</td><td colspan="5">Right bank</td></tr>
<tr><td colspan="5">Convex</td><td colspan="5">Concave</td></tr>
<tr><td rowspan="2">Bank slope</td><td colspan="5">Left bank</td><td colspan="5">Right bank</td></tr>
<tr><td colspan="5">30°</td><td colspan="5">20°</td></tr>
<tr><td>Associated watercourse</td><td colspan="10">Stanley Creek</td></tr>
<tr><td>Factors affecting bank stability</td><td colspan="10">Low ground cover on edges, high weed presence.</td></tr>
<tr><td>Artificial bank stability features</td><td colspan="10">Farmer dam, access tracks, fence line.</td></tr>
<tr><td>Large woody debris (%)</td><td colspan="10">0%</td></tr>
<tr><td rowspan="2">Turbidity, water and sediment oils and odours</td><td colspan="2">Turbidity</td><td colspan="2">Sediment oils</td><td colspan="2">Water oils</td><td colspan="2">Sediment odours</td><td colspan="2">Water odours</td></tr>
<tr><td colspan="2">-</td><td colspan="2">None</td><td colspan="2">-</td><td colspan="2">None</td><td colspan="2">-</td></tr>
<tr><td>Water level</td><td colspan="10">Dry at time of survey. No access 2020.</td></tr>
<tr><td>Bare ground</td><td colspan="10">Little (1-10%).</td></tr>
<tr><td>Exposed tree roots</td><td colspan="10">None (0%).</td></tr>
<tr><td>Gully erosion</td><td colspan="10">None (0%).</td></tr>
<tr><td>Bank slumping</td><td colspan="10">None (0%).</td></tr>
<tr><td>Local catchment erosion</td><td colspan="10">Some (10-50%).</td></tr>
</table>

Characteristic	DAI8 (2020)				
Bank shape	**Left bank**		**Right bank**		
	Concave		Concave		
Bank slope	**Left bank**		**Right bank**		
	30°		50°		
Associated watercourse	Duckworth Creek				
Factors affecting bank stability	Low ground cover on banks, high weed presence.				
Artificial bank stability features	Currant road bridge, old bridge ridge reinforcing and debris.				
Large woody debris (%)	0%				
Turbidity, water and sediment oils and odours	**Turbidity**	**Sediment oils**	**Water oils**	**Sediment odours**	**Water odours**
	Opaque	None	None	None	None
Water level	0.3 m				
Bare ground	Little (1-10%).				
Exposed tree roots	Little (1-10%).				
Gully erosion	Little (1-10%).				
Bank slumping	Little (1-10%).				
Local catchment erosion	Moderate (50-75%).				

<table>
<tr><th>Characteristic</th><th colspan="6">DWR6 (2020)</th></tr>
<tr><td rowspan="2">Bank shape</td><td colspan="3">Left bank</td><td colspan="3">Right bank</td></tr>
<tr><td colspan="3">Concave</td><td colspan="3">Concave</td></tr>
<tr><td rowspan="2">Bank slope</td><td colspan="3">Left bank</td><td colspan="3">Right bank</td></tr>
<tr><td colspan="3">Flat</td><td colspan="3">Flat</td></tr>
<tr><td>Associated watercourse</td><td colspan="6">Springton Creek (tributary)</td></tr>
<tr><td>Factors affecting bank stability</td><td colspan="6">-</td></tr>
<tr><td>Artificial bank stability features</td><td colspan="6">None.</td></tr>
<tr><td>Large woody debris (%)</td><td colspan="6">2%</td></tr>
<tr><td rowspan="2">Turbidity, water and sediment oils and odours</td><td>Turbidity</td><td>Sediment oils</td><td colspan="2">Water oils</td><td>Sediment odours</td><td>Water odours</td></tr>
<tr><td>-</td><td>None</td><td colspan="2">-</td><td>None</td><td>-</td></tr>
<tr><td>Water level</td><td colspan="6">Dry at time of survey.</td></tr>
<tr><td>Bare ground</td><td colspan="6">None (0%).</td></tr>
<tr><td>Exposed tree roots</td><td colspan="6">None (0%).</td></tr>
<tr><td>Gully erosion</td><td colspan="6">Little (1-10%).</td></tr>
<tr><td>Bank slumping</td><td colspan="6">None (0%).</td></tr>
<tr><td>Local catchment erosion</td><td colspan="6">Little (1-10%).</td></tr>
</table>

<table>
<tr><th>Characteristic</th><th colspan="10">DAR2 (2020)</th></tr>
<tr><td rowspan="2">Bank shape</td><td colspan="5">Left bank</td><td colspan="5">Right bank</td></tr>
<tr><td colspan="5">Convex</td><td colspan="5">Convex</td></tr>
<tr><td rowspan="2">Bank slope</td><td colspan="5">Left bank</td><td colspan="5">Right bank</td></tr>
<tr><td colspan="5">60°</td><td colspan="5">55°</td></tr>
<tr><td>Associated watercourse</td><td colspan="10">Springton Creek</td></tr>
<tr><td>Factors affecting bank stability</td><td colspan="10">Cattle crossing, heavy erosion in areas.</td></tr>
<tr><td>Artificial bank stability features</td><td colspan="10">Old farm track, fencing.</td></tr>
<tr><td>Large woody debris (%)</td><td colspan="10">8%</td></tr>
<tr><td rowspan="2">Turbidity, water and sediment oils and odours</td><td colspan="2">Turbidity</td><td colspan="2">Sediment oils</td><td colspan="2">Water oils</td><td colspan="2">Sediment odours</td><td colspan="2">Water odours</td></tr>
<tr><td colspan="2">Opaque</td><td colspan="2">None</td><td colspan="2">None</td><td colspan="2">None</td><td colspan="2">None</td></tr>
<tr><td>Water level</td><td colspan="10">0.3 m</td></tr>
<tr><td>Bare ground</td><td colspan="10">Little (1-10%).</td></tr>
<tr><td>Exposed tree roots</td><td colspan="10">Moderate (50-75%).</td></tr>
<tr><td>Gully erosion</td><td colspan="10">Some (10-50%).</td></tr>
<tr><td>Bank slumping</td><td colspan="10">Some (10-50%).</td></tr>
<tr><td>Local catchment erosion</td><td colspan="10">Moderate (50-75%).</td></tr>
</table>

<table>
<tr><th>Characteristic</th><th colspan="5">DWI8 (2020)</th></tr>
<tr><td rowspan="2">Bank shape</td><td colspan="2">Left bank</td><td colspan="3">Right bank</td></tr>
<tr><td colspan="2">Convex</td><td colspan="3">Convex</td></tr>
<tr><td rowspan="2">Bank slope</td><td colspan="2">Left bank</td><td colspan="3">Right bank</td></tr>
<tr><td colspan="2">75°</td><td colspan="3">85°</td></tr>
<tr><td>Associated watercourse</td><td colspan="5">Springton Creek (tributary).</td></tr>
<tr><td>Factors affecting bank stability</td><td colspan="5">Low vegetation cover on edges, steep bank edges, heavy clearing in surrounding areas, high cattle traffic.</td></tr>
<tr><td>Artificial bank stability features</td><td colspan="5">None.</td></tr>
<tr><td>Large woody debris (%)</td><td colspan="5">30%</td></tr>
<tr><td rowspan="2">Turbidity, water and sediment oils and odours</td><td>Turbidity</td><td>Sediment oils</td><td>Water oils</td><td>Sediment odours</td><td>Water odours</td></tr>
<tr><td>-</td><td>None</td><td>-</td><td>None</td><td>-</td></tr>
<tr><td>Water level</td><td colspan="5">Dry at time of survey.</td></tr>
<tr><td>Bare ground</td><td colspan="5">Moderate (50-75%).</td></tr>
<tr><td>Exposed tree roots</td><td colspan="5">Moderate (50-75%).</td></tr>
<tr><td>Gully erosion</td><td colspan="5">Extensive (>75%).</td></tr>
<tr><td>Bank slumping</td><td colspan="5">Moderate (50-75%).</td></tr>
<tr><td>Local catchment erosion</td><td colspan="5">Moderate (50-75%).</td></tr>
</table>

B

<table>
<tr><th>Characteristic</th><th colspan="5">DWI9 (2020)</th></tr>
<tr><td rowspan="2">Bank shape</td><td colspan="2">Left bank</td><td colspan="3">Right bank</td></tr>
<tr><td colspan="2">Concave</td><td colspan="3">Concave</td></tr>
<tr><td rowspan="2">Bank slope</td><td colspan="2">Left bank</td><td colspan="3">Right bank</td></tr>
<tr><td colspan="2">10°</td><td colspan="3">15°</td></tr>
<tr><td>Associated watercourse</td><td colspan="5">Springton Creek (tributary).</td></tr>
<tr><td>Factors affecting bank stability</td><td colspan="5">Weed presence, low ground cover presence, signs of waterlogging.</td></tr>
<tr><td>Artificial bank stability features</td><td colspan="5">None.</td></tr>
<tr><td>Large woody debris (%)</td><td colspan="5">10%</td></tr>
<tr><td rowspan="2">Turbidity, water and sediment oils and odours</td><td>Turbidity</td><td>Sediment oils</td><td>Water oils</td><td>Sediment odours</td><td>Water odours</td></tr>
<tr><td>-</td><td>None</td><td>-</td><td>None</td><td>-</td></tr>
<tr><td>Water level</td><td colspan="5">Dry at time of survey.</td></tr>
<tr><td>Bare ground</td><td colspan="5">Little (1-10%).</td></tr>
<tr><td>Exposed tree roots</td><td colspan="5">None (0-10%).</td></tr>
<tr><td>Gully erosion</td><td colspan="5">Little (1-10%).</td></tr>
<tr><td>Bank slumping</td><td colspan="5">Little (1-10%).</td></tr>
<tr><td>Local catchment erosion</td><td colspan="5">Some (10-50%).</td></tr>
</table>

<table>
<tr><th>Characteristic</th><th colspan="10">DAI5 (2020)</th></tr>
<tr><td rowspan="2">Bank shape</td><td colspan="5">Left Bank</td><td colspan="5">Right Bank</td></tr>
<tr><td colspan="5">Concave</td><td colspan="5">Concave</td></tr>
<tr><td rowspan="2">Bank slope</td><td colspan="5">Left Bank</td><td colspan="5">Right Bank</td></tr>
<tr><td colspan="5">70°</td><td colspan="5">70°</td></tr>
<tr><td>Associated watercourse</td><td colspan="10">Springton Creek.</td></tr>
<tr><td>Factors affecting bank stability</td><td colspan="10">Steep bank edges, bank slumping and heavy erosion, cattle crossing.</td></tr>
<tr><td>Artificial bank stability features</td><td colspan="10">None.</td></tr>
<tr><td>Large woody debris (%)</td><td colspan="10">20%</td></tr>
<tr><td rowspan="2">Turbidity, water and sediment oils and odours</td><td colspan="2">Turbidity</td><td colspan="2">Sediment Oils</td><td colspan="2">Water Oils</td><td colspan="2">Sediment Odours</td><td colspan="2">Water Odours</td></tr>
<tr><td colspan="2">Opaque</td><td colspan="2">None</td><td colspan="2">None</td><td colspan="2">None</td><td colspan="2">None</td></tr>
<tr><td>Water level</td><td colspan="10">0.5 m</td></tr>
<tr><td>Bare ground</td><td colspan="10">Little (1-10%).</td></tr>
<tr><td>Exposed tree roots</td><td colspan="10">Moderate (50-75%).</td></tr>
<tr><td>Gully erosion</td><td colspan="10">Some (10-50%).</td></tr>
<tr><td>Bank slumping</td><td colspan="10">Some (10-50%).</td></tr>
<tr><td>Local catchment erosion</td><td colspan="10">Moderate (50-75%).</td></tr>
</table>

<table>
<tr><th>Characteristic</th><th colspan="10">DWI6 (2020)</th></tr>
<tr><td rowspan="2">Bank shape</td><td colspan="5">Left bank</td><td colspan="5">Right bank</td></tr>
<tr><td colspan="5">Convex</td><td colspan="5">Convex</td></tr>
<tr><td rowspan="2">Bank slope</td><td colspan="5">Left bank</td><td colspan="5">Right bank</td></tr>
<tr><td colspan="5">60°</td><td colspan="5">65°</td></tr>
<tr><td>Associated watercourse</td><td colspan="10">Springton Creek.</td></tr>
<tr><td>Factors affecting bank stability</td><td colspan="10">Low ground cover on edges, erosion, presence of weeds.</td></tr>
<tr><td>Artificial bank stability features</td><td colspan="10">Located at highway crossing, large bridge, concrete base in areas.</td></tr>
<tr><td>Large woody debris (%)</td><td colspan="10">0%</td></tr>
<tr><td rowspan="2">Turbidity, water and sediment oils and odours</td><td colspan="2">Turbidity</td><td colspan="2">Sediment oils</td><td colspan="2">Water oils</td><td colspan="2">Sediment odours</td><td colspan="2">Water odours</td></tr>
<tr><td colspan="2">Opaque</td><td colspan="2">None</td><td colspan="2">None</td><td colspan="2">None</td><td colspan="2">None</td></tr>
<tr><td>Water level</td><td colspan="10">0.8 m</td></tr>
<tr><td>Bare ground</td><td colspan="10">Little (1-10%).</td></tr>
<tr><td>Exposed tree roots</td><td colspan="10">Some (10-50%).</td></tr>
<tr><td>Gully erosion</td><td colspan="10">Moderate (50-75%).</td></tr>
<tr><td>Bank slumping</td><td colspan="10">Moderate (50-75%).</td></tr>
<tr><td>Local catchment erosion</td><td colspan="10">Some (10-50%).</td></tr>
</table>

<table>
<tr><th>Characteristic</th><th colspan="10">DAR1 (2020)</th></tr>
<tr><td rowspan="2">Bank shape</td><td colspan="5">Left bank</td><td colspan="5">Right bank</td></tr>
<tr><td colspan="5">Concave</td><td colspan="5">Convex</td></tr>
<tr><td rowspan="2">Bank slope</td><td colspan="5">Left bank</td><td colspan="5">Right bank</td></tr>
<tr><td colspan="5">50°</td><td colspan="5">45°</td></tr>
<tr><td>Associated watercourse</td><td colspan="10">Charlevue Creek.</td></tr>
<tr><td>Factors affecting bank stability</td><td colspan="10">Low ground cover on edges, steep bank, exposed roots, signs of flooding, cattle access, high weed presence.</td></tr>
<tr><td>Artificial bank stability features</td><td colspan="10">None</td></tr>
<tr><td>Large woody debris (%)</td><td colspan="10">20%</td></tr>
<tr><td rowspan="2">Turbidity, water and sediment oils and odours</td><td colspan="2">Turbidity</td><td colspan="2">Sediment oils</td><td colspan="2">Water oils</td><td colspan="2">Sediment odours</td><td colspan="2">Water odours</td></tr>
<tr><td colspan="2">Opaque</td><td colspan="2">None</td><td colspan="2">None</td><td colspan="2">None</td><td colspan="2">None</td></tr>
<tr><td>Water level</td><td colspan="10">0.4 m</td></tr>
<tr><td>Bare ground</td><td colspan="10">Little (1-10%).</td></tr>
<tr><td>Exposed tree roots</td><td colspan="10">Little (1-10%).</td></tr>
<tr><td>Gully erosion</td><td colspan="10">Little (1-10%).</td></tr>
<tr><td>Bank slumping</td><td colspan="10">Some (10-50%).</td></tr>
<tr><td>Local catchment erosion</td><td colspan="10">Moderate (50-75%).</td></tr>
</table>

<table>
<tr><th>Characteristic</th><th colspan="10">DWR5 (2020)</th></tr>
<tr><td rowspan="2">Bank shape</td><td colspan="5">Left bank</td><td colspan="5">Right bank</td></tr>
<tr><td colspan="5">Convex</td><td colspan="5">Concave</td></tr>
<tr><td rowspan="2">Bank slope</td><td colspan="5">Left bank</td><td colspan="5">Right bank</td></tr>
<tr><td colspan="5">5°</td><td colspan="5">50°</td></tr>
<tr><td>Associated watercourse</td><td colspan="10">Charlevue Creek (tributary).</td></tr>
<tr><td>Factors affecting bank stability</td><td colspan="10">Low ground cover on edges, high cattle traffic, cleared area, high weed presence.</td></tr>
<tr><td>Artificial bank stability features</td><td colspan="10">None.</td></tr>
<tr><td>Large woody debris (%)</td><td colspan="10">10%</td></tr>
<tr><td rowspan="2">Turbidity, water and sediment oils and odours</td><td colspan="2">Turbidity</td><td colspan="2">Sediment oils</td><td colspan="2">Water oils</td><td colspan="2">Sediment odours</td><td colspan="2">Water odours</td></tr>
<tr><td colspan="2">Opaque</td><td colspan="2">None</td><td colspan="2">None</td><td colspan="2">None</td><td colspan="2">None</td></tr>
<tr><td>Water level</td><td colspan="10">0.3 m</td></tr>
<tr><td>Bare ground</td><td colspan="10">Little (1-10%).</td></tr>
<tr><td>Exposed tree roots</td><td colspan="10">Little (1-10%).</td></tr>
<tr><td>Gully erosion</td><td colspan="10">Little (1-10%).</td></tr>
<tr><td>Bank slumping</td><td colspan="10">Some (10-50%).</td></tr>
<tr><td>Local catchment erosion</td><td colspan="10">Moderate (50-75%).</td></tr>
</table>

<table>
<tr><th>Characteristic</th><th colspan="10">DAI1 (2020)</th></tr>
<tr><td rowspan="2">Bank shape</td><td colspan="5">Left bank</td><td colspan="5">Right bank</td></tr>
<tr><td colspan="5">Concave</td><td colspan="5">Convex</td></tr>
<tr><td rowspan="2">Bank slope</td><td colspan="5">Left bank</td><td colspan="5">Right bank</td></tr>
<tr><td colspan="5">55°</td><td colspan="5">70°</td></tr>
<tr><td>Associated watercourse</td><td colspan="10">Charlevue Creek.</td></tr>
<tr><td>Factors affecting bank stability</td><td colspan="10">Low ground cover on edges, steep banks, high weed presence.</td></tr>
<tr><td>Artificial bank stability features</td><td colspan="10">None.</td></tr>
<tr><td>Large woody debris (%)</td><td colspan="10">40%</td></tr>
<tr><td rowspan="2">Turbidity, water and sediment oils and odours</td><td colspan="2">Turbidity</td><td colspan="2">Sediment oils</td><td colspan="2">Water oils</td><td colspan="2">Sediment odours</td><td colspan="2">Water odours</td></tr>
<tr><td colspan="2">Opaque</td><td colspan="2">None</td><td colspan="2">None</td><td colspan="2">None</td><td colspan="2">None</td></tr>
<tr><td>Water level</td><td colspan="10">0.2 m</td></tr>
<tr><td>Bare ground</td><td colspan="10">Moderate (50-75%).</td></tr>
<tr><td>Exposed tree roots</td><td colspan="10">Little (1-10%).</td></tr>
<tr><td>Gully erosion</td><td colspan="10">Little (1-10%).</td></tr>
<tr><td>Bank slumping</td><td colspan="10">Little (1-10%).</td></tr>
<tr><td>Local catchment erosion</td><td colspan="10">Moderate (50-75%).</td></tr>
</table>

<table>
<tr><th>Characteristic</th><th colspan="5">DAI2 (2020)</th></tr>
<tr><td rowspan="2">Bank shape</td><td colspan="2">Left bank</td><td colspan="3">Right bank</td></tr>
<tr><td colspan="2">Concave</td><td colspan="3">Concave</td></tr>
<tr><td rowspan="2">Bank slope</td><td colspan="2">Left bank</td><td colspan="3">Right bank</td></tr>
<tr><td colspan="2">35°</td><td colspan="3">35°</td></tr>
<tr><td>Associated watercourse</td><td colspan="5">Charlevue Creek.</td></tr>
<tr><td>Factors affecting bank stability</td><td colspan="5">Low ground cover on edges, cattle access.</td></tr>
<tr><td>Artificial bank stability features</td><td colspan="5">None.</td></tr>
<tr><td>Large woody debris (%)</td><td colspan="5">20%</td></tr>
<tr><td rowspan="2">Turbidity, water and sediment oils and odours</td><td>Turbidity</td><td>Sediment oils</td><td>Water oils</td><td>Sediment odours</td><td>Water odours</td></tr>
<tr><td>Opaque</td><td>None</td><td>None</td><td>None</td><td>None</td></tr>
<tr><td>Water level</td><td colspan="5">0.3 m</td></tr>
<tr><td>Bare ground</td><td colspan="5">Little (1-10%).</td></tr>
<tr><td>Exposed tree roots</td><td colspan="5">Little (1-10%).</td></tr>
<tr><td>Gully erosion</td><td colspan="5">Little (1-10%).</td></tr>
<tr><td>Bank slumping</td><td colspan="5">Some (10-50%).</td></tr>
<tr><td>Local catchment erosion</td><td colspan="5">Moderate (50-75%).</td></tr>
</table>

<table>
<tr><th>Characteristic</th><th colspan="5">DWR4 (2020)</th></tr>
<tr><td rowspan="2">Bank shape</td><td colspan="2">Left bank</td><td colspan="3">Right bank</td></tr>
<tr><td colspan="2">Concave</td><td colspan="3">Concave</td></tr>
<tr><td rowspan="2">Bank slope</td><td colspan="2">Left bank</td><td colspan="3">Right bank</td></tr>
<tr><td colspan="2">Flat</td><td colspan="3">Flat</td></tr>
<tr><td>Associated watercourse</td><td colspan="5">Charlevue Creek (tributary).</td></tr>
<tr><td>Factors affecting bank stability</td><td colspan="5">Bank highly stable, small depression/wetland area.</td></tr>
<tr><td>Artificial bank stability features</td><td colspan="5">None.</td></tr>
<tr><td>Large woody debris (%)</td><td colspan="5">2%</td></tr>
<tr><td rowspan="2">Turbidity, water and sediment oils and odours</td><td>Turbidity</td><td>Sediment oils</td><td>Water oils</td><td>Sediment odours</td><td>Water odours</td></tr>
<tr><td>Opaque</td><td>None</td><td>None</td><td>None</td><td>None</td></tr>
<tr><td>Water level</td><td colspan="5">0.5 m</td></tr>
<tr><td>Bare ground</td><td colspan="5">Little (1-10%).</td></tr>
<tr><td>Exposed tree roots</td><td colspan="5">None (0-10%).</td></tr>
<tr><td>Gully erosion</td><td colspan="5">None (0-10%).</td></tr>
<tr><td>Bank slumping</td><td colspan="5">None (0-10%).</td></tr>
<tr><td>Local catchment erosion</td><td colspan="5">Moderate (50-75%).</td></tr>
</table>

<table>
<tr><th>Characteristic</th><th colspan="5">DAI3 (2020)</th></tr>
<tr><td rowspan="2">Bank shape</td><td colspan="2">Left bank</td><td colspan="3">Right bank</td></tr>
<tr><td colspan="2">Convex</td><td colspan="3">Convex</td></tr>
<tr><td rowspan="2">Bank slope</td><td colspan="2">Left bank</td><td colspan="3">Right bank</td></tr>
<tr><td colspan="2">75°</td><td colspan="3">75°</td></tr>
<tr><td>Associated watercourse</td><td colspan="5">Charlevue Creek.</td></tr>
<tr><td>Factors affecting bank stability</td><td colspan="5">Low ground cover on edges, slumping and erosion, cattle access.</td></tr>
<tr><td>Artificial bank stability features</td><td colspan="5">None.</td></tr>
<tr><td>Large woody debris (%)</td><td colspan="5">20%</td></tr>
<tr><td rowspan="2">Turbidity, water and sediment oils and odours</td><td>Turbidity</td><td>Sediment oils</td><td>Water oils</td><td>Sediment odours</td><td>Water odours</td></tr>
<tr><td>Opaque</td><td>None</td><td>Slick</td><td>Algal</td><td>None</td></tr>
<tr><td>Water level</td><td colspan="5">0.2 m</td></tr>
<tr><td>Bare ground</td><td colspan="5">Little (1-10%).</td></tr>
<tr><td>Exposed tree roots</td><td colspan="5">Little (1-10%).</td></tr>
<tr><td>Gully erosion</td><td colspan="5">Little (1-10%).</td></tr>
<tr><td>Bank slumping</td><td colspan="5">Some (10-50%).</td></tr>
<tr><td>Local catchment erosion</td><td colspan="5">Moderate (50-75%).</td></tr>
</table>

<table>
<tr><th>Characteristic</th><th colspan="5">DAI4 (2020)</th></tr>
<tr><td rowspan="2">Bank shape</td><td colspan="2">Left bank</td><td colspan="3">Right bank</td></tr>
<tr><td colspan="2">Concave</td><td colspan="3">Convex</td></tr>
<tr><td rowspan="2">Bank slope</td><td colspan="2">Left bank</td><td colspan="3">Right bank</td></tr>
<tr><td colspan="2">45°</td><td colspan="3">40°</td></tr>
<tr><td>Associated watercourse</td><td colspan="5">Charlevue Creek.</td></tr>
<tr><td>Factors affecting bank stability</td><td colspan="5">Low ground cover on edges, cattle access, flooding, high exposed roots.</td></tr>
<tr><td>Artificial bank stability features</td><td colspan="5">Access tracks.</td></tr>
<tr><td>Large woody debris (%)</td><td colspan="5">10%</td></tr>
<tr><td rowspan="2">Turbidity, water and sediment oils and odours</td><td>Turbidity</td><td>Sediment oils</td><td>Water oils</td><td>Sediment odours</td><td>Water odours</td></tr>
<tr><td>Opaque</td><td>None</td><td>None</td><td>None</td><td>None</td></tr>
<tr><td>Water level</td><td colspan="5">0.3 m</td></tr>
<tr><td>Bare ground</td><td colspan="5">Little (1-10%).</td></tr>
<tr><td>Exposed tree roots</td><td colspan="5">Little (1-10%).</td></tr>
<tr><td>Gully erosion</td><td colspan="5">Little (1-10%).</td></tr>
<tr><td>Bank slumping</td><td colspan="5">Some (10-50%).</td></tr>
<tr><td>Local catchment erosion</td><td colspan="5">Moderate (50-75%).</td></tr>
</table>

<table>
<tr><th>Characteristic</th><th colspan="10">DWI3</th></tr>
<tr><td rowspan="2">Bank shape</td><td colspan="5">Left bank</td><td colspan="5">Right bank</td></tr>
<tr><td colspan="5">Convex</td><td colspan="5">Convex</td></tr>
<tr><td rowspan="2">Bank slope</td><td colspan="5">Left bank</td><td colspan="5">Right bank</td></tr>
<tr><td colspan="5">45°</td><td colspan="5">35°</td></tr>
<tr><td>Associated watercourse</td><td colspan="10">Charlevue Creek (tributary).</td></tr>
<tr><td>Factors affecting bank stability</td><td colspan="10">Low ground cover on edges, steep banks, high cattle traffic, low presence of mature trees.</td></tr>
<tr><td>Artificial bank stability features</td><td colspan="10">Creek crossing.</td></tr>
<tr><td>Large woody debris (%)</td><td colspan="10">5%</td></tr>
<tr><td rowspan="2">Turbidity, water and sediment oils and odours</td><td colspan="2">Turbidity</td><td colspan="2">Sediment oils</td><td colspan="2">Water oils</td><td colspan="2">Sediment odours</td><td colspan="2">Water odours</td></tr>
<tr><td colspan="2">-</td><td colspan="2">None</td><td colspan="2">-</td><td colspan="2">None</td><td colspan="2">-</td></tr>
<tr><td>Water level</td><td colspan="10">Dry at time of survey.</td></tr>
<tr><td>Bare ground</td><td colspan="10">Little (1-10%).</td></tr>
<tr><td>Exposed tree roots</td><td colspan="10">Little (1-10%).</td></tr>
<tr><td>Gully erosion</td><td colspan="10">Some (10-50%).</td></tr>
<tr><td>Bank slumping</td><td colspan="10">Moderate (50-75%).</td></tr>
<tr><td>Local catchment erosion</td><td colspan="10">Moderate (50-75%).</td></tr>
</table>

Characteristic	DAI7 (2020)				
Bank shape	**Left bank**	**Right bank**			
	Concave	Convex			
Bank slope	**Left bank**	**Right bank**			
	45°	60°			
Associated watercourse	Springton Creek.				
Factors affecting bank stability	Low ground cover on banks, high weed presence.				
Artificial bank stability features	Currant road bridge, old bridge ridge reinforcing and debris.				
Large woody debris (%)	0%				
Turbidity, water and sediment oils and odours	**Turbidity**	**Sediment oils**	**Water oils**	**Sediment odours**	**Water odours**
	Opaque	None	None	None	None
Water level	0.4 m				
Bare ground	Little (1-10%).				
Exposed tree roots	Little (1-10%).				
Gully erosion	Little (1-10%).				
Bank slumping	Little (1-10%).				
Local catchment erosion	Moderate (50-75%).				

Appendix C Macroinvertebrate Taxonomic List

		Catchment	Duckworth Creek		Springton Creek							Charlevue Creek																Specimen Total
		Site	DAI8	Sub-total	DAR2	DWI9	DAI5		DWI6		Sub-total	DAR1		DRW5		DAI1		DAI2		DWR4		DAI3		DAI4		DAI7	Sub-total	
Class / Order	Family / Sub-family	SIGNAL 2 Value	2020		2020	2019	2019	2020	2019	2020		2019	2020^	2019	2020	2019	2020	2019	2020	(Bank) 2020	(Bed)	2019	2020	2019	2020	2020		
Acarina	sp.	6			1						1						3			19	22				2		46	47
Cladocera	sp.	N/A	3	3	1		17	24	66	2	110	27	80	200	6	12	12	60	120	225	60	1	8	16	35	75	937	1050
Coleoptera	Chrysomelidae	2						1*			1																	1
Coleoptera	Dytiscidae	2			1	2		4	1	2	10	3	1	4		3	12	3	2	24	11		3		1		67	77
Coleoptera	Gyrinidae	4						1		1	2					1	2				3						6	8
Coleoptera	Heteroceridae	1																					1				1	1
Coleoptera	Hydraenidae	3			2	1				1	4	1	2	1	1				2	5							12	16
Coleoptera	Hydrophilidae	2											3						1	8	1		1				14	14
Coleoptera	Limnichidae	4													1*												1	1
Coleoptera	Nanophyidae	3																1#									1	1
Coleoptera	Scirtidae	6				6					6		1	1		5		2									9	15
Coleoptera	Spercheidae	2						1		3	4		3				3		3	1							10	14
Copepoda	sp.	N/A	6	6	3	113	23	8	24	10	181	46	45	350	2	15	48	60	31	60	165		11	16	17	80	946	1133
Decapoda	Atyidae	3																2									2	2
Decapoda	Palaemonidae	4																2									2	2
Decapoda	Parastacidae	4							1		1			1													1	2
Decapoda	Parathelphusidae	3				1					1					3	1								1		5	6
Diptera	Ceratopogonidae	4						2			2				1					2	2	1				2	8	10
Diptera	Chaoboridae	2				2			3		5	4				13		10						4		1	32	37
Diptera	Chironominae	3	5	5	6			53	1	23	83	4	29		3		25	2	5	42	82		4		8	9	213	301
Diptera	Culicidae	1			4	22	2	13	12	6	59		49	12	3	8	1	20	6				2	6		1	108	167
Diptera	Dolichopodidae	3							1		1																	1
Diptera	Orthocladiinae	4						1		3	4																	4
Diptera	Tanypodinae	4	5	5	12			24		9	45		1		2		8	2	2	9	4				3	7	38	88
Ephemeroptera	Baetidae	5						1			1	1	5			1		2	1				1	1	1		13	14
Ephemeroptera	Caenidae	4						5			5		1				3		1				1		5	1	12	17

		Catchment	**Duckworth Creek**		**Springton Creek**							**Charlevue Creek**																**Specimen Total**
		Site	**DAI8**	**Sub-total**	**DAR2**	**DWI9**	**DAI5**		**DWI6**		**Sub-total**	**DAR1**		**DRW5**		**DAI1**		**DAI2**		**DWR4**		**DAI3**		**DAI4**		**DAI7**	**Sub-total**	
Class / Order	**Family / Sub-family**	**SIGNAL 2 Value**	**2020**		**2020**	**2019**	**2019**	**2020**	**2019**	**2020**		**2019**	**2020^**	**2019**	**2020**	**2019**	**2020**	**2019**	**2020**	**2020 (Bank)**	**2020 (Bed)**	**2019**	**2020**	**2019**	**2020**	**2020**		
Gastropoda	Planorbidae	2								1	**1**							4									**4**	**5**
Hemiptera	Corixidae	2													1					6	3						**10**	**10**
Hemiptera	Gerridae	4							2	1	**3**		3		1		1		5				1		3		**14**	**17**
Hemiptera	Micronectidae	2			2			3	2	4	**11**		3	5			7	3	5	35			2			3	**63**	**74**
Hemiptera	Nepidae	3																1									**1**	**1**
Hemiptera	Notonectidae	1				1		4	1		**6**		1	2	1		5	1	1	4			3				**18**	**24**
Hemiptera	Veliidae	3			6	14		4	6	4	**34**	1	12	47	10	1	1	2	24				3	18	4		**123**	**157**
Hydrazoa	Hydridae	2	6	**6**				1			**1**						1										**1**	**8**
Lepidoptera	Crambidae	2																							1		**1**	**1**
Nematoda	sp.	3				25			3	1	**29**			1		1	1			2	2			1			**8**	**37**
Odonata	Corduliidae	5	1	**1**				3			**3**						1										**1**	**5**
Odonata	Isostictidae	3																				1					**1**	**1**
Odonata	Libellulidae	4															1		7				2				**10**	**10**
Oligochaeta	sp.	2			1	2	2	1			**6**	1	2					1			7			2			**13**	**19**
Ostracoda	sp.	N/A			5			11	2		**18**	1	14	1			37		16	50	14		2		8	6	**149**	**167**
Trichoptera	Hydroptilidae	4						2			**2**																	**2**
Trichoptera	Leptoceridae	6	1	**1**				1		1	**2**																	**3**
Turbellaria	Dugesiidae	2																		1							**1**	**1**
Turbellaria	Temnocephalidae	5				1					**1**																	**1**
Site Specimen Abundance			**27**	**27**	**44**	**190**	**44**	**168**	**125**	**72**	**643**	**89**	**255**	**625**	**32**	**63**	**173**	**178**	**232**	**493**	**376**	**3**	**45**	**64**	**89**	**185**	**2902**	**3572**
Site Family Abundance			**7**	**7**	**12**	**12**	**4**	**22**	**14**	**16**	**33**	**10**	**18**	**12**	**12**	**11**	**20**	**18**	**17**	**16**	**13**	**3**	**15**	**8**	**13**	**10**	**39**	**45**

Notes: * Chrysomelidae is an adult.
* Limnichidae is an adult.
# Nanophyidae is a larva (semi-aquatic).
^ One terrestrial Collembola collected (not included in data).

Appendix D Aquatic and Semi-aquatic Fauna Species List

Family	*Scientific Name*	Common Name	NC Act/ Biosecurity Act Status	EPBC Act Status	DAI1	DAI2	DAI3	DAI4	DAI5	DAR1	Sub-total	DAI2	DAI3	DAI4	DAI5	DAI7	DAI8	DAR1	DAR2	DWI6	Sub-total	Total
					2019	**2019**	**2019**	**2019**	**2019**	**2019**	**2019**	**2020**	**2020**	**2020**	**2020**	**2020**	**2020**	**2020**	**2020**	**2020**	**2020**	
Crustaceans																						
Atyidae	*Caridina sp.*	a freshwater atyid shrimp	LC	-							0									2	2	2
Atyidae	*Paratya australiensis*	Freshwater shrimp	LC	-				2			2										0	2
Palaemonidae	*Macrobrachium australiense*	Freshwater prawn	LC	-							0					15	35			7	57	57
Parastacidae	*Cherax destructor*	Blue claw crayfish	LC	-	5	7		20	21	1	54					1	3		2	3	9	63
Parathelphusidae	*Austrothelphusa transversa*	Freshwater crab	LC	-	10	5			1	5	21	65	97	89	41	63	18	77	102	16	568	589
CRUSTACEANS					**15**	**12**		**22**	**22**	**6**	**77**	**65**	**97**	**89**	**41**	**79**	**56**	**77**	**104**	**28**	**636**	**713**
Fish																						
Ambassidae	*Ambassis agassizii*	Agassiz's glassfish	LC	-				2	3		5		4	3		2	5	2	2	2	20	25
Butidae	*Oxyeleotris lineolata*	Sleepy cod	LC	-							0						1				1	1
Eleotridae	*Hypseleotris sp.*	Midgley's carp gudgeon	LC	-							0		2			2	6				10	10
Melanotaeniidae	*Melanotaenia splendida*	Eastern rainbowfish	LC	-										3							3	3
Plotosidae	*Neosilurus hyrtlii*	Hyrtl's catfish	LC	-							0					2	2		1	6	11	11
Poeciliidae	*Gambusia holbrooki*	Eastern mosquitofish	I	-							0								2		2	2
Terapontidae	*Leiopotherapon unicolor*	Spangled perch	LC	-		2		1			3		1	2		3	36			3	45	48
FISH						**2**		**3**	**3**		**8**		**7**	**8**		**9**	**50**	**2**	**5**	**11**	**92**	**100**
Amphibians																						
Bufonidae	*Rhinella marina*	Cane toad	I	-	3						3			1							1	4
Hylidae	*Litoria inermis*	Bumpy rocket frog	LC	-					1		1										0	1
Limnodynastidae	*Limnodynastes terraereginae*	Scarlet-sided pobblebonk	LC	-							0	1						5	2		8	8
Pelodryadidae	*Cyclorana novaehollandiae*	New Holland frog	LC	-							0								1		1	1
AMPHIBIANS					**3**				**1**		**4**	**1**		**1**				**5**	**3**		**10**	**14**
Reptiles																						
Colubridae	*Tropidonophis mairii*	Keelback snake	LC	-	1						1										0	1
SNAKES					**1**						**1**										**0**	**1**
TOTAL AQUATIC & SEMI AQUATIC FAUNA SPECIES					**4**	**3**	**0**	**4**	**4**	**2**	**8**	**2**	**4**	**5**	**1**	**7**	**8**	**3**	**7**	**7**	**14**	**17**

Notes:	LC	least concern
	I	introduced

D

Appendix E Riparian Fauna Species List

Family	*Scientific Name*	Common Name	NC Act/ Biosecurity Act Status	EPBC Act Status	DAR1	DAI1	DAI2	DAI3	DAI4	DAI5	Total
					2019	2019	2019	2019	2019	2019	
Mammals											
Phalangeridae	*Trichosurus vulpecula*	Common brushtail possum	LC	-			1		1		2
Pseudocheiridae	*Petauroides volans volans*	Greater glider	V	V		4	2				6
				MAMMALS	0	4	3	0	1	0	8
Reptiles											
Agamidae	*Diporiphora australis*	Tommy roundhead	LC	-					1		**1**
Gekkonidae	*Gehyra dubia*	Dubious dtella	LC	-		3	1				**4**
Scincidae	*Carlia rubigo*	Orange-flanked rainbow skink	LC	-	2	3	1	2	2	1	**11**
Scincidae	*Carlia vivax*	Lively rainbow skink	LC	-		1		1			**2**
Scincidae	*Cryptoblepharus virgatus*	Wall skink	LC	-					1		**1**
Scincidae	*Menetia greyii*	Common dwarf skink	LC	-			1	2		1	**4**
Scincidae	*Morethia boulengeri*	South-eastern morethia skink	LC	-				1			**1**
				LIZARDS	**2**	**7**	**3**	**6**	**4**	**2**	**24**
Birds											
Acanthizidae	*Gerygone albogularis*	White-throated gerygone	LC	-	3						**3**
Acanthizidae	*Smicrornis brevirostris*	Weebill	LC	-	2		1	1			**4**
Accipitridae	*Accipiter fasciatus*	Brown goshawk	LC	-					2		**2**
Accipitridae	*Aquila audax*	Wedge-tailed eagle	LC	-				1			**1**
Accipitridae	*Haliastur sphenurus*	Whistling kite	LC	-			3		1		**4**
Alcedinidae	*Dacelo leachii*	Blue-winged kookaburra	LC	-				2			**2**
Artamidae	*Cracticus nigrogularis*	Pied butcherbird	LC	-		3	1		4	4	**12**
Artamidae	*Cracticus tibicen*	Australian magpie	LC	-	5	1	4	2	4	5	**21**
Artamidae	*Strepera graculina*	Pied currawong	LC	-	5		1				**6**
Cacatuidae	*Cacatua galerita*	Sulphur-crested cockatoo	LC	-	2	2		1		4	**9**
Cacatuidae	*Calyptorhynchus banksii*	Red-tailed black-cockatoo	LC	-	1	3					**4**
Cacatuidae	*Eolophus roseicapilla*	Galah	LC	-	4		2	2	1	1	**10**
Campephagidae	*Coracina novaehollandiae*	Black-faced cuckoo-shrike	LC	-	2	2					**4**
Campephagidae	*Coracina papuensis*	White-bellied cuckoo-shrike	LC	-	1						**1**
Charadriidae	*Vanellus miles*	Masked lapwing	LC	-						2	**2**
Columbidae	*Geopelia humeralis*	Bar-shouldered dove	LC	-		2					**2**
Columbidae	*Geopelia striata placida*	Peaceful dove	LC	-	1		2		1		**4**
Columbidae	*Ocyphaps lophotes*	Crested pigeon	LC	-			1				**1**
Coraciidae	*Eurystomus orientalis*	Dollarbird	LC	-	2						**2**
Corcoracidae	*Struthidea cinerea*	Apostlebird	LC	-	1	9		4		4	**18**
Corvidae	*Corvus orru*	Torresian crow	LC	-	4		4	7	6	3	**24**
Dicruridae	*Dicrurus bracteatus*	Spangled drongo	LC	-	2						**2**
Estrildidae	*Taeniopygia bichenovii*	Double-barred finch	LC	-					3		**3**
Falconidae	*Falco cenchroides*	Nankeen kestrel	LC	-				1			**1**
Gruidae	*Grus rubicunda*	Brolga	LC	-					2		**2**
Halcyonidae	*Dacelo novaeguineae*	Laughing kookaburra	LC	-	3	9		1		1	**14**
Maluridae	*Malurus leucopterus*	White-winged fairywren	LC	-					1	2	**3**
Maluridae	*Malurus melanocephalus*	Red-backed fairywren	LC	-	5		1				**6**
Megaluridae	*Cincloramphus cruralis*	Brown songlark	LC	-			1			1	**2**
Meliphagidae	*Entomyzon cyanotis*	Blue-faced honeyeater	LC	-		3		1			**4**
Meliphagidae	*Lichenostomus virescens*	Singing honeyeater	LC	-	1				3	2	**6**
Meliphagidae	*Lichmera indistincta*	Brown honeyeater	LC	-				1			**1**
Meliphagidae	*Manorina melanocephala*	Noisy miner	LC	-	1	13	1	2		2	**19**
Meliphagidae	*Melithreptus albogularis*	White-throated honeyeater	LC	-		1	2				**3**
Meliphagidae	*Philemon citreogularis*	Little friarbird	LC	-						1	**1**
Meliphagidae	*Philemon corniculatus*	Noisy friarbird	LC	-	2						**2**
Meropidae	*Merops ornatus*	Rainbow bee-eater	LC	Ma	1						**1**
Monarchidae	*Grallina cyanoleuca*	Magpie-lark	LC	-		2	1	2	3	4	**12**
Monarchidae	*Myiagra inquieta*	Restless flycatcher	LC	-				1			**1**
Monarchidae	*Myiagra rubecula*	Leaden flycatcher	LC	-	1				2		**3**
Oriolidae	*Sphecotheres vieilloti*	Australasian figbird	LC	-	3						**3**
Pachycephalidae	*Colluricincla harmonica*	Grey shrike-thrush	LC	-	2	1	3	1			**7**
Pachycephalidae	*Pachycephala pectoralis*	Golden whistler	LC	-	1						**1**
Pardalotidae	*Pardalotus striatus*	Striated pardalote	LC	-	2	2	2	2	2	1	**11**
Pomatostomidae	*Pomatostomus temporalis*	Grey-crowned babbler	LC	-	2			1			**3**
Psittacidae	*Aprosmictus erythropterus*	Red-winged parrot	LC	-				1		1	**2**
Psittacidae	*Platycercus adscitus*	Pale-headed rosella	LC	-	4	1	3	1		3	**12**
Psittacidae	*Trichoglossus moluccanus*	Rainbow lorikeet	LC	-	11	1				4	**16**
Ptilonorhynchidae	*Chlamydera maculata*	Spotted bowerbird	LC	-			1				**1**
Rhipiduridae	*Rhipidura albiscapa*	Grey fantail	LC	-		1					**1**
Rhipiduridae	*Rhipidura leucophrys*	Willie wagtail	LC	-	1	1		4		1	**7**
Strigidae	*Ninox boobook*	Southern boobook	LC	-	1						**1**
Threskiornithidae	*Threskiornis spinicollis*	Straw-necked ibis	LC	-						1	**1**
Tytonidae	*Tyto alba*	Barn owl	LC	-		1					**1**
				BIRDS	**76**	**58**	**34**	**39**	**35**	**47**	**289**
				TOTAL RIPARIAN FAUNA SPECIES	**31**	**23**	**23**	**25**	**18**	**22**	**63**

Notes: LC least concern V vulnerable Ma marine

E

Appendix F Flora Species List

Scientific Name	Common Name	NC Act/ Biosecurity	EPBC Act Status	DWR1	DWR4	DWR5	DWR6	DWI1	DWI3	DWI6		DWI8	DWI9	DAR1		DAR2	DAI1	DAI2		DAI3		DAI4		DAI5		DAI7	DAI8
				2019	2019	2019	2019	2019	2019	2019	2020	2019	2019	2019	2020	2020	2019	2019	2020	2019	2020	2019	2020	2019	2020	2020	2020
Abutilon oxycarpum	Flannel weed	LC	-																								x
Abutilon sp.		-	-																							x	
Acacia cretata		LC	-	x		x	x	x		x	x		x											x		x	
Acacia excelsa	Ironwood	LC	-			x			x																		
Acacia salicina	Sally wattle	LC	-			x				x	x	x				x					x		x		x	x	
Acalypha eremorum	Soft acalypha	LC	-															x	x								
Acanthospermum hispidum	Starrburr	I	-					x								x											
Achyranthes aspera	Chaff flower	LC	-																						x		
Aeschynomene indica	Buddha pea	LC	-								x					x			x				x		x	x	
Afrohybanthus enneaspermus	Spade flower	LC	-									x															x
Agave americana	Agave	I	-							x																	
Ageratum houstonianum	Billy goat weed	LC	-					x				x															
Alectryon diversifolius	Hollybush	LC	-											x			x										
Alectryon oleifolius	Boonaree	LC	-																		x						
Allocasuarina leuhmanii	Bulloak	LC	-									x															
Alphitonia excelsa	Soap tree	LC	-	x			x	x	x			x	x	x		x									x		
Alternanthera denticulata	Lesser joyweed	LC	-								x					x									x		
Archidendropsis basaltica	Red lancewood	LC	-			x										x					x						
Aristida calycina	Dark wiregrass	LC	-			x			x			x				x							x				
Aristida latifolia	Feathertop wiregrass	LC	-											x										x			
Arundinella nepalensis	Reedgrass	LC	-								x																
Atalaya hemiglauca	Whitewood	LC	-											x	x	x	x			x	x	x		x	x		
Bauhinia carronii	Red bauhinia	LC	-											x	x		x	x	x	x		x	x				
Bauhinia hookeri	White bauhinia	LC	-																x		x					x	x
Bidens pilosa	Cobblers peggs	I	-								x			x	x	x	x	x	x				x		x		
Boerhavia sp.		-	-																						x		
Bothriochloa bladhii	Forest blugrass	LC	-								x				x	x									x		
Bothriochloa pertusa	Indian bluegrass	I	-			x	x	x		x	x			x	x	x		x		x	x		x	x	x		
Breynia oblongifolia	Coffee bush	LC	-																				x				
Bryophyllum daigremontianum	Mother of thousands	I	-					x																			
Bryophyllum delagoense	Mother of millions	RI	-																	x							
Bulbostylis barbata	Dainty sedge	LC	-			x						x		x				x		x	x	x		x			
Capparis laisantha	Nipan	LC	-						x	x														x	x		
Capparis mitchellii	Native orange	LC	-			x																					
Cardiospermum grandiflorum	Balloon vine	RI	-													x											
Carissa spinarum	Currant bush	LC				x		x		x				x	x				x	x	x	x	x	x			
Cassia brewsteri	Leichhardt bean	LC	-					x									x		x		x	x					x
Casuarina cunninghamiana	River she-oak	LC												x	x		x	x	x								
Cenchrus ciliaris	Buffel grass	I	-			x		x	x			x		x				x				x			x	x	
Centipeda minima	Spreading sneezeweed	LC	-																								
Cheilanthes sieberi subsp sieberi	Poison rock fern	LC	-						x																		
Chloris gayana	Rhodes grass	I	-				x		x	x			x														
Chloris inflata	Purpletop Rhodes grass	I	-				x			x															x		
Chrysocephalum apiculatum	Yellow button	LC	-						x			x															
Chrysopogon fallax	Golden beard grass	LC	-												x	x									x		
Commelina diffusa	Native wandering jew	LC	-				x										x	x						x		x	x
Commelina ensifolia	Scurvy grass	LC	-																x		x						
Convolvulaceae sp.		-	-												x												
Coreopsis lanceolata	Coreopsis	I	-					x																			
Corymbia clarksoniana	Clarkson's bloodwood	LC	-				x		x			x				x			x					x	x		
Corymbia dallachiana	Dallachy's ghost gum	LC	-			x				x																	
Corymbia tessellaris	Moreton Bay ash	LC	-	x					x					x	x									x			

F

Scientific Name	Common Name	NC Act/ Biosecurity	EPBC Act Status	DWR1	DWR4	DWR5	DWR6	DWI1	DWI3	DWI6		DWI8	DWI9	DAR1		DAR2	DAI1	DAI2		DAI3		DAI4		DAI5		DAI7	DAI8
				2019	2019	2019	2019	2019	2019	2019	2020	2019	2019	2019	2020	2020	2019	2019	2020	2019	2020	2019	2020	2019	2020	2020	2020
Crinum vulgaris	Crinum lily	LC	-													x											
Crotalaria brevis		LC	-																				x				
Crotalaria medicaginea	Trefoil rattlepod	LC	-													x											
Crotalaria montana		LC	-							x																	
Crotalaria pallida	Streaked rattlepod	I	-		x			x																			
Cryptostegia grandiflora	Rubber vine	RI	WoNS							x	x			x	x	x		x							x		x
Cyanthillium cinereum	Little ironweed	LC	-								x				x	x				x	x				x		
Cynondon dactylon	Green couch grass	I	-		x						x																
Cyperus difformis	Rice sedge	LC	-								x																
Cyperus esculentus	Yellow nutgrass	LC	-																						x		
Cyperus exaltatus	Tall flatsedge	LC	-													x			x		x				x		
Cyperus gracilis	Slender flat sedge	LC	-													x					x		x			x	
Cyperus iria	Variable sedge	LC	-								x								x						x		
Cyperus rotundus	Purple nutsedge	I	-																	x							x
Cyperus sp.		-	-													x											
Dactyloctenium radulans	Button grass	LC	-		x											x									x		
Denhamia oleaster	Stiff denhamia	LC	-																		x						
Desmodium variance	Small leaved ebony	LC	-									x															
Dichanthium fecundum	Curly bluegrass	LC	-																				x				
Dichanthium sericeum	Queensland bluegrass	LC	-													x									x		
Digitaria divaricatissima	Spreading umbrella grass	LC	-																				x				
Digitaria sp.		-	-																						x		
Diospyros humilis	Small-leaved ebony	LC	-																			x					
Echinochloa colona	Awnless barnyard grass	I	-		x						x				x	x			x				x		x	x	x
Ehretia membranifolia	Peach bush	LC	-																								x
Enneapogon lindleyanus	Canetop nineawn	LC	-						x																		
Enteropogon acicularis	Curly windmill grass	LC	-					x	x	x		x	x					x		x		x					
Eragrostis elongata	Clustered lovegrass	LC	-		x							x															
Eragrostis sororia	Woodland lovegrass	LC	-								x																
Eragrostis trichophora	Hairyflower lovegrass	I	-							x														x			
Erythrina vespertilio	Bat's wing coral tree	LC	-															x	x								
Erythroxylum australe	Cocaine bush	LC	-			x														x							
Eucalyptus camaldulensis	River red gum	LC	-	x		x	x	x	x	x			x	x			x	x		x		x		x			x
Eucalyptus coolabah	Coolibah	LC	-																							x	x
Eucalyptus crebra	Narrow-leaved ironbark	LC	-			x	x																		x		
Eucalyptus tereticornis	Queensland blue gum	LC	-								x				x	x			x		x		x		x	x	
Eulalia aurea	Silky browntop	LC	-								x																
Euphorbia drummondii	Caustic weed	LC	-		x						x					x			x				x		x		
Euphorbia sp.		-	-																							x	x
Eustrephus latifolius	Wombat berry	LC	-											x	x	x		x	x	x	x	x	x	x	x	x	x
Everstia vaccinifolia	Spiny canthium	LC	-																			x					
Evolvulus alsinoides	Slender dwarf morning-glory	LC	-			x															x						
Ficus opposita	Sandpaper fig	LC	-											x	x	x	x		x	x	x				x	x	x
Galactia tenuiflora	Snail flower	LC	-				x			x		x						x		x				x			
Glinus lotoides	Hairy carpet weed	LC	-		x		x					x															
Glycine tabacina	Glycine pea	LC	-								x					x			x				x	x	x		
Glycine tomentella	Wooly glycine	LC	-												x	x				x	x						
Gomphrena celosioides	Gomphrena weed	I	-		x	x				x	x														x		
Grewia latifolia	Dysentery bush	LC	-													x					x				x		
Grewia retusifolia	Emu berry	LC	-						x									x		x				x	x		
Harrisia martinii	Harrisia cactus	RI	-																		x	x					
Heteropogon contortus	Black spear grass	LC	-				x	x	x	x		x	x														

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Scientific Name	Common Name	NC Act/ Biosecurity	EPBC Act Status	DWR1	DWR4	DWR5	DWR6	DWI1	DWI3	DWI6		DWI8	DWI9	DAR1		DAR2	DAI1	DAI2		DAI3		DAI4		DAI5		DAI7	DAI8
				2019	2019	2019	2019	2019	2019	2019	2020	2019	2019	2019	2020	2020	2019	2019	2020	2019	2020	2019	2020	2019	2020	2020	2020
Hibiscus heterophyllus	Queensland sorrel	LC	-											x													
Hibiscus meraukensis	Merauke hibiscus	LC	-																						x		
Imperata cylindrica	Blady grass	LC	-						x	x	x																
Indigofera colutea	Sticky indigo	LC	-																						x		
Indigofera sp.		-	-								x					x											
Indigofera tinctoria	True indigo	I	-																					x			
Ipomoea plebeia	Bellvine	LC	-								x	x			x	x			x		x		x		x	x	x
Jasminum didymum	Native jasmine	LC	-								x										x		x		x	x	
Lantana camara	Lantana	RI	WoNS										x														
Lobelia concolor	Poison pratia	LC	-															x									
Lobelia purpurascens	White root	LC	-																		x						
Lomandra longifolia	Common mat rush	LC	-	x						x	x			x	x	x	x	x	x		x	x	x	x	x	x	
Lophostemon grandiflorus	Northern swamp box	LC	-							x				x	x		x	x	x	x	x	x	x	x			
Ludwigia octovalvis	Willow primrose	LC	-		x																						
Macroptilium atropurpureum	Siratro	I	-	x				x			x				x	x	x	x	x		x		x	x	x	x	
Macroptilium lathyroides	Phasey bean	I	-													x			x		x				x	x	x
Malvastrum americanum	Spiked malvastrum	I	-										x	x													
Malvastrum coromandelianum	Prickly malvastrum	I	-													x										x	
Megathyrsus maximus	Guinea grass	I	-	x				x		x	x		x	x	x	x	x	x	x	x	x	x	x	x	x	x	xx
Melaleuca leucadendra	Borad-leaved tea-tree	LC	-								x																
Melaleuca nervosa	Paperbark	LC	-				x		x			x	x														
Melinis repens	Red natal grass	I	-									x	x														
Murdannia gramenea	Grass lilies	LC	-				x																				
Neptunia gracilis	Native sensitive plant	LC	-															x		x	x						
Opuntia tomentosa	Velvety tree pear	RI	WoNS	x			x								x					x	x			x			
Orchidaceae sp.		-	-				x																				
Oxalis sp.		-	-									x															
Parthenium hysterophorus	Parthenium weed	RI	WoNS										x	x	x		x	x		x							
Passiflora foetida	Stinking passionflower	I	-	x										x			x	x		x				x			
Perotis rara	Comet grass	LC	-						x			x															
Petalostigma pubescens	Quinine tree	LC	-						x			x															
Phyllanthus maderaspatensis	Spurge	LC	-								x					x									x	x	x
Phyllantus virgatus		LC	-						x																		
Physalis lanceifolia	Ground cherry	I	-																							x	x
Pittosporum spinescens	Wallaby apple	LC	-																				x				
Plumbago zeylanica	Native plumbago	LC	-															x									
Poaceae sp. 1		-	-																						x		
Poaceae sp. 2		-	-																				x				
Polymeria sp.		-	-																				x				x
Portulaca oleracea	Pigweed	I	-													x											
Portulaca pilosa	Hairy pigweed	I	-			x					x	x															
Pseuderanthemum variabile	Pastel flower	LC	-													x							x		x		
Rhynchosia minima	Rhyncho	LC	-		x									x		x					x				x		
Ricinus communis	Caster oil plant	I	-														x									x	
Rostellularia adscendacea	Pink tongues	LC	-			x																					
Santalatum lanceolatum	Queensland sandalwood	LC	-					x																			
Sclerolaena birchii	Galvanised burr	LC	-																						x		
Scleroleana lanicuspis	Woolly copperburr	LC	-						x															x			
Scoparia dulcis	Scoparia weed	I	-						x			x															
Senna occidentalis	Coffee senna	I	-																							x	
Sesbania cannabina	Yellow pea bush	LC	-												x										x	x	x

F

Scientific Name	Common Name	NC Act/ Biosecurity	EPBC Act Status	DWR1	DWR4	DWR5	DWR6	DWI1	DWI3	DWI6		DWI8	DWI9	DAR1		DAR2	DAI1	DAI2		DAI3		DAI4		DAI5		DAI7	DAI8
				2019	2019	2019	2019	2019	2019	2019	2020	2019	2019	2019	2020	2020	2019	2019	2020	2019	2020	2019	2020	2019	2020	2020	2020
Sida acuta	Spinyhead sida	I	-	x				x				x															
Sida cordifolia	Flannel sida	I	-	x																							
Sida hackettiana	Spiked sida	LC	-	x		x	x	x	x	x		x	x					x		x		x		x	x		
Sida rhombifolia	Paddy lucerne	I	-							x	x			x		x			x		x		x		x	x	
Sida rohlenae	Shrub sida	LC	-								x																
Sida sp.		-	-																x								
Sida spinosa	Spiny sida	I	-												x	x					x		x		x		
Sonchus oleraceus	Common sowthistle	I	-																x				x				
Sporobolos sp.		-	-				x	x		x				x													
Sporobolus caroli	Fairy grass	LC	-																						x		
Stachytarpheta cayennensis	Purple snake weed	I	-	x				x		x																	
Stylosanthes hamata	Caribbean stylo	I	-													x									x		
Stylosanthes scabra	Shrubby stylo	I	-			x	x	x	x	x	x		x								x		x				
Stylosanthes viscosa	Sticky stylo	I	-	x		x	x	x		x		x	x	x						x				x			
Terminalia oblongata	Yellow-wood	LC	-															x	x	x	x	x	x			x	x
Themeda triandra	Kangaroo grass	LC	-				x			x			x	x		x								x			
Tragus australianus	Small burr grass	LC	-																						x		
Trianthema portulacastrum	Black pigweed	I	-																								x
Urochloa mosambicensis	Sabi grass	I	-		x	x	x			x	x			x		x	x	x	x	x	x	x	x	x	x		xx
Vachellia farnesiana	Mimosa bush	I	-															x	x								
Ventilago viminalis	Supplejack	LC	-																		x		x				
Verbena rigida	Veined verbana	I	-															x									
Vigna lanceolata	Maloga bean	LC	-								x					x									x		
Vigna vexillata	Zombie pea	LC	-																								x
Xanthium occidentale	Noogoora burr	I	-	x				x			x			x	x	x	x	x	x		x		x		x	x	x
-	Forb sp. 1	-	-								x																
-	Forb sp. 2	-	-																x							x	
-	Forb sp. 3	-	-																								x
-	Forb sp. 4	-	-																								x
-	Shrub sp. 1	-	-													x									x		x
-	Tree sp. 1	-	-																		x						

Notes:	LC	least concern
	I	introduced
	RI	restricted invasive species
	WoNS	weed of national significance

Appendix G Queensland Herbarium Identification Results

Queensland
Government

Department of
Environment and Science

Queensland Herbarium
Brisbane Botanic Gardens Mt Coot-tha•Toowong 4066 Queensland•Australia
Telephone +61 7 3199 7699 • Facsimile +61 7 3876 1278
e-mail Queensland.Herbarium@qld.gov.au
http://www.qld.gov.au/herbarium

Enquiries	Tony Bean
Telephone	07 3896 9318
Your reference	
Our reference	ARB:mh 252/19

29 April 2019

Caitlin Eales
AARC Environmental Solutions
Suite 5a, 1 Swann Road
TARINGA Qld 4068

Dear Caitlin

The botanical specimens received by the Queensland Herbarium on 11 April 2019 have been identified as:

DWI 6	**Eragrostis trichophora*
DWR 4	*Ammannia multiflora*
DWR 4	*Cyperus difformis*
DA 12	*Lobelia concolor*
DWR 4	*Glinus lotoides*
DA 15	*Arundinella nepalensis*
DWR 6	*Murdannia graminea*
DAR 1	*Arundinella nepalensis*
DAI 5	**Indigofera tinctoria*

*Naturalised, non-native species

There is a charge of $228.80 (2 hrs @ $114.40 per hr incl GST) for these identifications.

You can contribute to Queensland's biodiversity information by submitting this/these plant identification(s) and associated information to the Atlas of Living Australia using the 'Report a sighting' template at (https://www.ala.org.au/)

Yours sincerely

G.P.Guymer
Director

Download a full version of Census of the Queensland Flora 2018
https://data.qld.gov.au/dataset/census-of-the-queensland-flora-2018

QUEENSLAND GOVERNMENT

June 2016

Botanical specimens – cover sheet

Botanical Specimens for Identification

Complete this form (one for **each** specimen) & send with specimen/s to:

Botanical Information and Advisory Service
Queensland Herbarium, DSITI
Brisbane Botanic Gardens Mt Coot-tha
Mt Coot-tha Road, TOOWONG QLD 4066
Queensland.Herbarium@qld.gov.au

Office Use Only

Date received 11 APR 2019
Identification no. 252
Date of despatch 29/4/19

Name: Caitlin Eales
Company / Department: AARC Environmental Solutions
Postal Address Suite 5a 1 Swann Road Taringa
Postcode 4068
Telephone: 3217 8772 **Fax:** 3217 8775
Email: ceales@aarc.net.au

Please send results by: ☐ post ☒ email ☐ fax ☐ telephone
Purpose: ☐ weed detection ☐ poisonous ☐ conservation ☒ commercial
Additional information required:

Label Information: Specimens sent to the Herbarium for identification are frequently retained in the collection for scientific, distribution and voucher records. The label information below when accompanying **each** specimen aids the identification process and greatly increases the scientific value of your specimen.

Collector's Name & No.: Caitlin Eales 0448855514 **Date of collection** 7/4/2019
Botanical name (if known) Arundinella nepalensis Det ARBean, Apr 2019
Locality (include road name &/or distance & direction from nearest town):
west of Dingo, South of Red Rock Accomodation park

Coordinates:
Latitude: °S **Longitude:** °E
(DD MM SS.SSSS – seconds preferred but not compulsory. Please don't supply decimal degrees or decimal minutes)

Or **MGA / AMG Coordinates:**	**DATUM:** [✓ GDA94] /WGS84 *or* AGD84 (circle)	**Zone:** 55K	**Easting:** 727640	**Northing:** 7381080

Or **Map** (e.g. 9442) **and grid reference** (eg 333 666)	**Map number**:	**Grid reference**:

Source of Coordinates: ☒ GPS ☐ Map ☐ Gazetteer ☐ Other
Situation (e.g. plain, creek bank, mountain) near creek line, but heavily disturbed
Cultivated? ☐ YES ☒ NO
Vegetation type (e.g. forest, heath, woodland) open woodland / pasture
Soil / geology / regional ecosystem: 11.3.25 edge of cleared pasture
Kind of plant (e.g. tree, vine, herb): grass
Description (e.g. height, flower or fruit colour):

Abundance: ☐ number of individuals ☐ number seedlings/ juveniles ☐ ha/m^2 size of clump
Other Notes

Specimens submitted automatically become the property of the Queensland Herbarium

For more information phone (07) 3896 9326 or email Queensland.Herbarium@qld.gov.au

QUEENSLAND GOVERNMENT

June 2016

Botanical specimens – cover sheet

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Brisbane Botanic Gardens Mt Coot-tha
Mt Coot-tha Road, TOOWONG QLD 4066
Queensland.Herbarium@qld.gov.au

Office Use Only

Date received ....

Identification no. ....

Date of despatch ....

Name: Caitlin Eales

Company / Department: AARC Environmental Solutions

Postal Address Suite 5a 1 Swann Road Taringa

Postcode 4068

Telephone: 3217 877[illegible]2 **Fax:** 3217 8775

Email: ceales@aarc.net.au

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Purpose: ☐ weed detection ☐ poisonous ☐ conservation ☒ commercial

Additional information required:

Label Information: Specimens sent to the Herbarium for identification are frequently retained in the collection for scientific, distribution and voucher records. The label information below when accompanying **each** specimen aids the identification process and greatly increases the scientific value of your specimen.

Collector's Name & No.: Caitlin Eales 0448855514 **Date of collection** 7/4/2019

Botanical name (if known) Glinus lotoides Det ARBean, Apr 2019

Locality (include road name &/or distance & direction from nearest town):

west of Dingo, South of Red Rock Accommodation park

Coordinates:

Latitude: °S **Longitude:** °E

(DD MM SS.SSSS – seconds preferred but not compulsory. Please don't supply decimal degrees or decimal minutes)

Or **MGA / AMG Coordinates:**	**DATUM:** [✓ GDA94]/WGS84 *or* AGD84 (circle)	**Zone:** 55k	**Easting:** 727640	**Northing:** 7381080

Or **Map** (e.g. 9442) **and grid reference** (eg 333 666) **Map number:** **Grid reference:**

Source of Coordinates: ☒ GPS ☐ Map ☐ Gazetteer ☐ Other

Situation (e.g. plain, creek bank, mountain) near creek line, but heavily disturbed

Cultivated? ☐ YES ☒ NO

Vegetation type (e.g. forest, heath, woodland) open woodland / pasture

Soil / geology / regional ecosystem: 11.3.25 edge of cleared pasture

Kind of plant (e.g. tree, vine, herb): herb

Description (e.g. height, flower or fruit colour: ....

Abundance: ☐ number of individuals ☐ number seedlings/ juveniles ☐ ha/m² size of clump

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Mt Coot-tha Road, TOOWONG QLD 4066
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Date received ....
Identification no. ....
Date of despatch ....

Name: Caitlin Eales
Company / Department: AARC Environmental Solutions
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Postcode 4068
Telephone: 3217 877~~[illegible]~~2 **Fax:** 3217 8775
Email: ceales@aarc.net.au
Please send results by: ☐ post ☒ email ☐ fax ☐ telephone
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Label Information: Specimens sent to the Herbarium for identification are frequently retained in the collection for scientific, distribution and voucher records. The label information below when accompanying **each** specimen aids the identification process and greatly increases the scientific value of your specimen.

Collector's Name & No.: Caitlin Eales 0448855514 **Date of collection** 7/4/2019
Botanical name (if known) Eragrostis trichophora
Locality (include road name &/or distance & direction from nearest town):
west of Dingo, South of Red Rock Accommodation park
Coordinates:
Latitude: °S **Longitude:** °E
(DD MM SS.SSSS – seconds preferred but not compulsory. Please don't supply decimal degrees or decimal minutes)

Or **MGA / AMG Coordinates:**	**DATUM:** [✓ GDA94]/WGS84 *or* AGD84 (circle)	**Zone:** 55K	**Easting:** 727640	**Northing:** 7381080

Or **Map** (e.g. 9442) **and grid reference** (eg 333 666) **Map number:** **Grid reference:**

Source of Coordinates: ☒ GPS ☐ Map ☐ Gazetteer ☐ Other
Situation (e.g. plain, creek bank, mountain) near creek line, but heavily disturbed
Cultivated? ☐ YES ☒ NO
Vegetation type (e.g. forest, heath, woodland) open woodland / pasture
Soil / geology / regional ecosystem: 11.3.25 edge of cleared pasture
Kind of plant (e.g. tree, vine, herb): grass
Description (e.g. height, flower or fruit colour: ....

Abundance: ☐ number of individuals ☐ number seedlings/ juveniles ☐ ha/m² size of clump
Other Notes DWI6

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Mt Coot-tha Road, TOOWONG QLD 4066
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Date received

Identification no.

Date of despatch

Name: Caitlin Eales

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Postcode 4068

Telephone: 3217 877~~[illegible]~~2 **Fax:** 3217 8775

Email: ceales@aarc.net.au

Please send results by: ☐ post ☒ email ☐ fax ☐ telephone

Purpose: ☐ weed detection ☐ poisonous ☐ conservation ☒ commercial

Additional information required:

Label Information:

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Collector's Name & No.: Caitlin Eales 0448855514 **Date of collection** 7/4/2019

Botanical name (if known) Ammannia multiflora Det AR Bean, Apr 2019

Locality (include road name &/or distance & direction from nearest town):

west of Dingo, South of Red Rock Accomodation park

Coordinates:

Latitude: °S **Longitude:** °E

(DD MM SS.SSSS – seconds preferred but not compulsory. Please don't supply decimal degrees or decimal minutes)

Or **MGA / AMG Coordinates:**	**DATUM:** [✓ GDA94] /WGS84 *or* AGD84 (circle)	**Zone:** 55k	**Easting:** 727640	**Northing:** 7381080

Or **Map** (e.g. 9442) **and grid reference** (eg 333 666) **Map number:** **Grid reference:**

Source of Coordinates: ☒ GPS ☐ Map ☐ Gazetteer ☐ Other

Situation (e.g. plain, creek bank, mountain) near creek line, but heavily disturbed

Cultivated? ☐ YES ☒ NO

Vegetation type (e.g. forest, heath, woodland) open woodland / pasture

Soil / geology / regional ecosystem: 11.3.25 edge of cleared pasture

Kind of plant (e.g. tree, vine, herb): Small erect herb

Description (e.g. height, flower or fruit colour:

Abundance: ☐ number of individuals ☐ number seedlings/ juveniles ☐ ha/m² size of clump

Other Notes DWR 4

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QUEENSLAND GOVERNMENT

June 2016

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Email: ceales@aarc.net.au

Please send results by: ☐ post ☒ email ☐ fax ☐ telephone

Purpose: ☐ weed detection ☐ poisonous ☐ conservation ☒ commercial

Additional information required:

Label Information: Specimens sent to the Herbarium for identification are frequently retained in the collection for scientific, distribution and voucher records. The label information below when accompanying **each** specimen aids the identification process and greatly increases the scientific value of your specimen.

Collector's Name & No.: Caitlin Eales 0448855514 **Date of collection** 7/4/2019

Botanical name (if known) Cyperus difformis Det ARBean, Apr 2019

Locality (include road name &/or distance & direction from nearest town):

west of Dingo, South of Red Rock Accommodation park

Coordinates:

Latitude: °S **Longitude:** °E

(DD MM SS.SSSS – seconds preferred but not compulsory. Please don't supply decimal degrees or decimal minutes)

Or **MGA / AMG Coordinates:**	**DATUM:** [✓ GDA94]/WGS84 *or* AGD84 (circle)	**Zone:** 55K	**Easting:** 727640	**Northing:** 7381080

Or **Map** (e.g. 9442) **and grid reference** (eg 333 666) **Map number:** **Grid reference:**

Source of Coordinates: ☒ GPS ☐ Map ☐ Gazetteer ☐ Other

Situation (e.g. plain, creek bank, mountain) near creek line, but heavily disturbed

Cultivated? ☐ YES ☒ NO

Vegetation type (e.g. forest, heath, woodland) open woodland / pasture

Soil / geology / regional ecosystem: 11.3.25 edge of cleared pasture

Kind of plant (e.g. tree, vine, herb): ....

Description (e.g. height, flower or fruit colour: ....

Abundance: ☐ number of individuals ☐ number seedlings/ juveniles ☐ ha/m^2 size of clump

Other Notes DWR4

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For more information phone (07) 3896 9326 or email Queensland.Herbarium@qld.gov.au

QUEENSLAND GOVERNMENT

June 2016

Botanical specimens – cover sheet

Botanical Specimens for Identification

Complete this form (one for **each** specimen) & send with specimen/s to:

Botanical Information and Advisory Service
Queensland Herbarium, DSITI
Brisbane Botanic Gardens Mt Coot-tha
Mt Coot-tha Road, TOOWONG QLD 4066
Queensland.Herbarium@qld.gov.au

Office Use Only

Date received

Identification no.

Date of despatch

Name: Caitlin Eales

Company / Department: AARC Environmental Solutions

Postal Address Suite 5a 1 Swann Road Taringa

Postcode 4068

Telephone: 3217 877[illegible]2 **Fax:** 3217 8775

Email: ceales@aarc.net.au

Please send results by: ☐ post ☒ email ☐ fax ☐ telephone

Purpose: ☐ weed detection ☐ poisonous ☐ conservation ☒ commercial

Additional information required:

Label Information: Specimens sent to the Herbarium for identification are frequently retained in the collection for scientific, distribution and voucher records. The label information below when accompanying **each** specimen aids the identification process and greatly increases the scientific value of your specimen.

Collector's Name & No.: Caitlin Eales 0448855514 **Date of collection** 7/4/2019

Botanical name (if known) Lobelia concolor Det AR Bean, Apr 2019

Locality (include road name &/or distance & direction from nearest town):
west of Dingo, South of Red Rock Accommodation park

Coordinates:
Latitude: °S **Longitude:** °E

(DD MM SS.SSSS – seconds preferred but not compulsory. Please don't supply decimal degrees or decimal minutes)

Or **MGA / AMG Coordinates:**	**DATUM:** [✓ GDA94]/WGS84 *or* AGD84 (circle)	**Zone:** 55K	**Easting:** 727640	**Northing:** 7381080

Or **Map** (e.g. 9442) **and grid reference** (eg 333 666)	**Map number:**	**Grid reference:**

Source of Coordinates: ☒ GPS ☐ Map ☐ Gazetteer ☐ Other

Situation (e.g. plain, creek bank, mountain) near creek line, but heavily disturbed

Cultivated? ☐ YES ☒ NO

Vegetation type (e.g. forest, heath, woodland) open woodland / pasture

Soil / geology / regional ecosystem: 11.3.25 edge of cleared pasture

Kind of plant (e.g. tree, vine, herb): herb

Description (e.g. height, flower or fruit colour:

Abundance: ☐ number of individuals ☐ number seedlings/ juveniles ☐ ha/m^2 size of clump

Other Notes

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Mt Coot-tha Road, TOOWONG QLD 4066
Queensland.Herbarium@qld.gov.au

Office Use Only

Date received ....

Identification no. ....

Date of despatch ....

Name: Caitlin Eales

Company / Department: AARC Environmental Solutions

Postal Address Suite 5a 1 Swann Road Taringa

Postcode 4068

Telephone: 3217 8772 **Fax:** 3217 8775

Email: ceales@aarc.net.au

Please send results by: ☐ post ☒ email ☐ fax ☐ telephone

Purpose: ☐ weed detection ☐ poisonous ☐ conservation ☒ commercial

Additional information required:

Label Information: Specimens sent to the Herbarium for identification are frequently retained in the collection for scientific, distribution and voucher records. The label information below when accompanying **each** specimen aids the identification process and greatly increases the scientific value of your specimen.

Collector's Name & No.: Caitlin Eales 0448855514 **Date of collection** 7/4/2019

Botanical name (if known) Murdannia graminea Det AR Bean, Apr 2019

Locality (include road name &/or distance & direction from nearest town):
west of Dingo, South of Red Rock Accommodation park

Coordinates:
Latitude: °S **Longitude:** °E

(DD MM SS.SSSS – seconds preferred but not compulsory. Please don't supply decimal degrees or decimal minutes)

Or **MGA / AMG Coordinates:** **DATUM:** [✓ GDA94]/WGS84 *or* AGD84 (circle) **Zone:** 55K **Easting:** 727640 **Northing:** 7381080

Or **Map** (e.g. 9442) **and grid reference** (eg 333 666) **Map number:** **Grid reference:**

Source of Coordinates: ☒ GPS ☐ Map ☐ Gazetteer ☐ Other

Situation (e.g. plain, creek bank, mountain) near creek line, but heavily disturbed

Cultivated? ☐ YES ☒ NO

Vegetation type (e.g. forest, heath, woodland) open woodland / pasture

Soil / geology / regional ecosystem: 11.3.25 edge of cleared pasture

Kind of plant (e.g. tree, vine, herb): grass/orchid

Description (e.g. height, flower or fruit colour): ....

Abundance: ☐ number of individuals ☐ number seedlings/ juveniles ☐ ha/m² size of clump

Other Notes

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Date received ....
Identification no. ....
Date of despatch ....

Name: Caitlin Eales
Company / Department: AARC Environmental Solutions
Postal Address Suite 5a 1 Swann Road Taringa
Postcode 4068
Telephone: 3217 877[illegible]2 **Fax:** 3217 8775
Email: ceales@aarc.net.au
Please send results by: ☐ post ☒ email ☐ fax ☐ telephone
Purpose: ☐ weed detection ☐ poisonous ☐ conservation ☒ commercial
Additional information required:

Label Information: Specimens sent to the Herbarium for identification are frequently retained in the collection for scientific, distribution and voucher records. The label information below when accompanying **each** specimen aids the identification process and greatly increases the scientific value of your specimen.

Collector's Name & No.: Caitlin Eales 0448855514 **Date of collection** 7/4/2019
Botanical name (if known) Arundinella nepalensis Det ARBean, Apr 2019
Locality (include road name &/or distance & direction from nearest town):
west of Dingo, South of Red Rock Accommodation park

Coordinates:
Latitude: °S **Longitude:** °E
(DD MM SS.SSSS – seconds preferred but not compulsory. Please don't supply decimal degrees or decimal minutes)

Or **MGA / AMG Coordinates:** **DATUM:** [✓ GDA94]/WGS84 or AGD84 (circle) **Zone:** 55K **Easting:** 727640 **Northing:** 7381080
Or **Map** (e.g. 9442) **and grid reference** (eg 333 666) **Map number:** **Grid reference:**

Source of Coordinates: ☒ GPS ☐ Map ☐ Gazetteer ☐ Other
Situation (e.g. plain, creek bank, mountain) near creek line, but heavily disturbed
Cultivated? ☐ YES ☒ NO
Vegetation type (e.g. forest, heath, woodland) open woodland / pasture
Soil / geology / regional ecosystem: 11.3.25 edge of cleared pasture
Kind of plant (e.g. tree, vine, herb): grass
Description (e.g. height, flower or fruit colour: ....

Abundance: ☐ number of individuals ☐ number seedlings/ juveniles ☐ ha/m^2 size of clump
Other Notes

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Date received ....

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Date of despatch ....

Name: Caitlin Eales

Company / Department: AARC Environmental Solutions

Postal Address Suite 5a 1 Swann Road Taringa

Postcode 4068

Telephone: 3217 8772 **Fax:** 3217 8775

Email: ceales@aarc.net.au

Please send results by: ☐ post ☒ email ☐ fax ☐ telephone

Purpose: ☐ weed detection ☐ poisonous ☐ conservation ☒ commercial

Additional information required:

Label Information: Specimens sent to the Herbarium for identification are frequently retained in the collection for scientific, distribution and voucher records. The label information below when accompanying **each** specimen aids the identification process and greatly increases the scientific value of your specimen.

Collector's Name & No.: Caitlin Eales 0448855514 **Date of collection** 7/4/2019

Botanical name (if known) Indigofera tinctoria Det ARBean, Apr 2019

Locality (include road name &/or distance & direction from nearest town):

west of Dingo, South of Red Rock Accommodation park

Coordinates:

Latitude: °S **Longitude:** °E

(DD MM SS.SSSS – seconds preferred but not compulsory. Please don't supply decimal degrees or decimal minutes)

Or MGA / AMG Coordinates: **DATUM:** [✓ GDA94]/WGS84 *or* AGD84 (circle) **Zone:** 55K **Easting:** 727640 **Northing:** 7381080

Or **Map** (e.g. 9442) **and grid reference** (eg 333 666) **Map number:** **Grid reference:**

Source of Coordinates: ☒ GPS ☐ Map ☐ Gazetteer ☐ Other

Situation (e.g. plain, creek bank, mountain) near creek line, but heavily disturbed

Cultivated? ☐ YES ☒ NO

Vegetation type (e.g. forest, heath, woodland) open woodland / pasture

Soil / geology / regional ecosystem: 11.3.25 edge of cleared pasture

Kind of plant (e.g. tree, vine, herb): shrub

Description (e.g. height, flower or fruit colour: ....

Abundance: ☐ number of individuals ☐ number seedlings/ juveniles ☐ ha/m² size of clump

Other Notes

Specimens submitted automatically become the property of the Queensland Herbarium

For more information phone (07) 3896 9326 or email Queensland.Herbarium@qld.gov.au

Appendix H Weed Fact Sheets

Department of Agriculture and Fisheries

Biosecurity Queensland

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

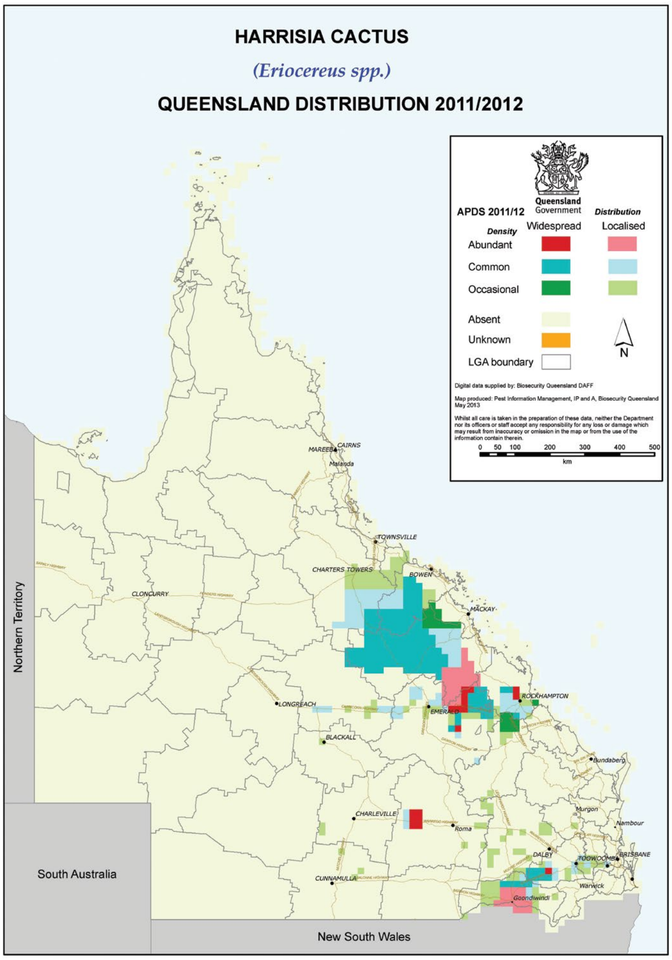
Fruit and seed are readily eaten by birds, mammals and to a lesser extent by feral pigs.

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.

Fact sheets are available from Department of Agriculture and Fisheries (DAF) service centres and our Customer Service Centre (telephone 13 25 23). Check our website at www.biosecurity.qld.gov.au to ensure you have the latest version of this fact sheet. The control methods referred to in this fact sheet should be used in accordance with the restrictions (federal and state legislation, and local government laws) directly or indirectly related to each control method. These restrictions may prevent the use of one or more of the methods referred to, depending on individual circumstances. While every care is taken to ensure the accuracy of this information, DAF does not invite reliance upon it, nor accept responsibility for any loss or damage caused by actions based on it.

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.

Department of Agriculture and Fisheries

Biosecurity Queensland

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.

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

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.

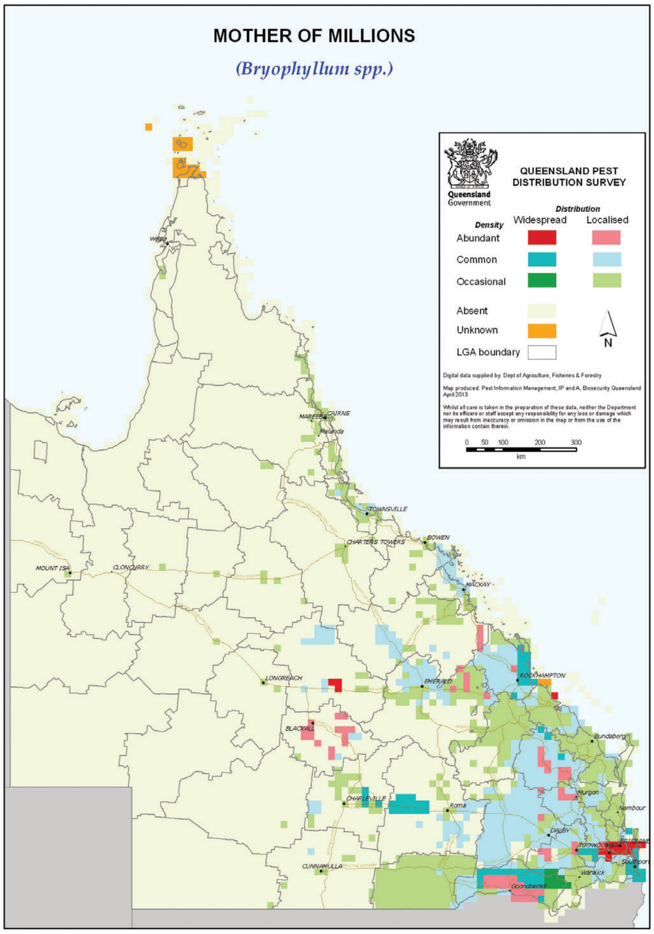
Methods of spread

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.

Fact sheets are available from Department of Agriculture and Fisheries (DAF) service centres and our Customer Service Centre (telephone 13 25 23). Check our website at www.biosecurity.qld.gov.au to ensure you have the latest version of this fact sheet. The control methods referred to in this fact sheet should be used in accordance with the restrictions (federal and state legislation, and local government laws) directly or indirectly related to each control method. These restrictions may prevent the use of one or more of the methods referred to, depending on individual circumstances. While every care is taken to ensure the accuracy of this information, DAF does not invite reliance upon it, nor accept responsibility for any loss or damage caused by actions based on it.

Department of Agriculture and Fisheries

Biosecurity Queensland

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.

Control

Managing parthenium

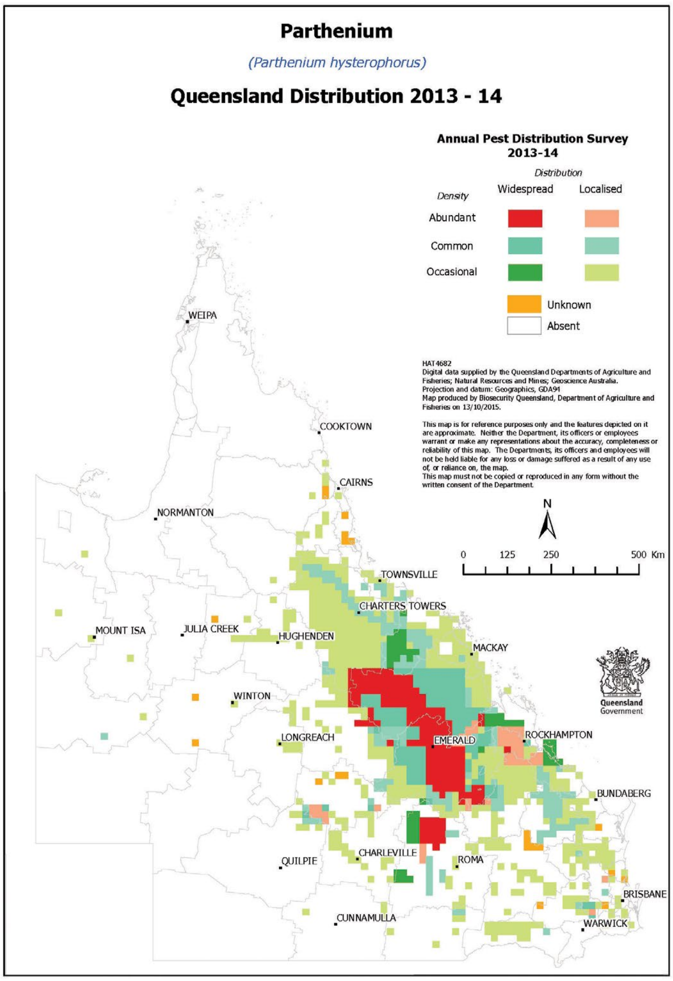
The GBO requires a person to take reasonable and practical steps to minimise the risks posed by parthenium. This fact sheet provides information and some options for controlling parthenium.

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.

Map 1. Distribution of parthenium in Queensland



HAT4682
Digital data supplied by the Queensland Departments of Agriculture and Fisheries; Natural Resources and Mines; Geoscience Australia.
Projection and datum: Geographics, GDA94
Map produced by Biosecurity Queensland, Department of Agriculture and Fisheries on 13/10/2015.

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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.

Department of Agriculture and Fisheries

Biosecurity Queensland

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.

Department of Agriculture and Fisheries
Biosecurity Queensland

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.

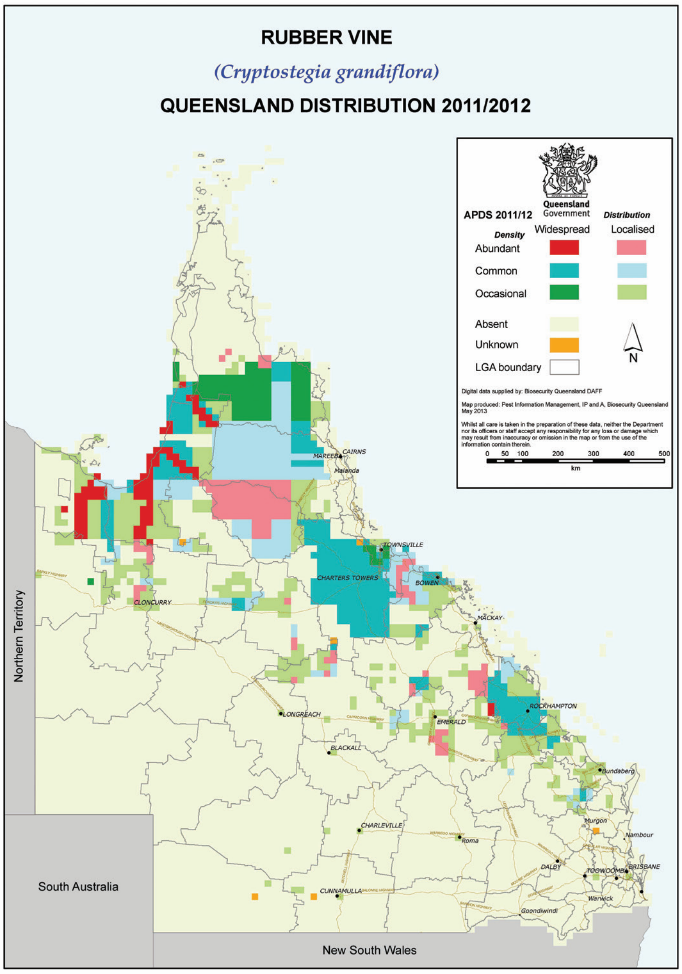
Flowers are pink-purple, 4–6 cm long, found near branchlet ends. Pods are 7–9 cm long, contain seeds 5–5.9 mm long, 1.8–3.5 mm wide, topped with silky tuft of white hairs.

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

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11/17

Appendix L Air Quality and Greenhouse Gas Assessment

Gemini Project: Air Quality and Greenhouse Gas Assessment

Prepared for:

Magnetic South Pty Ltd

November 2020

Final

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Contents

Executive summary....vi
1. Introduction.... 1
2. Project description 2
3. Air quality assessment 5
  3.1 Regulatory framework for air quality in Queensland 5
  3.2 Methodology 6
    3.2.1 Surrounding environment 6
    3.2.2 Site-specific meteorology....6
    3.2.3 Assessment scenarios....6
    3.2.4 Dust emission rates 7
    3.2.5 Dispersion modelling....7
    3.2.6 Limitations of dispersion modelling 7
    3.2.7 Cumulative impacts 8
    3.2.8 Presentation of results 8
  3.3 Existing environment....9
    3.3.1 Local terrain and land-use 9
    3.3.2 Sensitive receptors 9
    3.3.3 Existing air quality 11
  3.4 Emissions to the atmosphere....16
    3.4.1 Overview 16
    3.4.2 Standard mitigation measures....16
    3.4.3 Additional mitigation measures 17
    3.4.4 Emissions inventory....17
  3.5 Air quality impact assessment 23
    3.5.1 Year 2....23
    3.5.2 Year 8....30
    3.5.3 Year 15....38
  3.6 Mitigation 43
4. Greenhouse gas assessment.... 44
  4.1 Background....44
  4.2 Regulatory Framework for Greenhouse Gas Emissions 44
    4.2.1 National policy 44
    4.2.2 National Greenhouse and Energy Reporting (NGER) 45
  4.3 Methodology 45
    4.3.1 Emissions 46
    4.3.2 Emissions estimation 48
  4.4 Results 49
    4.4.1 Scope 1 and 2 GHG emissions and energy use summary 49
    4.4.2 Scope 3 GHG emissions....52
    4.4.3 Regulatory obligations – NGER and the safeguard mechanism 53
    4.4.4 GHG mitigation and management 54
5. Conclusions 55
6. References 57
Appendix A Modelling methodology 79
  A1 Meteorology....79
    A1.1 TAPM meteorological modelling 79
    A1.2 CALMET meteorological modelling 79
    A1.3 Analysis of dispersion meteorology 80
  A2 CALPUFF dispersion modelling 86
    A2.1 Source configuration 86
Appendix B Activity data.... 87
Appendix C Air Quality Management Plan.... 90
  C1 Introduction....90
    C1.1 Overview 90
    C1.2 Objective....90

C2 Regulatory Requirements 91
C3 Gemini project Overview 92
  C3.1 Project Description 92
  C3.2 Potential air quality impacts 94
C4 Description of the Existing Environment 95
  C4.1 Location of sensitive receptors 95
  C4.2 Existing air quality monitoring 95
C5 Dust Control Measures 95
  C5.1 Standard Dust Management 95
  C5.2 Additional Dust Management 96
  C5.3 Stakeholder engagement and response to complaints 103
C6 Review and Revision 103
  C6.1 Continuous improvement 103
  C6.2 Revision 104
C7 Training 104
C8 Roles and Responsibilities 105
C9 References 106

Tables

Table 1 Relevant ambient air quality objectives (Air EPP) 6
Table 2 Sensitive receptors surrounding the Project (receptors not considered in this report due to purchase or pending purchase by Magnetic South highlighted grey) 10
Table 3 2018 - 2019 Annual NPI dust emissions existing coal mines surrounding the Project 12
Table 4 Summary of 24-hour averaged PM_{10} exceedances for Blackwater 14
Table 5 Ambient background concentrations used to assess cumulative impacts 15
Table 6 Standard dust control measures and relative reduction in emissions 16
Table 7 Emissions inventory for year 2, year 8 and year 15 18
Table 8 Predicted ground-level concentrations of TSP, PM_{10}, $PM_{2.5}$ and dust deposition rates at sensitive receptors during year 2 using standard mitigation measures 25
Table 9 Number of days per year predicted to exceed in year 2 26
Table 10 Predicted ground-level concentrations of TSP, PM_{10}, $PM_{2.5}$ and dust deposition rates at sensitive receptors during year 8 using standard mitigation measures 31
Table 11 Number of days per year predicted to exceed in year 8 32
Table 12 Predicted ground-level concentrations of TSP, PM_{10}, $PM_{2.5}$ and dust deposition rates at sensitive receptors during year 15 using standard mitigation measures 39
Table 13 Number of days per year predicted to exceed in year 15 40
Table 14 NGER annual reporting thresholds – greenhouse gas emissions and energy use 45
Table 15 Summary of GHG emission sources by year of mining operations 47
Table 16 Coal transportation - Scope 3 GHG Parameters 48
Table 17 Emission factors and energy content for GHG emission sources 49
Table 18 Summary of GHG emissions by year of mining operations 50
Table 19 Summary of energy use (GJ/y) by year of mining operations 51
Table 20 Summary of annual Scope 3 GHG emissions in tCO_2-e 53

Table A1 CALPUFF area source characteristics 86

Table B1 Summary of activity data used in emissions calculations 87
Table C2 Expected air quality objectives 91
Table C3 Concentrations of PM_{10} at DES Blackwater monitoring station from April 2019 to April 2020 95
Table C4 Concentrations of $PM_{2.5}$ at DES Blackwater monitoring station from April 2019 to April 2020 95
Table C5 Standard dust control measures and relative reduction in emissions 96
Table C6 Trigger values for rolling 24-hour average concentrations of PM_{10} 97
Table C7 Example of actions and responses for ambient monitoring data triggers 98
Table C8 Australian Standards that are relevant to Project dust monitoring program 100
Table C9 Proposed Project air quality monitoring requirements 102
Table C10 Responsibilities of Project staff members 105

Figures

Figure 1 Project Location 3
Figure 2 Proposed Project Layout 4
Figure 3 Study area terrain (contours in metres above sea-level) 9
Figure 4 Location of sensitive receptors (utm metres) 11
Figure 5 Timeseries of 24-hour average PM_{10} for Blackwater April 2019 to April 2020 13
Figure 6 Timeseries of 24-hour average $PM_{2.5}$ for Blackwater April 2019 to April 2020 13
Figure 7 Year 2 - Dust emission source areas 20
Figure 8 Year 8 - Dust emission source areas 21
Figure 9 Year 15 - Dust emission source areas 22
Figure 10 Year 2 – Timeseries of 24-hour average PM_{10} at SR03 including additional mitigation (when required) 26
Figure 11 Year 2 – Timeseries of 24-hour average PM_{10} at SR13 including additional mitigation (when required) 27
Figure 12 Year 2 – Timeseries of 24-hour average PM_{10} at SR22 including additional mitigation (when required) 27
Figure 13 Year 2 – Timeseries of 24-hour average PM_{10} at SR27 including additional mitigation (when required) 28
Figure 14 Year 2 – Timeseries of 24-hour average PM_{10} at SR28 including additional mitigation (when required) 28
Figure 15 Year 2 – Timeseries of 24-hour average PM_{10} at SR31 including additional mitigation (when required) 29
Figure 16 Year 2 – Timeseries of 24-hour average PM_{10} at SR32 including additional mitigation (when required) 29
Figure 17 Year 8 – Timeseries of 24-hour average PM_{10} at SR03 including additional mitigation (when required) 32
Figure 18 Year 8 – Timeseries of 24-hour average PM_{10} at SR07 including additional mitigation (when required) 33
Figure 19 Year 8 – Timeseries of 24-hour average PM_{10} at SR10 including additional mitigation (when required) 33
Figure 20 Year 8 – Timeseries of 24-hour average PM_{10} at SR13 including additional mitigation (when required) 34
Figure 21 Year 8 – Timeseries of 24-hour average PM_{10} at SR16 including additional mitigation (when required) 34
Figure 22 Year 8 – Timeseries of 24-hour average PM_{10} at SR22 including additional mitigation (when required) 35
Figure 23 Year 8 – Timeseries of 24-hour average PM_{10} at SR26 including additional mitigation (when required) 35
Figure 24 Year 8 – Timeseries of 24-hour average PM_{10} at SR27 including additional mitigation (when required) 36
Figure 25 Year 8 – Timeseries of 24-hour average PM_{10} at SR28 including additional mitigation (when required) 36
Figure 26 Year 8 – Timeseries of 24-hour average PM_{10} at SR31 including additional mitigation (when required) 37
Figure 27 Year 8 – Timeseries of 24-hour average PM_{10} at SR32 including additional mitigation (when required) 37
Figure 28 Year 15 - Timeseries of 24-hour average PM_{10} at SR14 including additional mitigation (when required) 40
Figure 29 Year 15 - Timeseries of 24-hour average PM_{10} at SR17 including additional mitigation (when required) 41
Figure 30 Year 15 – Timeseries of 24-hour average PM_{10} at SR22 including additional mitigation (when required) 41
Figure 31 Year 15 – Timeseries of 24-hour average PM_{10} at SR31 including additional mitigation (when required) 42
Figure 32 Year 15 – Timeseries of 24-hour average PM_{10} at SR32 including additional mitigation (when required) 42
Figure 33 Summary of annual GHG emissions by emission source and emission scope 52

Figure A1 Annual distribution of winds at the Project site predicted by TAPM/CALMET 81
Figure A2 Seasonal distribution of winds at the Project site predicted by TAPM/CALMET 82
Figure A3 Diurnal distribution of winds at the Project site predicted by TAPM/CALMET 83
Figure A4 Diurnal stability class at the Project site predicted by TAPM/CALMET 84
Figure A5 Diurnal mixing height at the Project site predicted by TAPM/CALMET 85

Contour Plates

Plate 1 Year 2 - Predicted annual average cumulative ground-level concentration of TSP using standard mitigation measures 58
Plate 2 Year 2 - Predicted maximum 24-hour average cumulative ground-level concentration of PM_{10} using standard mitigation measures 59
Plate 3 Year 2 - Predicted annual average cumulative ground-level concentration of PM_{10} using standard mitigation measures 60
Plate 4 Year 2 - Predicted maximum 24-hour average cumulative ground-level concentration of $PM_{2.5}$ using standard mitigation measures 61
Plate 5 Year 2 - Predicted annual average cumulative ground-level concentration of $PM_{2.5}$ using standard mitigation measures 62
Plate 6 Year 2 - Predicted maximum monthly cumulative dust deposition rate using standard mitigation measures 63
Plate 7 Year 2 - Predicted maximum 24-hour average cumulative ground-level concentration of PM_{10} using standard mitigation measures and additional mitigation when necessary 64
Plate 8 Year 8 - Predicted annual average cumulative ground-level concentration of TSP using standard mitigation measures 65
Plate 9 Year 8 - Predicted maximum 24-hour average cumulative ground-level concentration of PM_{10} using standard mitigation measures 66
Plate 10 Year 8 - Predicted annual average cumulative ground-level concentration of PM_{10} using standard mitigation measures 67
Plate 11 Year 8 - Predicted maximum 24-hour average cumulative ground-level concentration of $PM_{2.5}$ using standard mitigation measures 68
Plate 12 Year 8 - Predicted annual average cumulative ground-level concentration of $PM_{2.5}$ using standard mitigation measures 69
Plate 13 Year 8 - Predicted maximum monthly cumulative dust deposition rate using standard mitigation measures 70
Plate 14 Year 8 - Predicted maximum 24-hour average cumulative ground-level concentration of PM_{10} using standard mitigation measures and additional mitigation when necessary 71
Plate 15 Year 15 - Predicted annual average cumulative ground-level concentration of TSP using standard mitigation measures 72
Plate 16 Year 15 - Predicted maximum 24-hour average cumulative ground-level concentration of PM_{10} using standard mitigation measures 73
Plate 17 Year 15 - Predicted annual average cumulative ground-level concentration of PM_{10} using standard mitigation measures 74
Plate 18 Year 15 - Predicted maximum 24-hour average cumulative ground-level concentration of $PM_{2.5}$ using standard mitigation measures 75
Plate 19 Year 15 - Predicted annual average cumulative ground-level concentration of $PM_{2.5}$ using standard mitigation measures 76
Plate 20 Year 15 - Predicted maximum monthly cumulative dust deposition rate using standard mitigation measures 77
Plate 21 Year 15 - Predicted maximum 24-hour average cumulative ground-level concentration of PM_{10} using standard mitigation measures and additional mitigation when necessary 78

Glossary

Term	**Definition**
%	percentage
$\mu g/m^3$	micrograms per cubic metre
m^3	cubic metre
g/s	gram per second
ha	hectare
kg/year	Kilogram per year
km	kilometre
km/h	kilometre per hour
$L/m^2/hour$	litres per metre square per hour
m	metre
m/s	metre per second
µm	micrometre (micron)
$mg/m^2/day$	milligram per square metre per day
Mtpa	million tonnes per annum
t	tonne (metric)
tCO_2-e	tonnes of carbon dioxide equivalents
VKT	vehicle kilometre travelled
Nomenclature	**Definition**
PM_{10}	particulate matter with an equivalent aerodynamic diameter of 10 µm or less
$PM_{2.5}$	particulate matter with an equivalent aerodynamic diameter of 2.5 µm or less
TSP	total suspended particles
Abbreviations	**Definition**
Air EPP	*Environmental Protection (Air) Policy 2019*
CHPP	Coal Handling and Processing Plant
DES	Department of Environment and Science
E	East
EA	Environmental Authority
EP Act	*Environmental Protection Act 1994*
GHG	Greenhouse Gas
MIA	Mine Infrastructure Area
ML	Mining Lease
MLA	Mining Lease Application
N	North
NGER Act	*National Greenhouse and Energy Reporting Act 2007*
NPI	National Pollutant Inventory
OB	Overburden
PCI	Pulverised coal injection
Project	Gemini Project
ROM	Run of Mine
SE	Southeast
SSE	South-southeast
SSW	South-southwest
TLO	Train loadout facility
US EPA	United States Environmental Protection Agency

EXECUTIVE SUMMARY

Katestone Environmental Pty Ltd (Katestone) was commissioned by Magnetic South Pty Ltd to conduct an air quality and greenhouse gas assessment of the proposed Gemini Project (the Project).

The Project involves the development of an open cut coal mine located approximately 3 km west of the township of Dingo and 35 kilometres east of Blackwater in Central Queensland.

This air quality assessment has investigated the potential for the Project to affect air quality in the region. Three operational scenarios have been considered that represent the worst-case potential for dust emissions over the life of the Project, given the proposed mining schedule and proximity of sensitive receptors. The assessment has used site-specific meteorological data and industry standard dispersion modelling techniques to predict ground-level concentrations of particulate matter (TSP, PM_{10} and $PM_{2.5}$) and dust deposition rates due to the Project.

The air quality assessment has considered the potential impacts of the Project in isolation and with the inclusion of representative background levels of dust. Predicted ground-level concentrations of dust have been presented across a 20 x 20 kilometre domain and at identified sensitive receptors. Predictions have been compared with the relevant air quality objectives and guidelines.

The findings of the cumulative impact assessment are as follows:

- Predicted annual average concentrations of TSP ***comply*** with the relevant air quality objective at all sensitive receptors using standard mitigation measures.
- Predicted maximum 24-hour concentrations of PM_{10} ***comply*** with the relevant air quality objective at all sensitive receptors using standard mitigation measures and additional mitigation when necessary.
- Predicted annual average concentrations of PM_{10} ***comply*** with the relevant air quality objective at all sensitive receptors using standard mitigation and additional mitigation measures when necessary, except at SR22, SR31, and SR32 for Project Years 2 and 8, and SR14, SR17, SR22, SR31, and SR32 for Project Year 15. The Project contributes approximately 15% in Year 2, 12% in Year 8 and 44% in Year 5 to the Air EPP objective for annual average PM_{10} of 25 µg/m^3.
- Predicted 24-hour concentrations of $PM_{2.5}$ ***comply*** with the relevant air quality objectives at all sensitive receptors using standard mitigation measures.
- Predicted annual average concentrations of $PM_{2.5}$ ***comply*** with the relevant air quality objectives at all sensitive receptors using standard mitigation and additional mitigations measures when necessary for Year 2, Year 8 and Year 15, except at SR22 (within Project ML), SR31, and SR32 for Project Year 15. The Project contributes approximately 23% to the Air EPP objective for annual average $PM_{2.5}$ of 8 µg/m^3.
- Predicted monthly dust deposition rates ***comply*** with the relevant air quality guideline at all sensitive receptors using standard mitigation measures.

It is recommended that Magnetic South manages potential particulate matter impacts of the Project at sensitive receptors by:

- Developing and implementing an ambient air quality monitoring program
- Developing and implementing an Air Quality Management Plan

- As appropriate, consult with surrounding landholders in relation to appropriate mitigation measures or property purchases.

The greenhouse gas assessment of the Project found the following:

- Average annual GHG emissions (Scope 1 + Scope 2) associated with the Project are estimated to be 141 tCO_2-e
- Maximum annual GHG emissions (Scope 1 + Scope 2) associated with the Project are estimated to be 211 kt CO2-e (Year 16) Compared to national and state greenhouse gas inventory levels, the maximum annual GHG emissions from the Project would account for approximately 0.04% and 0.13%, respectively
- Greenhouse gas emissions from the Project are predominantly due to diesel use (66.5%), electricity generation (indirect emissions) (10.1%) and fugitive methane releases (22.0%)

It is recommended the Magnetic South monitor, manage and assess Project related greenhouse gas emissions.

1. INTRODUCTION

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, 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.

Katestone Environmental Pty Ltd (Katestone) was commissioned by Magnetic South to conduct the air quality and greenhouse assessments for the Project.

The scope of works for the air quality and greenhouse assessment includes:

Air quality

- A description of the Project with a focus on elements pertaining to impacts to air quality
- A description of regulatory requirements relevant to the Project, including air quality objectives and indicators in the *Environmental Protection (Air) Policy 2019*
- A description of the environmental values in and surrounding the Project areas including sensitive receptors, site topography and built environment, background levels of air pollutants, and an assessment of meteorology
- A description of onsite sources of air pollutants and production of an air pollutant emission inventory for three worst-case scenarios of the mine
- A dispersion modelling assessment to predict ground-level concentrations of air pollutants associated with each scenario for the mine
- Analysis of incremental and cumulative concentrations of air pollutants associated with the mine against the relevant air quality criteria and objectives for dust deposition and suspended particulates
- A discussion of proposed management and mitigation measures for minimising air quality impacts.

Greenhouse gas

- Determine obligations under the Commonwealth *National Greenhouse and Energy Reporting Act 2007* (NGER Act)
- Provide an inventory of projected annual emissions of greenhouse gases (GHG) in terms of tonnes of carbon dioxide equivalents (tCO_2-e)
- Assess the potential impacts of the Project on the state and national greenhouse gas inventories and propose greenhouse gas abatement measures.

This report presents the findings of an air quality and greenhouse gas impact assessment conducted for the Project.

2. PROJECT DESCRIPTION

The Gemini Project is located in the Queensland Central Highlands, approximately 3 kilometres west of the township of Dingo and 15 kilometres east of the town of Bluff (refer Figure 1).

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, wash bay, laydown area, sewage, effluent and liquid waste storage, and heli-pad
- 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])
- 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 from the accommodation facility 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 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
- 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.

The proposed mine layout is shown in Figure 2.

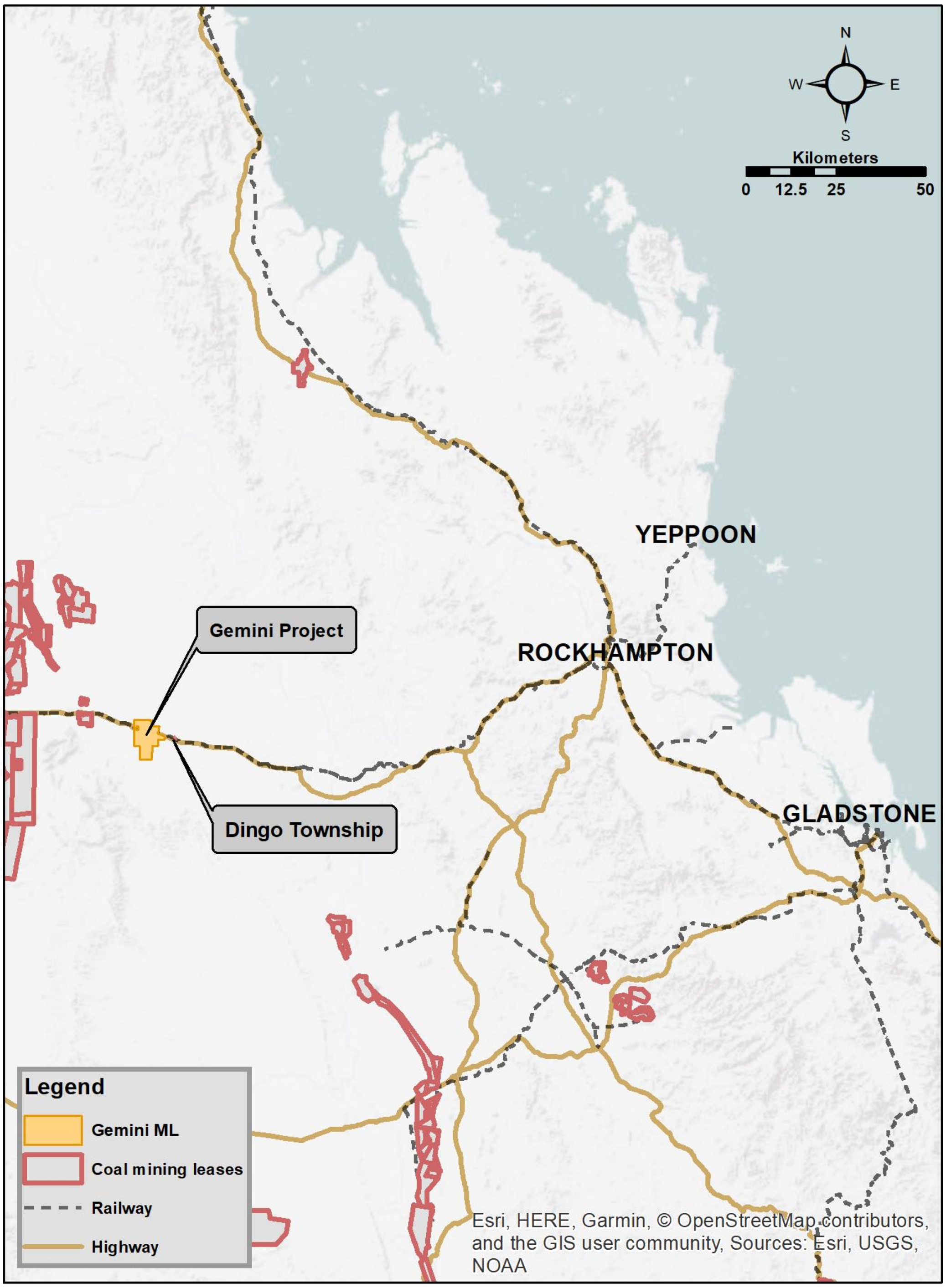

Figure 1 **Project Location**

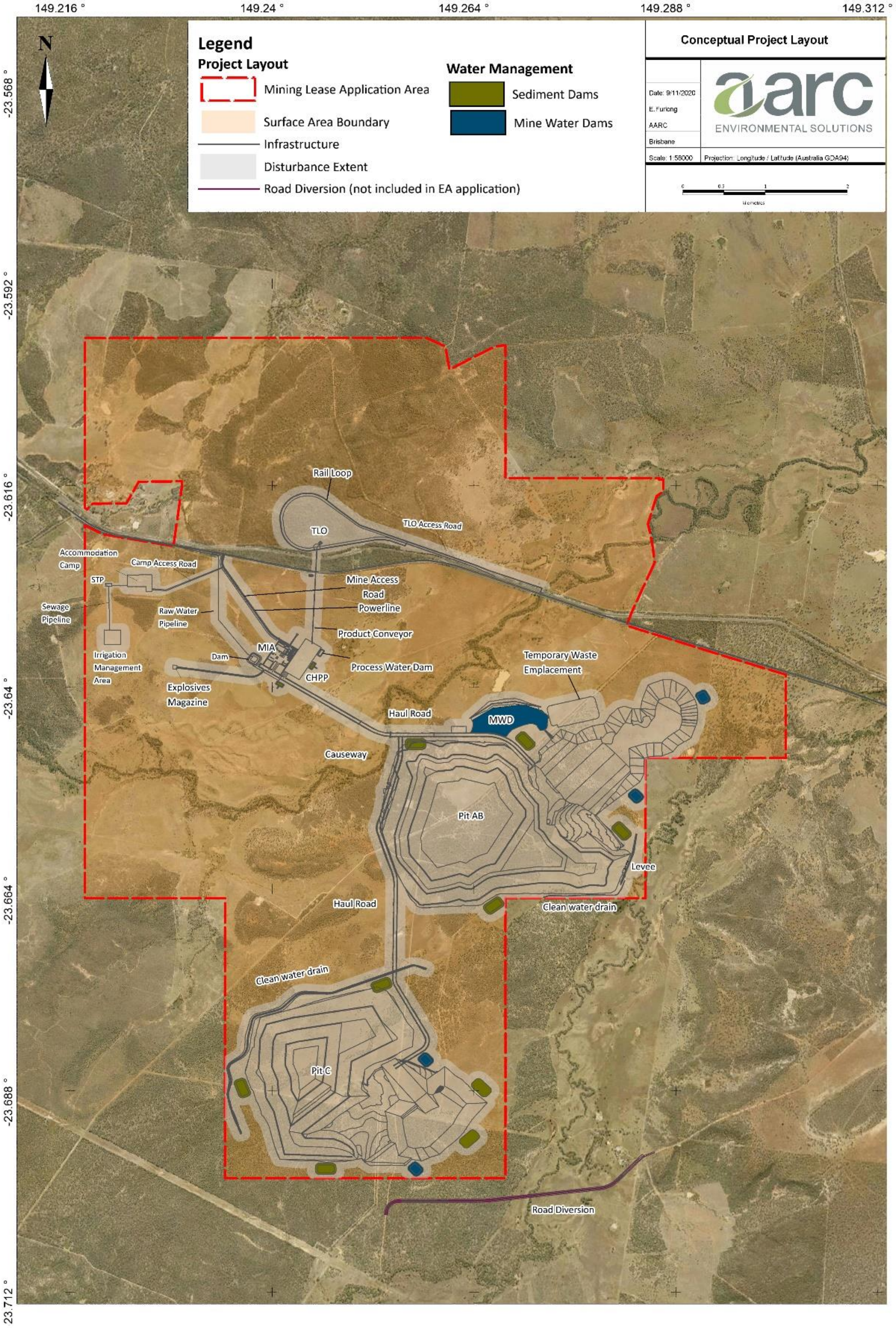

Figure 2 Proposed Project Layout

3. AIR QUALITY ASSESSMENT

3.1 Regulatory framework for air quality in Queensland

The *Environmental Protection Act 1994* (EP Act) provides for the management of the air environment in Queensland. The EP Act gives the Department of Environment and Science (DES) the power to create Environmental Protection Policies that identify, and aim to protect, environmental values of the atmosphere that are conducive to the health and well-being of humans and biological integrity. *The Environmental Protection (Air) Policy* (Air EPP) was made under the EP Act and gazetted in 1997; the Air EPP was revised and reissued in 2019.

The objective of the Air EPP is:

> *...to identify the environmental values of the air environment to be enhanced or protected and to achieve the objective of the Environmental Protection Act 1994, i.e. ecologically sustainable development.*

The environmental values to be enhanced or protected under the Air EPP are the qualities of the environment that are conducive to:

- protecting health and biodiversity of ecosystems
- human health and wellbeing
- protecting the aesthetics of the environment, including the appearance of building structures and other property
- protecting agricultural use of the environment.

The administering authority must consider the requirements of the Air EPP when it decides an application for an environmental authority, amendment of a licence or approval of a draft environmental management plan. Schedule 1 of the Air EPP specifies air quality indicators and objectives for contaminants that may be present in the air environment.

The Air EPP air quality objectives relevant to the key air pollutants that may be generated from the Project are presented in Table 1.

Also relevant is the DES's *Application requirements for activities with impacts to air*, which outlines the information to be provided to DES as part of the application process for environmentally relevant activities and how the information is used. This outlines how the proposed activity will be assessed by comparison with the requirements stipulated in the EP Act.

In particular, this requires an application to include, if applicable:

- Description of the site and surrounding areas, including topography, prevailing winds and ambient air quality (Section 3.3 and Appendix A1)
- Identification of any nearby sensitive places must be identified and assessed appropriately (Section 3.3.2)
- Identification and evaluation of possible impacts on air quality (Section 3.5)
- Proposed management (Section 3.4).

This air quality assessment has been conducted in accordance with the application requirements.

Table 1 **Relevant ambient air quality objectives (Air EPP)**

Pollutant	Environmental Value	Averaging Period	Air Quality Objective	Number exceedances allowed per year
TSP	Health and wellbeing	1 year	90 µg/m^3	None
PM$_{10}$ [a]		24 hours	50 µg/m^3	None
		1 year	25 µg/m^3	None
PM$_{2.5}$ [b]		24 hours	25 µg/m^3	None
		1 year	8 µg/m^3	None
Dust deposition [c,d]	Amenity	1 month	120 mg/m²/day	None

Table note:

[a] PM$_{10}$ are particles that have aerodynamic diameters that are less than 10 µm.

[b] PM$_{2.5}$ are particles that have aerodynamic diameters that are less than 2.5 µm.

[c] Applies to total insoluble solids.

[d] Value provided for dust deposition is a DES recommended design objective rather than Air EPP objective.

3.2 Methodology

The following sections describe the modelling methodology that was adopted for the air quality assessment. The methodology uses standard industry dispersion models suitable for use in Australia and regulatory approved assessment techniques to predict ground-level concentrations of air pollutants in the areas surrounding the Project.

3.2.1 Surrounding environment

The location of the Project and surrounding environment has been described in terms of land use, terrain features and sensitive receptor locations. Details are provided in Section 3.3.

3.2.2 Site-specific meteorology

Site-specific meteorological data was generated by coupling the prognostic model TAPM (version 4.0.5) (The Air Pollution Model) with the diagnostic meteorological model CALMET (version 6.5.0). The coupled TAPM/CALMET modelling system was developed to enable high resolution modelling capabilities for regulatory and environmental assessments. The modelling system incorporates synoptic, mesoscale and local atmospheric conditions, detailed topographic and land use categorisation schemes to simulate synoptic and regional scale meteorology for input into pollutant dispersion models such as CALPUFF.

The assessment was conducted using the most recent versions of TAPM and CALMET available at the time of undertaking the study.

Technical details of the TAPM and CALMET model configurations are provided in Appendix A.

3.2.3 Assessment scenarios

Based on a review of the proposed mining schedule, annual production schedule and the relative location of the closest sensitive receptors, Year 2, Year 8, and Year 15 of the Project were identified as being likely to generate the worst-case potential for dust impacts over the life of the Project.

3.2.4 Dust emission rates

To assess potential air quality impacts due to the Project, potential dust emissions from individual mining activities for the modelling scenario were accounted for and have been explicitly modelled. Specific activity information used to calculate dust emission rates associated with individual mining activities were provided or confirmed by Magnetic South.

Dust emission rates were estimated using the base equation:

$$ER = A \times EF \times (1 - CF)$$

where:

ER	emission rate
A	activity / operations data
EF	emission factor
CF	reduction in emissions due to the implementation of control measures.

Emissions of TSP, PM_{10} and $PM_{2.5}$ from mining activities were estimated using recognised and accepted methods of dust emissions estimation. These include approximation of emission rates from NPI emissions estimation technique handbooks and the United States Environmental Protection Agency (US EPA) AP42 emission handbooks (US EPA, 1998; US EPA, 2006; NPI, 2012).

The emissions estimation techniques applied in this assessment are based on standard methods that are applied throughout Australia and in the United States. These methods are consistent with those adopted for other air quality assessments conducted for other coal mines in Australia. The size distribution of dust particles was derived from the emission rates estimated for TSP, PM_{10}, and $PM_{2.5}$.

A dust emission inventory for years 2, 8, and 15 is detailed in Section 3.4. The activity data that were used to estimate dust emissions are detailed in Appendix B.

3.2.5 Dispersion modelling

Source characteristics and dust emission rates for each scenario were incorporated into a dispersion modelling study conducted using a standard and regulated model developed by Earth Tech, Inc., namely, the CALPUFF dispersion model (version 7.2.1).

CALPUFF is an advanced non-steady-state air quality modelling system. The meteorological data generated by TAPM/CALMET was used as input for CALPUFF in order to include all weather conditions likely to be experienced in the region during a typical year. This system has been used to predict ground-level particulate concentrations and dust deposition rates at nearby sensitive receptor locations and across a cartesian grid representing the Project region.

Dust emissions have been modelled over a 365-day year, assuming 24-hour mine operation with the exception of haulage of ROM that will occur for 15 hours per day and blasting that will only occur during daylight hours.

Technical details of the CALPUFF model configuration are provided in Appendix A.

3.2.6 Limitations of dispersion modelling

This study relies on the accuracy of a number of datasets including, but not limited to:

- Meteorological information
- Mining schedule

- Calculation of emission rates from mining activities.

It is important to note that numerical models are based on an approximation of governing equations that represent complex natural processes. These will inherently be associated with some degree of uncertainty. The more complex the physical model, the greater the number of physical processes that must be included. Where uncertainty exists in characterising important properties of the environment or activities associated with the Project, this study has erred on the side of caution and selected conservative inputs.

3.2.7 Cumulative impacts

In order to assess the potential impacts of the Project upon the surrounding environment, representative ambient levels of particulate matter and dust deposition have been added to dispersion modelling predictions for the Project. These levels are derived in Section 3.3.3.

3.2.8 Presentation of results

Modelling results for particulate matter are presented as ground-level concentrations or dust deposition rates at sensitive receptors as well as contours across the modelling domain and are presented in Section 3.5.

3.3 Existing environment

3.3.1 Local terrain and land-use

Figure 3 illustrates the area considered in the air quality impact assessment of the Project. The study area covers approximately 400 km^2 and extends beyond the borders of the proposed Mining Lease Application (MLA) in order to assess the potential impact of the Project on the air quality of the wider community and, in particular, the sensitive receptors in the region as shown in Figure 4 and Table 2.

The terrain and land-use in the surrounding area is primarily flat open and agricultural bush and shrubland. Other features include Taunton National Park to the north of the proposed MLA, established as conservation land for the endangered Bridled Nailtail Wallaby, and Blackdown Tablelands National Park approximately 9 km south-west of the Project ML boundary.

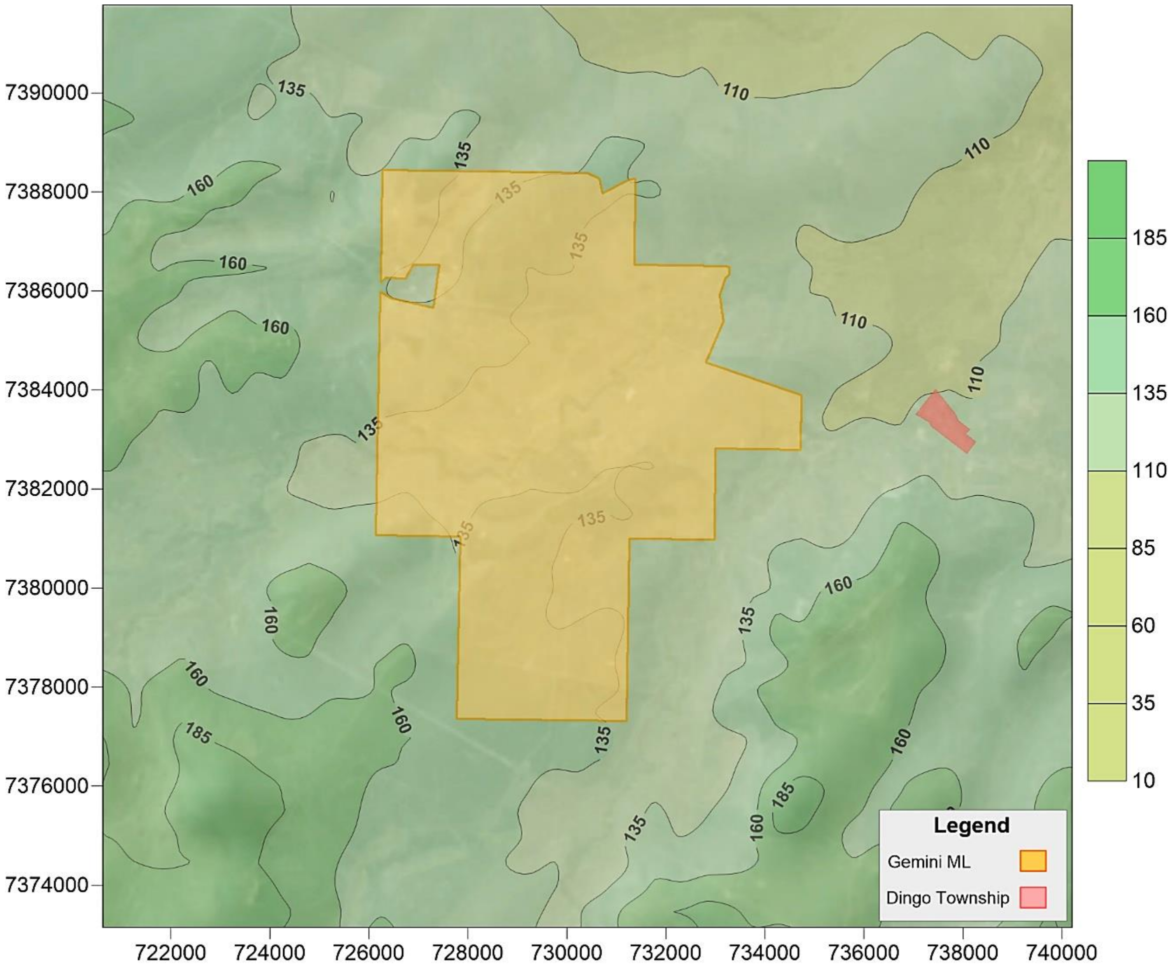

Figure 3 **Study area terrain (contours in metres above sea-level)**

3.3.2 Sensitive receptors

Sensitive receptors considered in the assessment are presented in Table 2 and Figure 4, encompassing residences, businesses, and recreational areas.

Dingo Township is represented by SR07. Sensitive receptors SR09, SR18, and SR23 are located within the Project MLA. At the time of reporting the following sensitive receptors are owned or pending purchase by Magnetic South, and have not been considered further in this assessment: SR09, SR14, SR15, SR18, SR19, SR20, SR21, SR23, SR24.

Table 2 **Sensitive receptors surrounding the Project (receptors not considered in this report due to purchase or pending purchase by Magnetic South highlighted grey)**

Receptor ID	Receptor type	Property name	Easting (m)	Northing (m)	Location relative to MLA boundary
SR01	Residential	3SP165527	721380	7386940	4.8 km W
SR03	Residential	6SP152759	737915	7382328	3.2 km E
SR05	Residential	Charlevue	721937	7382077	4.2 km W
SR07	Residential, facilities (sports oval, tennis court, school) & businesses (Post Office, hotel, shops, sawmills, etc.)	Dingo Township	737777 (town centre)	7383220 (town centre)	2.3 km E (from point closest to the Project)
SR08	Residential	Dunkerinn	722022	7384327	4.2 km W
SR09	Residential	2RP904099	731988	7385624	Within MLA
SR10	Residential	Fairview Park	736181	7382995	1.4 km E
SR13	Residential	Fairview Park	737113	7382802	2.3 km E
SR14	Residential	Glenwood	728569	7374873	2.5 km S
SR15	Residential	4HT165	729144	7388750	0.3 km N
SR16	Residential	Lanlea	735273	7388705	3 km NE
SR17	Residential	Myimbarr	722415	7384928	3.9 km W
SR18	Residential	1HT424	729626	7384531	Within MLA
SR19	Residential	2HT138	732684	7377515	1.4 km SE
SR20	Residential	2HT138	732671	7377581	1.4 km SE
SR21	Residential	2HT138	732614	7377700	1.4 km SE
SR22	Residential and Accommodation Facility	Redrock Park	726358	7386469	Within MLA
SR23	Residential	47H406	734446	7383534	Within MLA
SR24	Residential	20H4017	735824	7384500	1.2 km NE
SR26	Residential	The Lazy H and Hopevale	739747	7382306	5 km E
SR27	Residential	The Lazy H and Hopevale	739278	7383145	4.5 km E
SR28	Residential	The Lazy H and Hopevale	739157	7383337	4.4 km E
SR30	Residential	The Lazy H and Hopevale	739319	7383894	4.6 km E
SR31	Residential	Unknown	725109	7385743	1.1 km NW
SR32	Residential	Unknown	725075	7386813	1.2 km NW

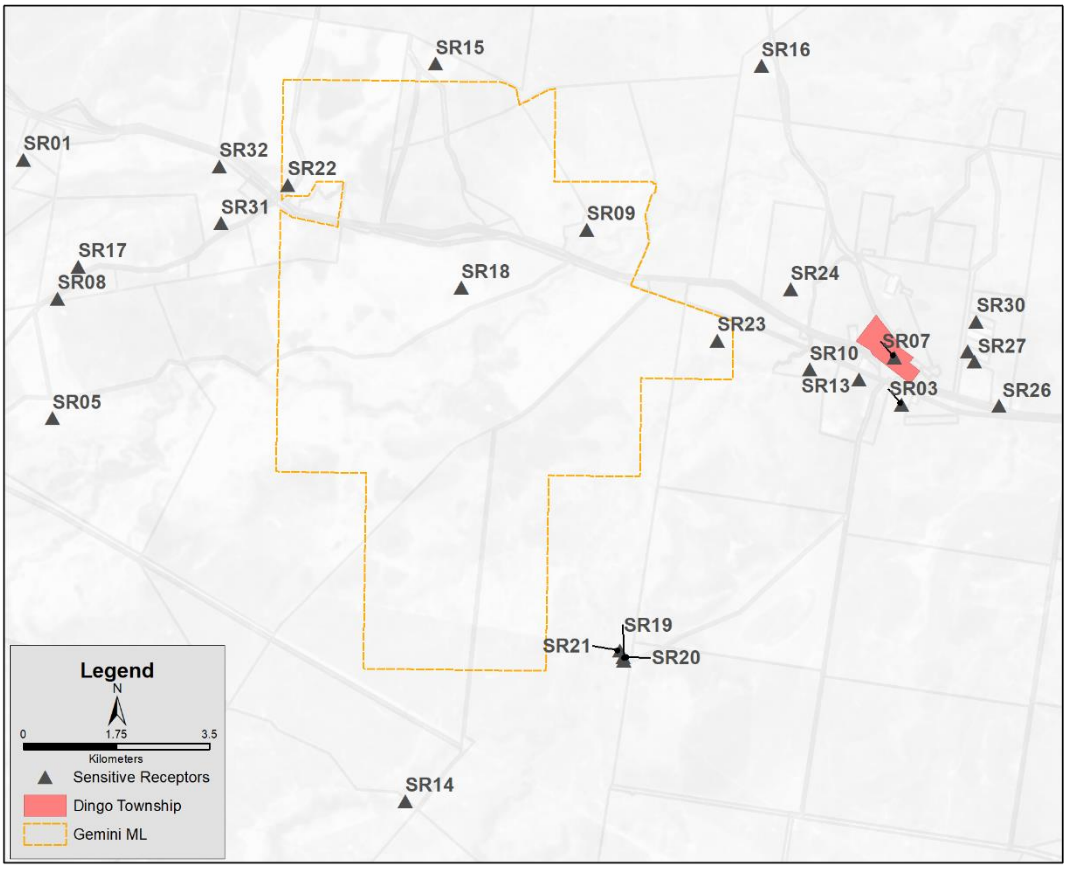

Figure 4 Location of sensitive receptors (utm metres)

3.3.3 Existing air quality

3.3.3.1 Existing sources of emissions

Ambient dust levels across the area will be influenced by natural sources of dust such as wind erosion and fires, as well as dust emissions from existing anthropogenic sources in the area, possibly including local agriculture or horticulture, and existing mines.

The National Pollution Inventory (NPI) is a public database of annual emissions of 93 substances reported by industries across Australia. The closest facility currently reporting to the NPI program is more than 10 km away from the Project and is unlikely to contribute existing levels of dust within the study domain. NPI reporting facilities within a 50 km radius of the Project are listed in Table 3, presenting reported emissions of PM_{10} and $PM_{2.5}$ for the 2018 - 2019 reporting period. As indicated, the coal mines are sufficiently far from the Project site to have a minimal impact on the local dust levels near the Project area.

Table 3 2018 - 2019 Annual NPI dust emissions existing coal mines surrounding the Project

Facility	Approximate Distance from Project boundary(km)	Dust emissions (kg/year)	
		PM_{10}	$PM_{2.5}$
Jellinbah Mine	35 km north-west	8,935,604	123,682
Cook Colliery	33 km west	177,264	843
Yancoal - Yarrabee	35 km north-west	4,493,330	148,190
Curragh Mine	25 km north-west	7,351,894	126,837
Tolmie Creek	40 km west	33,452	931
Bluff Coal Mine	11 km north-west	403	396
Blackwater Mine	40 km west	14,074,370	141,150

3.3.3.2 Existing ambient air quality

3.3.3.2.1 PM_{10} and $PM_{2.5}$

The nearest available monitoring site for PM_{10} and $PM_{2.5}$ is located at Blackwater Township, approximately 35 km west of the Project site. Operated by DES, monitoring commenced in April 2019. The nearest alternative monitoring station for particulates is 200 km northwest of the Project at Moranbah. Therefore, the Blackwater monitoring site is likely more representative of ambient particulate levels local to the Project. Background particulate values based on the Blackwater monitoring site are likely to be representative of the region and reflect the existing mines in the Blackwater region (included in Table 3).

Timeseries of the measured 24-hour average concentrations of PM_{10} and $PM_{2.5}$ are provided in Figure 5 and Figure 6. $PM_{2.5}$ concentrations at Blackwater exceeded the Air EPP 24-hour $PM_{2.5}$ objective of 25 µg/m³ on 8 September 2019. DES's Air Quality Bulletin Central Queensland September 2019 (DES, 2019) attributed this to strong southwesterly winds carrying dust from a possible combination of surrounding dry surfaces, ground works, or mining activities.

PM_{10} concentrations at Blackwater exceeded the Air EPP 24-hour PM_{10} objective of 50 µg/m³ on 17 occasions across June, September, October, November and December. Concentrations on these days and likely causes summarised in Table 4.

For the purposes of the cumulative impact assessment, the ambient background concentrations of PM_{10} and $PM_{2.5}$ were taken as the 70th percentile 24-hour average from the Blackwater monitoring site. Use of the 70th percentile value is based on the methodology published by EPA Victoria (EPA Victoria, 2007) and is accepted in Queensland.

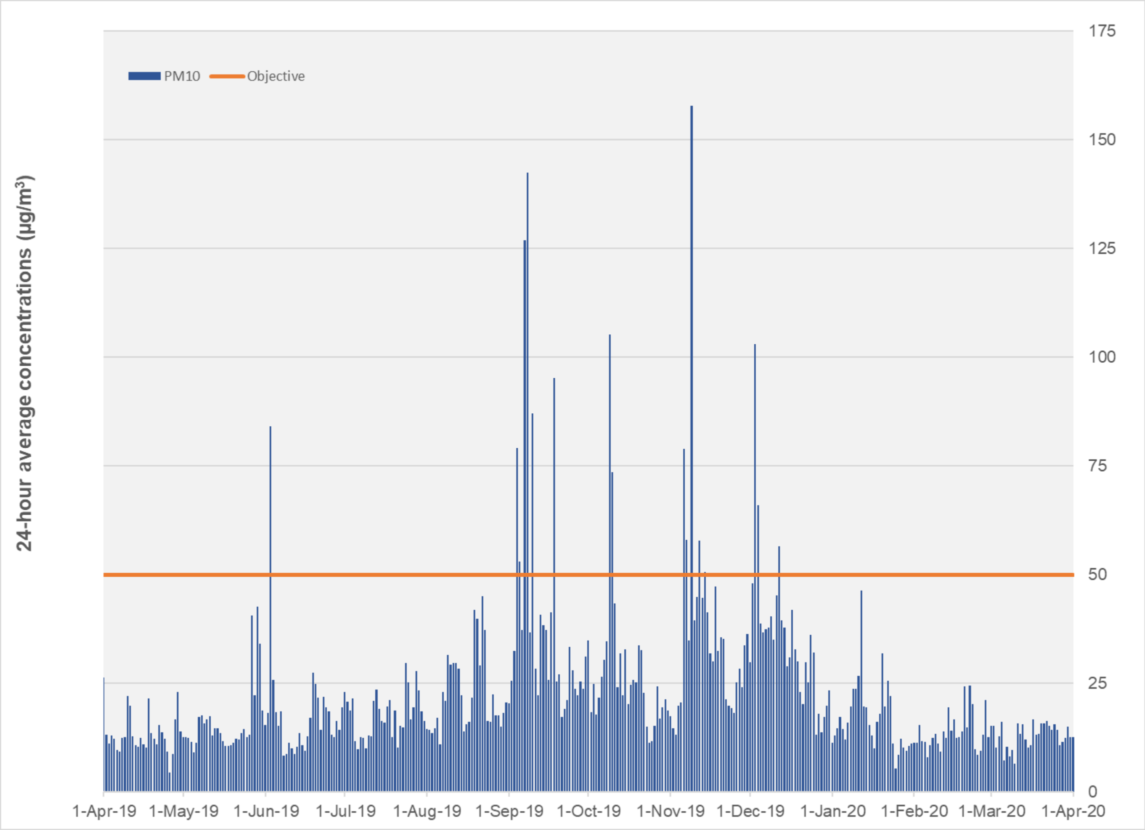

Figure 5 Timeseries of 24-hour average PM_{10} for Blackwater April 2019 to April 2020

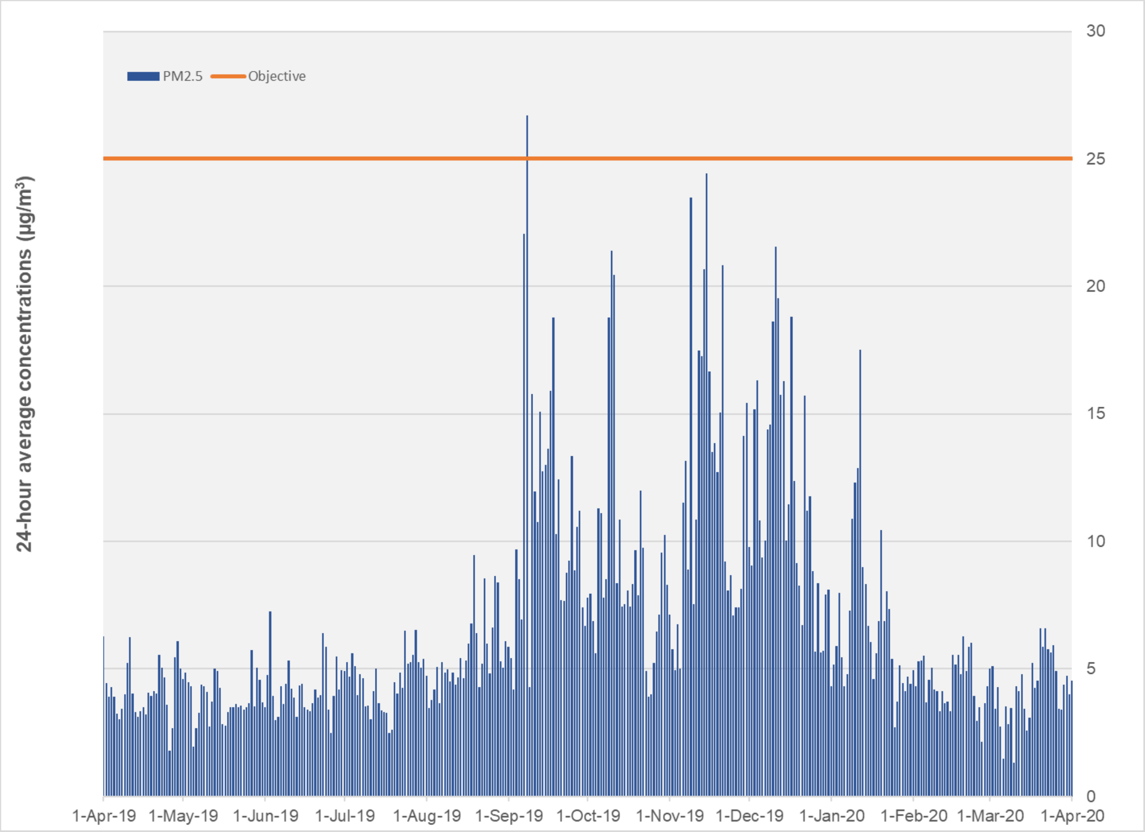

Figure 6 Timeseries of 24-hour average $PM_{2.5}$ for Blackwater April 2019 to April 2020

Table 4 **Summary of 24-hour averaged PM_{10} exceedances for Blackwater**

Date of Exceedance	PM_{10} Concentration (µg/m^3)	DES Bulletin Explanation
03-Jun-19	84.18	Strong south westerly winds and windblown dust from dry ground surfaces as likely cause. Possible contributions from mining and earth works (DES, *Air quality bulletin Central Queensland*, June 2019).
04-Sep-19	79.14	Strong south westerly winds carrying dust from further inland (DES, *Air quality bulletin Central Queensland*, September 2019).
05-Sep-19	53.00	
07-Sep-19	126.97	
08-Sep-19	142.51	
10-Sep-19	87.03	
18-Sep-19	95.15	
09-Oct-19	105.26	Windblown dust from across Central Queensland (DES, *Air quality bulletin Central Queensland*, October 2019).
10-Oct-19	73.48	
06-Nov-19	78.92	Dry conditions combined with strong westerly winds carrying dust from central Australia across Central Queensland (DES, *Air quality bulletin Central Queensland*, November 2019).
07-Nov-19	57.97	
09-Nov-19	157.88	
12-Nov-19	57.80	
14-Nov-19	50.52	
03-Dec-19	103.01	Dry conditions and strong winds carrying dust from central Australia. 12 December exceedance occurred during easterly winds, mining activities therefore unlikely cause, but rather dust-generating activities in the vicinity of the monitoring station (DES, *Air quality bulletin Central Queensland*, December 2019).
04-Dec-19	65.87	
12-Dec-19	56.43	

3.3.3.2.2 TSP and dust deposition

DES does not conduct monitoring for TSP and dust deposition at its Blackwater site and publicly available data for the region is limited. Therefore, background levels of TSP have been derived from the measured PM_{10} data at Blackwater. Dust deposition rates have been based on typical dust deposition rates for rural areas.

3.3.3.2.3 Summary of background levels

Representative background levels of TSP, PM_{10}, $PM_{2.5}$ and dust deposition for the region, as derived in the preceding sections, are summarised in Table 5. These values have been used to assess potential cumulative impacts of the Project in the context of the existing environment.

Table 5 **Ambient background concentrations used to assess cumulative impacts**

Pollutant	Averaging Period	Concentration	Source
TSP	Annual	45.8 µg/m^3	Calculated from the average PM_{10} data measured at Blackwater using PM_{10}/TSP ratio of 0.5
PM_{10}	24-hour	23.8 µg/m^3	70th percentile of monitoring data at Blackwater
	Annual	22.9 µg/m^3	Average of monitoring data at Blackwater
$PM_{2.5}$	24-hour	7.4 µg/m^3	70th percentile of monitoring data at Blackwater
	Annual	6.8 µg/m^3	Average of monitoring data at Blackwater
Dust deposition	Monthly	50 mg/m^2/day	Typical value

3.4 Emissions to the atmosphere

Dust emissions will be generated over the life of the Project as a result of material extraction, handling, haulage and wind erosion of exposed mine areas. Emissions of oxides of nitrogen, sulfur dioxide and carbon monoxide would also occur due to blasting activities and vehicle movements (combustion of fuels) on site. However, these emissions are transient (contained within the haul road corridor and open-cut pits) and low in magnitude, Their impact outside of the Project site likely to be negligible. For these reasons, dust (and associated particulate matter) is the critical air pollutant for this assessment.

Odour is unlikely to be emitted from typical mining activities. Spontaneous combustion is a potential source of odour from mining activities but the potential for this is low and, therefore, odour has not been assessed further in this assessment.

The following sections provide an inventory of dust emissions for the assessment scenarios and a description of dust mitigation measures proposed by Magnetic South.

3.4.1 Overview

Key dust-generating activities associated with the Project include:

- Drilling and blasting
- Material extraction and handling (overburden and ROM coal)
- Bulldozer activity
- Material haulage (overburden and ROM coal)
- Road grading
- Wind erosion of exposed mine areas.

3.4.2 Standard mitigation measures

Dust mitigation and operational controls have been included in the Project design to minimise dust emissions from mining activities, including application of water to haul roads. Standard efficiency factors for these control measures are presented in Table 6.

Table 6 Standard dust control measures and relative reduction in emissions

Activity	Control measure	Reduction
ROM coal haulage	Watering and/or suppressants/vehicle speed reduction	85%
Overburden haulage	Watering and/or suppressants/vehicle speed reduction	85%
Drilling	Drill dust suppression sprays	70%
ROM unloading at CHPP	Water sprays	70%
Crushing	Enclosure	70%
Product stockpile	Wet from CHPP	50%
Train loading	Telescopic chute with water spray	85%

Conveyor	Enclosure	70%
Conveyor	Uncovered	0%

3.4.3 Additional mitigation measures

For the Project, there will be ongoing implementation of the standard dust control measures. Application of additional mitigation measures will occur under adverse meteorological conditions that are conducive to dust impacts, when necessary. Additional mitigation measures may include but are not limited to the modification of activity rate or ceasing of certain operations. Specific measures are detailed in section 3.5.

3.4.4 Emissions inventory

A breakdown of the total dust emission rates estimated for years 2, 8, and 15 of the Project is presented in Table 7. The corresponding emission areas are illustrated schematically in Figure 7, Figure 8, and Figure 9. Emissions have been estimated as described in Section 3.2.4 and are presented inclusive of standard mitigation control factors described in Table 6.

Table 7 **Emissions inventory for year 2, year 8 and year 15**

Activity	Year 2 (kg/year)			Year 8 (kg/year)			Year 15 (kg/year)		
	TSP	PM$_{10}$	PM$_{2.5}$	TSP	PM$_{10}$	PM$_{2.5}$	TSP	PM$_{10}$	PM$_{2.5}$
Active Pit									
Drilling	2,936	1,543	88	2,240	1,177	67	2,055	1,080	62
Blasting	46,090	23,883	1,383	35,211	18,246	1,056	32,263	16,718	968
Bulldozer assist after blasting - coal	79,839	27,072	1,756	63,871	21,657	1,405	159,678	54,144	3,513
Bulldozer assist after blasting - OB	24,267	4,607	2,548	24,267	4,607	2,548	24,267	4,607	2,548
Excavator - ROM removal	146	69	10	193	91	14	184	87	13
Excavator overburden removal	9,281	4,390	665	10,625	5,025	761	10,187	4,818	730
Truck loading /dumping overburden	9,281	4,390	665	10,625	5,025	761	10,187	4,818	730
Bulldozer on overburden spoil	16,178	3,071	1,699	16,178	3,071	1,699	16,178	3,071	1,699
Bulldozer on rehabilitation	24,267	4,607	2,548	24,267	4,607	2,548	8,089	1,536	849
CHPP/TLO									
Processing activities (crushing/screening)	31,050	11,207	2,578	32,731	11,814	2,718	31,211	11,265	2,592
Truck dumping ROM	55	26	4	58	27	4	55	26	4
Load to CHPP	91	43	7	96	46	7	92	43	7
Dozer reclaim from product stockpile to conveyor	205	97	15	205	97	15	210	99	15
Transfer from conveyor to surge bin	45	21	3	45	21	3	45	21	3
Train loading from surge bin	68	32	5	68	32	5	68	32	5
Truck loading reject coal	41	19	3	51	24	4	38	18	3
Conveying	234	110	17	234	110	17	234	110	17
HAULS									
ROM haulage	231,494	65,986	6,599	304,744	86,866	8,687	365,959	104,315	10,432
Overburden haulage	1,310,944	373,679	37,368	1,186,931	338,330	33,833	1,627,043	463,782	46,378
Rejects haulage	105,330	47,954	27,366	128,159	36,531	3,653	191,356	54,545	5,455
GRADING - ROM hauls	87,410	16,772	2,710	128,565	24,669	3,986	124,168	23,825	3,849
GRADING - other hauls	74,722	41,173	6,652	33,567	6,441	1,041	37,964	7,285	1,177

Activity	Year 2 (kg/year)			Year 8 (kg/year)			Year 15 (kg/year)		
	TSP	PM_{10}	$PM_{2.5}$	TSP	PM_{10}	$PM_{2.5}$	TSP	PM_{10}	$PM_{2.5}$
WIND EROSION									
Exposed mine area	53,908	26,954	4,043	62,677	31,339	4,701	46,560	23,280	3,492
Coal stockpiles	150,331	75,166	11,275	150,331	75,166	11,275	150,331	75,166	11,275
Active rehabilitation areas	89,353	44,677	6,702	91,910	45,955	6,893	75,365	37,682	5,652
Rehabilitated areas	NA	NA	NA	81,779	40,889	6,133	222,157	111,079	16,662
Overburden dump areas	164,270	82,135	12,320	90,871	45,436	6,815	163,211	81,605	12,241
Total	**2,511,837**	**859,684**	**129,027**	**2,480,498**	**807,299**	**100,648**	**3,299,153**	**1,085,058**	**130,368**

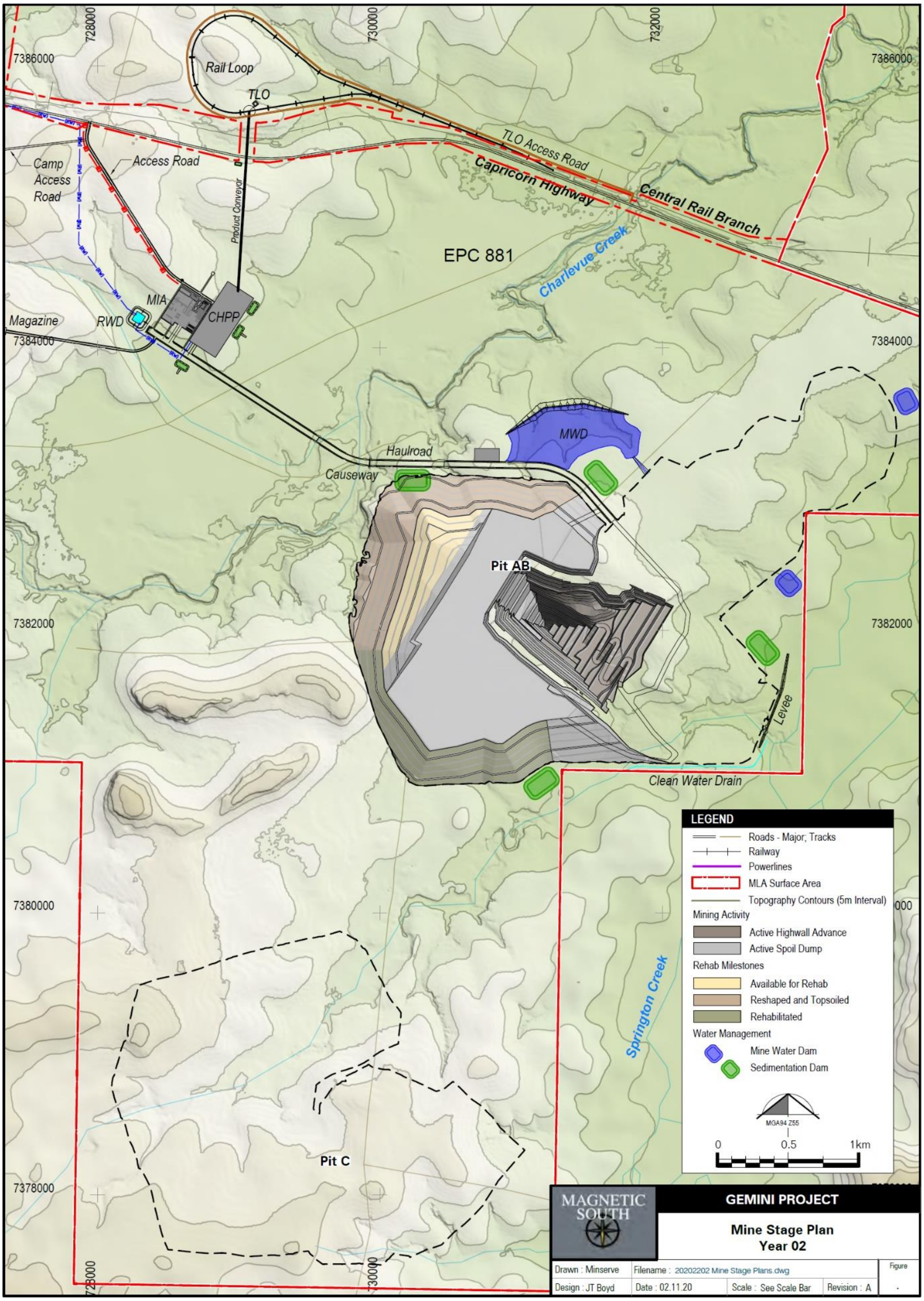

Figure 7 Year 2 - Dust emission source areas

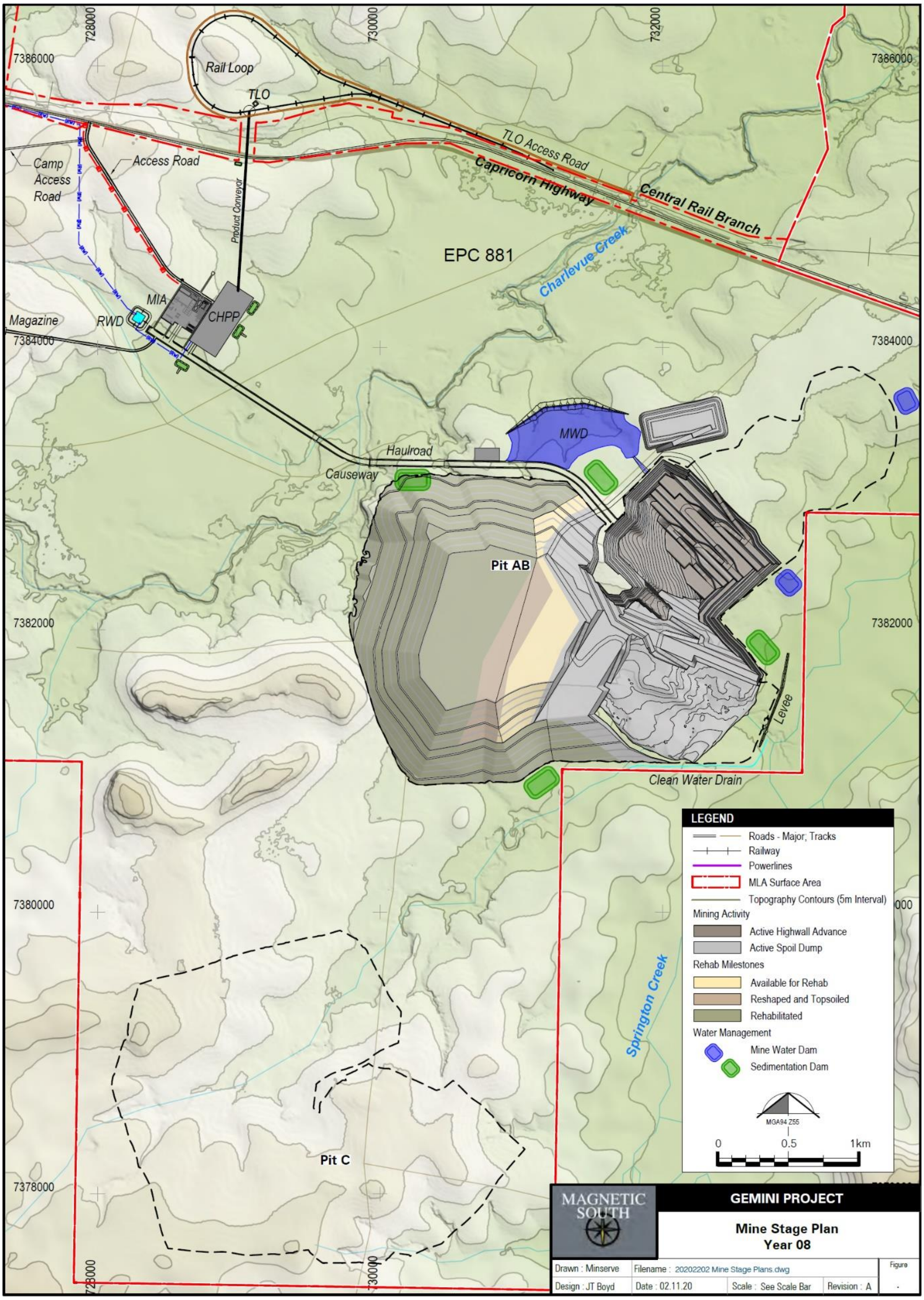

Figure 8 Year 8 - Dust emission source areas

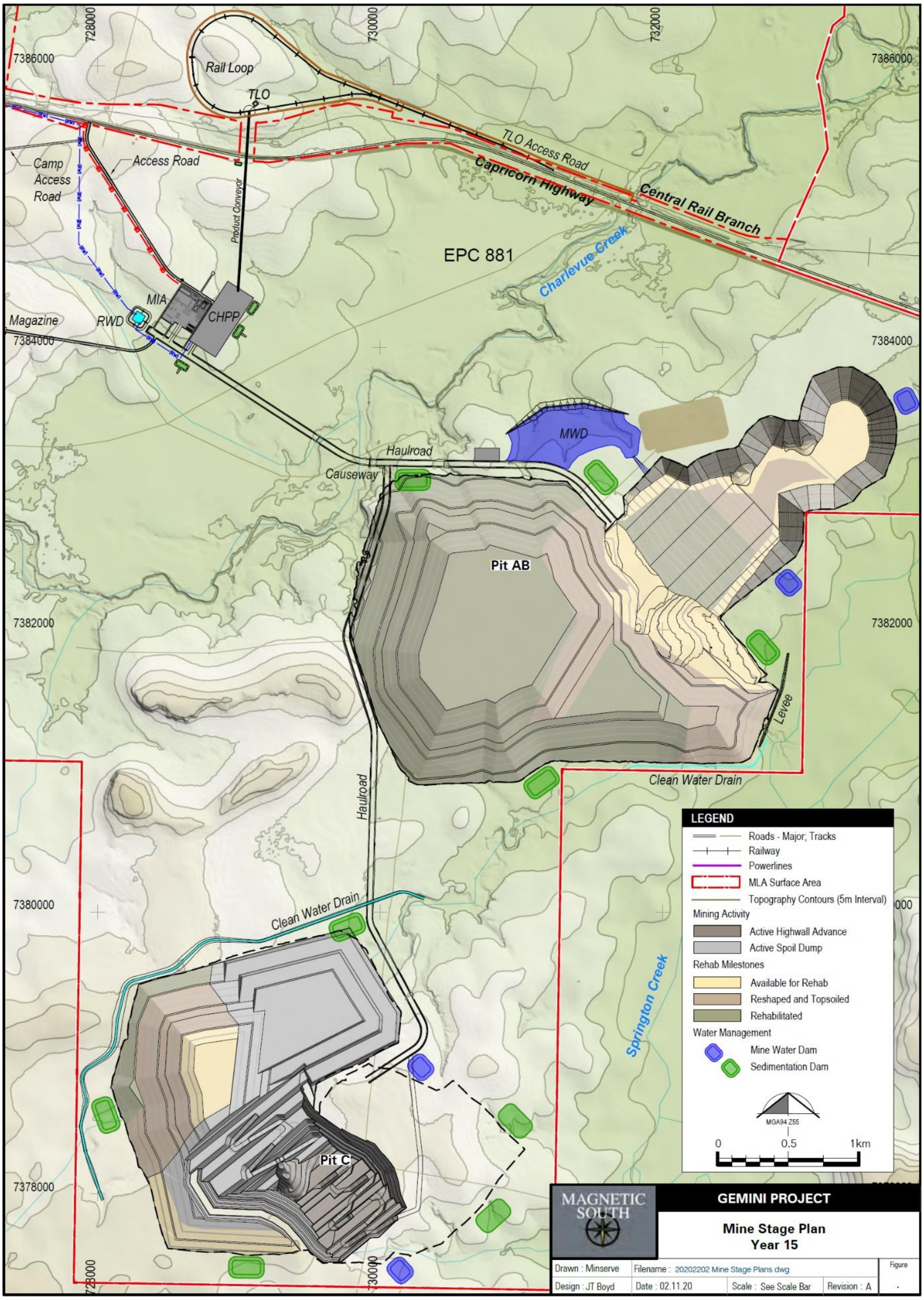

Figure 9 Year 15 - Dust emission source areas

3.5 Air quality impact assessment

This section presents the results of the dispersion modelling assessment of the Project. As outlined in Section 3.2.6, this study has erred on the side of caution and selected conservative inputs and, therefore, the predicted concentrations of dust are conservative overestimates. Results have been presented for mining years 2, 8, and 15 as ground-level concentrations or deposition rates at the sensitive receptors as well as contours across the modelling domain. These results are subject to the standard mitigation measures outlined in Section 3.4.2.

Background dust levels have been added to the incremental model predictions in order to estimate the potential cumulative impacts of the Project with existing sources of dust in the region. Results have been assessed by comparing the cumulative concentrations and dust deposition rates with the air quality objectives described in Section 3.1.

When interpreting the results, it is important to note that the predictions are not contemporaneous. The values presented are the maximum concentration predicted independently at each sensitive receptor or grid point for the entire modelling period and thus constitute a worst-case or near worst-case result. These values do not necessarily occur at the same time or under the same meteorological conditions.

3.5.1 Year 2

Table 8 presents the predicted ground-level concentrations of TSP, PM_{10} and $PM_{2.5}$ as well as dust deposition rates at the sensitive receptors due to the Project in year 2 in isolation and with a background. The corresponding contours for each cumulative scenario are presented in Plate 1 to Plate 7.

The results show that:

- Predicted annual average concentrations of TSP ***comply*** with the relevant air quality objective at all sensitive receptors in isolation and cumulatively, with the application of standard mitigation measures (Plate 1).
- Predicted 24-hour average concentrations of PM_{10} ***comply*** with the relevant air quality objective at all sensitive receptors in isolation and cumulatively, with the application of standard mitigation measures with the exception of SR03, SR13, SR22 (within Project ML), SR27, SR28, SR31 and SR32 (Plate 2).
- Predicted annual average concentrations of PM_{10} ***comply*** with the relevant air quality objective at all sensitive receptors with the exception of SR22 (within Project ML), SR31, and SR32 (Plate 3). The annual average concentration of PM_{10} due to the Project in isolation is predicted to be at most 15% of the Air EPP objective.
- Predicted 24-hour concentrations of $PM_{2.5}$ ***comply*** with the relevant air quality objectives at all sensitive receptors, in isolation and cumulatively with the application of standard mitigation measures (Plate 4).
- Predicted annual average concentrations of $PM_{2.5}$ ***comply*** with the relevant air quality objectives at all sensitive receptors in isolation and cumulatively, with the application of standard mitigation measures (Plate 5).
- Predicted monthly dust deposition rates ***comply*** with the relevant air quality guideline at all sensitive receptors in isolation and cumulatively, with the application of standard mitigation measures (Plate 6).

Further analysis of the 24-hour average PM_{10} concentrations indicate:

- Predicted 24-hour average concentrations of PM_{10} are only expected to exceed at most one to three days per year (Table 9).
- Using standard and, when necessary, additional mitigation measures, predicted 24-hour average concentrations of PM_{10} ***comply*** with the relevant air quality objective at all sensitive receptors. (Plate 7).

- Additional mitigation measures may include ceasing night-time overburden hauling on days when 24-hour averaged maximum PM_{10} is predicted to exceed 50 µg/m^3. This would result in compliance with the air quality objective as shown in Figure 10 to Figure 16.

Table 8 **Predicted ground-level concentrations of TSP, PM_{10}, $PM_{2.5}$ and dust deposition rates at sensitive receptors during year 2 using standard mitigation measures**

Label	PM_{10} (µg/m^3)				$PM_{2.5}$ (µg/m^3)				TSP (µg/m^3)		Dust deposition rate (mg/m^2/day)	
	Maximum 24-hour		Annual		Maximum 24-hour		Annual		Annual		Maximum monthly	
	Project	With bkgd	Project	With bkgd	Project	With bkgd	Project	With bkgd	Project	With bkgd	Project	With bkgd
SR01	12.1	35.9	1.0	23.9	3.4	10.8	0.2	7.0	1.2	47.0	3.0	53.0
SR03	32.6	48.2^	0.9	23.8	5.1	12.5	0.1	6.9	1.0	46.8	3.5	53.5
SR05	7.6	31.4	1.0	23.9	2.0	9.4	0.2	7.0	1.3	47.1	2.1	52.1
SR07	26.0	49.8	0.6	23.5	3.8	11.2	0.1	6.9	0.7	46.5	2.7	52.7
SR08	14.1	37.9	1.2	24.1	3.8	11.2	0.3	7.1	1.4	47.2	3.1	53.1
SR10	25.8	49.6	0.9	23.8	3.9	11.3	0.1	6.9	1.2	47.0	4.3	54.3
SR13	40.8	48.2^	0.9	23.8	5.8	13.2	0.1	6.9	1.2	47.0	4.7	54.7
SR14	15.0	38.8	0.7	23.6	3.4	10.8	0.1	6.9	0.9	46.7	2.7	52.7
SR16	24.8	48.6	1.1	24.0	4.7	12.1	0.2	7.0	1.2	47.0	1.1	51.1
SR17	15.9	39.7	1.4	24.3	4.3	11.7	0.3	7.1	1.6	47.4	3.9	53.9
SR22	23.3^	47.1^	3.8^	26.7^	5.5	12.9	0.8	7.6	4.6	50.4	5.8	55.8
SR26	23.0	46.8	0.5	23.4	4.0	11.4	0.1	6.9	0.5	46.3	1.7	51.7
SR27	30.6	41.8^	0.5	23.4	4.7	12.1	0.1	6.9	0.6	46.4	2.3	52.3
SR28	29.7	48.4^	0.5	23.4	4.7	12.1	0.1	6.9	0.6	46.4	2.2	52.2
SR30	16.4	40.2	0.4	23.3	2.6	10.0	0.1	6.9	0.5	46.3	1.5	51.5
SR31	25.9^	49.7^	3.0^	25.9^	6.7	14.1	0.6	7.4	3.5	49.3	5.9	55.9
SR32	22.9^	46.7^	2.8^	25.7^	7.4	14.8	0.6	7.4	3.3	49.1	4.4	54.4
Objective	**-**	**50**	**-**	**25**	**-**	**25**	**-**	**8**	**-**	**90**	**-**	**120**

[1] Values in parentheses indicate values after additional mitigation has been applied

[2] Shaded cells indicate an exceedance of the respective criteria

Table 9 Number of days per year predicted to exceed in year 2

ID	Receptor Description	# days above 24-hr average PM_{10} guideline of 50 µg/m³
SR03	Residential	3
SR13	Residential	2
SR22	Residential and Accommodation Facility (within ML)	2
SR27	Residential	2
SR28	Residential	1
SR31	Residential	1
SR32	Residential	2

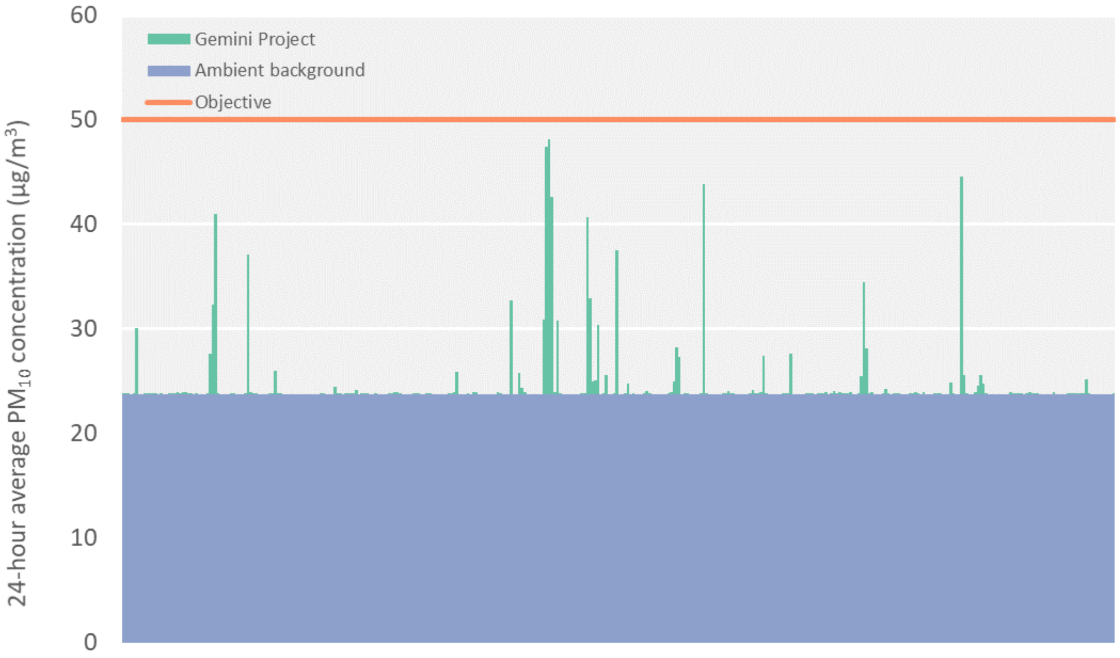

Figure 10 Year 2 – Timeseries of 24-hour average PM_{10} at SR03 including additional mitigation (when required)

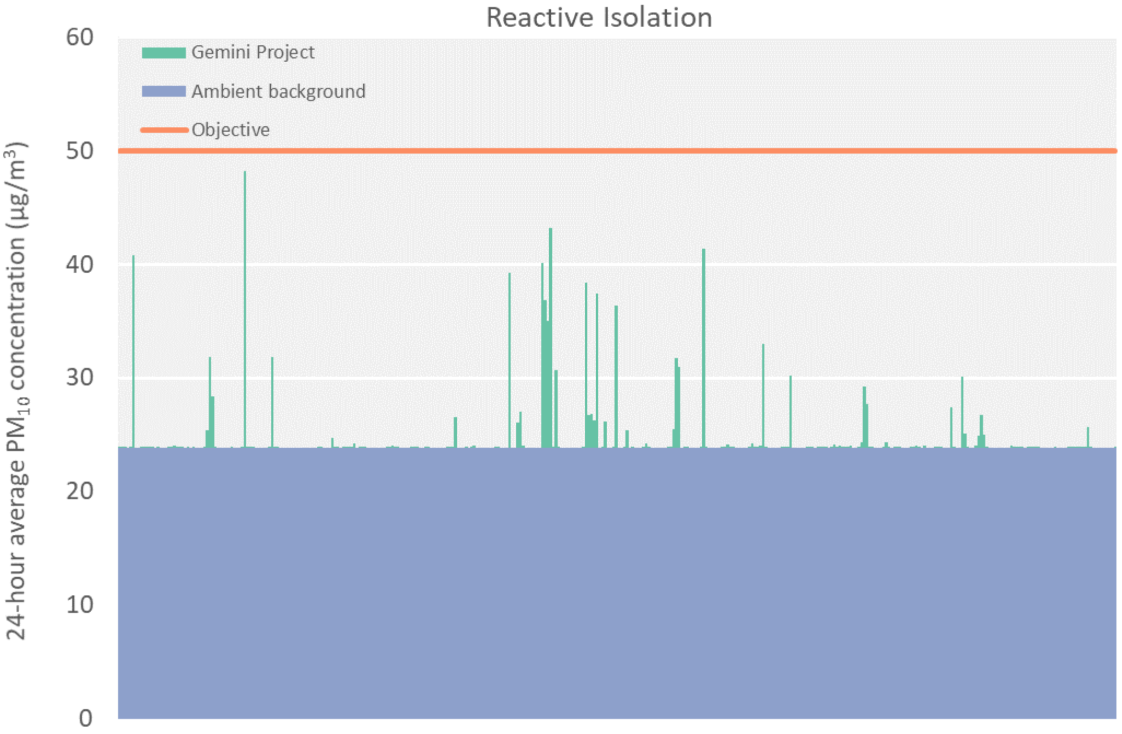

Figure 11 Year 2 – Timeseries of 24-hour average PM_{10} at SR13 including additional mitigation (when required)

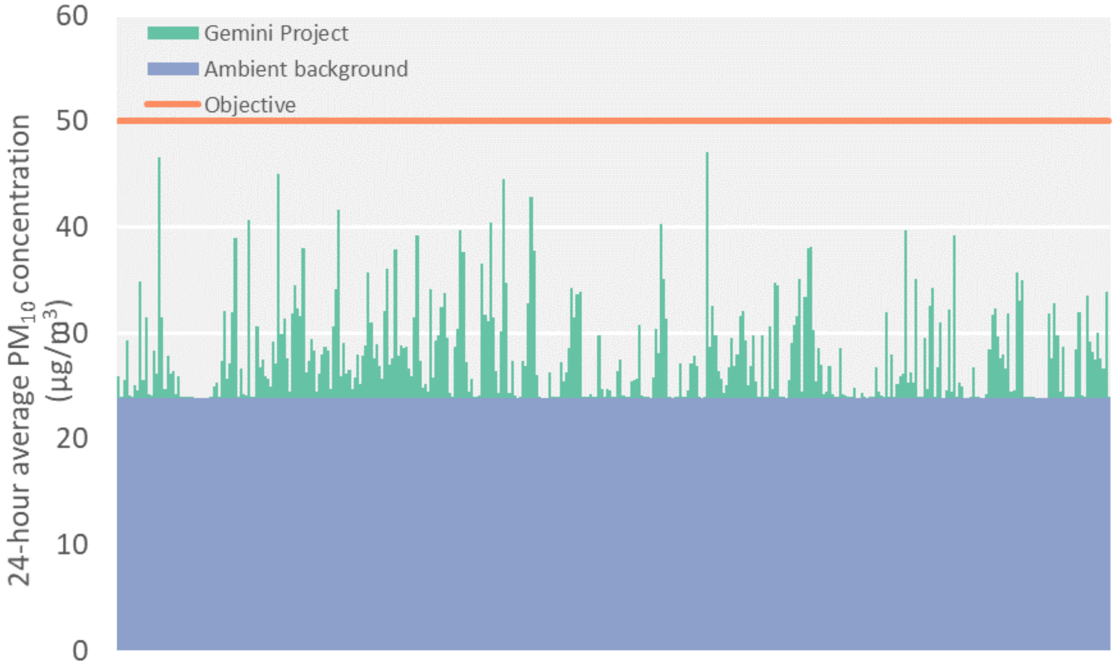

Figure 12 Year 2 – Timeseries of 24-hour average PM_{10} at SR22 including additional mitigation (when required)

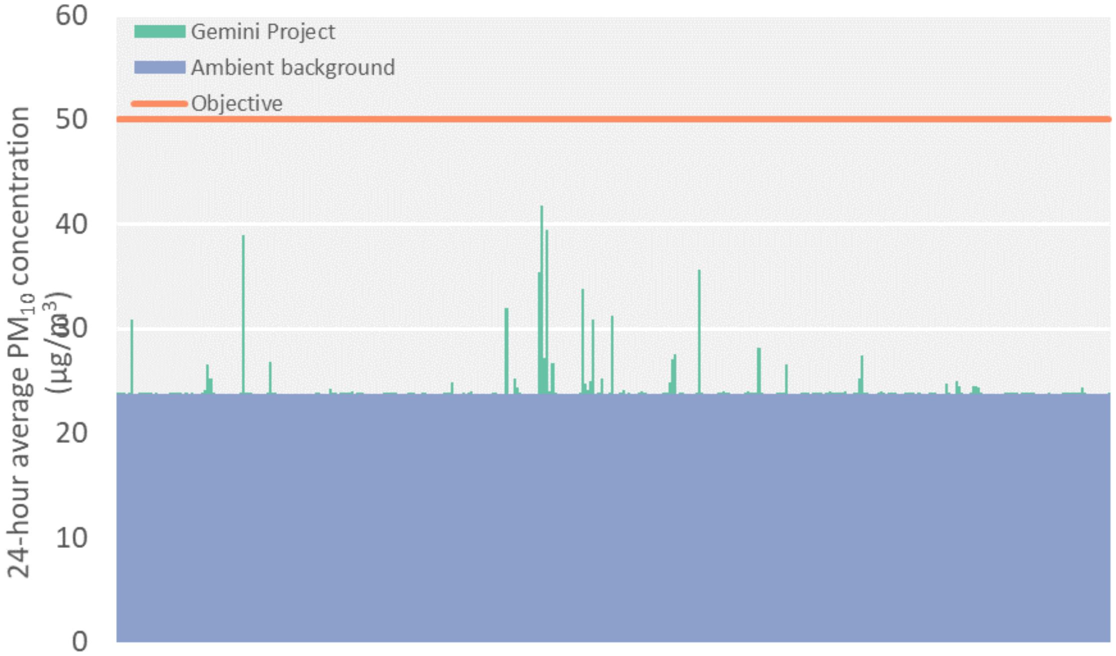

Figure 13 **Year 2 – Timeseries of 24-hour average PM_{10} at SR27 including additional mitigation (when required)**

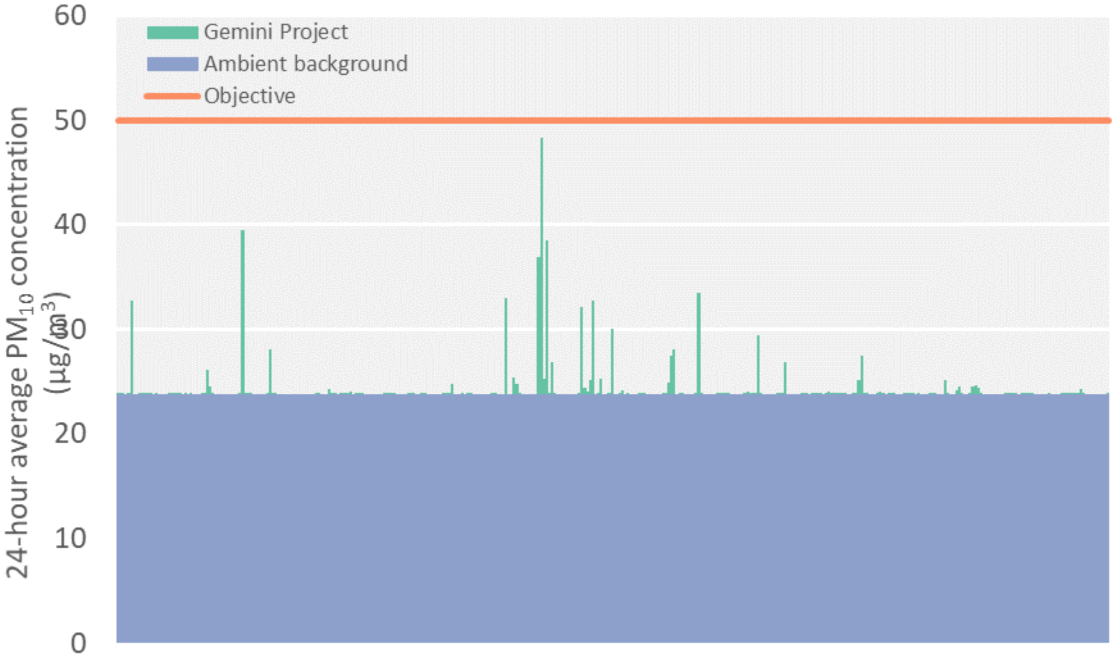

Figure 14 **Year 2 – Timeseries of 24-hour average PM_{10} at SR28 including additional mitigation (when required)**

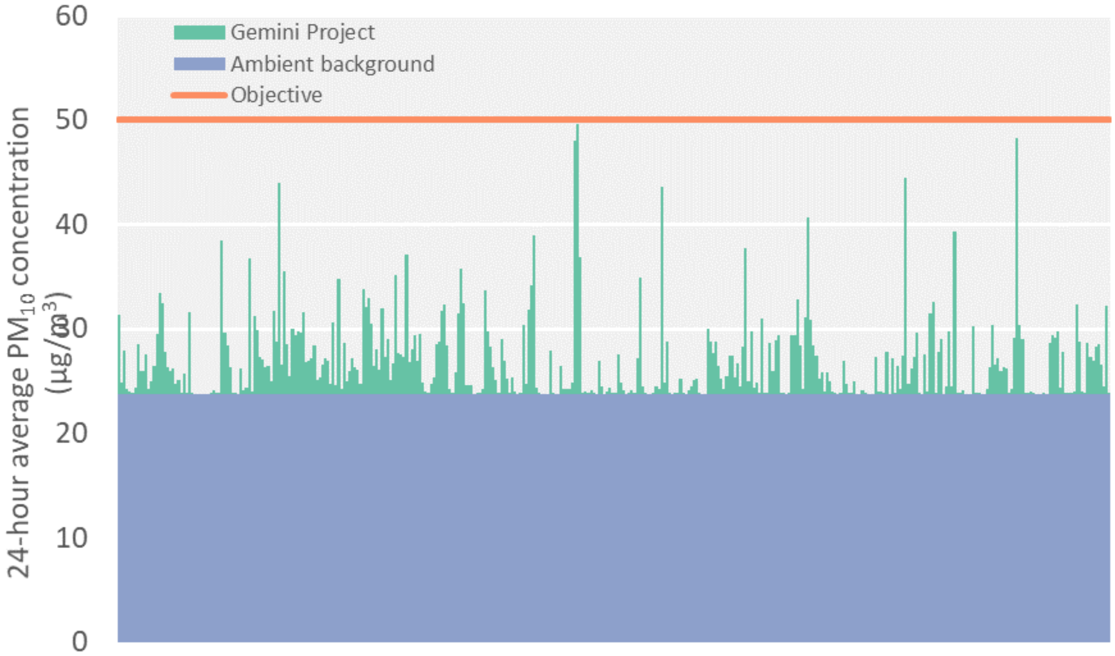

Figure 15 Year 2 – Timeseries of 24-hour average PM_{10} at SR31 including additional mitigation (when required)

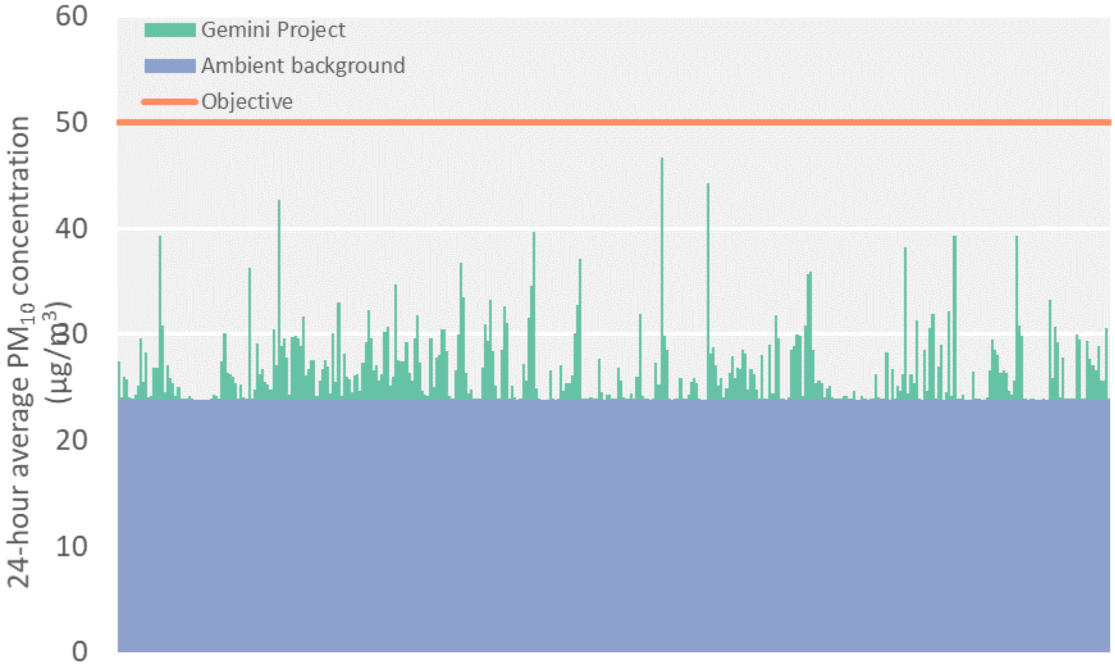

Figure 16 Year 2 – Timeseries of 24-hour average PM_{10} at SR32 including additional mitigation (when required)

3.5.2 Year 8

Table 10 presents the predicted ground-level concentrations of TSP, PM_{10} and $PM_{2.5}$ as well as dust deposition rates at the sensitive receptors due to the Project in year 8 in isolation and with a background.

The corresponding contours for each cumulative scenario are presented in Plate 8 to Plate 14.

The results show that

- Predicted annual average concentrations of TSP ***comply*** with the relevant air quality objective at all sensitive receptors, in isolation and cumulatively, with the application of standard mitigation measures (Plate 8).
- Predicted 24-hour average concentrations of PM_{10} ***comply*** with the relevant air quality objectives at four sensitive receptors in isolation and cumulatively with the application of standard mitigation measures. The predicted 24-hour average concentrations of PM_{10} are predicted to be above the air quality objective atSR03, SR07, SR10, SR13, SR16, SR22 (within Project ML), SR26, SR27, SR28, SR31 and SR32 (Plate 9).
- Predicted annual average concentrations of PM_{10} ***comply*** with the relevant air quality objective at all sensitive receptors with the exception of SR22 (within Project ML), SR31, and SR32 (Plate 10). The annual average concentration of PM_{10} due to the project in isolation is predicted to be at most 12% of the Air EPP objective.
- Predicted 24-hour concentrations of $PM_{2.5}$ ***comply*** with the relevant air quality objectives at all sensitive receptors, in isolation and cumulatively with the application of standard mitigation measures (Plate 11).
- Predicted annual average concentrations of $PM_{2.5}$ ***comply*** with the relevant air quality objectives at all sensitive receptors, in isolation and cumulatively with the application of standard mitigation measures.
- Predicted monthly dust deposition rates ***comply*** with the relevant air quality guideline at all sensitive receptors using standard mitigation measures, in isolation and cumulatively with the application of standard mitigation measures (Plate 13).

Further analysis of the 24-hour average PM_{10} concentrations indicate:

- The predicted 24-hour average concentrations of PM_{10} are only expected to exceed at most one to five days per year (Table 11).
- Using standard and, when necessary, additional mitigation measures, predicted 24-hour average concentrations of PM_{10} ***comply*** with the relevant air quality objective at all sensitive receptors (Plate 14).
- Additional mitigation measures may include ceasing night-time overburden hauling on days when 24-hour averaged maximum PM_{10} is predicted to exceed 50 µg/m^3. This would result in compliance with the air quality objective as shown in Figure 17 to Figure 27.

Table 10 Predicted ground-level concentrations of TSP, PM_{10}, $PM_{2.5}$ and dust deposition rates at sensitive receptors during year 8 using standard mitigation measures

Label	PM_{10}(µg/m^3)				$PM_{2.5}$ (µg/m^3)				TSP (µg/m^3)		Dust deposition rate (mg/m^2/day)	
	Maximum 24-hour		Annual		Maximum 24-hour		Annual		Annual		Maximum monthly	
	Project	With bkgd	Project	With bkgd	Project	With bkgd	Project	With bkgd	Project	With bkgd	Project	With bkgd
SR01	9.1	32.9	0.8	23.7	2.8	10.2	0.2	7.0	0.9	46.7	2.2	52.2
SR03	24.4^	48.2^	1.1	24	11.6	19.0	0.2	7.0	1.2	47.0	3.2	53.2
SR05	7.1	30.9	0.9	23.8	1.9	9.3	0.2	7.0	1.0	46.8	1.4	51.4
SR07	37.6	48.7^	0.7	23.6	5.7	13.1	0.1	6.9	0.8	46.6	2.4	52.4
SR08	10.7	34.5	1.0	23.9	3.2	10.6	0.2	7.0	1.1	46.9	1.9	51.9
SR10	40.4	48.4^	1.1	24	5.7	13.1	0.2	7.0	1.4	47.2	3.9	53.9
SR13	23.7^	47.5^	1.3	24.2	7.7	15.1	0.2	7.0	1.5	47.3	4.6	54.6
SR14	12.6	36.4	0.6	23.5	2.7	10.1	0.1	6.9	0.7	46.5	1.5	51.5
SR16	29.9	49.5^	1.3	24.2	5.6	13.0	0.3	7.1	1.4	47.2	1.2	51.2
SR17	11.4	35.2	1.2	24.1	3.5	10.9	0.3	7.1	1.3	47.1	2.6	52.6
SR22	21.8^	45.6^	3.1^	26.0^	8.6	16.0	0.7	7.5	3.7	49.5	4.4	54.4
SR26	21.9^	45.7^	0.6	23.5	8.8	16.2	0.1	6.9	0.7	46.5	1.7	51.7
SR27	34.6	43.7^	0.6	23.5	5.0	12.4	0.1	6.9	0.7	46.5	1.8	51.8
SR28	35.1	42.9^	0.6	23.5	5.6	13.0	0.1	6.9	0.7	46.5	1.8	51.8
SR30	23.8	47.6	0.4	23.3	3.9	11.3	0.1	6.9	0.5	46.3	1.2	51.2
SR31	23.7^	47.5^	2.4^	25.3^	8.2	15.6	0.6	7.4	2.8	48.6	4.4	54.4
SR32	21.0^	44.8^	2.2^	25.1^	7.8	15.2	0.5	7.3	2.6	48.4	3.2	53.2
Objective	**-**	**50**	**-**	**25**	**-**	**25**	**-**	**8**	**-**	**90**	**-**	**120**

^ Indicate values after additional proactive mitigation has been applied

Table 11 Number of days per year predicted to exceed in year 8

ID	Receptor Description	Number of days above 50 µg/m^3
SR03	Residential	3
SR07	Residential, facilities (sports oval, tennis court, school) & businesses (Post Office, hotel, shops, sawmills, etc.)	1
SR10	Residential	2
SR13	Residential	5
SR16	Residential	2
SR22	Residential and Accommodation Facility (within ML)	3
SR26	Residential	1
SR27	Residential	2
SR28	Residential	2
SR31	Residential	2
SR32	Residential	2

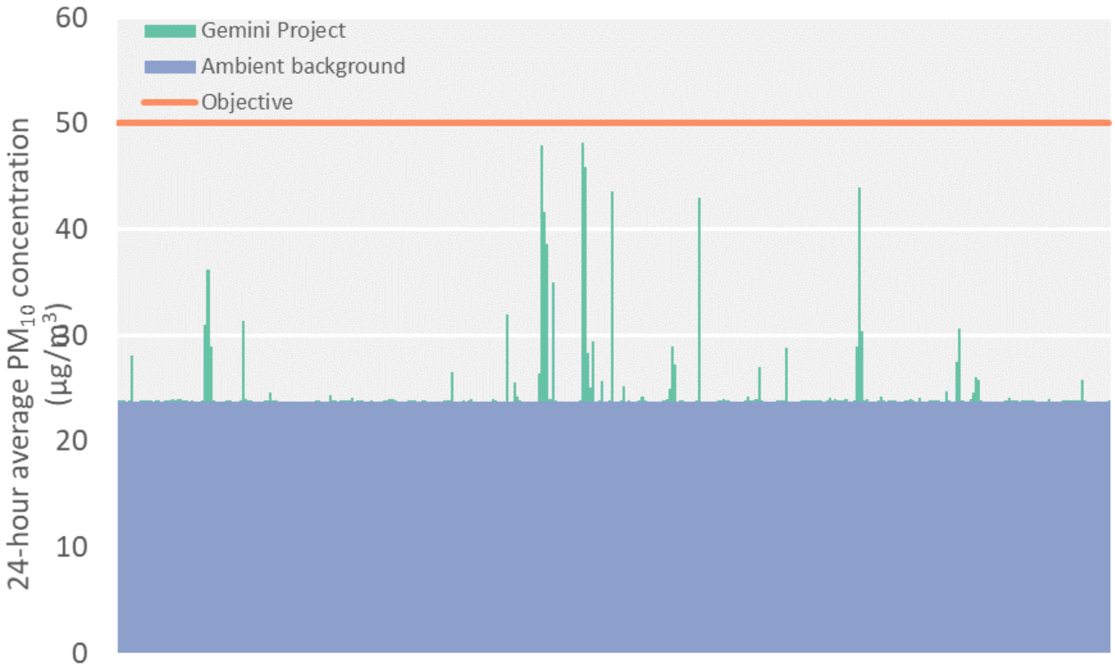

Figure 17 Year 8 – Timeseries of 24-hour average PM$_{10}$ at SR03 including additional mitigation (when required)

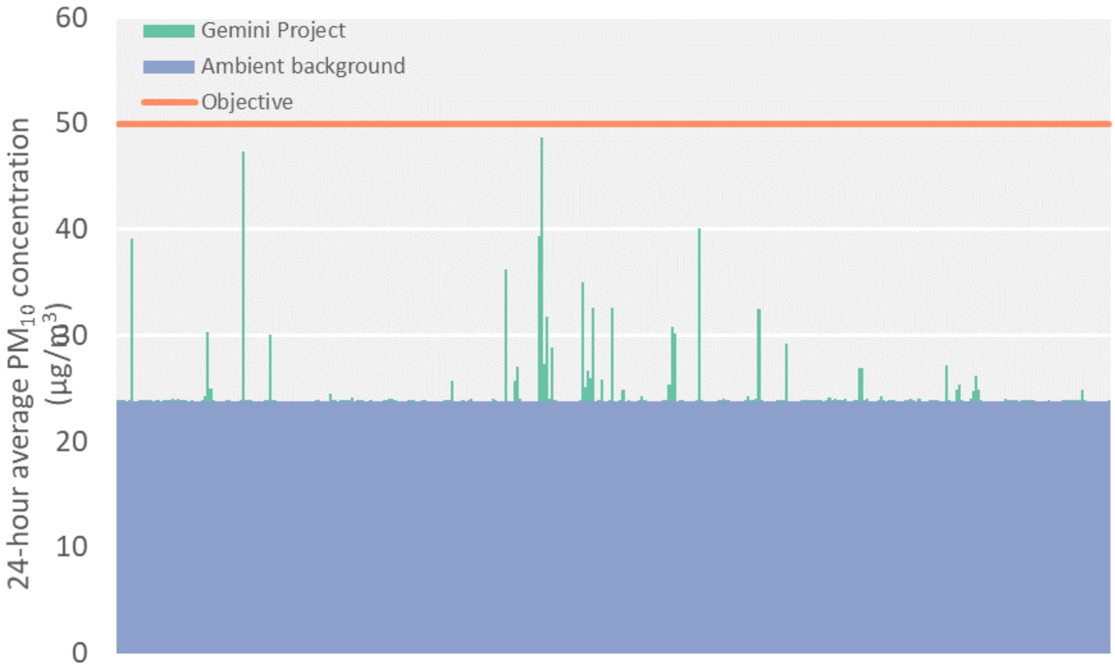

Figure 18 Year 8 – Timeseries of 24-hour average PM_{10} at SR07 including additional mitigation (when required)

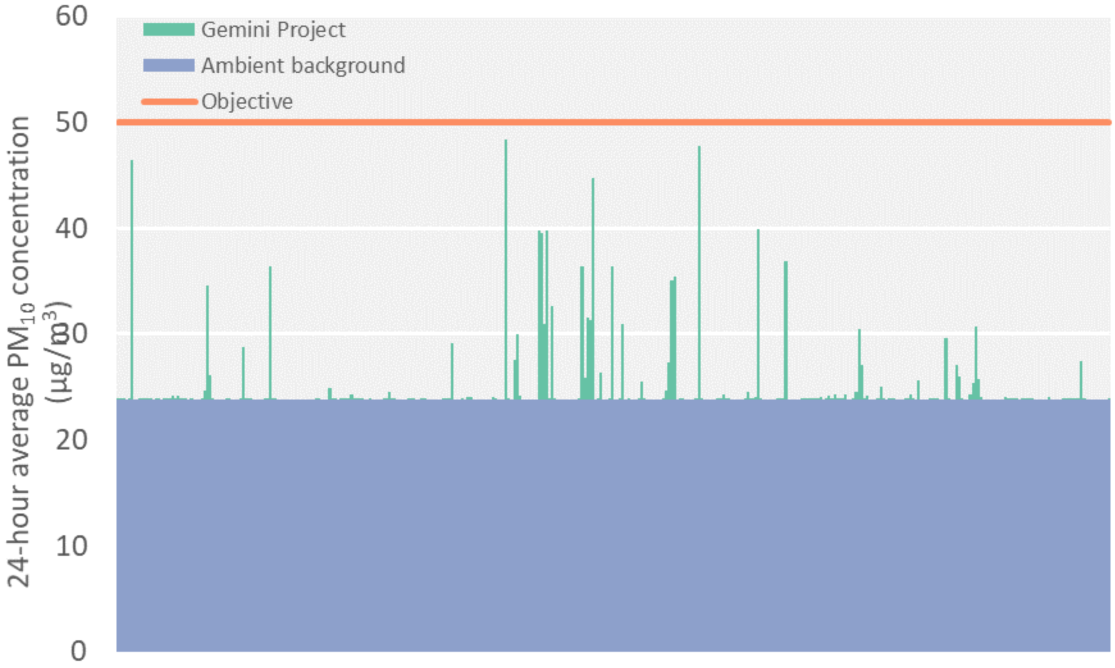

Figure 19 Year 8 – Timeseries of 24-hour average PM_{10} at SR10 including additional mitigation (when required)

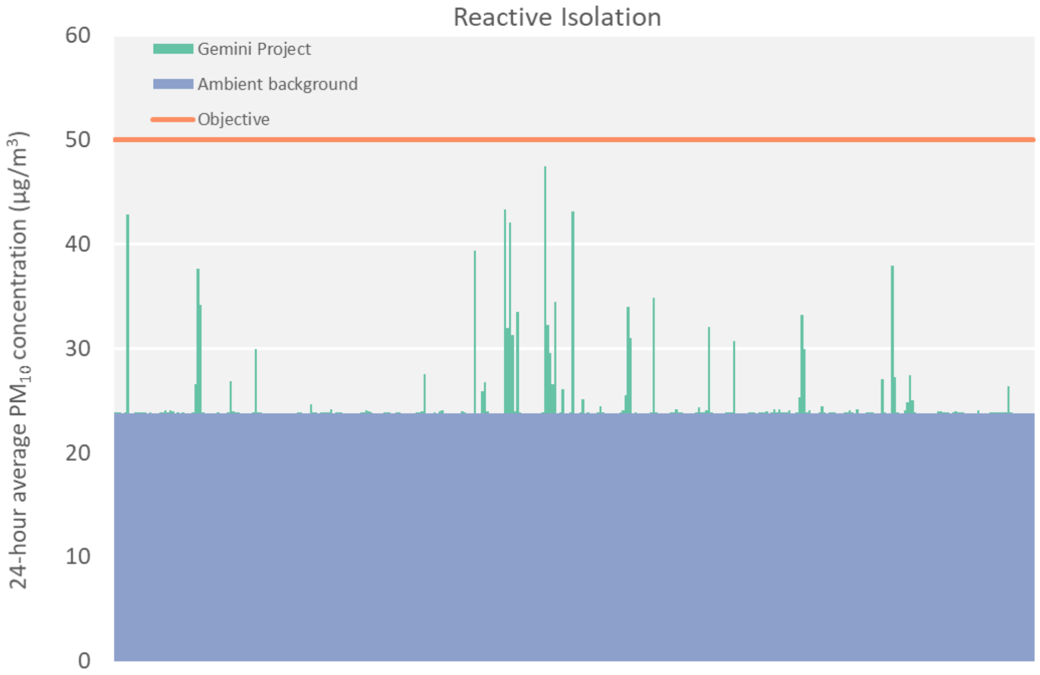

Figure 20 Year 8 – Timeseries of 24-hour average PM_{10} at SR13 including additional mitigation (when required)

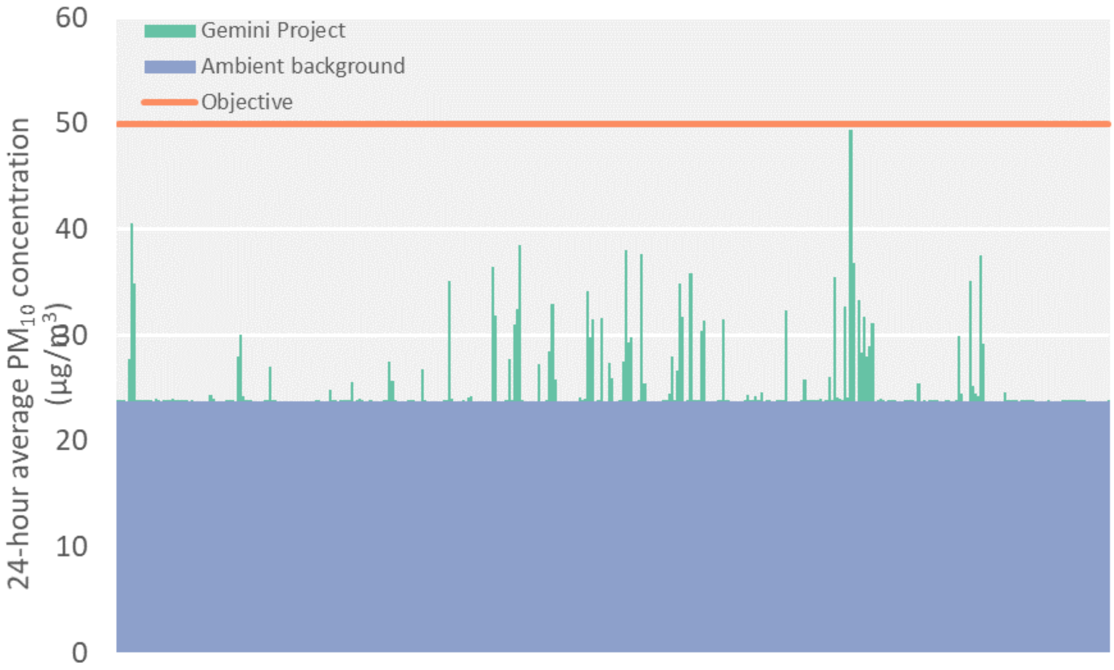

Figure 21 Year 8 – Timeseries of 24-hour average PM_{10} at SR16 including additional mitigation (when required)

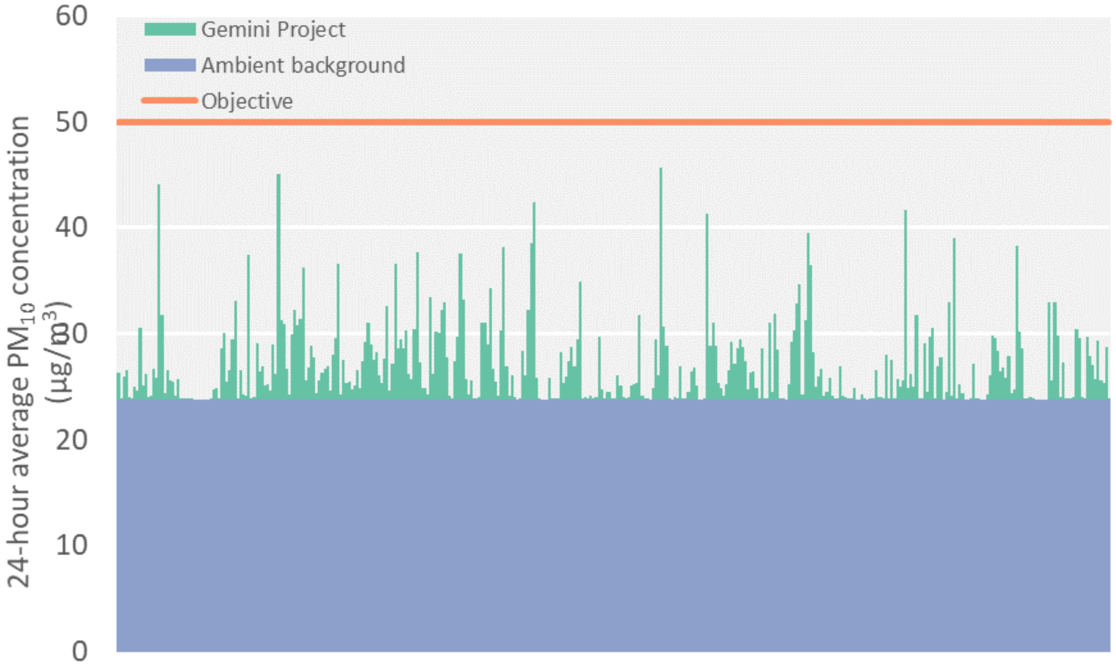

Figure 22 Year 8 – Timeseries of 24-hour average PM_{10} at SR22 including additional mitigation (when required)

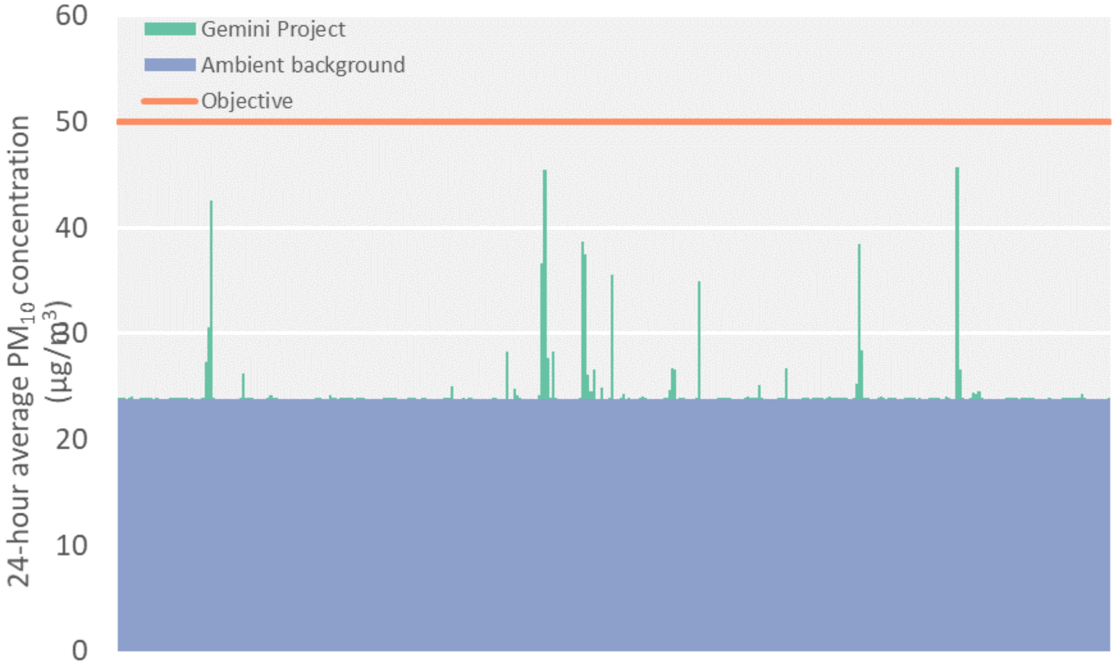

Figure 23 Year 8 – Timeseries of 24-hour average PM_{10} at SR26 including additional mitigation (when required)

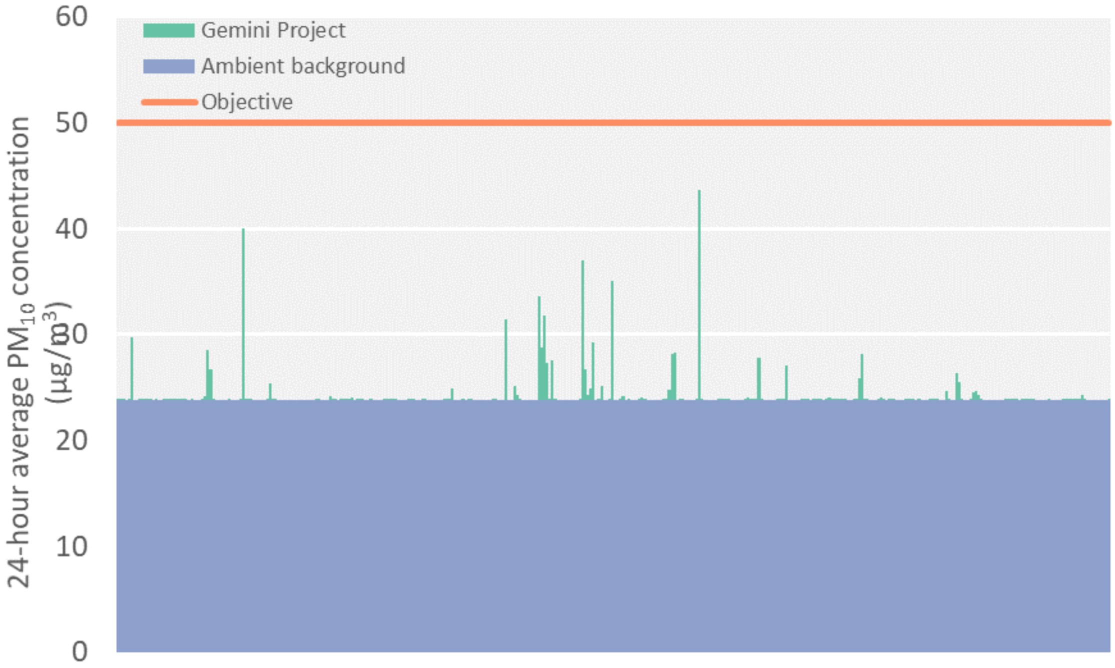

Figure 24 **Year 8 – Timeseries of 24-hour average PM_{10} at SR27 including additional mitigation (when required)**

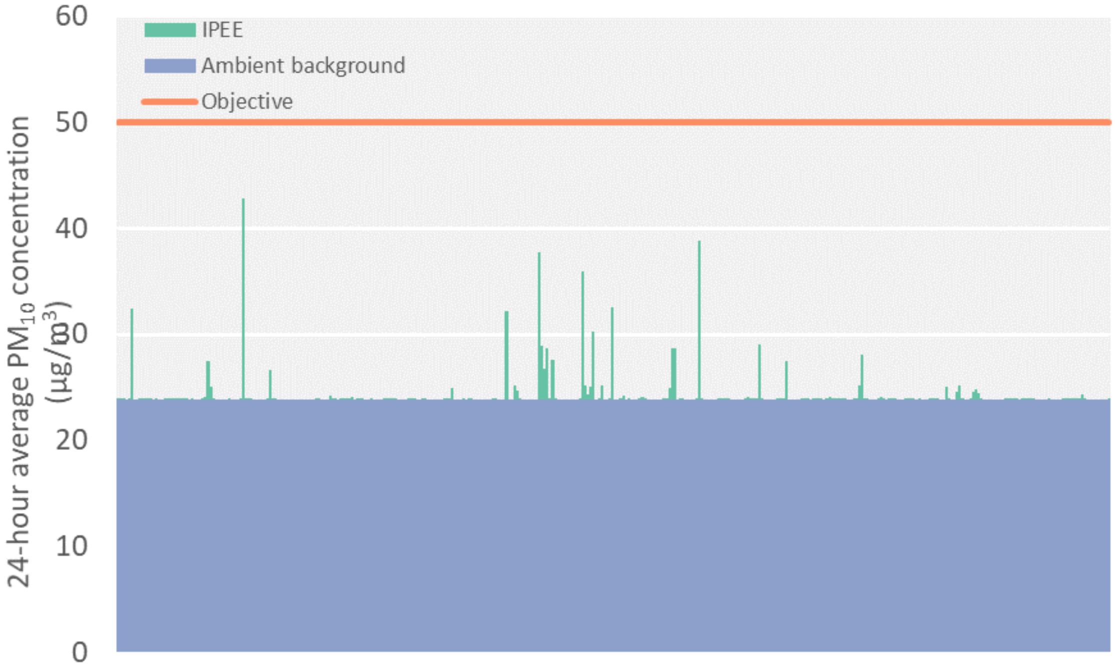

Figure 25 **Year 8 – Timeseries of 24-hour average PM_{10} at SR28 including additional mitigation (when required)**

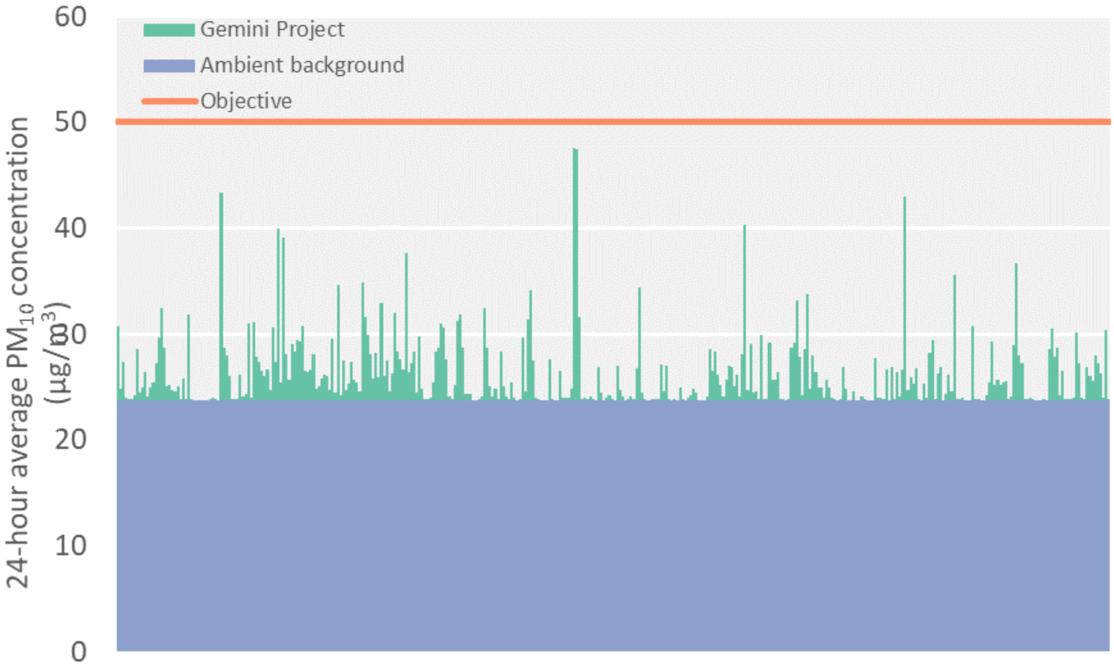

Figure 26 Year 8 – Timeseries of 24-hour average PM$_{10}$ at SR31 including additional mitigation (when required)

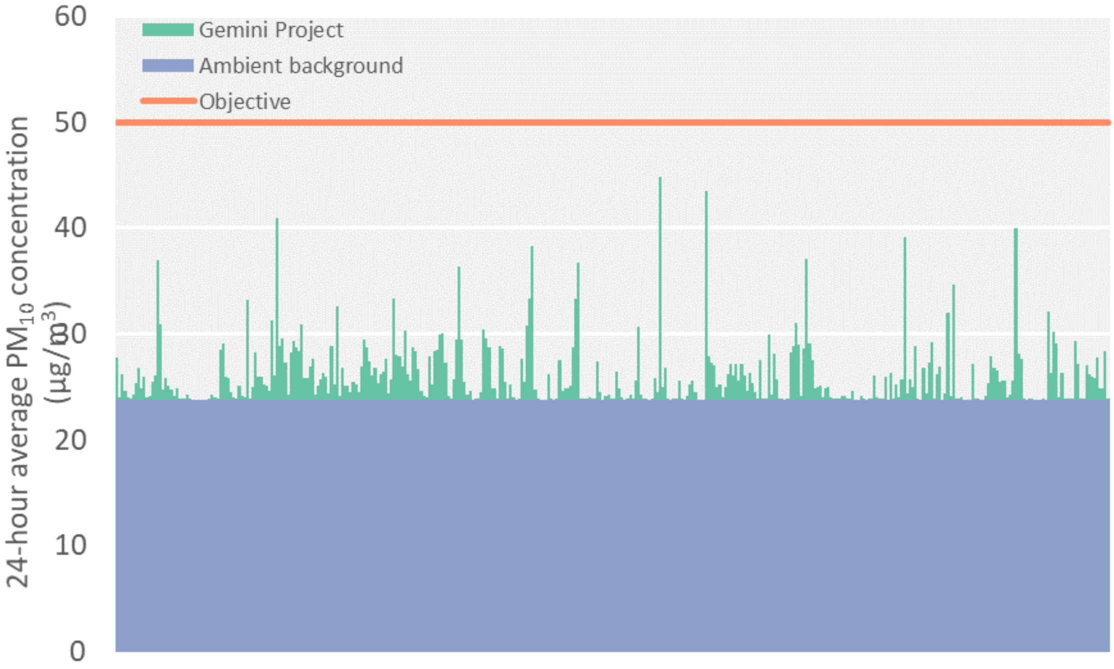

Figure 27 Year 8 – Timeseries of 24-hour average PM$_{10}$ at SR32 including additional mitigation (when required)

3.5.3 Year 15

Table 12 presents the predicted ground-level concentrations of TSP, PM_{10} and $PM_{2.5}$ as well as dust deposition rates at the sensitive receptors due to the Project in year 15 in isolation and with a background.

The corresponding contours for each cumulative scenario are presented in Plate 15 to Plate 21.

The results show that:

- Predicted annual average concentrations of TSP ***comply*** with the relevant air quality objective at all sensitive receptors in isolation and cumulatively, with the application of standard mitigation measures (Plate 15).
- Predicted 24-hour average concentrations of PM_{10} ***comply*** with the relevant air quality objective at the majority of sensitive receptors in isolation and cumulatively with the application of standard mitigation measures. The predicted 24-hour average concentrations of PM_{10} are predicted to be above the air quality objective at SR14, SR17, SR22 (within Project ML), SR31 and SR32 (Plate 16).
- Predicted annual average concentrations of PM_{10} ***comply*** with the relevant air quality objective at all sensitive receptors with the exception of SR14, SR17, SR22 (within Project ML), SR31, and SR32 (Plate 17). The annual average concentration of PM_{10} due to the project in isolation is predicted to be at most 44% of the Air EPP objective.
- Predicted 24-hour concentrations of $PM_{2.5}$ ***comply*** with the relevant air quality objectives at all sensitive receptors in isolation and cumulatively with the application of standard mitigation measures (Plate 18).
- Predicted annual average concentrations of $PM_{2.5}$ ***comply*** with the relevant air quality objectives at the majority of sensitive receptors in isolation and cumulatively with the application of standard mitigation measures. The predicted annual average concentrations of $PM_{2.5}$ are predicted to be above the air quality objective at SR22 (within Project ML), SR31, and SR32 (Plate 19).
- Predicted monthly dust deposition rates ***comply*** with the relevant air quality guideline at all sensitive receptors using standard mitigation measures in isolation and cumulatively with the application of standard mitigation measures (Plate 20).

Further analysis of the 24-hour average PM_{10} concentrations indicate:

- The predicted 24-hour average concentrations of PM_{10} are expected to exceed at most 50 days per year (Table 13).
- Using standard and, when necessary, additional mitigation measures, predicted 24-hour average concentrations of PM_{10} ***comply*** with the relevant air quality objective at all sensitive receptors (Plate 21).
- Additional mitigation measures may include ceasing night-time overburden hauling on days when 24-hour averaged maximum PM_{10} is predicted to exceed 50 µg/m^3. This would result in compliance with the air quality objective as shown in Figure 28 to Figure 32.

Table 12 Predicted ground-level concentrations of TSP, PM_{10}, $PM_{2.5}$ and dust deposition rates at sensitive receptors during year 15 using standard mitigation measures

Label	PM_{10}(µg/m^3)				$PM_{2.5}$ (µg/m^3)				TSP (µg/m^3)		Dust deposition rate (mg/m^2/day)	
	Maximum 24-hour		Annual		Maximum 24-hour		Annual		Annual		Maximum monthly	
	Project	With bkgd	Project	With bkgd	Project	With bkgd	Project	With bkgd	Project	With bkgd	Project	With bkgd
SR01	10.8	34.6	1.5	24.4	2.8	10.2	0.3	7.1	1.7	47.5	2.9	52.9
SR03	5.8	29.6	0.2	23.1	1.0	8.4	0.0	6.8	0.3	46.1	0.8	50.8
SR05	9.3	33.1	1.3	24.2	1.9	9.3	0.3	7.1	1.6	47.4	3.9	53.9
SR07	7.5	31.3	0.2	23.1	1.2	8.6	0.0	6.8	0.3	46.1	0.7	50.7
SR08	16.0	39.8	1.8	24.7	4.4	11.8	0.4	7.2	2.1	47.9	4.2	54.2
SR10	9.0	32.8	0.4	23.3	1.7	9.1	0.1	6.9	0.5	46.3	1.0	51.0
SR13	9.2	33.0	0.3	23.2	1.4	8.8	0.1	6.9	0.4	46.2	0.8	50.8
SR14	21.2^	45.0^	2.2^	25.1^	9.0	16.4	0.5	7.3	3.8	49.6	11.9	61.9
SR16	19.8	43.6	0.5	23.4	3.9	11.3	0.1	6.9	0.5	46.3	0.5	50.5
SR17	17.5^	41.3^	2.2^	25.1^	4.7	12.1	0.5	7.3	2.5	48.3	4.4	54.4
SR22	26.2^	50.0^	7.0^	29.9^	10.0	17.4	1.9	8.7	12.5	58.3	12.5	62.5
SR26	5.2	29.0	0.2	23.1	0.9	8.3	0.0	6.8	0.2	46.0	0.7	50.7
SR27	5.1	28.9	0.2	23.1	0.8	8.2	0.0	6.8	0.2	46.0	0.6	50.6
SR28	5.2	29.0	0.2	23.1	0.8	8.2	0.0	6.8	0.2	46.0	0.6	50.6
SR30	5.7	29.5	0.2	23.1	0.9	8.3	0.0	6.8	0.2	46.0	0.5	50.5
SR31	26.2^	50.0^	6.7^	29.6^	8.1	15.5	1.4	8.2	8.5	54.3	8.0	58.0
SR32	26.1^	49.9^	6.8^	29.7^	8.5	15.9	1.5	8.3	9.3	55.1	7.0	57.0
Objective	**-**	**50**	**-**	**25**	**-**	**25**	**-**	**8**	**-**	**90**	**-**	**120**

[1] Indicate values after proactive mitigation has been applied

Table 13 **Number of days per year predicted to exceed in year 15**

ID	Receptor Description	Number of days above 50 µg/m^3
SR14	Residential	11
SR17	Residential	1
SR22	Residential and Accommodation Facility (within ML)	50
SR31	Residential	11
SR32	Residential	22

Figure 28 **Year 15 - Timeseries of 24-hour average PM$_{10}$ at SR14 including additional mitigation (when required)**

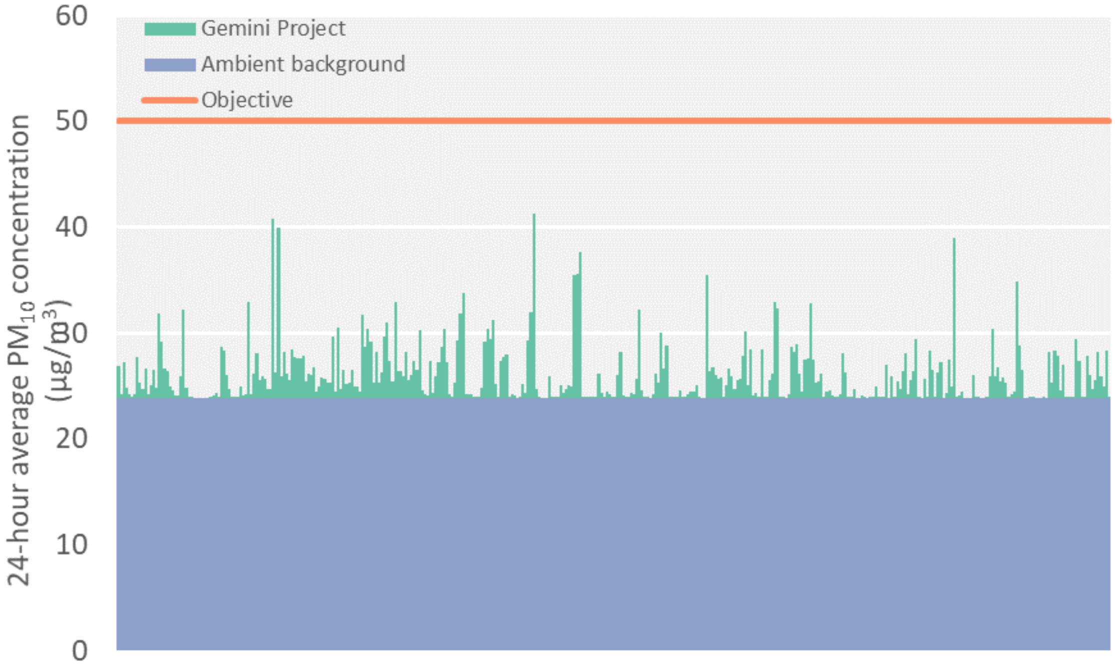

Figure 29 Year 15 - Timeseries of 24-hour average PM$_{10}$ at SR17 including additional mitigation (when required)

Figure 30 Year 15 – Timeseries of 24-hour average PM$_{10}$ at SR22 including additional mitigation (when required)

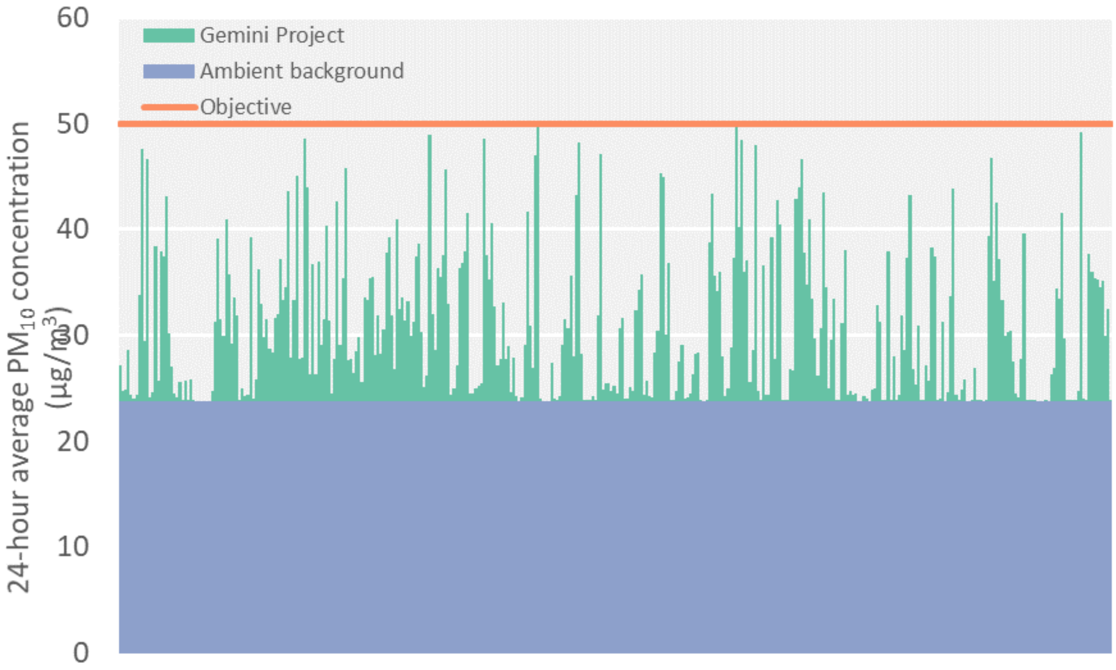

Figure 31 Year 15 – Timeseries of 24-hour average PM_{10} at SR31 including additional mitigation (when required)

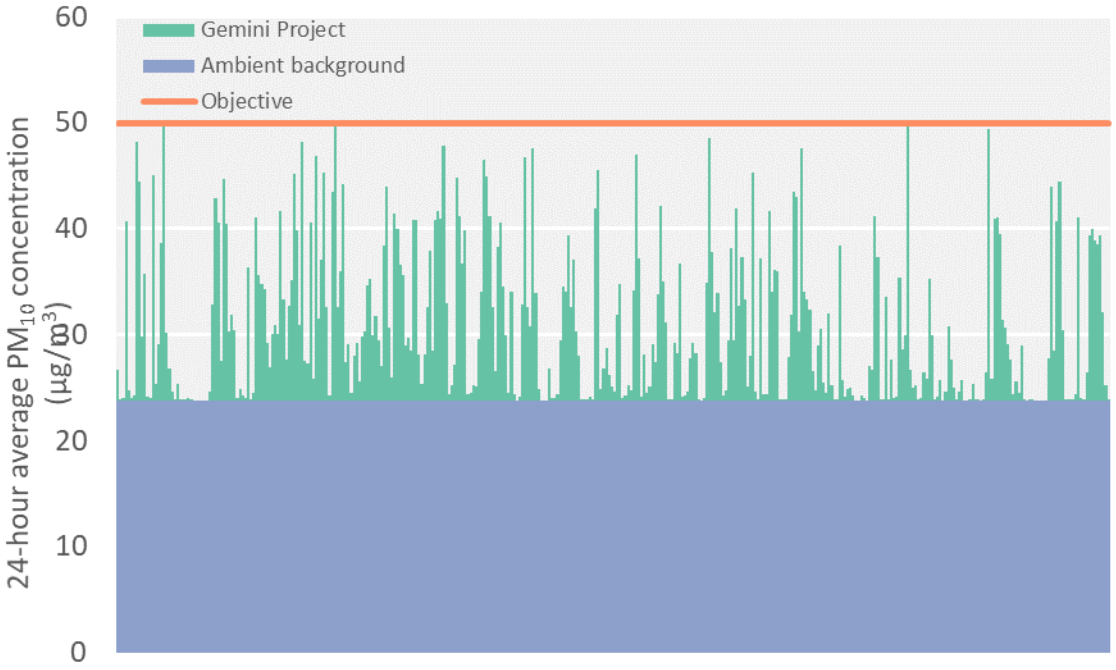

Figure 32 Year 15 – Timeseries of 24-hour average PM_{10} at SR32 including additional mitigation (when required)

3.6 Mitigation

Dust management and mitigation measures will be implemented for the Project. It is recommended that Magnetic South implement the following measures:

1. Develop and implement an ambient air quality monitoring program at sites representative of surrounding sensitive receptors
2. Develop an Air Quality Management Plan (AQMP) and include a range of available measures to be implemented as necessary to ensure compliance with approval conditions. Measures that would be considered for inclusion in the AQMP include:
    - Use of real-time measurement of dust levels and meteorological conditions
    - Nomination of triggers (e.g. based on complaints and/or real-time dust and meteorological measurement) and a range of additional measures which will be implemented, as necessary, for example:
        - applying additional at-source and/or at-receptor dust controls
        - increasing the intensity of dust controls
        - modifying certain operations
    - Procedures to investigate, if monitoring indicates unexpected exceedances of air quality objectives.

    An example of the Air Quality Management Plan is provided in Appendix C.
3. Enter into discussions and, as appropriate, commercial arrangements with surrounding landholders which could include:
        - measures (e.g. purchase or relocation) which result in homesteads no longer being considered a sensitive receptor
        - installation of receptor-side mitigation (e.g. air conditioners / purifiers in affected residences).

4. GREENHOUSE GAS ASSESSMENT

4.1 Background

The term greenhouse gases (GHG) comes from the ‘greenhouse effect’, which refers to the natural process that warms the Earth’s surface. GHG in the atmosphere absorb the solar radiation released by the Earth’s surface and then radiate some heat back towards the ground, increasing the surface temperature. Human activity, especially burning fossil fuels and deforestation, is increasing the concentration of GHG in the atmosphere and hence increasing the absorption of outgoing heat energy. Even a small increase in long-term average surface temperatures has numerous direct and indirect consequences for climate.

Australia is a signatory to United Nations Framework Convention on Climate Change (UNFCCC), the associated Kyoto Protocol signalling its commitment to reducing GHG emissions at a national level. Under the Paris Agreement, the most recent progression of the UNFCCC, Australia has set an ambitious target to reduce emissions by 26-28 per cent below 2005 levels by 2030, building on the 2020 target of reducing emissions by five per cent below 2000 levels.

The main GHG associated with the Project is carbon dioxide (CO_2), with smaller contributions from methane (CH_4) and nitrous oxide (N_2O). These gases vary in effect and longevity in the atmosphere, however a system named Global Warming Potential (GWP) allows them to be described in terms of CO_2 (the most prevalent greenhouse gas) called carbon dioxide equivalents (CO_2-e). A unit of one tonne of CO_2-e is the basic unit used in carbon accounting. In simple terms the greenhouse gas emissions associated with the Project can be expressed as the sum of the emission rate of each greenhouse gas multiplied by its associated GWP (denoted in squares). For example:

tonnes **CO_2-e** = tonnes **CO_2** x $\boxed{\mathbf{1}}$ + tonnes **CH_4** x $\boxed{\mathbf{25}}$ + tonnes **N_2O** x $\boxed{\mathbf{310}}$

While few, if any, individual Projects would make a noticeable change to the Earth’s climate, the summation of human activities increasing the concentrations of GHG in the upper atmosphere does. Climate change is an environmental concern at a global level. Governments and the global scientific community have established conventions for accounting for GHG emissions to enable the transparent and verifiable assessment of GHG emissions among all global jurisdictions. This assessment employs these established conventions so that the relative impact of the Project can be assessed and understood.

4.2 Regulatory Framework for Greenhouse Gas Emissions

4.2.1 National policy

Australia will meet its targets through the Government’s Direct Action Plan. The Emissions Reduction Fund (ERF) is a central component of the Direct Action policies that is made up of an element to credit emissions reductions, a fund to purchase emissions reductions, and a Safeguard Mechanism.

The Safeguard Mechanism has been put in place to ensure that emissions reductions purchased by the Government through the ERF are not offset by significant increases in emissions by large emitters elsewhere in the economy. The Safeguard Mechanism commenced on 1 July 2016 and requires Australia’s largest emitters to keep emissions within baseline levels. It applies to around 140 large businesses that have facilities with direct emissions (Scope 1 Emissions) of more than 100,000 tonnes of carbon dioxide equivalent (t CO_2-e) a year and is expected to cover approximately half of Australia’s emissions.

Direct emissions associated with the Project are anticipated to exceed 100,000 t CO_2-e for all years with the exception of the first year of operation. As a result, the Project will be subject to the requirements of the Safeguard Mechanism.

4.2.2 National Greenhouse and Energy Reporting (NGER)

The *National Greenhouse and Energy Reporting Act 2007* (NGER Act) established a national framework for corporations to report GHG emissions and energy consumption.

The NGER Regulation recognises Scope 1 and Scope 2 emissions as follows:

- Scope 1 emissions – in relation to a facility, means the release of GHG into the atmosphere as a direct result of an activity or series of activities (including ancillary activities) that constitute the facility.
- Scope 2 emissions – in relation to a facility, means the release of GHG into the atmosphere as a direct result of one or more activities that generate electricity, heating, cooling or steam that is consumed by the facility but that do not form part of the facility.

A third category of GHG emissions, namely Scope 3 emissions, are defined as indirect greenhouse gas emissions other than scope 2 emissions that are generated in the wider economy. They occur as a consequence of the activities of a company, but from sources not owned or controlled by that company. Some examples are production and manufacture of purchased materials, transportation of products, use of sold products and services, and air travel. Scope 1 and Scope 2 emissions generated by one company effectively become Scope 3 emissions for another company. Scope 3 emissions are not included in NGER reporting, to limit the potential of double counting of GHG emissions on a national scale.

Registration and reporting is mandatory for corporations that have energy production, energy use or GHG emissions that exceed specified thresholds. GHG emission thresholds include Scope 1 and Scope 2 emissions. NGER reporting thresholds are summarised in Table 14.

Table 14 NGER annual reporting thresholds – greenhouse gas emissions and energy use

Threshold level	Threshold type	
	GHG (kt CO_2-e)	Energy consumption (TJ)
Facility	25	100
Corporate	50	200
Note: kt CO_2-e = kilotonnes of carbon dioxide equivalent. TJ = terajoules.		

With annual emissions (Scope 1 + Scope 2) ranging from 18 kt CO_2-e to 211kt CO_2-e, Magnetic South will have reporting obligations associated with the Project under the NGER Scheme, including estimating and reporting their GHG emissions on an annual basis.

4.3 Methodology

Pollutants of importance to climate change, associated with the Project, are carbon dioxide, methane and nitrous oxide. This study will assess the emissions of greenhouse gases from the Project during construction and operation based on activity data representative of the proposed activities and the methods described in the following resources:

- The National Greenhouse Accounts, July 2017 (Commonwealth Department of the Environment and Energy, 2017)
- *National Greenhouse and Energy Reporting (Measurement) Determination 2008*
- The Greenhouse Gas Protocol
- FullCAM – Full Carbon Accounting Model (used to account for GHG emissions from land clearing).

4.3.1 Emissions

Scope 1 and 2 greenhouse gas emissions will be estimated on an annual basis for the Project. This will include emissions from:

Scope 1 GHG emissions

- Diesel combustion
    - Heavy machinery and equipment
    - Haulage vehicles
- Fugitive emissions of methane from mining of coal deposits – also referred to as waste mine gas
- Explosives use
- Land clearing and rehabilitation

Scope 2 GHG Emissions

- Electricity usage
    - Conveyors
    - Coal processing plant
    - Amenities.

Scope 3 GHG Emissions:

- Transport of coal- Rail transport to coal terminal
- Use of coal – Coking applications

A summary of production rates and emission sources associated with the both the construction phase and mining production is provided in Table 15. Emissions sources would reduce during the post production/rehabilitation phase of the mine.

Table 15 Summary of GHG emission sources by year of mining operations

Year	ROM Coal (t)	Product Coal (t)	Diesel (L)	Electricity (kWh)	Explosives (t/yr)
Year 1	-	-	6,200,000	2,000,000	-
Year 2	900,000	673,000	56,911,490	22,527,890	19,867
Year 3	1,900,000	1,360,733	37,531,815	22,527,890	11,234
Year 4	1,900,000	1,366,114	40,987,689	22,527,890	12,409
Year 5	1,900,000	1,364,411	45,413,261	22,527,890	14,139
Year 6	1,900,000	1,359,847	38,148,132	22,527,890	11,431
Year 7	1,900,000	1,339,859	48,778,289	22,527,890	13,622
Year 8	1,900,000	1,349,097	51,109,310	22,527,890	15,185
Year 9	1,900,000	1,329,283	38,913,541	22,527,890	11,004
Year 10	1,900,000	1,352,540	38,107,769	22,527,890	11,100
Year 11	1,900,000	1,335,118	37,030,381	22,527,890	10,689
Year 12	1,900,000	1,298,272	40,218,955	22,527,890	12,094
Year 13	1,800,000	1,390,812	43,619,124	22,527,890	13,982
Year 14	1,800,000	1,393,048	46,218,509	22,527,890	14,316
Year 15	1,800,000	1,383,218	45,322,232	22,527,890	13,913
Year 16	1,800,000	1,393,169	54,648,151	22,527,890	16,330
Year 17	1,800,000	1,347,589	44,877,181	22,527,890	11,846
Year 18	1,800,000	1,384,637	54,606,897	22,527,890	16,239
Year 19	1,593,048	1,218,545	26,028,185	22,527,890	5,744
Year 20	-	-	10,541,000	4,909,000	-
Year 21	-	-	10,695,000	3,272,000	-
Year 22	-	-	4,144,000	3,272,000	-
Year 23	-	-	4,068,000	3,272,000	-
Year 24	-	-	4,068,000	1,636,000	-

4.3.1.1 Land clearing

The establishment of the Project will require the clearing of vegetation to enable planned mining activities to take place. Land clearing will occur during the construction phase of the Project, with progressive rehabilitation taking place during the operations phase. GHG emissions associated with land clearing do not occur instantaneously but rather over a period of years. To account for this to some extent total GHG emissions associated with land clearing for the life of the Project have been averaged across each year of the Project.

Land clearing required for the Project is made up of:

- Eucalyptus woodland – 407.17 ha
- Acacia woodland – 313.57 ha
- Grazing land (previously cleared) – 1,240 ha

GHG emissions associated with land clearing are Scope 1 emissions and have been estimated based on the Full Carbon Accounting Model (FullCAM) developed by the Australian government to support the estimation of carbon stock change on forest systems. The forest type used for the assessment has been selected based on location specific attributes and approximated as the acacia shrubland category available in FullCAM.

GHG emissions associated with clearing of grazing land have not been included in the assessment. Grazing land is made up of previously cleared land vegetated to varying extents with perennial grasses. The nature of grazing land is that is undergoes an ongoing cycle of clearing and renewal based on the level of grazing activity occurring over the area. The carbon content of grazing land is rapidly regenerated with complete regeneration occurring within approximately 2 years. As a result, the carbon content of grazing land cleared for the Project will be regenerated within 2 years of the completion of mining operations and can be considered as carbon neutral over the life of the Project.

Regeneration of woodland vegetation is gradual and will be realised in the years following the conclusion of the Project, GHG sequestration associated with land rehabilitation has not been included in the assessment due to its delayed impact on GHG emissions associated with the Project. GHG emissions associated with land clearing are not covered by the NGER scheme.

4.3.1.2 Coal transport and use

Coal produced by the Project will be transported by rail to the Dalrymple Bay Coal Terminal (DBCT) A summary of key parameters used in the quantification of Scope 3 emissions associated with coal transportation is provided in Table 16.

Table 16 Coal transportation - Scope 3 GHG Parameters

Parameter	Quantity	Units
Rail transport distance	255	km
Diesel rate for rail transport	100	tonne.km/L

Product coal is assumed to be used for coking application to provide a conservative estimate of Scope 3 GHG emissions.

4.3.2 Emissions estimation

GHG emissions associated with the Project have been considered on an annual basis for the life of the Project. A summary of estimated emissions associated with mining operations, expressed as tonnes per annum expressed in terms of CO_2-e is presented. Reporting obligations based on a conservative estimate of annual GHG emissions are summarised, along with measures to mitigate GHG emissions through avoidance and minimisation.

The methodologies used to estimate the GHG emissions resulting from the Project are consistent with:

1. *National Greenhouse and Energy Reporting (Measurement) Determination 2008*
2. The National Greenhouse Accounts, July 2017 (Commonwealth Department of the Environment and Energy, 2017)
3. FullCAM – Full Carbon Accounting Model (used to account for GHG emissions from land clearing) (Commonwealth of Australia, 2020)

4. The Greenhouse Gas Protocol.

In particular, the methodology is consistent with a Method 1 approach as detailed in the *National Greenhouse and Energy Reporting (Measurement) Determination*.

The emission factors and energy content for each of the emissions sources that have been used in the assessment are summarised in Table 17.

Table 17 Emission factors and energy content for GHG emission sources

Emission source	Scope	Energy content	Units	Emission factor	Units
Diesel	1	38.6	GJ/kL	70.4	kg CO_2-e/GJ
Fugitive methane (Qld – open cut)	1	-	-	0.023	t CO_2-e/t ROM
Explosives (Ammonium Nitrate Fuel Oil [ANFO])	1	2.4	GJ/t	0.17	t CO_2-e/t ANFO
Land clearing*	1	-	-	43	t CO_2-e/ha
Electricity (Queensland)	2	3.6	MJ/kWh	0.81	kg CO_2-e/kWh
Coking coal	3	30	GJ/t	92	kg CO_2-e/GJ

Sources: *National Greenhouse and Energy Reporting (Measurement) Determination (July 2020)*, National Greenhouse Accounts Factors (July 2019), NGA Workbook (January 2008).

Notes:

*Emissions factor derived from FullCAM based on eucalyptus woodland and acacia woodland assuming 100% conversion of carbon content in trees to CO_2

GJ/kL = gigajoules per kilolitres. GJ/t = gigajoules per tonne. MJ/kWh = megajoules per kilowatt hour. kg CO_2-e/GJ = kilograms of carbon dioxide equivalent per gigajoule. T CO_2-e/t ROM = tonnes of carbon dioxide equivalent per tonne of ROM coal. T CO_2-e/t ANFO = tonnes of carbon dioxide equivalent per tonne of ANFO. t CO_2-e/ha tonnes of carbon dioxide equivalent per hectare- kg CO_2-e/kWh = kilograms of carbon dioxide equivalent per kilowatt hour.

4.4 Results

4.4.1 Scope 1 and 2 GHG emissions and energy use summary

A summary of anticipated annual GHG emissions, by scope, along with estimated energy consumption corresponding with the mining years are summarised in Table 18 and Table 19.

Table 18 **Summary of GHG emissions by year of mining operations**

Year	GHG Emissions (t CO_2-e/yr)					TOTAL Scope 1 & 2	
	Scope 1				Scope 2	incl Land Clearing	excl Land clearing
	Fugitive methane	Diesel usage	Explosives	Land clearing	Electricity usage		
Year 1	-	16,848	-	5,981	1,620	24,449	18,468
Year 2	20,700	154,654	3,377	5,981	18,248	202,959	196,979
Year 3	43,700	101,990	1,910	5,981	18,248	171,829	165,848
Year 4	43,700	111,382	2,110	5,981	18,248	181,420	175,439
Year 5	43,700	123,408	2,404	5,981	18,248	193,740	187,759
Year 6	43,700	103,665	1,943	5,981	18,248	173,537	167,556
Year 7	43,700	132,552	2,316	5,981	18,248	202,796	196,815
Year 8	43,700	138,886	2,581	5,981	18,248	209,396	203,415
Year 9	43,700	105,745	1,871	5,981	18,248	175,544	169,564
Year 10	43,700	103,556	1,887	5,981	18,248	173,371	167,390
Year 11	43,700	100,628	1,817	5,981	18,248	170,373	164,393
Year 12	43,700	109,293	2,056	5,981	18,248	179,277	173,296
Year 13	41,400	118,532	2,377	5,981	18,248	186,538	180,557
Year 14	41,400	125,596	2,434	5,981	18,248	193,658	187,677
Year 15	41,400	123,160	2,365	5,981	18,248	191,154	185,173
Year 16	**41,400**	**148,503**	**2,776**	**5,981**	**18,248**	**216,908**	**210,927**
Year 17	41,400	121,951	2,014	5,981	18,248	189,593	183,613
Year 18	41,400	148,391	2,761	5,981	18,248	216,780	210,799
Year 19	36,640	70,730	977	5,981	18,248	132,575	126,594
Year 20	-	28,645	-	-	3,976	32,621	32,621
Year 21	-	29,063	-	-	2,650	31,713	31,713
Year 22	-	11,261	-	-	2,650	13,911	13,911
Year 23	-	11,055	-	-	2,650	13,705	13,705
Year 24	-	11,055	-	-	1,325	12,380	12,380
Total	**742,740**	**2,250,548**	**39,976**	**113,639**	**343,335**	**3,490,227**	**3,376,592**
Average	30,948	93,773	1,666	4,735	14,306	145,426	140,691

Table 19 **Summary of energy use (GJ/y) by year of mining operations**

Year	Energy use (GJ/y)			
	Diesel usage	Explosives	Electricity usage	TOTAL
Year 1	239,320	-	7,200	246,520
Year 2	2,196,784	48,112	81,100	2,325,996
Year 3	1,448,728	27,205	81,100	1,557,033
Year 4	1,582,125	30,050	81,100	1,693,276
Year 5	1,752,952	34,239	81,100	1,868,291
Year 6	1,472,518	27,682	81,100	1,581,301
Year 7	1,882,842	32,987	81,100	1,996,930
Year 8	1,972,819	36,772	81,100	2,090,691
Year 9	1,502,063	26,649	81,100	1,609,812
Year 10	1,470,960	26,879	81,100	1,578,940
Year 11	1,429,373	25,886	81,100	1,536,359
Year 12	1,552,452	29,288	81,100	1,662,840
Year 13	1,683,698	33,858	81,100	1,798,657
Year 14	1,784,034	34,667	81,100	1,899,802
Year 15	1,749,438	33,693	81,100	1,864,232
Year 16	2,109,419	39,546	81,100	2,230,065
Year 17	1,732,259	28,688	81,100	1,842,047
Year 18	2,107,826	39,325	81,100	2,228,252
Year 19	1,004,688	13,910	81,100	1,099,699
Year 20	406,883	-	17,672	424,555
Year 21	412,827	-	11,779	424,606
Year 22	159,958	-	11,779	171,738
Year 23	157,025	-	11,779	168,804
Year 24	157,025	-	5,890	162,914
TOTAL	**31,968,015**	**569,436**	**1,525,907**	**34,063,359**

The relative influence of the emissions sources on GHG emissions over the Project life is summarised in Figure 33. A similar breakdown of GHG by emissions scopes and emission sources is observed for individual years of operations. Over half of the GHG emissions associated with the Project are associated with diesel combustion for heavy machinery, mining equipment, haulage and other onsite vehicles as well as supplementary electricity generation. Fugitive methane and electricity have also been identified as significant sources of GHG emissions.

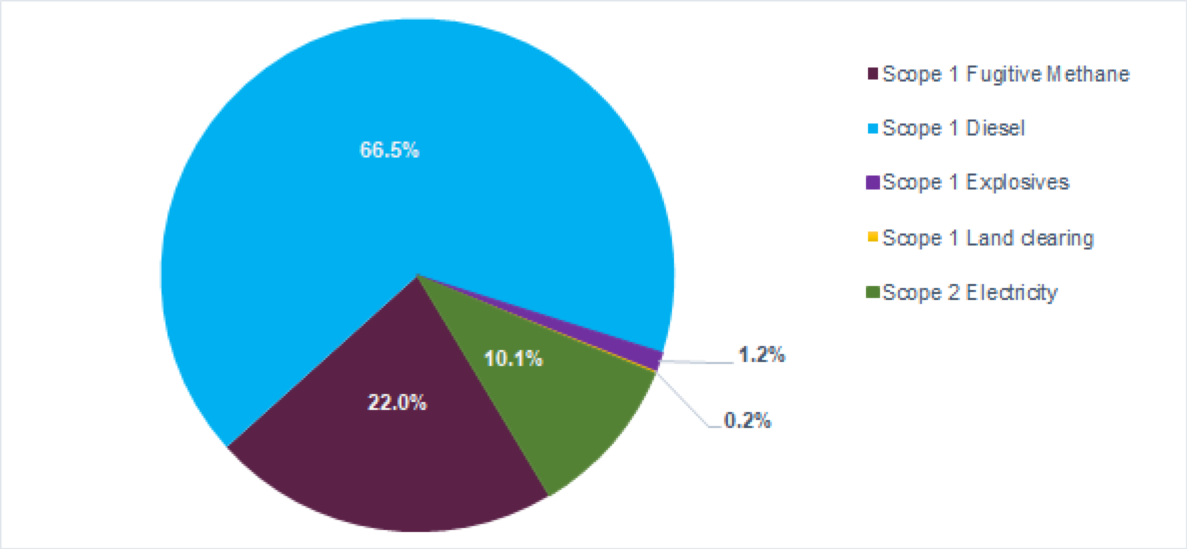

Figure 33 Summary of annual GHG emissions by emission source and emission scope

For comparative purposes the latest GHG inventory estimates for Australia and Queensland (excluding emissions from Land Use, Land Use Change and Forestry [LULUCF]) are 538 Mt CO_2-e and 162 Mt CO_2-e, respectively (Commonwealth of Australia, 2019a and Commonwealth of Australia, 2019b). With maximum annual GHG emissions of 211 kt CO2-e in Year 16, the Project could contribute up to 0.04% of national emissions and 0.13% of state emissions.

4.4.2 Scope 3 GHG emissions

Estimated annual Scope 3 emissions for the Project are summarised in Table 20.

Table 20 Summary of annual Scope 3 GHG emissions in tCO_2-e

Year	Rail transport of coal to coal terminal	End use of product coal (coking application)	Total
	tCO_2-e	**tCO_2-e**	**tCO_2-e**
Year 2	46,635	1,858,086	1,904,721
Year 3	94,292	3,756,849	3,851,141
Year 4	94,664	3,771,704	3,866,368
Year 5	94,546	3,767,002	3,861,548
Year 6	94,230	3,754,403	3,848,633
Year 7	92,845	3,699,217	3,792,062
Year 8	93,485	3,724,721	3,818,206
Year 9	92,112	3,670,017	3,762,130
Year 10	93,724	3,734,229	3,827,953
Year 11	92,517	3,686,126	3,778,643
Year 12	89,963	3,584,398	3,674,362
Year 13	96,376	3,839,894	3,936,270
Year 14	96,531	3,846,066	3,942,597
Year 15	95,850	3,818,927	3,914,777
Year 16	96,539	3,846,400	3,942,939
Year 17	93,381	3,720,559	3,813,940
Year 18	95,948	3,822,844	3,918,793
Year 19	84,439	3,364,280	3,448,719
TOTAL	**1,638,078**	**65,265,722**	**66,903,802**

4.4.3 Regulatory obligations – NGER and the safeguard mechanism

The annual GHG emissions for the Project are influenced by land clearing however GHG emissions from land clearing are not currently considered by the NGER scheme but do form part of Australia's national GHG inventory. As detailed in Table 18, the annual GHG emissions of the Project (excluding land clearing) range from:

- Scope 1: 11 – 193 kt CO_2-e/y
- Scope 2: 2 – 18 kt CO_2-e/y
- Total: 12 – 211 kt CO_2-e/y

Based on the NGER Reporting thresholds detailed in Table 14, Magnetic South Pty Ltd will have ongoing reporting obligations associated with the Project including annual assessment of GHG emissions as set out by the *NGER Act* and the *National Greenhouse and Energy Reporting (Measurement) Determination*.

In all years of mining operations (Year 2 to 19) Scope 1 emissions exceed 100 kt CO_2-e/y. Under the current Safeguard Mechanism facilities with Scope 1 emissions of more than 100 kt CO2-e/y are required to keep their emissions within baseline levels. This Safeguard Mechanism would apply to the Project, however the exact implications of this would need to be reviewed on an annual basis in communication with the regulator.

4.4.4 GHG mitigation and management

Energy use and GHG emissions associated with the Project will be optimized through the selection of mining and processing equipment:

- Energy efficiency design aspects will be investigated, where practicable as part of the detailed design process in order to reduce energy and fuel consumption.
- Fuel efficiency of the construction plant/equipment will be assessed prior to selection, and where practical, equipment with the highest fuel efficiency and which uses lower GHG intensive fuel (e.g. biodiesel) will be used.

Additional GHG mitigations measures that will be reviewed and implemented where appropriate include:

- Continuous improvement approach through ongoing monitoring and reporting GHG emissions and identifying opportunities to reduce GHG emissions
- Reduce mine equipment diesel consumption through equipment selection, load optimisation, route optimisation and production scheduling as well as reduced idle time
- Maintain equipment based on manufacturer/supplier guidelines and recommendations
- On site power factor correction optimised to minimise the usage of grid electricity
- Use of solar-powered lighting to reduce electricity demand
- Adjust peak electricity demand through production scheduling to allow for optimal and well utilised diesel power generation capacity.

5. CONCLUSIONS

Katestone Environmental Pty Ltd (Katestone) was commissioned by Magnetic South Pty Ltd on behalf of Magnetic South Pty Ltd to conduct an air quality and greenhouse gas assessment of the proposed Gemini Project (the Project).

The Project involves the development of an open cut coal mine located approximately 3 km west of the township of Dingo and 35 kilometres east of Blackwater in Central Queensland.

This air quality assessment has investigated the potential for the Project to affect air quality in the region. Three operational scenarios have been considered that represent the worst-case potential for dust emissions over the life of the Project, given the proposed mining schedule and proximity of sensitive receptors. The assessment has used site-specific meteorological data and industry standard dispersion modelling techniques to predict ground-level concentrations of particulate matter (TSP, PM_{10} and $PM_{2.5}$) and dust deposition rates due to the Project.

The air quality assessment has considered the potential impacts of the Project in isolation and with the inclusion of representative background levels of dust. Predicted ground-level concentrations of dust have been presented across a 20 x 20 kilometre domain and at identified sensitive receptors. Predictions have been compared with the relevant air quality objectives and guidelines.

The findings of the cumulative impact assessment are as follows:

- Predicted annual average concentrations of TSP ***comply*** with the relevant air quality objective at all sensitive receptors using standard mitigation measures.
- Predicted maximum 24-hour concentrations of PM_{10} ***comply*** with the relevant air quality objective at all sensitive receptors using standard mitigation measures and additional mitigation when necessary.
- Predicted annual average concentrations of PM_{10} ***comply*** with the relevant air quality objective at all sensitive receptors using standard mitigation and additional mitigation measures when necessary, except at SR22, SR31, and SR32 for Project Years 2 and 8, and SR14, SR17, SR22, SR31, and SR32 for Project Year 15. The Project contributes approximately 15% in Year 2, 12% in Year 8 and 44% in Year 5 to the Air EPP objective for annual average PM_{10} of 25 $\mu g/m^3$.
- Predicted 24-hour concentrations of $PM_{2.5}$ ***comply*** with the relevant air quality objectives at all sensitive receptors using standard mitigation measures.
- Predicted annual average concentrations of $PM_{2.5}$ ***comply*** with the relevant air quality objectives at all sensitive receptors using standard mitigation and additional mitigation measures when necessary for Year 2, Year 8 and Year 15, except at SR22 (within Project ML), SR31, and SR32 for Project Year 15. The Project contributes approximately 23% to the Air EPP objective for annual average $PM_{2.5}$ of 8 $\mu g/m^3$.
- Predicted monthly dust deposition rates ***comply*** with the relevant air quality guideline at all sensitive receptors using standard mitigation measures.

It is recommended that Magnetic South manages potential particulate matter impacts of the Project at sensitive receptors by:

- Developing and implementing an ambient air quality monitoring program
- Developing and implementing an Air Quality Management Plan
- As appropriate, consult with surrounding landholders in relation to appropriate mitigation measures or property purchases.

The greenhouse gas assessment of the Project found the following:

- Average annual GHG emissions (Scope 1 + Scope 2) associated with the Project are estimated to be 141 tCO_2-e
- Maximum annual GHG emissions (Scope 1 + Scope 2) associated with the Project are estimated to be 211 kt CO2-e (Year 16) Compared to national and state greenhouse gas inventory levels, the maximum annual GHG emissions from the Project would account for approximately 0.04% and 0.13%, respectively
- Greenhouse gas emissions from the Project are predominantly due to diesel use (66.5%), electricity generation (indirect emissions) (10.1%) and fugitive methane releases (22.0%)

It is recommended the Magnetic South monitor, manage and assess Project related greenhouse gas emissions.

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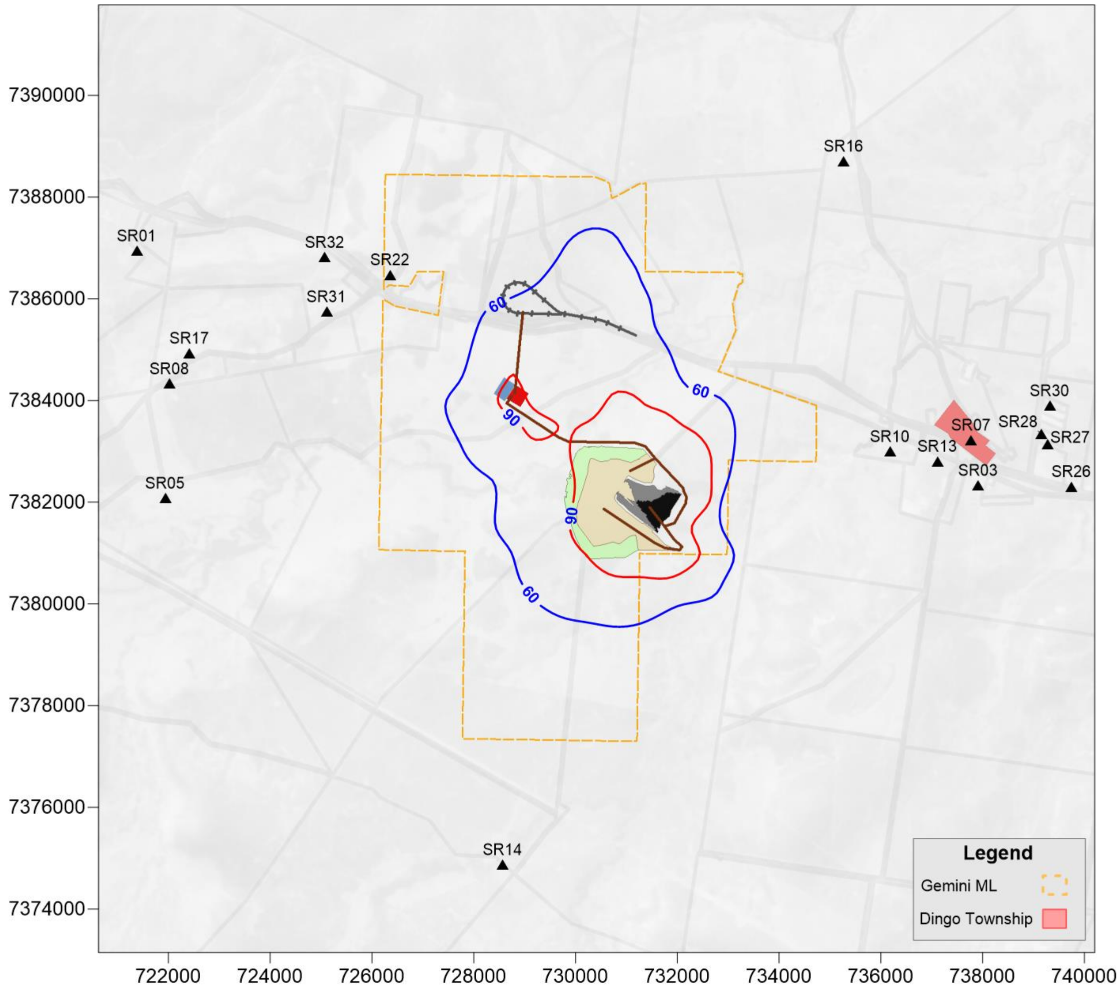

Plate 1	**Year 2 - Predicted annual average cumulative ground-level concentration of TSP using standard mitigation measures**		
Location: Gemini Project	**Averaging period:** 1 year	**Data source:** CALPUFF	**Units:** µg/m³
Type: Contour plot	**Objective:** 90 µg/m³ (red)	**Prepared by:** Daniel Gallagher	**Date:** November 2020

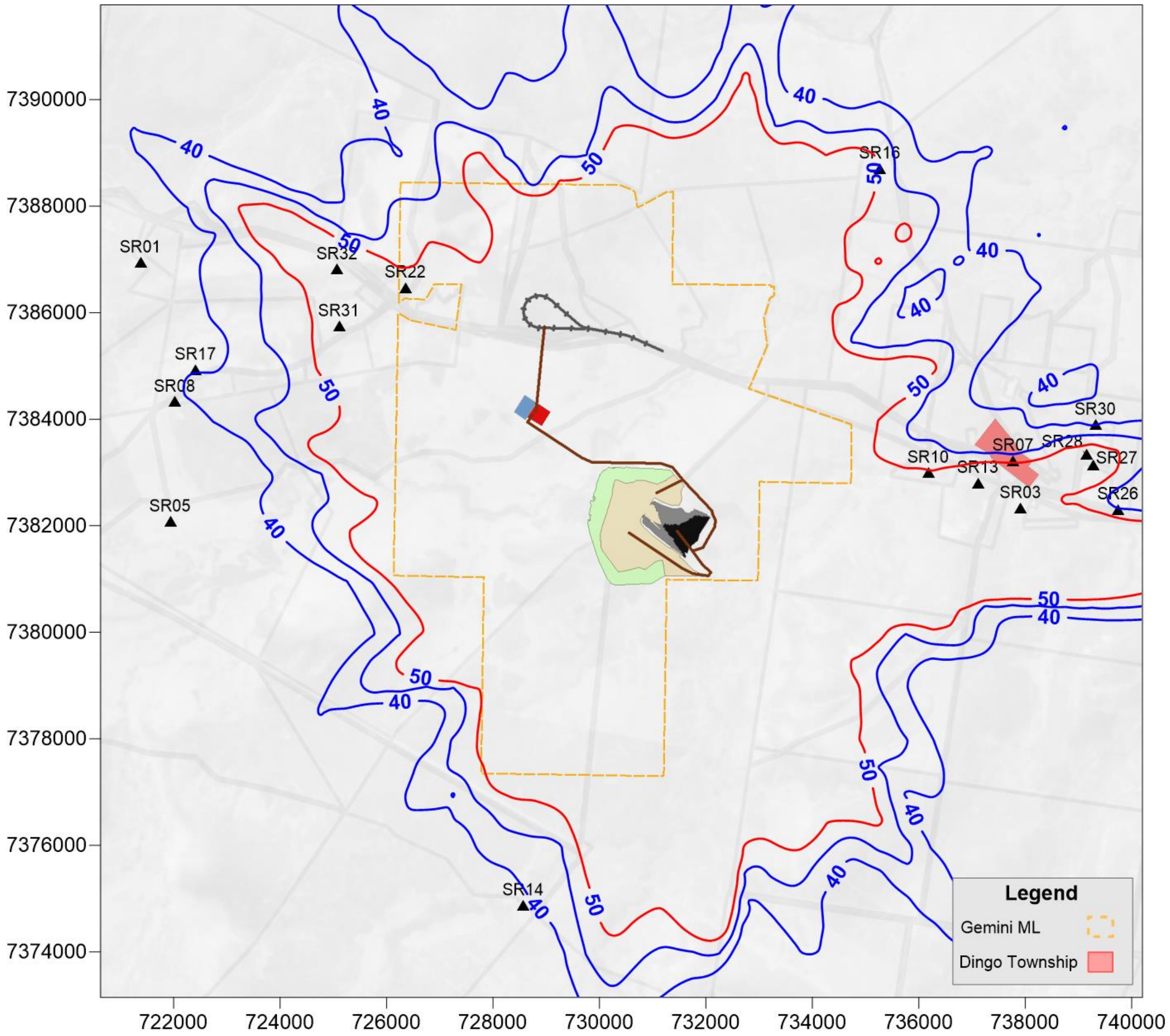

Plate 2 **Year 2 - Predicted maximum 24-hour average cumulative ground-level concentration of PM$_{10}$ using standard mitigation measures**

Location: Gemini Project	**Averaging period:** 24 hours	**Data source:** CALPUFF	**Units:** µg/m³
Type: Contour plot	**Objective:** 50 µg/m³ (red)	**Prepared by:** Daniel Gallagher	**Date:** November 2020

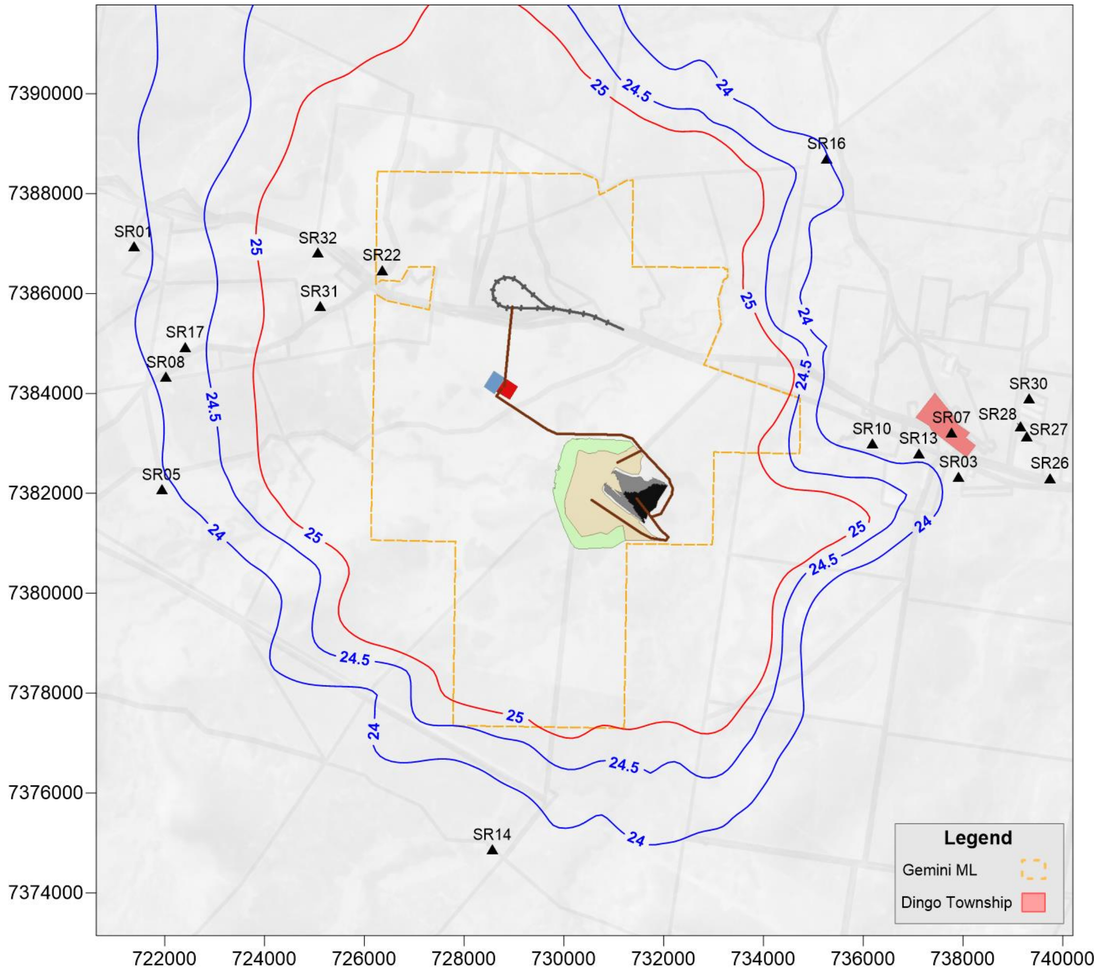

Plate 3	**Year 2 - Predicted annual average cumulative ground-level concentration of PM_{10} using standard mitigation measures**

Location: Gemini Project	**Averaging period:** 24 hours	**Data source:** CALPUFF	**Units:** µg/m³
Type: Contour plot	**Objective:** 25 µg/m³ (red)	**Prepared by:** Daniel Gallagher	**Date:** November 2020

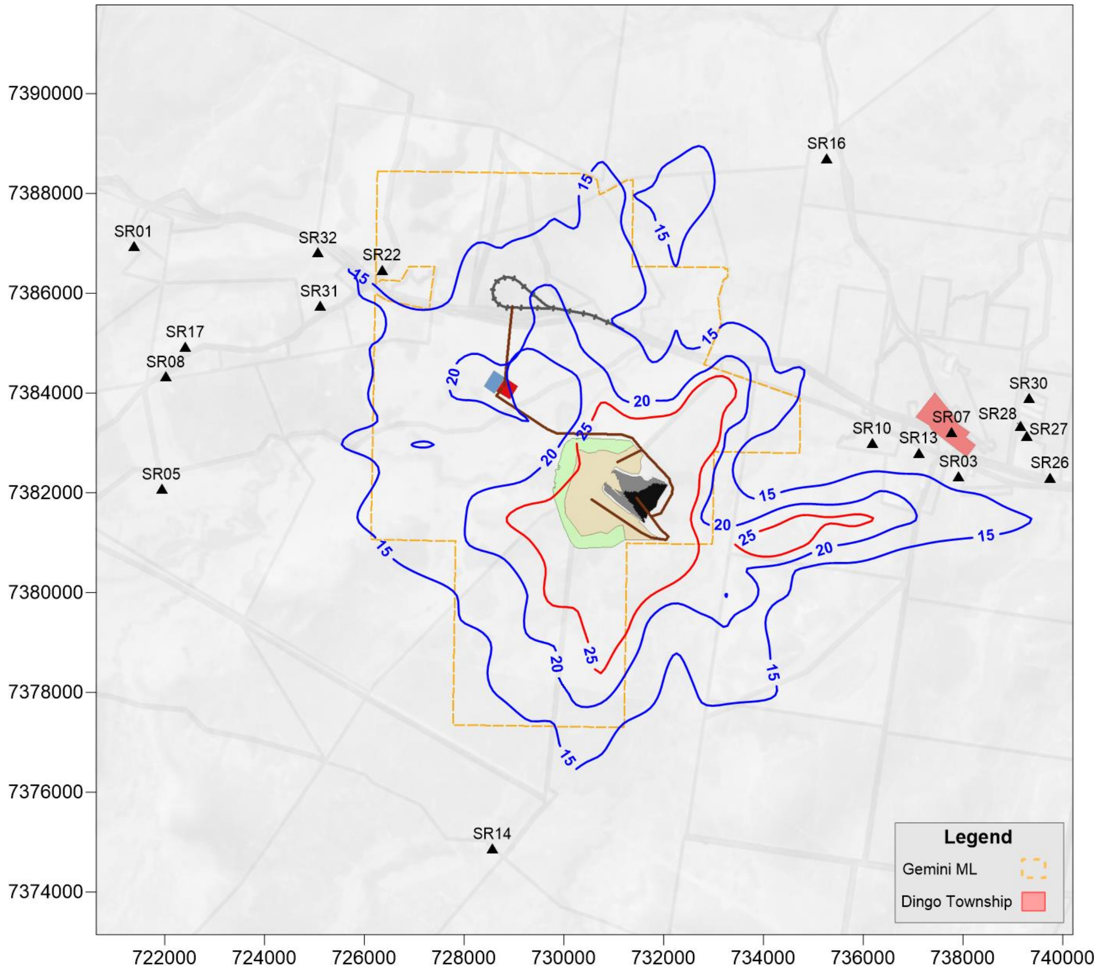

Plate 4 Year 2 - Predicted maximum 24-hour average cumulative ground-level concentration of $PM_{2.5}$ using standard mitigation measures

Location: Gemini Project	**Averaging period:** 24 hours	**Data source:** CALPUFF	**Units:** µg/m³
Type: Contour plot	**Objective:** 25 µg/m³ (red)	**Prepared by:** Daniel Gallagher	**Date:** November 2020

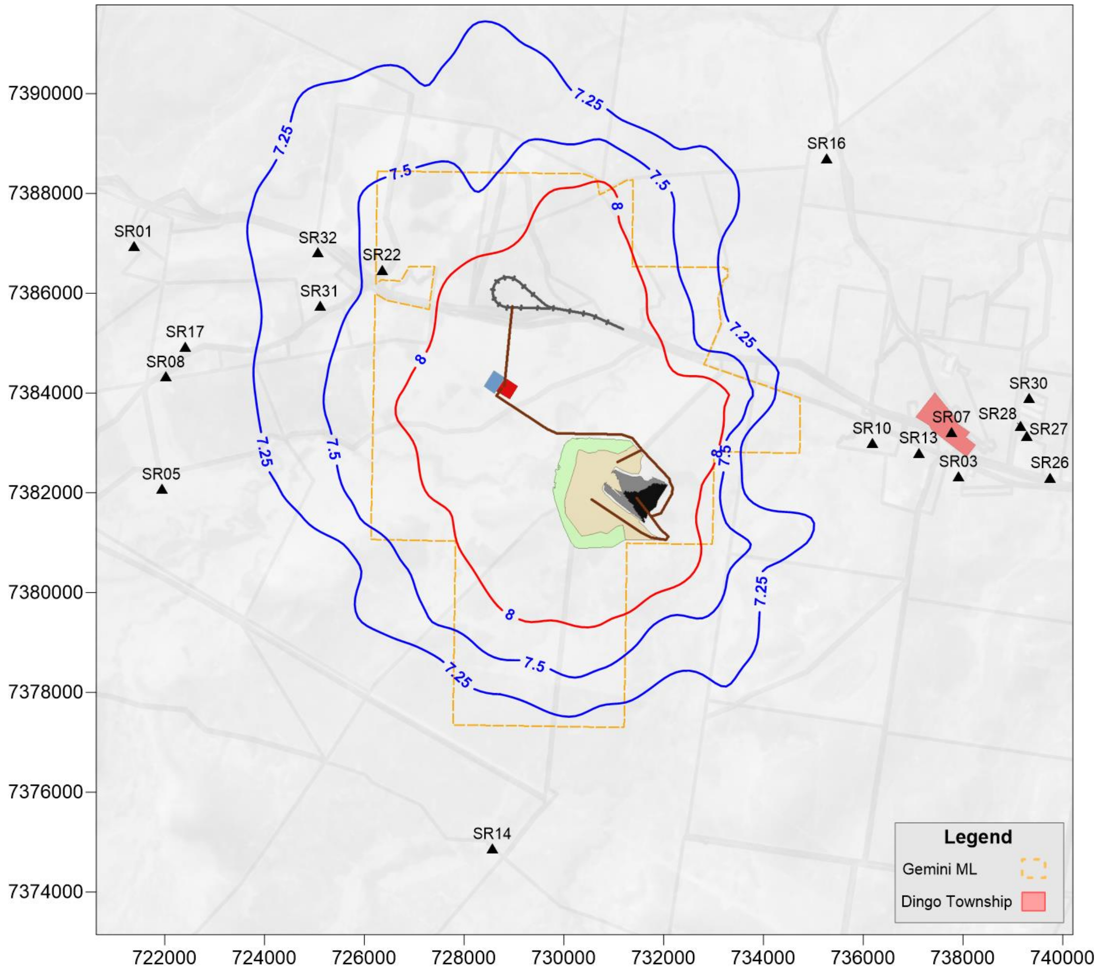

Plate 5 Year 2 - Predicted annual average cumulative ground-level concentration of $PM_{2.5}$ using standard mitigation measures

Location: Gemini Project	**Averaging period:** 1 year	**Data source:** CALPUFF	**Units:** µg/m³
Type: Contour plot	**Objective:** 8 µg/m³ (red)	**Prepared by:** Daniel Gallagher	**Date:** November 2020

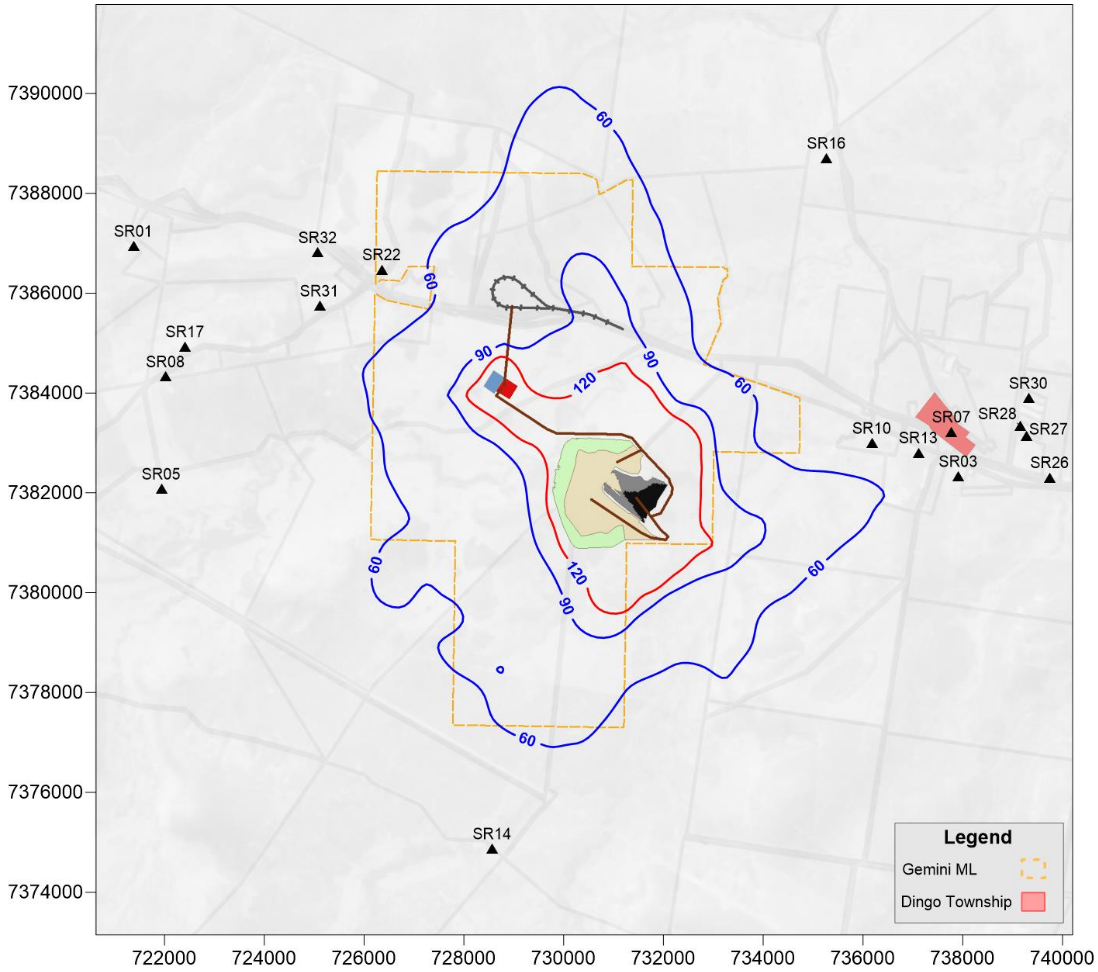

Plate 6 **Year 2 - Predicted maximum monthly cumulative dust deposition rate using standard mitigation measures**

Location: Gemini Project	**Averaging period:** 1 month	**Data source:** CALPUFF	**Units:** µg/m³
Type: Contour plot	**Guideline:** 120 mg/m²/day (red)	**Prepared by:** Daniel Gallagher	**Date:** November 2020

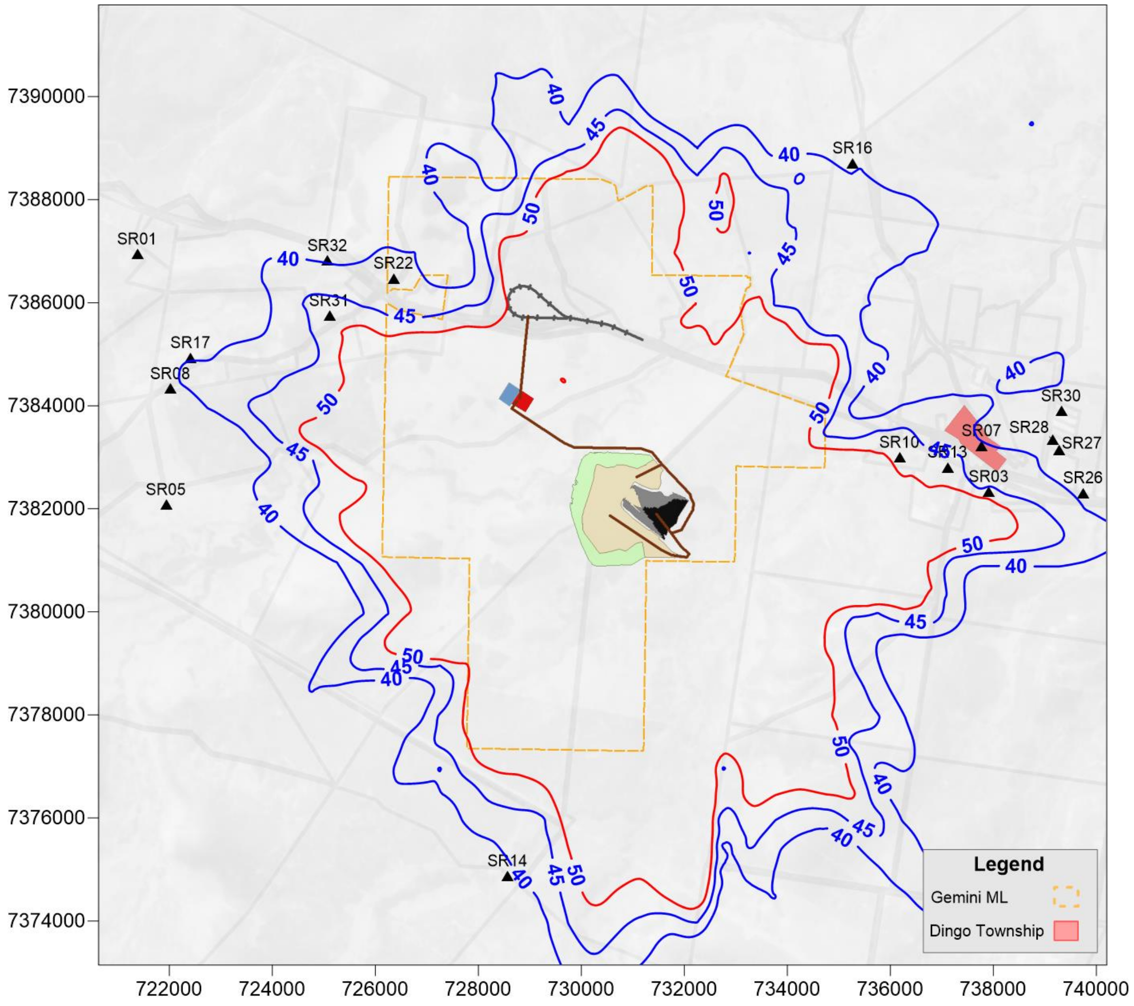

Plate 7	**Year 2 - Predicted maximum 24-hour average cumulative ground-level concentration of PM_{10} using standard mitigation measures and additional mitigation when necessary**

Location:	**Averaging period:**	**Data source:**	**Units:**
Gemini Project	24 hours	CALPUFF	µg/m³
Type:	**Objective:**	**Prepared by:**	**Date:**
Contour plot	50 µg/m³ (red)	Daniel Gallagher	November 2020

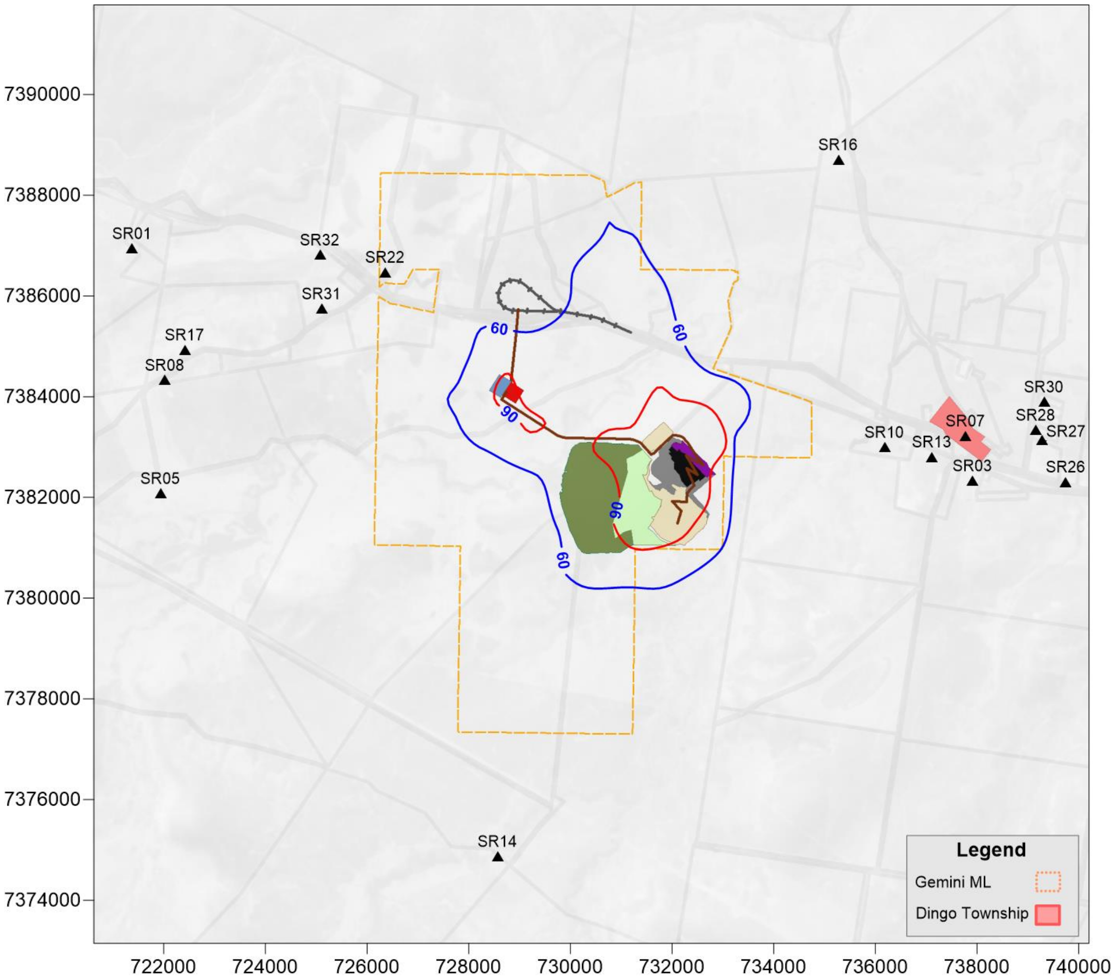

Plate 8	**Year 8 - Predicted annual average cumulative ground-level concentration of TSP using standard mitigation measures**

Location:	**Averaging period:**	**Data source:**	**Units:**
Gemini Project	1 year	CALPUFF	µg/m³
Type:	**Objective:**	**Prepared by:**	**Date:**
Contour plot	90 µg/m³ (red)	Daniel Gallagher	November 2020

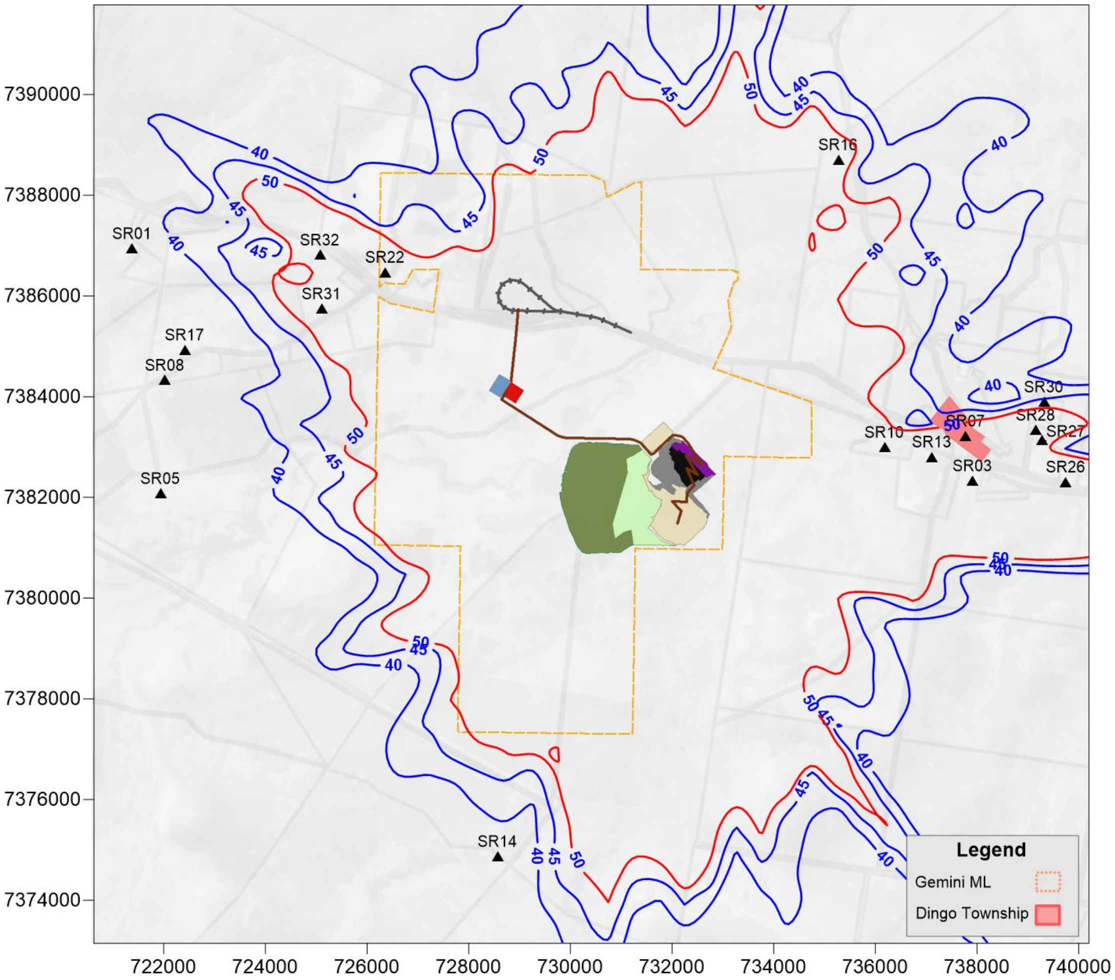

Plate 9	**Year 8 - Predicted maximum 24-hour average cumulative ground-level concentration of PM_{10} using standard mitigation measures**

Location: Gemini Project	**Averaging period:** 24 hours	**Data source:** CALPUFF	**Units:** µg/m³
Type: Contour plot	**Objective:** 50 µg/m³ (red)	**Prepared by:** Daniel Gallagher	**Date:** November 2020

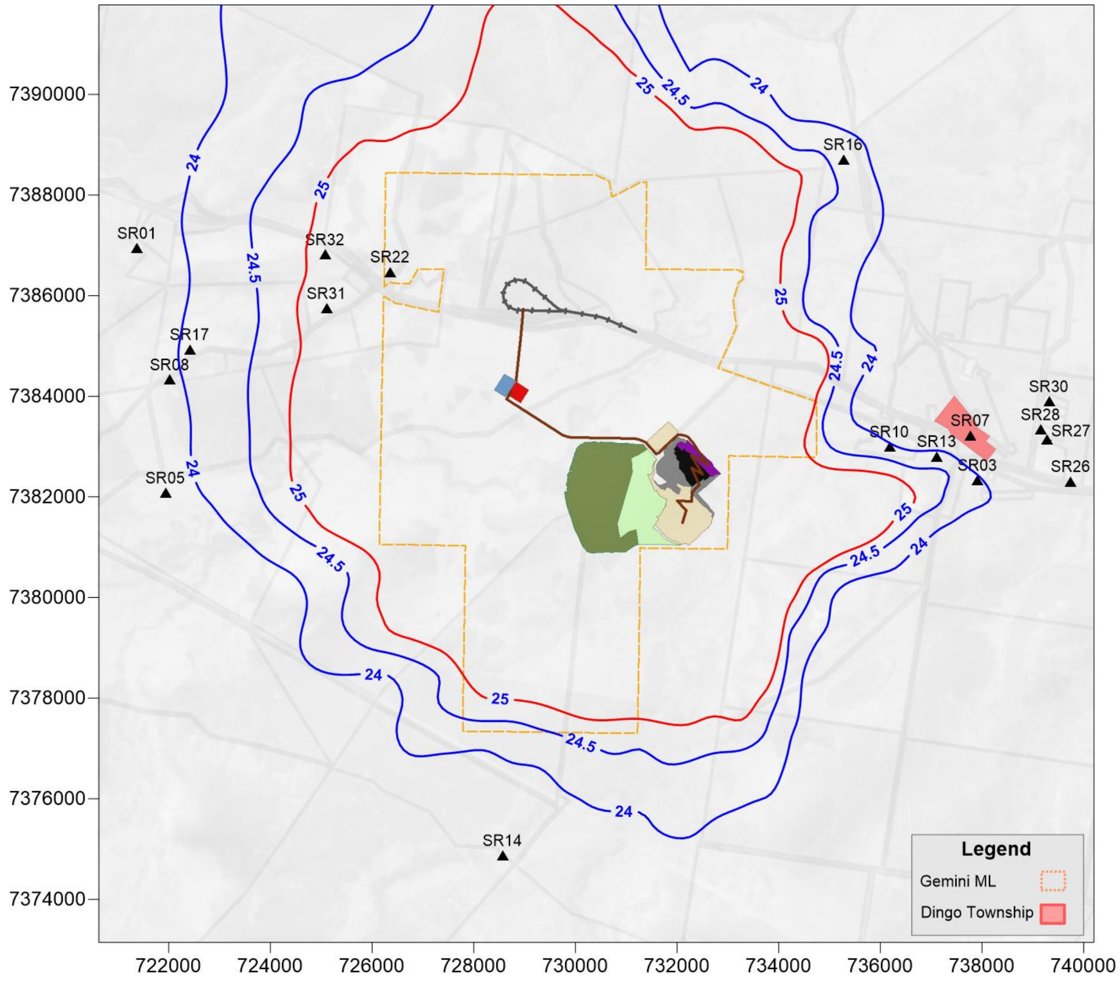

Plate 10	**Year 8 - Predicted annual average cumulative ground-level concentration of PM_{10} using standard mitigation measures**

Location:	**Averaging period:**	**Data source:**	**Units:**
Gemini Project	1 year	CALPUFF	µg/m³
Type:	**Objective:**	**Prepared by:**	**Date:**
Contour plot	25 µg/m³ (red)	Daniel Gallagher	November 2020

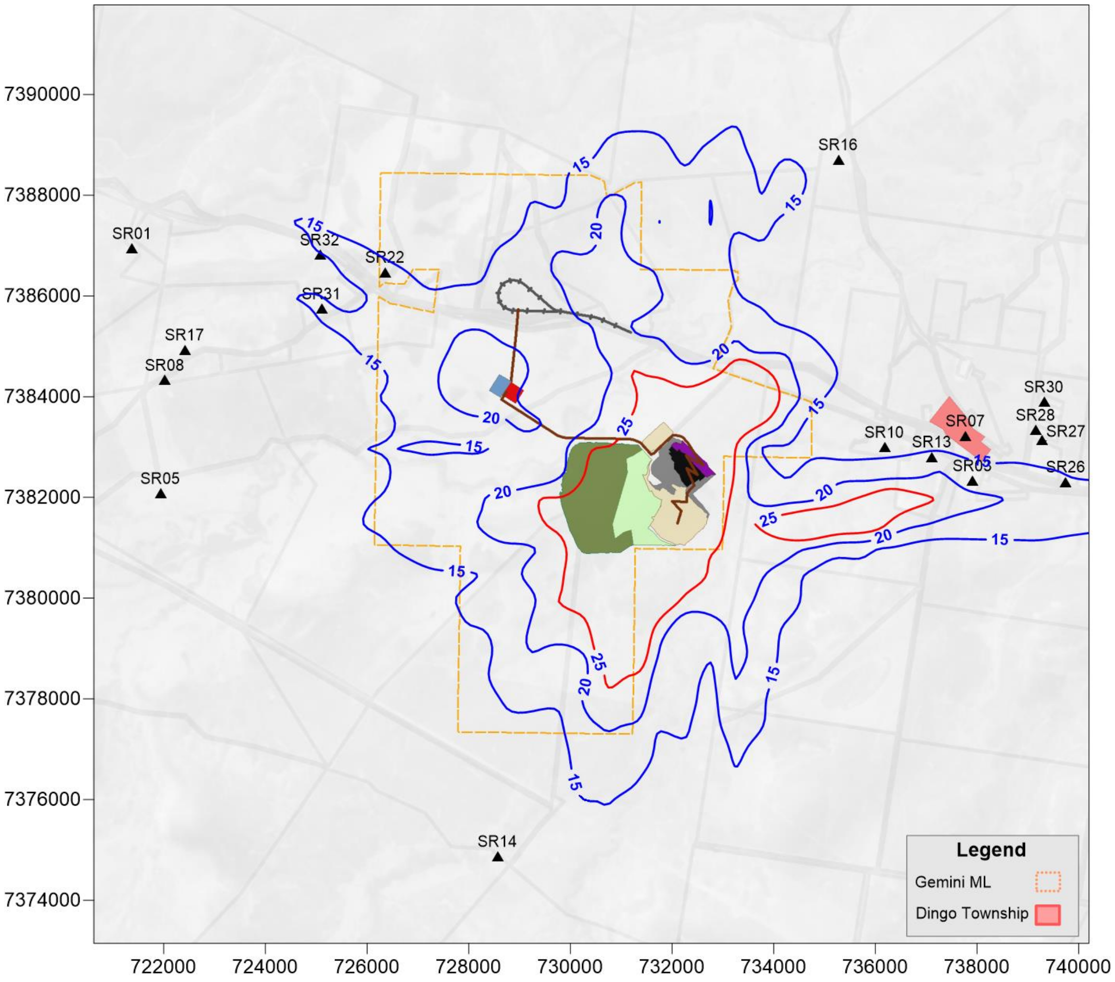

Plate 11	**Year 8 - Predicted maximum 24-hour average cumulative ground-level concentration of $PM_{2.5}$ using standard mitigation measures**

Location: Gemini Project	**Averaging period:** 24 hours	**Data source:** CALPUFF	**Units:** µg/m³
Type: Contour plot	**Objective:** 25 µg/m³ (red)	**Prepared by:** Daniel Gallagher	**Date:** November 2020

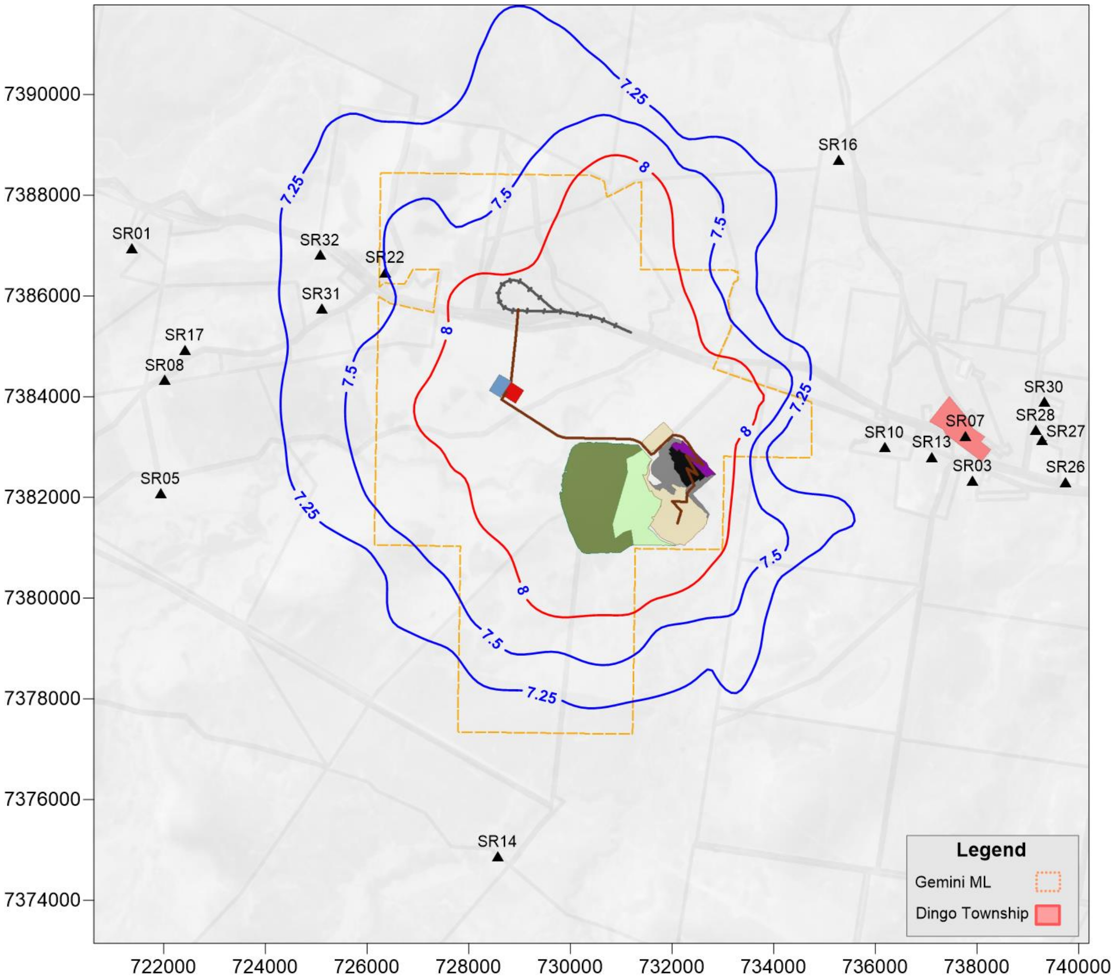

Plate 12	**Year 8 - Predicted annual average cumulative ground-level concentration of $PM_{2.5}$ using standard mitigation measures**

Location:	**Averaging period:**	**Data source:**	**Units:**
Gemini Project	1 year	CALPUFF	µg/m³
Type:	**Objective:**	**Prepared by:**	**Date:**
Contour plot	8 µg/m³ (red)	Daniel Gallagher	November 2020

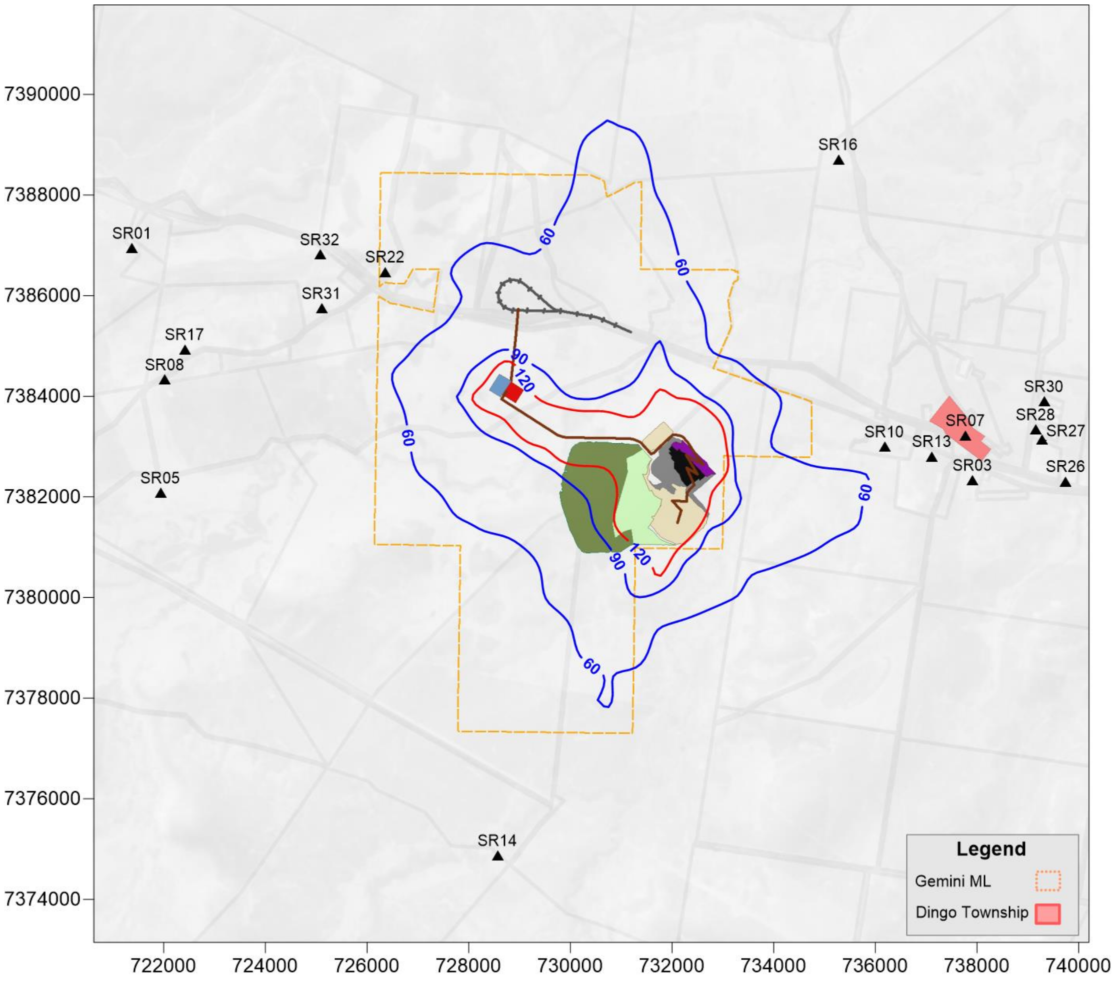

Plate 13 **Year 8 - Predicted maximum monthly cumulative dust deposition rate using standard mitigation measures**

Location: Gemini Project	**Averaging period:** 1 month	**Data source:** CALPUFF	**Units:** µg/m³
Type: Contour plot	**Guideline:** 120 mg/m²/day (red)	**Prepared by:** Daniel Gallagher	**Date:** November 2020

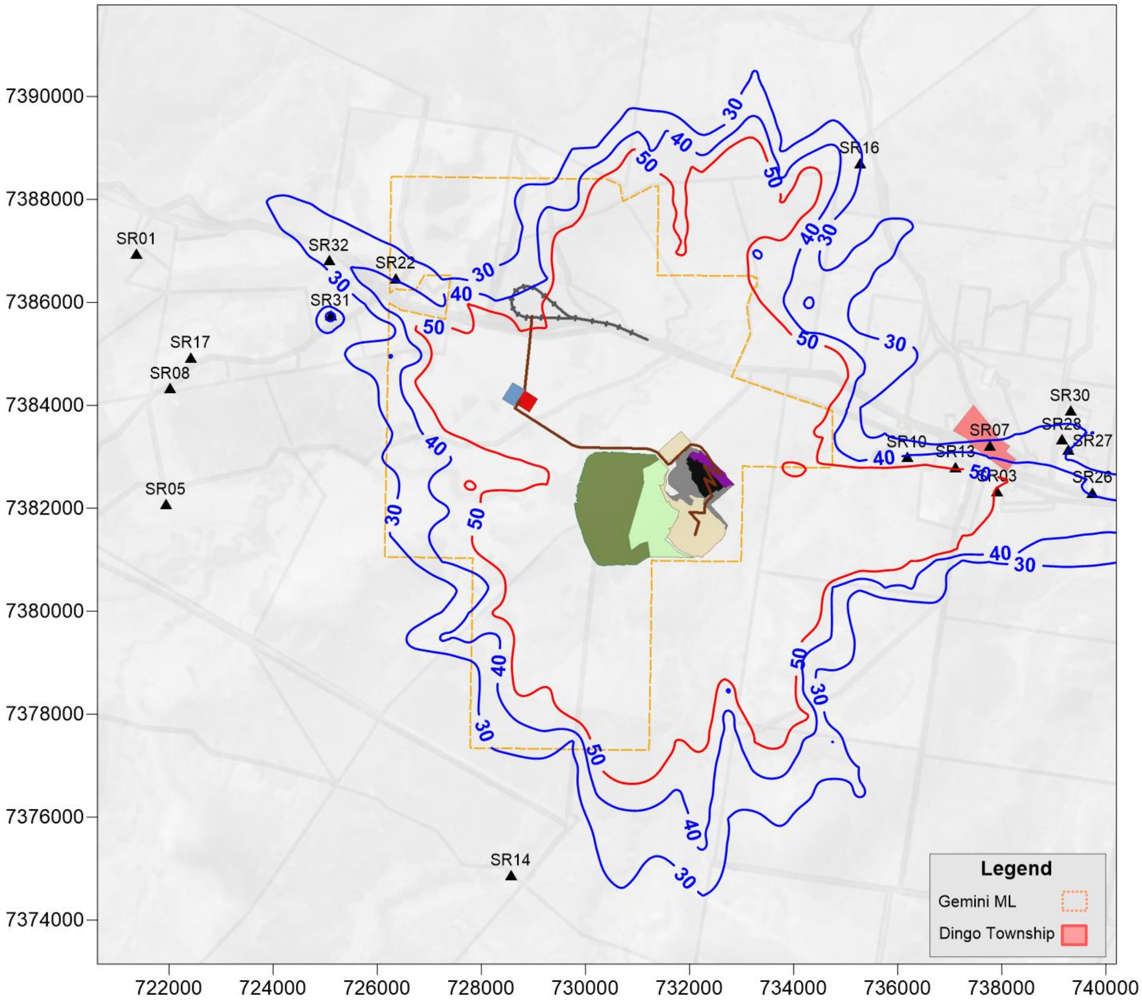

Plate 14	**Year 8 - Predicted maximum 24-hour average cumulative ground-level concentration of PM_{10} using standard mitigation measures and additional mitigation when necessary**

Location: Gemini Project	**Averaging period:** 24 hours	**Data source:** CALPUFF	**Units:** µg/m³
Type: Contour plot	**Objective:** 50 µg/m³ (red)	**Prepared by:** Daniel Gallagher	**Date:** November 2020

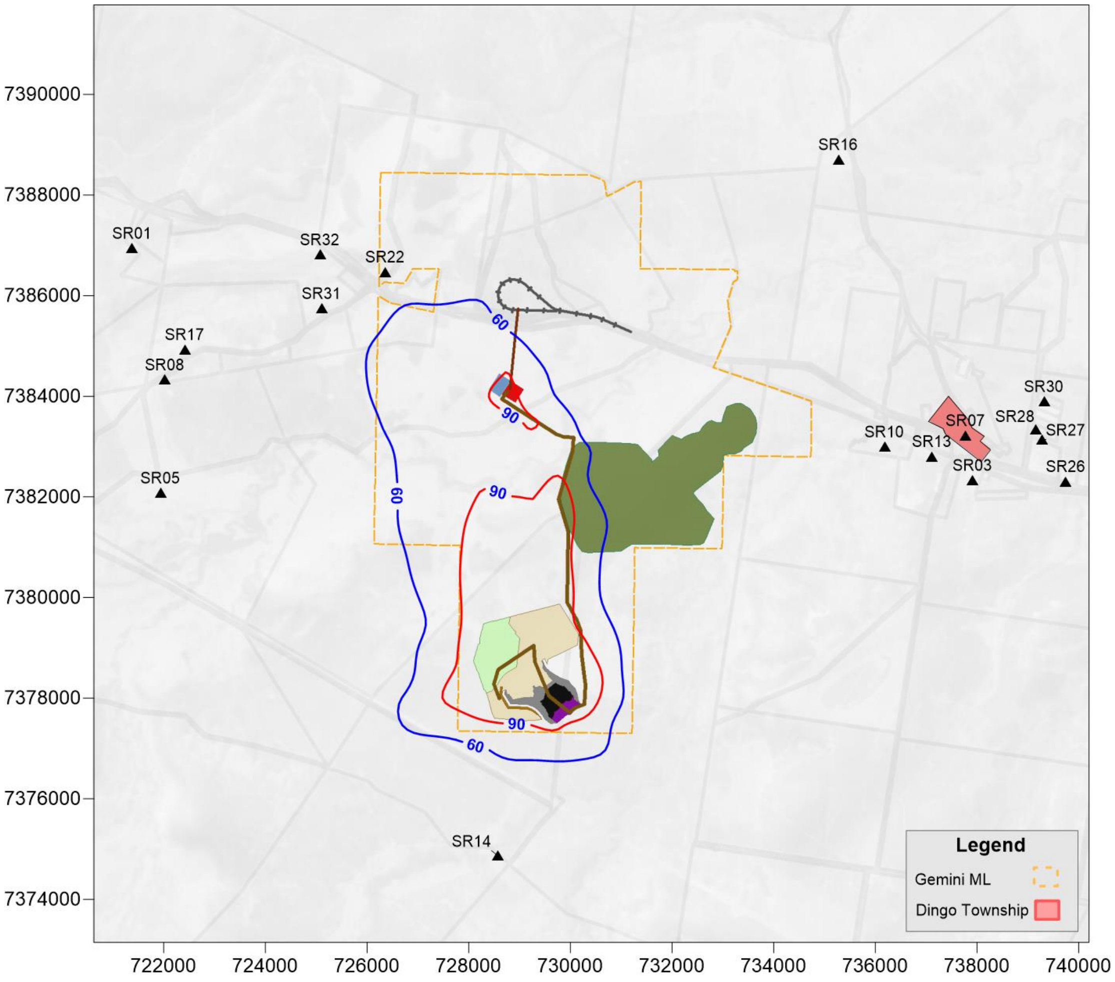

Plate 15 **Year 15 - Predicted annual average cumulative ground-level concentration of TSP using standard mitigation measures**

Location: Gemini Project	**Averaging period:** 1 year	**Data source:** CALPUFF	**Units:** µg/m³
Type: Contour plot	**Objective:** 90 µg/m³ (red)	**Prepared by:** Daniel Gallagher	**Date:** November 2020

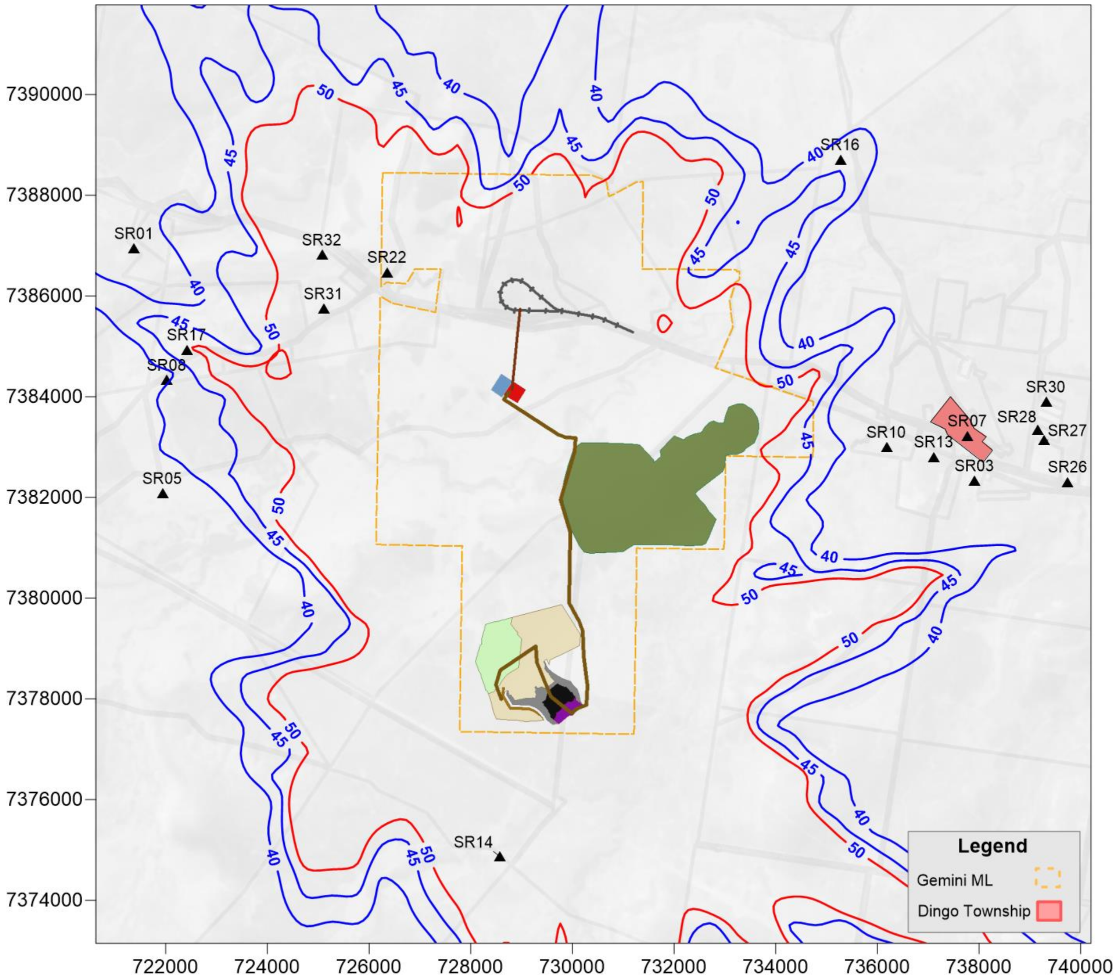

Plate 16 Year 15 - Predicted maximum 24-hour average cumulative ground-level concentration of PM$_{10}$ using standard mitigation measures

Location: Gemini Project	**Averaging period:** 24 hours	**Data source:** CALPUFF	**Units:** µg/m³
Type: Contour plot	**Objective:** 50 µg/m³ (red)	**Prepared by:** Daniel Gallagher	**Date:** November 2020

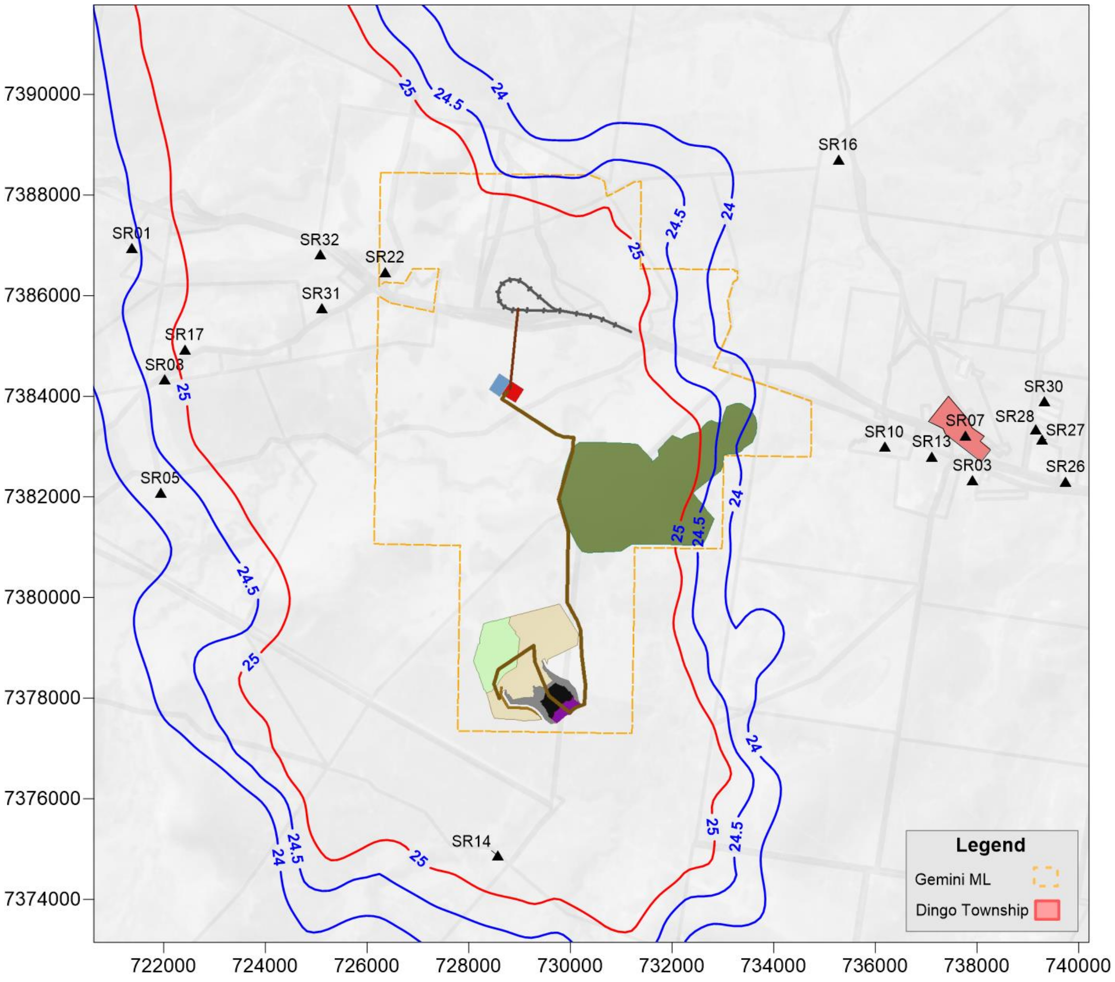

Plate 17	Year 15 - Predicted annual average cumulative ground-level concentration of PM_{10} using standard mitigation measures

Location: Gemini Project	**Averaging period:** 1 year	**Data source:** CALPUFF	**Units:** µg/m³
Type: Contour plot	**Objective:** 25 µg/m³ (red)	**Prepared by:** Daniel Gallagher	**Date:** November 2020

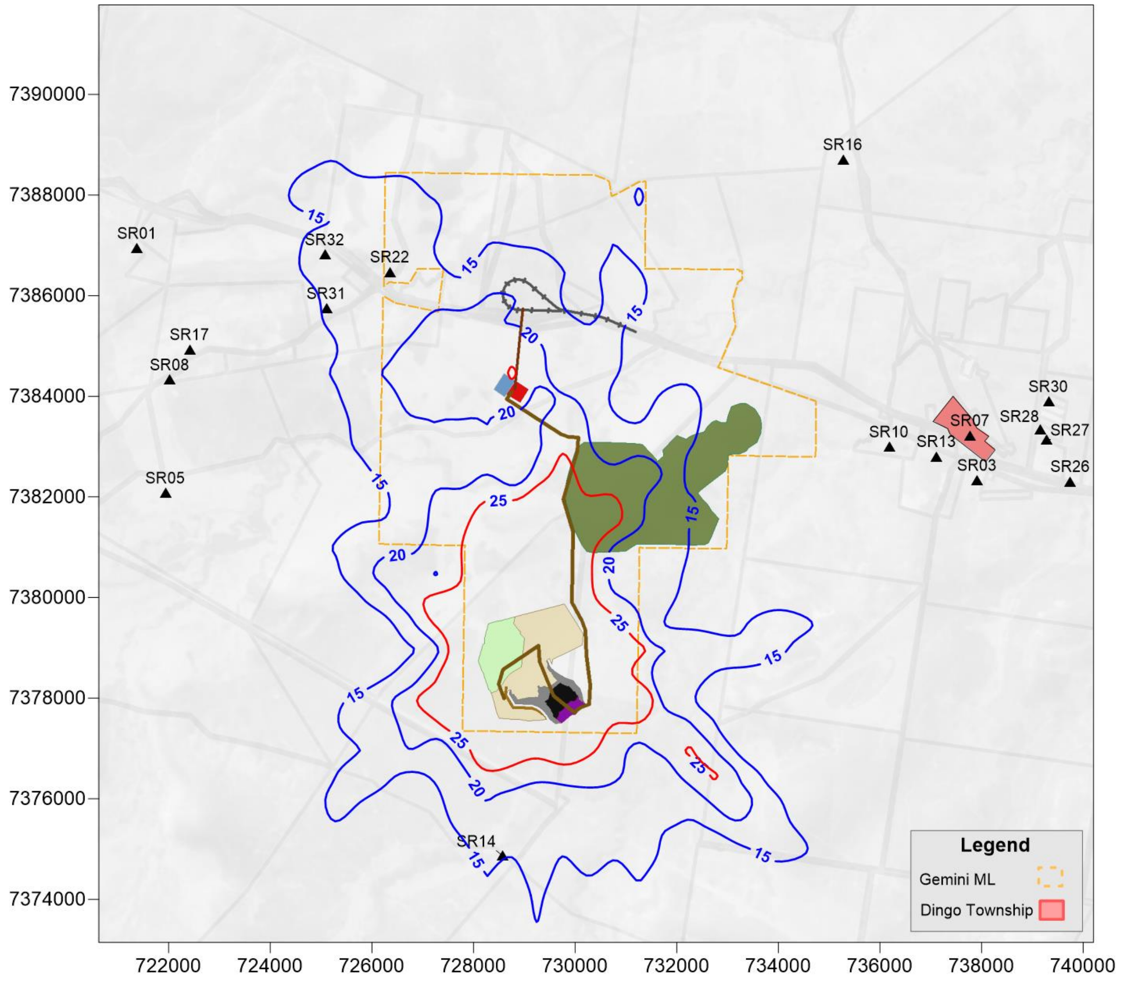

Plate 18	**Year 15 - Predicted maximum 24-hour average cumulative ground-level concentration of $PM_{2.5}$ using standard mitigation measures**

Location: Gemini Project	**Averaging period:** 24 hours	**Data source:** CALPUFF	**Units:** µg/m³
Type: Contour plot	**Objective:** 25 µg/m³ (red)	**Prepared by:** Daniel Gallagher	**Date:** November 2020

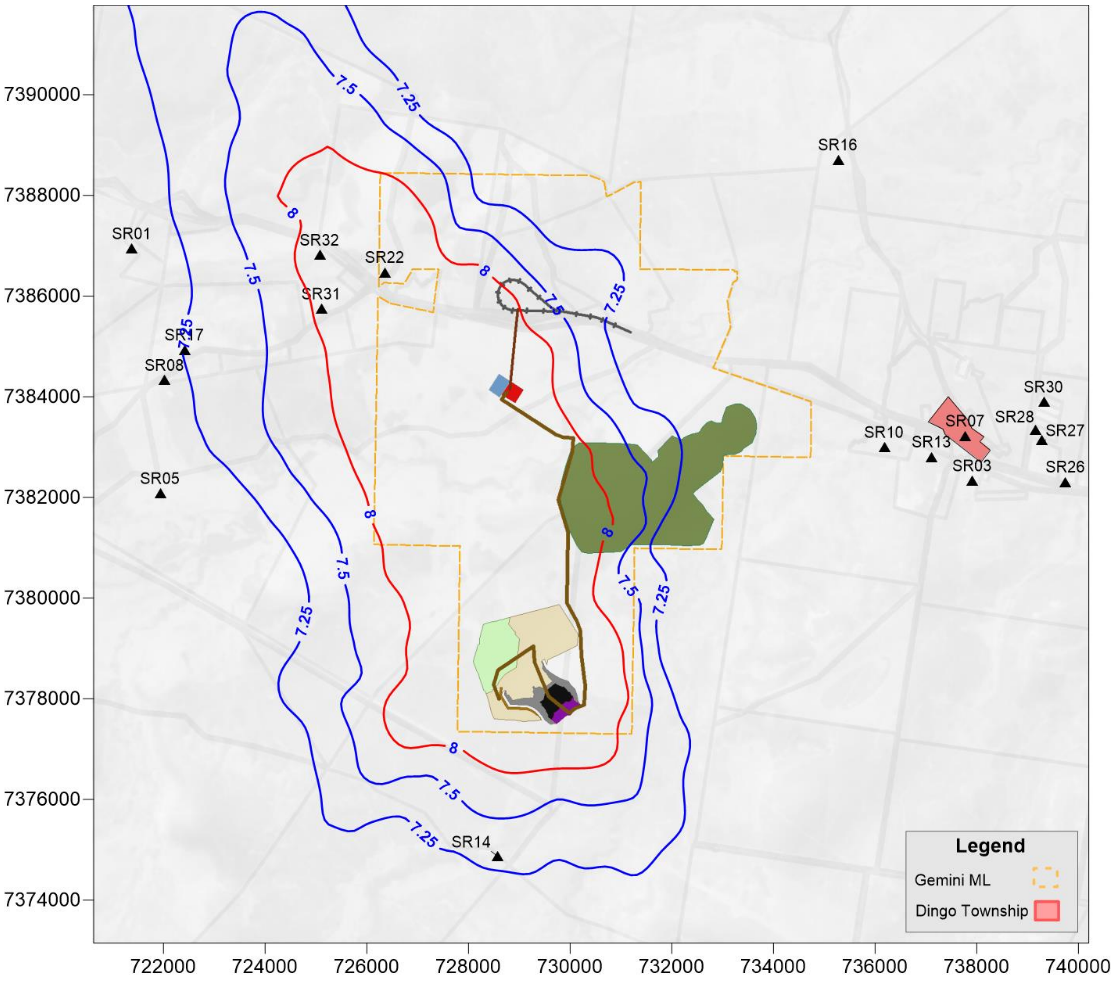

Plate 19	**Year 15 - Predicted annual average cumulative ground-level concentration of $PM_{2.5}$ using standard mitigation measures**

Location: Gemini Project	**Averaging period:** 1 year	**Data source:** CALPUFF	**Units:** µg/m³
Type: Contour plot	**Objective:** 8 µg/m³ (red)	**Prepared by:** Daniel Gallagher	**Date:** November 2020

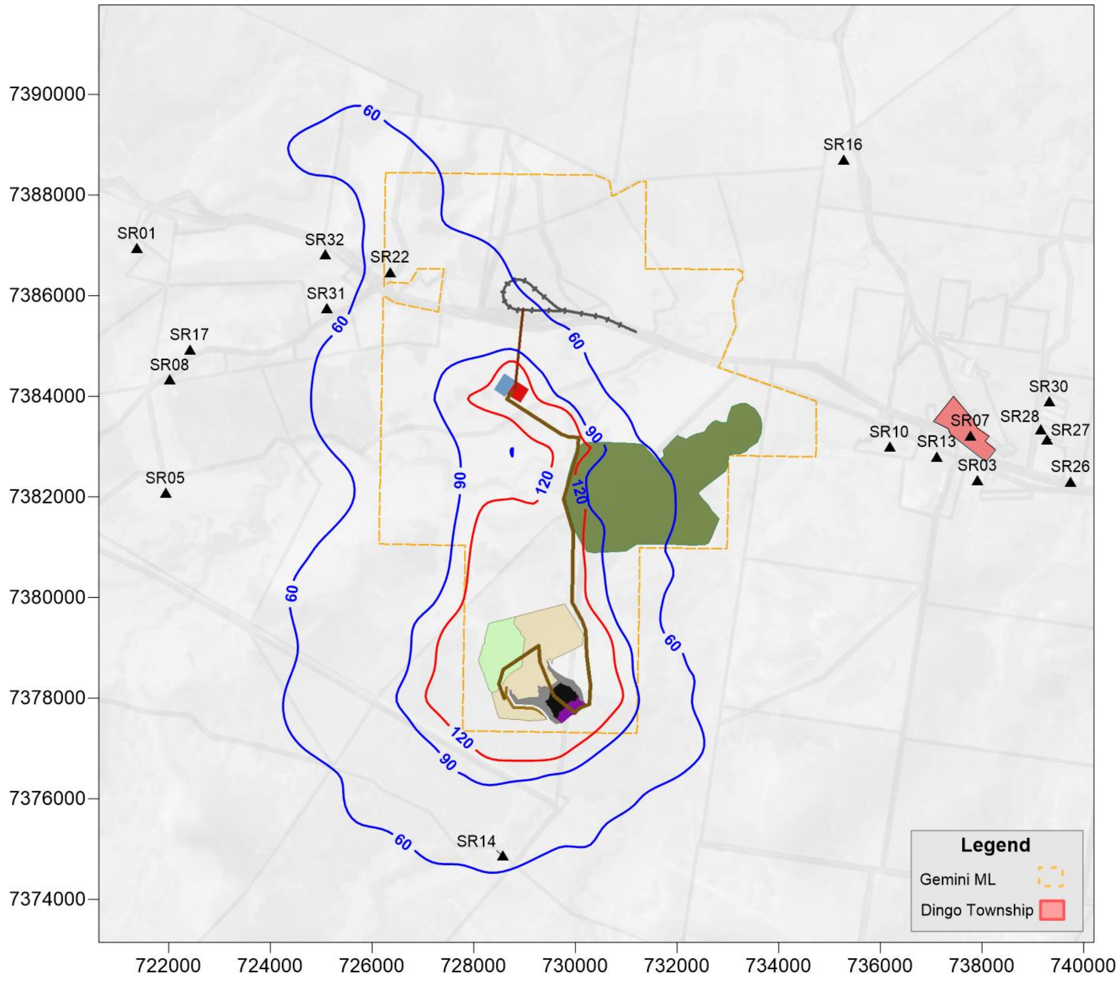

Plate 20 **Year 15 - Predicted maximum monthly cumulative dust deposition rate using standard mitigation measures**

Location: Gemini Project	**Averaging period:** 1 month	**Data source:** CALPUFF	**Units:** µg/m³
Type: Contour plot	**Guideline:** 120 mg/m²/day (red)	**Prepared by:** Daniel Gallagher	**Date:** November 2020

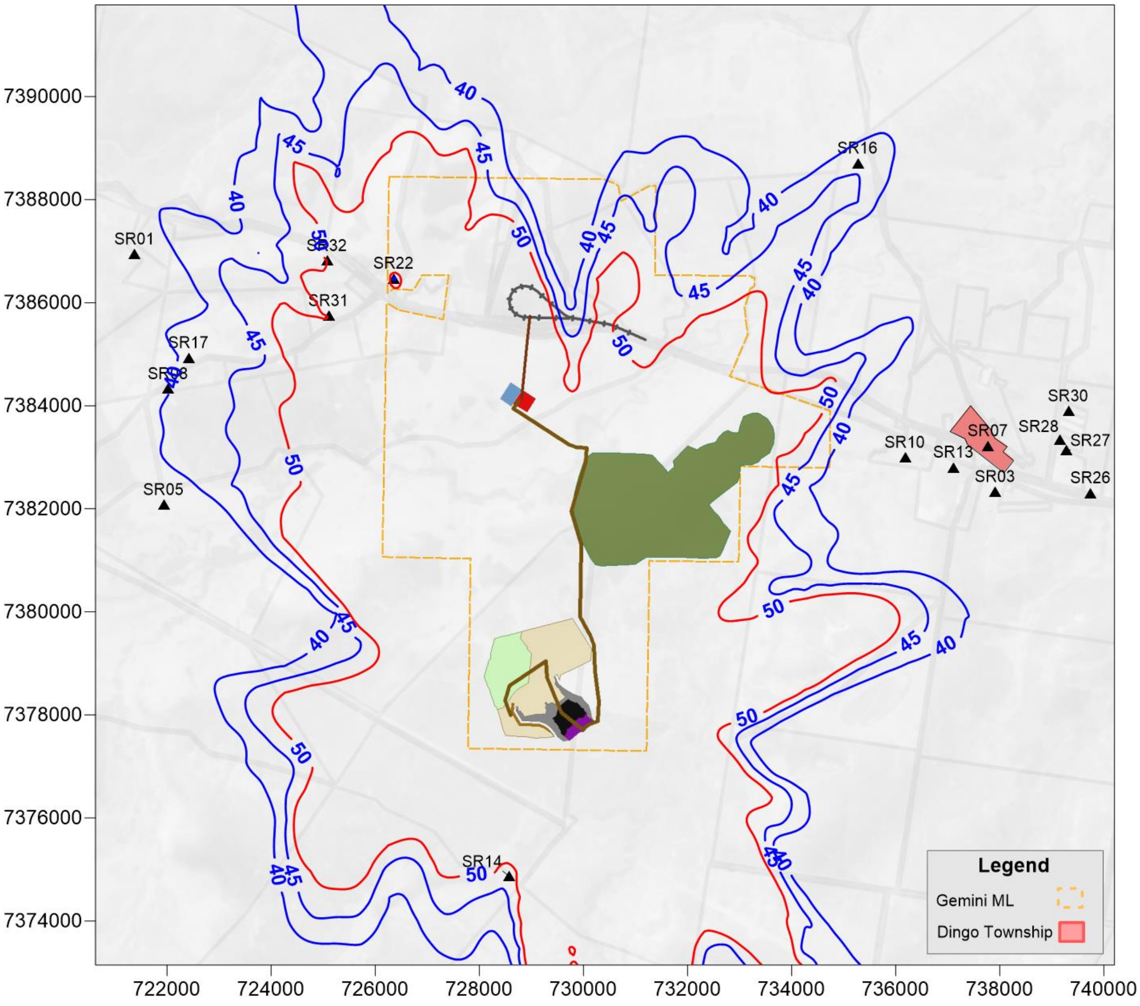

Plate 21	**Year 15 - Predicted maximum 24-hour average cumulative ground-level concentration of PM_{10} using standard mitigation measures and additional mitigation when necessary**

Location: Gemini Project	**Averaging period:** 24 hours	**Data source:** CALPUFF	**Units:** µg/m³
Type: Contour plot	**Objective:** 50 µg/m³ (red)	**Prepared by:** Daniel Gallagher	**Date:** November 2020

APPENDIX A MODELLING METHODOLOGY

A1 METEOROLOGY

A1.1 TAPM meteorological modelling

TAPM (The Air Pollution Model) was developed by the CSIRO and has been validated by the CSIRO, Katestone and others for many locations in Australia, in south-east Asia and in North America (CSIRO, 2008). Katestone has extensive experience with TAPM for sites throughout Australia and in parts of America, Bangladesh, New Caledonia and Vietnam. The model performs well in simulating regional wind patterns and has proven to be a useful tool for simulating meteorology in locations where monitoring data is unavailable.

TAPM is a prognostic meteorological model which predicts the flows important to regional and local scale meteorology, such as sea breezes and terrain-induced flows from the larger-scale meteorology provided by the synoptic analyses. TAPM solves the fundamental fluid dynamics equations to predict meteorology at a mesoscale (20 km to 200 km) and at a local scale (down to a few hundred metres). TAPM includes parameterisations for cloud/rain micro-physical processes, urban/vegetation canopy and soil, and radiative fluxes.

TAPM requires synoptic meteorological information for the region. This information is generated by a global model similar to the large-scale models used to forecast the weather. The data were supplied on a grid resolution of approximately 75km, and at elevations of 100m to 5km above the ground. TAPM uses this synoptic information, along with specific details of the location such as surrounding terrain, land-use, soil moisture content and soil type to simulate the meteorology of a region as well as at a specific location.

TAPM version 4.0.4 was configured with the following parameters:

- Modelling period from 1 January to 31 December 2016
- 50 x 50 grid point domain with nesting resolutions of 10 km, 3 km, and 10 km
- 25 vertical levels
- Grid centred on latitude -23° 39’, longitude 149° 15’
- Geoscience Australia 9 second DEM terrain data
- TAPM default land cover data and sea surface temperature
- Default options selected for advanced meteorological inputs.

A1.2 CALMET meteorological modelling

CALMET is an advanced non-steady-state diagnostic 3D meteorological model with micro-meteorological modules for overwater and overland boundary layers. It is the meteorological pre-processor for the CALPUFF modelling system. CALMET can read hourly meteorological data as data assimilation from multiple sites within the modelling domain; it can also be initialised with the gridded three-dimensional prognostic output from other meteorological models such as TAPM. This can improve dispersion model output, particularly over complex terrain as the near surface meteorological conditions are calculated for each grid point.

CALMET was used to simulate meteorological conditions in the region. The CALMET simulation was initialised with the gridded TAPM 3D wind field data from the 1 km grid. CALMET treats the prognostic model output as the initial guess field for the CALMET diagnostic model wind fields. The initial guess field is then adjusted for the kinematic effects of terrain, slope flows, blocking effects and 3D divergence minimisation.

CALMET version 6.5.0 was configured with default options and parameters, with the following exceptions:

- Modelling period from 1 January to 31 December 2016
- 94 x 94 grid point domain with 0.5 km resolution, nested within the TAPM inner domain
- 12 vertical levels at heights of 20, 60, 100, 150, 200, 250, 350, 500, 800, 1600, 2600 and 4600 metres
- Prognostic wind fields generated by TAPM input as MM5/3D.DAT at surface and upper air for “initial guess” field (no-observations mode)
- Gridded cloud cover from prognostic relative humidity at all levels
- No extrapolation of surface wind observations to upper layers
- Terrain radius of influence of 7 km
- Terrain radius of influence for temperature interpolation of 500 km.

A1.3 Analysis of dispersion meteorology

The following sections provide a description of the meteorological parameters that are important for dispersion of air pollutants in the atmosphere, namely wind speed and direction, atmospheric stability and mixing layer height. These parameters have been extracted from the TAPM/CALMET dataset at the Project site.

A1.3.1 Wind speed and wind direction

The annual, seasonal and diurnal distributions of winds predicted by TAPM/CALMET for 2016 are presented in Figure A1, Figure A2, and Figure A3 respectively. The winds are generally light to moderate and occur almost exclusively from the eastern quadrants with an average wind speed of 2.02 m/s (Figure A1). The distribution of winds is predominantly from the south-east (Figure A4). Winds are weaker during even hours (6 pm to 6 am), and stronger during daylight hours (6 am to 6 pm) (Figure A3).

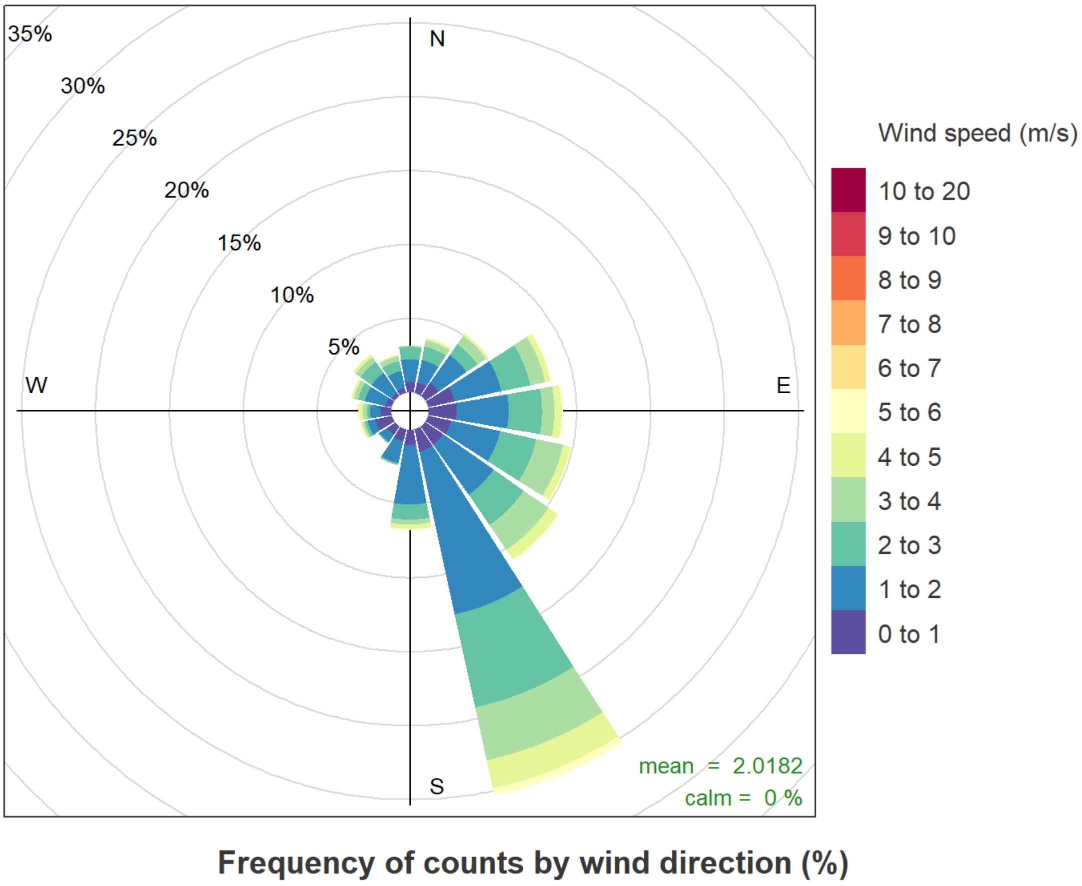

Figure A1 Annual distribution of winds at the Project site predicted by TAPM/CALMET

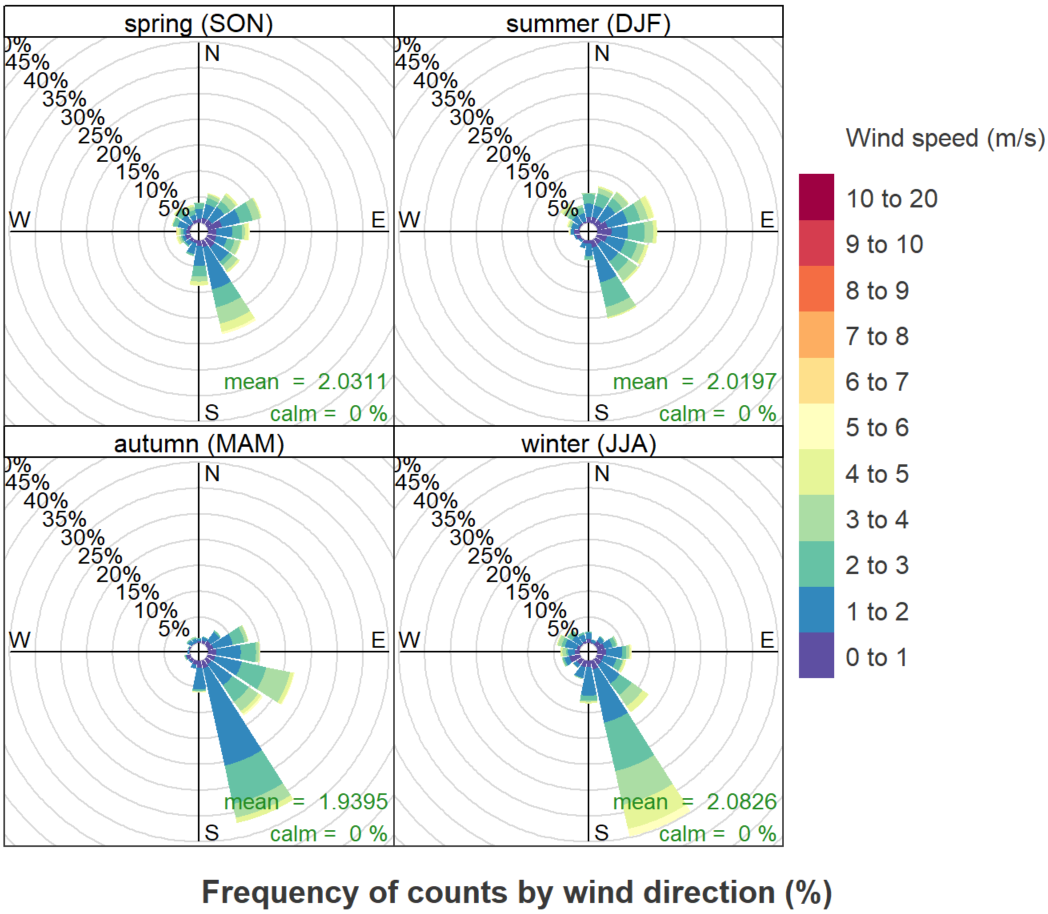

Figure A2 Seasonal distribution of winds at the Project site predicted by TAPM/CALMET

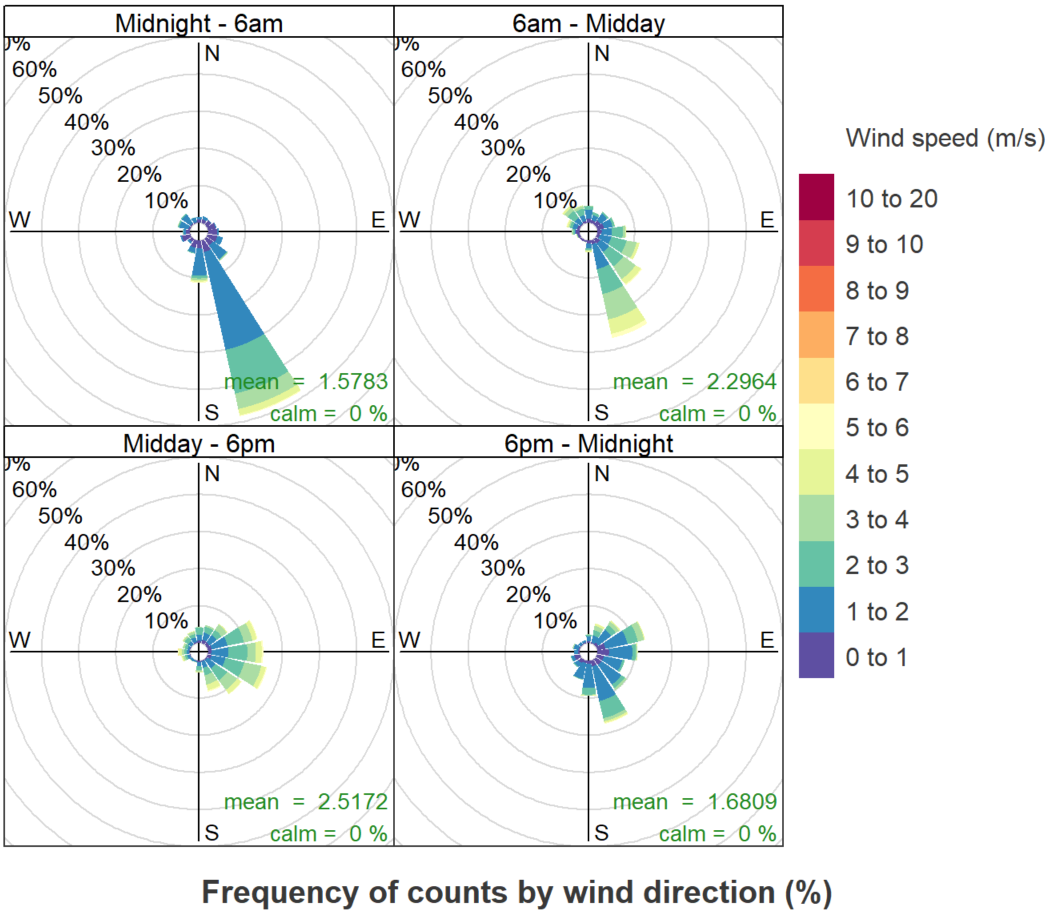

Figure A3 Diurnal distribution of winds at the Project site predicted by TAPM/CALMET

A1.3.2 Atmospheric stability

Stability classification is a measure of the stability of the atmosphere and can be determined from wind measurements and other atmospheric observations. The stability classes range from A Class, which represents very unstable atmospheric conditions that may typically occur on a sunny day, to F Class stability which represents very stable atmospheric conditions that typically occur during light wind conditions at night. Unstable conditions (Classes A to C) are characterised by strong solar heating of the ground that induces turbulent mixing in the atmosphere close to the ground. This turbulent mixing is the main driver of dispersion during unstable conditions. Dispersion processes for Class D conditions are dominated by mechanical turbulence generated as the wind passes over irregularities in the local surface. During the night, the atmospheric conditions are generally stable (often Classes E and F).

Figure A4 shows the distribution of stability classes at the Project site extracted from the TAPM/CALMET dataset, where Class A represents the most unstable conditions and Class F represents the most stable. Neutral (D class) conditions are present throughout the day. Very stable (F class) conditions are the next most frequent and only occur between 5 pm and 6 am.

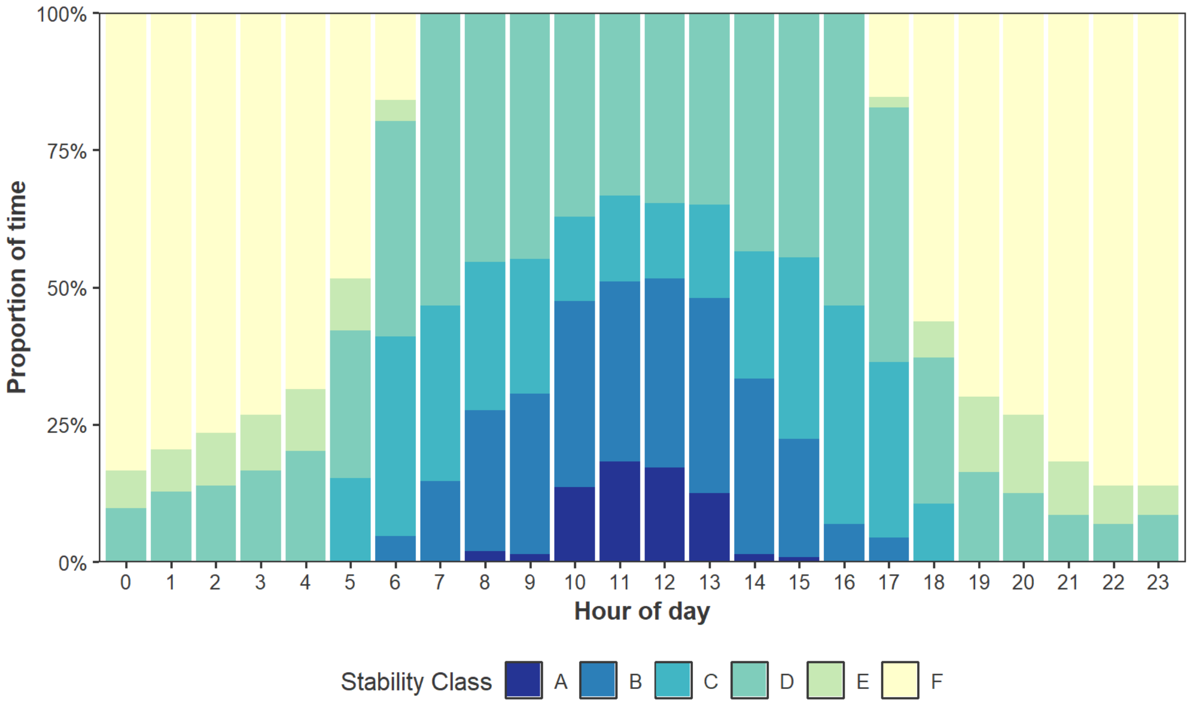

Figure A4 **Diurnal stability class at the Project site predicted by TAPM/CALMET**

A1.3.3 Mixing height

The mixing height defines the height of the mixed atmosphere above the ground (mixed layer), which varies diurnally. Particulate matter, or other pollutants released at or near the ground, will become dispersed within the mixed layer. During stable atmospheric conditions, the mixing height is often quite low and particulate dispersion is limited to within this layer. During the day, solar radiation heats the ground and causes the air above it to warm, resulting in convection and an increase to the mixing height. The growth of the mixing height is dependent on how well the warmer air from the ground can mix with the cooler upper level air and, therefore, depends on meteorological factors such as the intensity of solar radiation and wind speed. Strong winds cause the air to be well mixed, resulting in a high mixing height.

Mixing height information extracted from the TAPM/CALMET dataset at the Project site is presented in Figure A5 as a diurnal frequency (box and whisker) plot. The data shows that, on average, the mixing height develops around 6 am and peaks at 3-4 pm before descending rapidly until 6 pm.

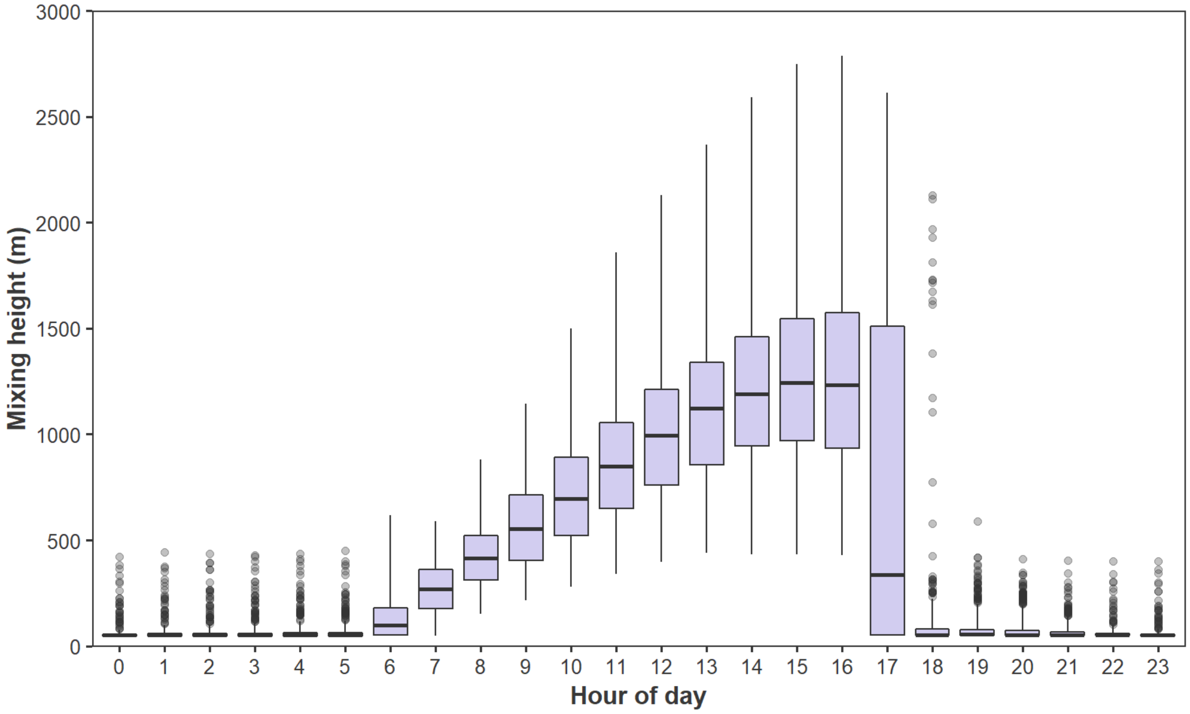

Figure A5 **Diurnal mixing height at the Project site predicted by TAPM/CALMET**

A2 CALPUFF DISPERSION MODELLING

CALPUFF simulates the dispersion of air pollutants to predict ground-level concentration and deposition rates across a network of receptors spaced at regular intervals, and at identified discrete locations. CALPUFF is a non-steady-state Lagrangian Gaussian puff model containing parameterisations for complex terrain effects, overwater transport, coastal interaction effects, building downwash, wet and dry removal, and simple chemical transformation.

CALPUFF employs the 3D meteorological fields generated from the CALMET model by simulating the effects of time and space varying meteorological conditions on pollutant transport, transformation and removal. CALPUFF takes into account the geophysical features of the study area that affects dispersion of pollutants and ground level concentrations of those pollutants in identified regions of interest. CALPUFF contains algorithms that can resolve near-source effects such as building downwash, transitional plume rise, partial plume penetration, sub grid scale terrain interactions, as well as the long-range effects of removal, transformation, vertical wind shear, overwater transport and coastal interactions. Emission sources can be characterised as arbitrarily-varying point, area, volume and lines or any combination of those sources within the modelling domain.

CALPUFF version 7.2.1 was configured with default options and parameters, with the following exceptions:

- Modelling period from 1 January to 31 December 2016
- 94 x 94 grid point domain with 0.5 km resolution
- Gridded three-dimensional hourly-varying meteorological conditions generated by CALMET
- No chemical transformation or wet removal modelled
- PDF used for dispersion under convective conditions
- Dispersion coefficients calculated internally from sigma v and sigma w using micrometeorological variables.

A2.1 Source configuration

Emissions were modelled in CALPUFF using area sources with a constant, diurnal (blasting) or hourly-varying (wind erosion) profile. Source characteristics for the modelled activity classes are presented in Table A1.

Table A1 CALPUFF area source characteristics

Emission source	Effective height (m)	Initial vertical dispersion coefficient (σ_Z)
Drilling and blasting	8.0	2.0
Material extraction	8.0	2.0
Dumping and bulldozing	10	2.5
Haulage	10.0	2.5
Rehabilitation activities	4.0	1.0
Wind erosion	1.0	0.25
CHPP and related activities	10.0	2.5

APPENDIX B ACTIVITY DATA

Operational parameters and activity data for the Project, used as input for the emissions calculations, are provided in Table B1.

Table B1 Summary of activity data used in emissions calculations

Activity	Values Year 2	Values Year 8	Values Year 15	Units	Information source
Operations					
Days per year	363	363	363	Days/year	MAGNETIC SOUTH
Standard hours of operation	24	24	24	hours/day	
Blasting hours	8	8	8	hours/day	
Hours on rehabilitation	8	8	8	hours/day	
Throughput					
Total ROM coal	900,000	1,830,000	1,800,000	tonnes	MAGNETIC SOUTH
Total product coal	673,000	1,383,000	1,383,000	tonnes	
Overburden - truck and shovel	29,093,000	29,869,000	28,638,000	tonnes	
Drilling and blasting					
Blasting frequency	53	40	37	blasts/year	MAGNETIC SOUTH
Holes drilled per blast (average)	313	313	313	holes/blast	
Blast area (average)	25,000	25,000	25,000	m^2	
Mine areas					
Active pit area	308,872	272,321	226,162	ha	Calculated
ROM stockpile	4	4	4	ha	MAGNETIC SOUTH
Product stockpile	1.5	1.5	1.5	ha	MAGNETIC SOUTH

Activity	Values Year 2	Values Year 8	Values Year 15	Units	Information source
Topsoil/Overburden dump area	1,948,563	1,077,910	1,935,996	ha	Calculated
Rehabilitating area	1,059,905	1,090,231	893,970	ha	
Rehabilitated area	NA	2,425,137	6,588,031	ha	
Pit shell	330,579	471,153	326,127	ha	
Transport					
ROM coal haulage to CHPP	91,440	240,748	289,108	VKT/year	Calculated
OB haulage to dump	1,035,646	937,676	1,285,363	VKT/year	
Rejects haulage to dump	19,812	63,278	58,143	VKT/year	
Bulldozing					
Number of dozers in operation	7	7	7	#	MAGNETIC SOUTH
Total hours of operation per vehicle per year	4,500	4,500	4,500	hr.op/year/vehicle	
Grading					
Number of graders in operation	2	2	2	#	MAGNETIC SOUTH
Grading speed (3500hrs/yr)	10	10	10	km/h	
Driving speed (1000hrs/yr)	30	30	30	km/h	
Total grader travel	130,000	130,000	130,000	VKT/year	Calculated
Conveying					
Length of enclosed conveyor	1.1	1.1	1.1	km	MAGNETIC SOUTH
Length of conveyor with windbreak	0.5	0.5	0.5	km	
Material characteristics					
ROM coal moisture content	10.4	10.4	10.4	%	AP42 Ch11.9 Table 11.9-4

Activity	Values Year 2	Values Year 8	Values Year 15	Units	Information source
ROM coal silt content	8.6	8.6	8.6	%	AP42 Ch11.9 Table 11.9-3
Overburden moisture content	7.9	7.9	7.9	%	AP42 Ch11.9 Table 11.9-3
Overburden silt content	6.9	6.9	6.9	%	AP42 Ch11.9 Table 11.9-3
Overburden density	2.3	2.3	2.3	%	MAGNETIC SOUTH
Pit haul road silt content	8.4	8.4	8.4	%	AP42 13.2.2-1
CHPP haul road silt content	8.4	8.4	8.4	%	AP42 13.2.2-1
Product moisture content	8.0	8.0	8.0	%	MAGNETIC SOUTH
Meteorology					
Mean onsite wind speed	2.018	2.018	2.018	m/s	TAPM/CALMET modelling

APPENDIX C AIR QUALITY MANAGEMENT PLAN

C1 INTRODUCTION

C1.1 Overview

This section details the Air Quality Management Plan (AQMP) for the Gemini Project, a greenfield open cut mine to produce Pulverised Coal Injection (PCI) coal and Coking Coal products for export for steel production.

The AQMP is an expected requirement to support the Air Quality and Greenhouse Gas Assessment for the Gemini Project (Katestone, 2020).

This AQMP is prepared with the understanding that it will be revised and updated, as necessary, to accommodate:

- Any potential Environmental Authority (EA) conditions of approval issued by Queensland Government
- Any improvements in dust management practices
- Changes in site conditions that are relevant to dust management
- Changes in technology or legislation
- Detail corrective actions and implementation strategy as the need arises
- Any other relevant events.

C1.2 Objective

The objective of the AQMP is to ensure that air quality related aspects of the Project comply with the regulatory requirements. This will be achieved through an AQMP that:

- Documents all relevant regulatory requirements
- Identifies Project activities that produce air pollutant emissions and the potential for impact
- Details existing air environment relevant to the Project
- Describes the routine management measures that will be implemented to minimise air pollutant emissions
- Describes the proactive and reactive dust management system that will be implemented to minimise air pollutant emissions, including:
    - Trigger Action Response Plan (TARP)
    - Air Quality Monitoring System (AQMS)
    - Meteorological Forecasting System (MFS)
- Details the protocol for managing and reporting any air quality incidents, complaints or non-compliances
- Documents the process for stakeholder consultation
- Documents the continual improvements including regular auditing of compliance, ongoing review and annual reporting.

C2 REGULATORY REQUIREMENTS

The regulatory instruments relevant to air quality are summarised below.

The *Environmental Protection Act 1994* (EP Act) provides for the management of the air environment in Queensland. The EP Act gives the Department of Environment and Science (DES) the power to create Environmental Protection Policies that identify, and aim to protect, environmental values of the atmosphere that are conducive to the health and wellbeing of humans and biological integrity.

The *Environmental Protection (Air) Policy* (Air EPP) was made under the EP Act and gazetted in 1997; the Air EPP was revised and reissued in 2019. The purpose of the Air EPP is to identify the environmental values of the air environment to be enhanced or protected and to achieve the objective of the *Environmental Protection Act 1994*, i.e. ecologically sustainable development.

The EP Act also gives DES the power to issue Environmental Authorities (EA) for prescribed activities (such as the Project). EA's include a range of conditions requiring the holder to conduct activities in an environmental responsible manner.

Environmental conditions relating to air quality that may be issued by the OCG are likely to include:

- Air quality objectives from the Air EPP (as used in the EIS assessment)
- A dust management plan including:
    - A preventative management system for dust control
    - A trigger Action Response Plan
    - Operation monitoring program
- Compliance monitoring
- Continuous improvement.

Expected objectives that could be contained within the draft conditions of an EA, are presented in Table C2.

Table C2 Expected air quality objectives

Pollutant	Environmental Value	Averaging Period	Air Quality Objective (µg/m³)
$PM_{2.5}$[1]	Health and wellbeing	24-hour	25
PM_{10}[2]		24-hour	50
TSP		1-year	90
Dust deposition rate for total insoluble solids	Amenity guideline[3]	1-month	120 mg/m²/day

Note:
[1] $PM_{2.5}$ are particles that have aerodynamic diameters that are less than 2.5 µm.
[2] PM_{10} are particles that have aerodynamic diameters that are less than 10 µm.
[3] DES' *Model Mining Conditions* guideline, not an air quality objective from the Air EPP.

C3 GEMINI PROJECT OVERVIEW

C3.1 Project Description

The Project is described in Section 2 of the Air Quality and Greenhouse Gas Assessment (Katestone, 2020).

Key dust-generating activities associated with the Project include:

- Drilling and blasting
- Material extraction and handling (overburden and ROM coal)
- Bulldozer activity
- Material haulage (overburden and ROM coal)
- Road grading
- Wind erosion of exposed mine areas.

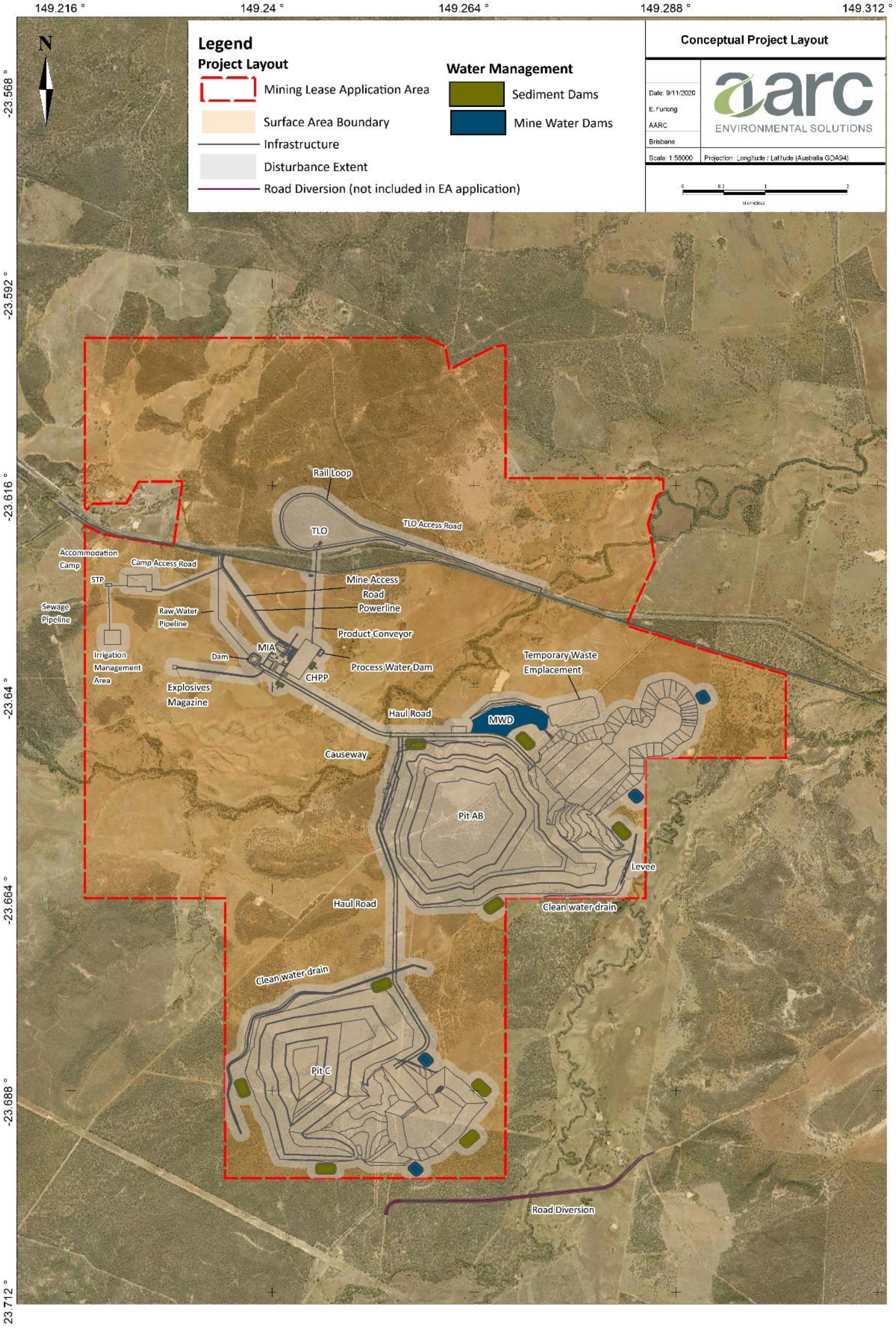

Figure C1 Project General Arrangement

C3.2 Potential air quality impacts

The Air Quality and Greenhouse Gas Assessment (Katestone, 2020) considered Project operations over the life of the mine and determined the potential for air quality impacts.

Overall, the air quality impact assessment of the Project operations predicted that:

- Annual average concentrations of TSP ***comply*** with the relevant air quality objective at all sensitive receptors using standard mitigation measures.
- Maximum 24-hour concentrations of PM_{10} ***comply*** with the relevant air quality objective at all sensitive receptors using standard mitigation measures and additional mitigation when necessary.
- Annual average concentrations of PM_{10} ***comply*** with the relevant air quality objective at ***most*** sensitive receptors using standard mitigation and additional mitigation measures when necessary.
- Annual average concentrations of $PM_{2.5}$ ***comply*** with the relevant air quality objectives at all sensitive receptors using standard mitigation and additional mitigation measures when necessary.
- 24-hour concentrations of $PM_{2.5}$ ***comply*** with the relevant air quality objectives at all sensitive receptors using standard mitigation measures.
- Predicted annual average concentrations of $PM_{2.5}$ ***comply*** with the relevant air quality objectives at all sensitive receptors using standard mitigation and additional mitigations measures when necessary for Year 2, Year 8 and Year 15, except at SR22 (within Project ML), SR31, and SR32 for Project Year 15.
- Monthly dust deposition rates ***comply*** with the relevant air quality guideline at all sensitive receptors using standard mitigation measures.

Air quality impacts at the nearest sensitive receptors will be managed using standard and additional dust mitigation measures. The Project dust mitigation measures are discussed further in this AQMP.

C4 DESCRIPTION OF THE EXISTING ENVIRONMENT

C4.1 Location of sensitive receptors

The location and description of sensitive receptors are detailed in Section 3.3.2 and Figure 4 of the Air Quality and Greenhouse Gas Assessment (Katestone, 2020).

C4.2 Existing air quality monitoring

C4.2.1 Onsite air quality

Air quality monitoring is not currently conducted on site. Details of the proposed siting of an onsite air quality monitor are detailed in Section C5.2.4.

C4.2.2 DES monitoring in Blackwater

The PM_{10} data shows there were 17 occasions over the monitoring period when Blackwater monitoring station recorded 24-hour average PM_{10} concentrations greater than the Air EPP air quality objective of 50 µg/m³. Data for $PM_{2.5}$ indicated one occasion over the monitoring period when Blackwater monitoring station exceeded the Air EPP 24-hour average $PM_{2.5}$ objective of 25 µg/m³.

Table C3 Concentrations of PM_{10} at DES Blackwater monitoring station from April 2019 to April 2020

Year	PM_{10} (µg/m³)			
	24-hour average (Maximum)	No. days above 50 µg/m³	24-hour average (70th percentile)	Annual average
April 2019 to April 2020	157.9	17	23.8	22.9

Table C4 Concentrations of $PM_{2.5}$ at DES Blackwater monitoring station from April 2019 to April 2020

Year	$PM_{2.5}$ (µg/m³)			
	24-hour average (Maximum)	No. days above 25µg/m³	24-hour average (70th percentile)	Annual average
April 2019 to April 2020	26.7	1	7.4	6.8

C5 DUST CONTROL MEASURES

C5.1 Standard Dust Management

Dust mitigation and operational controls have been included in the Project design to minimise dust emissions from mining activities, including application of water to haul roads. Standard efficiency factors for these control measures are presented in Table C5.

Table C5 Standard dust control measures and relative reduction in emissions

Activity	Control measure	Reduction
ROM coal haulage	Watering	85%
Overburden haulage	Watering	85%
Drilling	Drill dust suppression sprays	70%
ROM unloading at CHPP	Water sprays	70%
Crushing	Enclosure	70%
Product stockpile	Wet from CHPP	50%
Train loading	Telescopic chute with water spray	85%
Conveyor	Enclosure	70%
Conveyor	Uncovered	0%

C5.2 Additional Dust Management

Additional dust management at the Project will include a proactive dust management system to ensure dust generation during times of high potential for impact is minimised as far as practicable. The proactive system should include the use of the following tools to plan and manage operations to minimise the risk of adverse dust levels impacting nearby sensitive receptors, including:

- Trigger Action Response Plan (TARP)
- Weather and dust risk forecast
- Dust monitoring.

C5.2.1 TARP

A Trigger Action Response Program (TARP) is a dust management procedure that aims to investigate and mitigate dust emissions during operations through the following key steps:

- **Trigger**: A trigger is defined by one or more conditions and an associated trigger level. When the conditions of a trigger are met, an alert is issued.
- **Alert**: An alert occurs as a result of the conditions of a trigger being met. Each alert requires one or more responses.
- **Response**: A response is a dust management action that may be implemented as a result of an alert being issued.
- **Action**: An action is a specific activity that is conducted as part of a response.

The Project TARP will include a range of thresholds that will trigger alerts, responses and actions. Triggers identify circumstances when:

- Ground-level concentrations at offsite receptors are likely to be elevated due to activities onsite

- Activities onsite are generating dust outside of the normal range.

The following sections detail indicative TARP trigger levels for PM_{10} monitoring and proposed actions. A refinement to these trigger values and actions will be made following project start up.

C5.2.1.1 TARP trigger levels

PM_{10} monitoring data triggers at the Project have been derived from ambient air quality criteria. The following levels of trigger/response have been defined:

1. Normal condition – green – (No Action)
2. Low trigger – yellow - (Watch and wait). This is an early warning level to increase awareness of potential dust issues before they arise.
3. Medium trigger – orange - (Investigate). A medium trigger indicates that there may be a potential dust issue and specific investigation is warranted.
4. High trigger – red - (Escalate). A high trigger indicates that dust concentrations are outside of the normal range and that an action is warranted.

The TARP has been designed to provide as much warning as possible for the Project to allow proactive management of fugitive dust. Therefore, a trigger, particularly a low or medium trigger, does not indicate the presence of a dust impact.

Trigger values for 24-hour average concentrations of PM_{10} have been set at the 60th, 75th and 90th percent values for low, medium and high triggers relevant to the 24-hour average concentration of 50µg/m³ in the OCG draft conditions, as shown in Table C6.

These triggers will be calculated hourly to provide a rolling 24-hour average. Further to this, to ensure that the triggers are considering dust associated with the Project activities, the trigger levels include reference to the wind direction. If the 1-hour average wind direction is not blowing from the general direction of the mine, the trigger level will be downgraded by one e.g. Medium to Low.

The triggers will be optimised following collection of a few months of onsite monitoring data.

Table C6 Trigger values for rolling 24-hour average concentrations of PM_{10}

Parameter	Rolling 24-hour average concentration of $PM_{2.5}$ (µg/m³)	Wind direction
Normal	<20	-
Low	20	From mine towards monitor
Medium	26	From mine towards monitor
High	39	From mine towards monitor
EA Concentration Limit	50	

C5.2.1.2 Actions

Dust management actions and responses that would be triggered by the PM_{10} trigger level alerts are presented in Table C7. These actions will be refined by Gemini when the project commences.

Table C7 Example of actions and responses for ambient monitoring data triggers

Trigger Level	Action required	Responsibility
Normal	• Ensure all standard dust management practices have been implemented. If not, implement standard practices.	Shift environmental supervisor
Low	• Ensure all standard dust management practices have been implemented. If not, implement standard practices. • Alert relevant operators that dust levels are elevated therefore heightened awareness to sources of dust may be required.	Shift environmental supervisor
Medium	As for low, in addition: • Visual observations on site to check if there are any significant visible dust emissions in the region of the exceeding monitor – focusing on haul roads and material handling. • Apply mitigation to haul roads where dust emissions are visible. • Relocate material handling.	Shift environmental supervisor
High	As for medium, in addition: • Slow activities within pit and/or overburden dump nearest and upwind of the monitor. • Focus control application to haul roads in pit nearest and upwind of monitor. • Progressively cease dust generating activities	Shift environmental supervisor

C5.2.2 Weather and dust risk forecast

It is recommended The Project will implement a meteorological forecast system (MFS) and a dust risk forecast system (DRFS) to provide daily predictions of upcoming meteorological conditions that have the potential to generate high levels of dust from Project operations. The system would provide 3 levels of forecasting:

1. Next 24 hours
2. Next 2-3 days
3. Next 7 days

The system would also define three categories of warning:

1. CAT 1 – Take immediate action:
    - Take immediate action to minimise risk
2. CAT 2 – Watch and Act
    - Potential Risk looming
    - Watch and plan for action if necessary
3. CAT 3 – Advice
    - General advice of emerging risks in the 7-day horizon

C5.2.3 Dust monitoring

C5.2.3.1 Overview

The Project air quality monitoring program will have two main objectives:

1. Ensure the release of dust and/or particulate matter resulting from the Project does not cause an environmental nuisance at any dust sensitive place

2. Provide real-time data to the proactive dust management system on air quality levels at locations surrounding the mine.

It is recommended that the Project monitoring program will as a minimum include:

- Continuous monitoring of PM_{10} at one primary location
- Continuous monitoring of $PM_{2.5}$ at one primary location
- Dust deposition monitoring at one primary location
- Meteorological monitoring (including temperature, wind speed and direction) at a single location representative of the Project.

Monitoring must be undertaken in accordance with Australian Standard methods for analysis of ambient air If alternative monitoring methods are proposed, approval from the administering authority must be sought. Regular reporting of dust monitoring results should be conducted.

Considering the most impacted sensitive receptors as outlined in the Air Quality and Greenhouse Gas Assessment (Katestone, 2020), it is recommended that a primary dust monitoring location be sited to the north west of the Project CHPP as identified by the green circle in Figure C2.

It is recommended that two additional dust monitoring sites be included to monitor dust levels at Dingo Township to the east and SR14 (identified in Figure C2 by the purple and blue circles, respectively). The Air Quality and Greenhouse Gas Assessment (Katestone, 2020) indicated that there is a potential for concentrations of PM_{10} to be highest at Dingo Township at Year 8, whilst concentrations at SR14 are not expected to be highest until Year 15. Therefore, perhaps the additional monitor can be moved from Dingo Township to SR14 as the Project progresses.

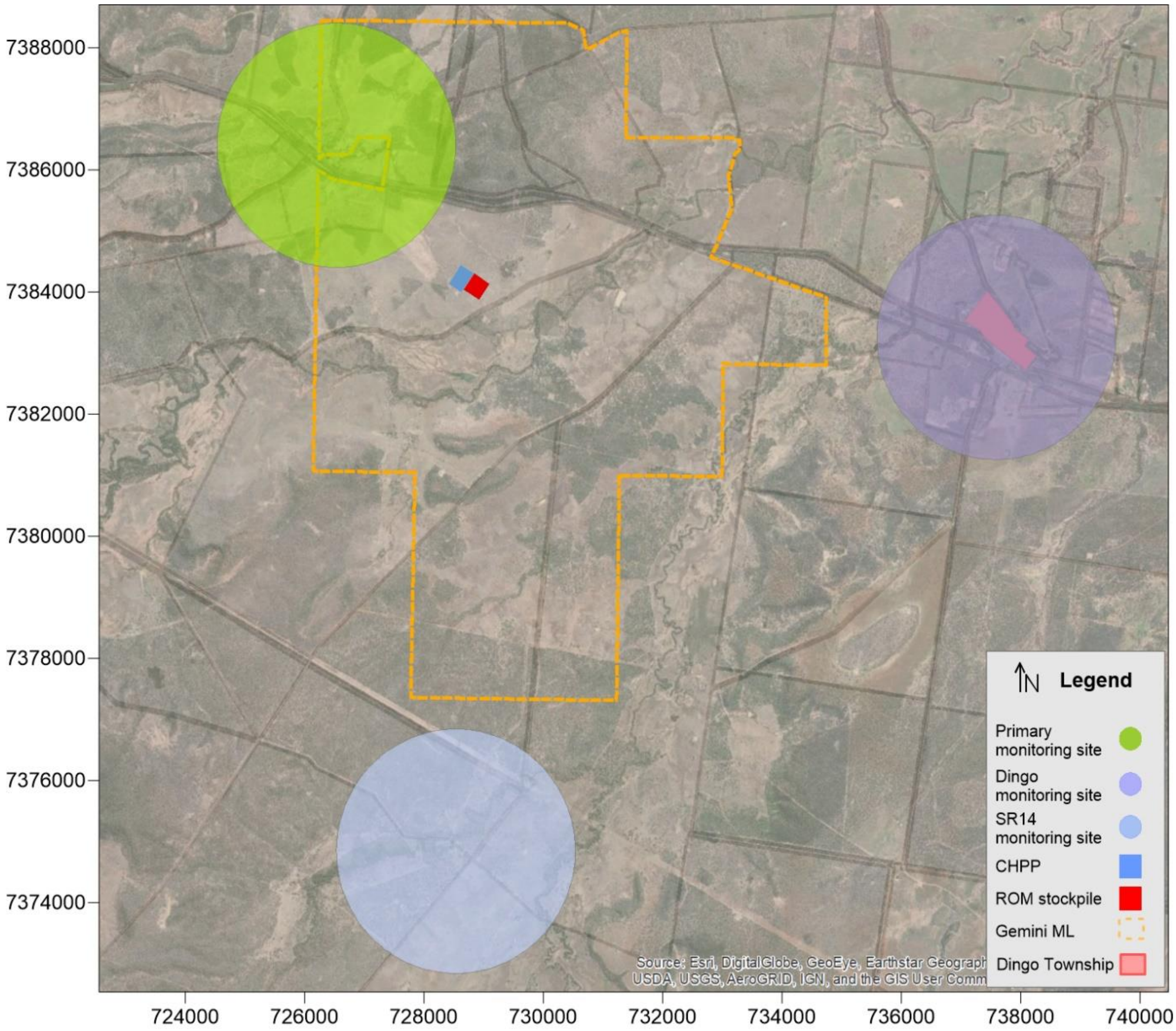

Figure C2 Suggested location of air quality monitoring site relative to the Project CHPP and mine lease

C5.2.3.2 Summary of Australian Standard methods for analysis of ambient air

The Australian Standards that are relevant to the proposed Project dust monitoring program are specified in Table C8.

Table C8 Australian Standards that are relevant to Project dust monitoring program

Pollutant	Australian Standard
Siting	AS/NZS 3580.1.1:2016 - Methods for sampling and analysis of ambient air - Guide to siting air monitoring equipment
Dust deposition rate	AS/NZS 3580.10.1:2003 - Methods for sampling and analysis of ambient air - Determination of particulate matter - Deposited matter - Gravimetric method

TSP	AS/NZS 3580.9.3:2015 - Methods for sampling and analysis of ambient air - Determination of suspended particulate matter -Total Suspended Particulate matter (TSP) – High Volume sampler - Gravimetric method
PM_{10}	AS/NZS 3580.9.6:2015 - Methods for sampling and analysis of ambient air - Determination of suspended particulate matter - PM_{10} high volume sampler with size-selective inlet - Gravimetric method; or equivalent
	AS/NZS 3580 9.8:2008 (R2018) - Methods for sampling and analysis of ambient air - Determination of suspended particulate matter - PM_{10} continuous direct mass method using a tapered element oscillating microbalance (TEOM) analyser
	AS/NZS 3580.9.9:2017 - Methods for sampling and analysis of ambient air - Determination of suspended particulate matter - PM_{10} low volume sampler - Gravimetric method
	AS/NZS 3580.9.11:2016 - Methods for sampling and analysis of ambient air Determination of suspended particulate matter - PM_{10} beta attenuation monitors
	AS/NZS 3580 9.16:2016 - Methods for sampling and analysis of ambient air - Determination of suspended particulate matter - PM_{10} continuous direct mass method using a tapered element oscillating microbalance (TEOM) monitor incorporation a filer dynamic measurement system (FDMS) unit
$PM_{2.5}$	AS/NZS 3580.9.10:2017 - Methods for sampling and analysis of ambient air - Determination of suspended particulate matter – $PM_{2.5}$ low volume sampler - Gravimetric method
	AS/NZS 3580.9.12:2013 - Methods for sampling and analysis of ambient air Determination of suspended particulate matter – $PM_{2.5}$ beta attenuation monitors
	AS/NZS 3580 9.13:2013 - Methods for sampling and analysis of ambient air - Determination of suspended particulate matter – $PM_{2.5}$ continuous direct mass method using a tapered element oscillating microbalance (TEOM)
	AS/NZS 3580.9.14:2013 - Methods for sampling and analysis of ambient air - Determination of suspended particulate matter – $PM_{2.5}$ high volume sampler with size-selective inlet - Gravimetric method; or equivalent
PM	AS/NZS 3580.9.17:2018 - Methods for sampling and analysis of ambient air -Demonstration of equivalence for ambient particulate matter monitoring methods

C5.2.3.3 Operational monitoring program

Real-time measurement of PM_{10} are intended for use as validation and feedback for the proactive dust management system. When PM_{10} monitoring data triggers TARP threshold values, responsible personnel will receive alerts and operations will be appropriately managed to minimise the risk of adverse dust levels impacting nearby sensitive receptors (as described by the TARP in Section C5.2.1).

C5.2.4 Project monitoring program summary

The air monitoring program for the Project would include the following:

- Installation of one dust deposition site within the area identified by Figure C2
- Installation of one to three operational PM_{10} monitoring sites within the area identified by Figure C2.

It should be noted that the operational PM_{10} monitoring sites need to provide continuous hourly data to inform operations. A suitable monitoring method needs to be approved by the administering authority (DES).

Notwithstanding this, the proposed air quality monitoring program for the Gemini Project is described in Table C9.

Table C9 Proposed Project air quality monitoring requirements

ID	Monitoring location*	Air quality indicator	Monitoring Method	Frequency
1	Location to the **north west** of the Project CHPP	PM_{10}	To be determined following approval by administering authority	Continuous
		Dust Deposition	AS/NZS 3580.10.1:2003	Continuous (monthly period as per AS)
		Wind speed & direction	AS/NZS 3580.14:2014	Hourly

C5.2.5 Reporting of monitoring data

Air quality and meteorological monitoring data will be reviewed daily by the site environmental staff to assist with the appropriate management of operations. In the event of any air quality incidents or non-compliance with air quality criteria, certain reporting protocols for incidents and non-compliance will be followed.

This would generally proceed through a number of stages as detailed below:

- Verification of non-compliance through data analysis and detailed site investigations
- Further investigations to identify probable and/or critical causes for non-compliance and identify possible solutions.

An annual review of the air quality monitoring results is recommended to be undertaken as part of this AQMP. The annual summary would include analysis on the performance of the Project and effectiveness of dust controls through comparison with relevant air quality criteria.

C5.2.6 Air Quality Management System

Data collection, processing, display and storage is a central component of the Project's air quality management system (AQMS). The AQMS would consist of the following elements:

- FTP server for receiving short-term averaged data from the monitoring network and the daily weather and dust risk forecasts
- Automated validation of all data, with alerts generated on missing or erroneous data above thresholds defined in the TARP
- Data display
- Database for storage of all data
- Data reporting tool
- Automated backup of all data.

C5.3 Stakeholder engagement and response to complaints

The Project will need to operate a complaint handling procedure. Community complaints that relate to air quality impacts should be logged and responded to in an appropriate and timely manner by the Project site environmental manager. A complaints register will be maintained.

A complaints procedure process will be developed, and a template complaints form produced. The form will include details such as:

- Time of complaint
- Type of complainant (eg nearby resident)
- Location of complaint
- Dust levels and meteorological conditions at the time
- Details of the complaint.

A twenty-four-hour telephone number should be made available to near neighbours for receiving concerns. Actions taken by Project environmental staff in relation to community concerns will include reviewing all available data at the time of the complaint including:

- Weather and dust risk forecasts
- Actual dust and meteorological data
- Mine operations including location and intensity.

Additional follow up actions may include:

- An inspection of the complainant's residence
- Sampling at the complainant's residence
- Investigation of any other potential dust generating sources in the vicinity of the complainant's residence.

C6 REVIEW AND REVISION

C6.1 Continuous improvement

Continuous improvement of this AQMP will be achieved through the ongoing evaluation of dust management performance against environmental policies, objectives and targets for the purpose of identifying opportunities for improvement.

Continuous improvement will be delivered through an annual review by the Project environmental manager and will:

- Review air quality monitoring data against relevant air quality criteria
- Identify areas for improvement of dust management and performance
- Determine the cause/s of any non-conformances
- develop and implement a plan of action to address any non-conformances
- document any changes in procedures resulting from process improvement.

C6.2 Revision

This AQMP should be reviewed at intervals not exceeding 2 years and amended where appropriate to ensure that the plan is effective in achieving its purpose and objectives. The review will consider:

- Frequency and cause of any exceedances of air quality objectives
- Dust complaints
- Future progression of Project activities
- Locations of sensitive receptors
- Mining activity modes.

Following any revision, a revised AQMP will be provided to DES for approval.

C7 TRAINING

All employees with responsibilities under this AQMP shall be trained in its contents and use. Training will occur when new employees start work and refresher training will occur every three years.

Regular meetings will also be held with all employees to reinforce dust management awareness and the procedures and work practices to minimise dust generation. Contractors working on site will undergo site induction and training that will refer to this AQMP and the dust control measures and practices contained within.

C8 ROLES AND RESPONSIBILITIES

The relevant staff members responsible for dust management practices at the Project are detailed in Table C10.

Table C10 Responsibilities of Project staff members

Position	Responsibilities
Site Environmental Manager or delegate	• Training staff in the use of the AQMP • Maintaining air quality monitoring equipment and ensuring their operation in accordance with Australian Standards • Daily checking of the proactive management system to plan operations • Limiting or ceasing operations if excessive dust is identified that cannot be controlled by watering • Regular inspections of the site and dust generating activities • Ensuring all complaints are recorded and investigated, and that corrective action is taken • NPI reporting • Prepare annual review report
Permanent site staff	• Undertake staff training as run by the Site Manager • When operating vehicles, conduct visual monitoring of dust and report as required • Notifying the Site Manager if excessive dust is identified
Contractors	• Undertake site induction • Adhering to site speed limits and designated haul road routes • Notify Site Manager if excessive dust is identified and report on the condition of the site haul road

C9 REFERENCES

Queensland Government, 2020, Air Quality Monitoring – 2019-20 (grouped by pollutant): Queensland hourly PM10 data, available for download at Queensland Government data (https://apps.des.qld.gov.au/air-quality/download/) (accessed June 2020)

Katestone, 2020, Air Quality and Greenhouse Gas Assessment for the Gemini Project: Air Quality and Greenhouse Gas Assessment, prepared for AustralAsian Resource Consultants Pty Ltd.

Appendix M Noise Impact Assessment

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Gemini Project

Noise Impact Assessment

Report: 197401.0181.R01V06

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Magnetic South Pty Ltd

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Contents

1. Introduction 5

2. Study Area Description 10

3. Proposed Development 12

3.1 Project Description 12
3.2 Projected Equipment Numbers 14

4. Existing Noise Environment 15

4.1 Overview and Locations 15
4.2 Weather 15
4.3 Attended Noise Measurements 15
4.4 Noise Logging 16

5. Acoustic Criteria 18

5.1 Overview 18
5.2 Environmental Protection Act 18
5.3 Environmental Protection (Noise) Policy 18
5.3.1 Overview 18
5.3.2 Acoustic Quality Objectives 18
5.3.3 Background Creep 19
5.4 Guideline – Planning for Noise Control 19
5.5 Guideline – Noise & Vibration from Blasting 19
5.6 Proposed Criteria 20
5.6.1 Noise Emissions 20
5.6.2 Blasting 20

6. Noise Assessment 21

6.1 Model Description 21
6.2 Meteorology 21
6.3 Noise Source Data 21
6.4 Modelling Scenarios 22
6.5 Predicted Noise Levels & Assessment 24
6.5.1 L_{Aeq} Noise Levels 24
6.5.2 L_{Amax}, L_{A01} and L_{A10} Noise Levels 24
6.6 Cumulative Noise Impacts 25

7. Blasting Assessment 29

7.1 Overview 29
7.2 Predictions 29
7.2.1 Ground Vibration 29

7.2.2 Airblast 30
7.3 Assessment 32

8. Noise Management Plan 33

8.1 Overview 33
8.2 Review of Noise Management Opportunities 33
8.2.1 Ceasing Operations in Various Time Periods 33
8.2.2 Ceasing Operations under Particular Meteorological Conditions 33
8.2.3 Moving Mine Equipment Further from the Receptors 34
8.2.4 Reduce Quantity of Mine Equipment, i.e. Lower Mine Output 34
8.2.5 Noise Mitigation of Equipment 34
8.2.6 Noise Mitigation between Equipment and Receptors 34
8.3 Mitigation Scenarios 34
8.4 Noise Monitoring 35

9. Recommendations and Conclusions 36

Appendices

Appendix A Glossary 37

Appendix B Noise Monitoring Photos 39

Appendix C Noise Monitoring Results 42

Appendix D Mining Equipment Locations 47

Appendix E Predicted Mining Noise Contours 50

1. Introduction

ASK Consulting Engineers (ASK) was commissioned by Magnetic South Pty Ltd to provide a noise and vibration impact assessment for the Gemini Project.

The Gemini Project consists of a greenfield open cut mine to produce Pulverised Coal Injection (PCI) coal and Coking Coal products for export for steel production. The Project is located within EPC 881 and the proposed Mining Lease Application (MLA) boundary in the Bowen Basin, Central Queensland. The site is located approximately 15 km east of Bluff and 3 km west of Dingo. The site location and surrounds are shown in **Figure 1.1**.

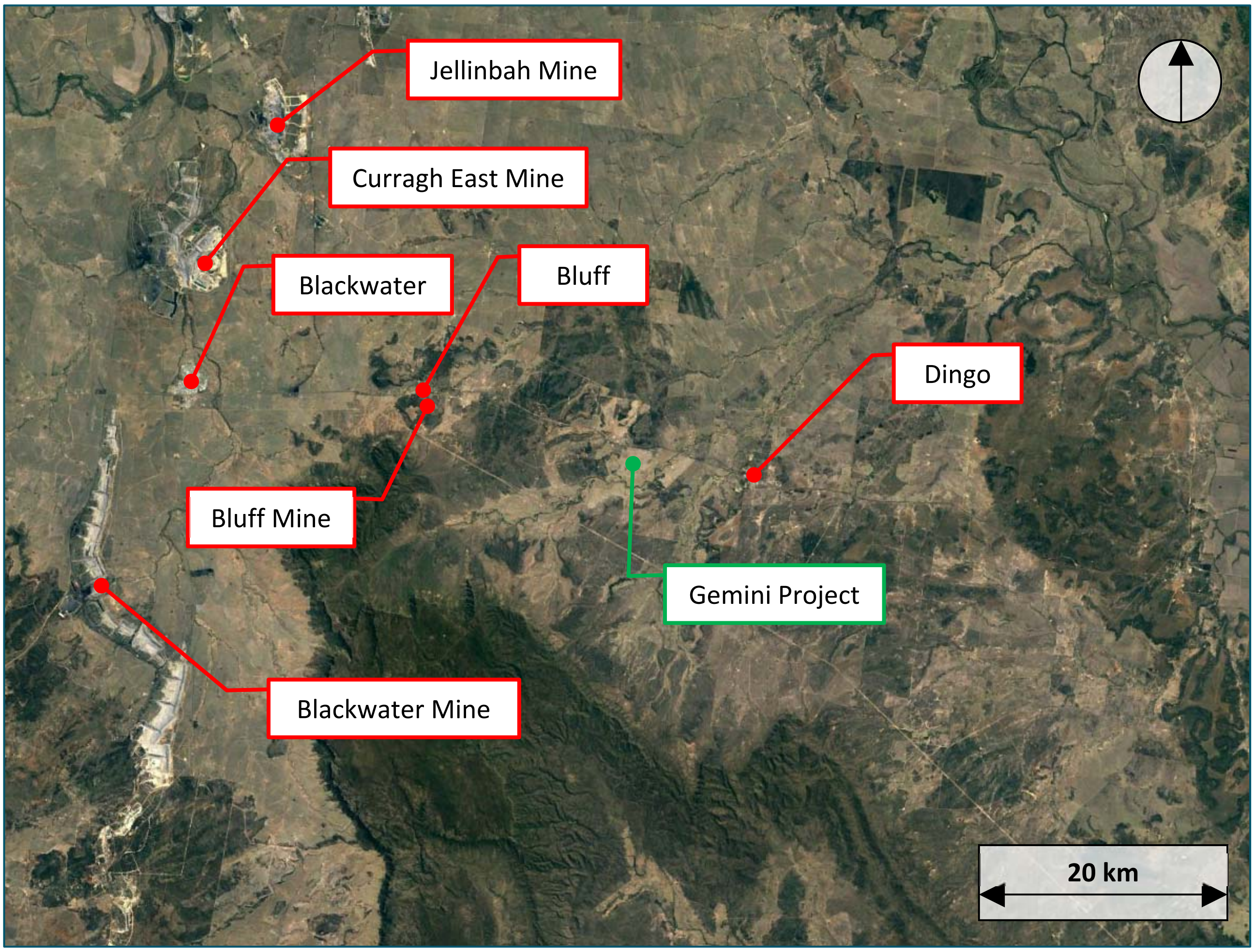


Figure 1.1 Site Location and Surrounds

The purpose of this report is as follows:

- Present the results of noise monitoring data of the existing environment at selected sensitive receptors.
- Propose appropriate noise and vibration criteria.
- Determine noise emission levels from the proposed fixed and mobile plant.
- Determine airblast and vibration levels due to blasting operations.
- Assess noise and vibration impacts for three scenarios of mining operations under adverse and neutral meteorological conditions in accordance with the nominated noise and vibration criteria.

To aid in the understanding of the terms in this report a glossary is included in **Appendix A**. The previous ASK report 197401.0181.R01V04, dated 02/10/2019 was submitted and further information was requested by

Department of Environment and Science (DES). This revised assessment has been prepared with the aim of addressing these information requests and a summary of the response is shown in **Table 1.1**.

Table 1.1 Further Information Request and ASK Responses

Section	Comment	Requirement	ASK Response
Appendix J Section 4.4 Noise Logging	Monitoring of environmental noise to determine background levels L90 [dB] was conducted between 7 and 19 June 2019. However, this doesn't represent a complete seasonal spectrum of levels of environmental noise.	Monitoring in other seasons should be considered before establishing (adopting) background levels (at least two seasons).	It is noted that ASK conducted noise measurements in a quiet period (during winter) and therefore measured noise levels are conservative. As per the discussion with Antoine David (AD) @ DES confirmed the ASK's approach is acceptable and further monitoring is not required.
Appendix J Section 5.3.3 Background creep	Background creep has been mentioned but no information has been provided. How will background creep be prevented or minimised? Give consideration to the requirement in the Noise Measurement Manual (EM1107)	Give consideration to the cumulative impacts on all affected environmental values.	Day and evening noise limit of 40 dBA L_{eq} and night time noise limit of 35 dBA L_{eq} were used in this revised assessment. These limits are consistent with other coal mining projects.
Appendix J Section 6.4 Modelling Scenarios	Mining noise emissions from the Gemini Project have been predicted for the following three mine year scenarios: • Year 2 • Year 8 • Year 15 These years were selected to give a representation of mine noise levels near the beginning, middle and end of the project. However, project life is 20 years and there will be considerate noise emissions from transport in the mine closure period (same as in the clearing/pre-mining phase) that must be taken into consideration.	Include preparation (years 0 and 1) and post-mining/closure phases (year 20) in the modelling.	AD @ DES confirmed the ASK's approach is acceptable and further scenarios are not required to be assessed.
Appendix J Section 6.6.2 Cumulative Noise Impacts	It has been stated that the nearest existing mine is Bluff Mine which is 12km to the west. The sensitive receptors that have the most potential to be impacted by the Gemini Project to the west are SR22, SR31 and SR32. The Bluff Mine is over 10 km	Present data/charts and present a scenario with noise levels under "No WIND" conditions, to support statements made.	Further noise predictions are made with different wind conditions and discussed in **Section 6.5**.

Section	Comment	Requirement	ASK Response
	from these receptors. Given the significant distance and that adverse wind conditions cannot occur for both mines simultaneously at these receptors since they are in opposite directions, it is unlikely that cumulative noise impacts from both mines will be an issue. Further information is required to identify the potential cumulative impacts.		Cumulative noise is addressed in **Section 6.6** and is predicted not to be an issue.
Measurements	The noise criteria have not been based on the Model Mining conditions (ESR/2016/1936). For night time the noise criteria following the Model Mining condition would be 2dB more stringent than the derivation made using the Environmental Protection (Noise) Policy 2019 Planning for noise control. The noise criteria should be derived using the Model Mining conditions. The night time criteria should be 35dBA instead of 37dBA and this worsens the noise exceedances during night time by 2dB with the worse exceedance going from 13dB to 15dB and add another 3 sensitive receptors in exceedance, raising the total number from 6 sensitive receptors exceeding night time noise criteria to 9 sensitive receptors exceeding the night time criteria. Further information is required about the mitigation of nuisances. In addition, L_{A1} (Model Mining Conditions) and L_{Amax} for sleep disturbance (EPP Noise 2019) has not been assessed. Further information is required.	Provide further information.	A day and evening noise limit of 40 dBA L_{eq} and night time noise limit of 35 dBA L_{eq} are used in the assessment. These limits are consistent with other coal mining projects. L_{Amax}, L_{A1} and L_{A10} parameters are discussed in **Section 6.5.2** of the report. ASK is unaware of an L_{max} limit within the EPP Noise 2019, though they are discussed in other documents. Usually the L_{eq} limit is the preferred parameter as used in this report.
Modelling	The weather scenarios considered are for neutral and adverse meteorological conditions. South-easterly or westerly winds have not been measured and noise impacts would be considered worse under those conditions. Report the percentage of days under those conditions.	Provide modelling for south-easterly and westerly wind conditions.	Further noise predictions are made with different wind conditions and discussed in **Section 6.5**

Section	Comment	Requirement	ASK Response
Sound sources	The sound power levels reported for the machines modelled are appropriate. The sound power level of the Drill Caterpillar MD6420 is not listed specifically but is listed as drill which may differ. Sound power level of Cat MD6420 should be used for the model for accuracy and should be listed.	Provide further information.	Caterpillar Drill noise data same as ASK data and hence report is updated just to refer to specific drill model.

2. Study Area Description

The Gemini Project is located approximately 3 km west of Dingo.

The nearest residential sensitive receptors are summarised in **Table 2.1**.

Table 2.1 Sensitive Receptors

Sensitive Receptor ID	Receptor type	Real Property Description	Easting (m)	Northing (m)	Location
SR01	Residential	3SP165527	721380	7386940	4.9 km W
SR03	Residential	6SP152759	737915	7382328	3.2 km E
SR05	Residential	2HT388	721937	7382077	4.3 km W
SR07	Residential, facilities (sports oval, tennis court, school) & businesses (Post Office, hotel, shops, sawmills, etc.)	Dingo Township	737777	7383220	3.0 km E
SR08	Residential	1RP801280	722022	7384327	4.2 km W
SR09	Residential	2RP904099	731988	7385624	Within MLA
SR10	Residential	28HT87	736181	7382995	1.4 km E
SR13	Residential	29HT489	737113	7382802	2.4 km E
SR14	Residential	3HT139	728569	7374873	2.5 km S
SR15	Residential	4HT165	729144	7388750	0.3 km N
SR16	Residential	8HT536	735273	7388705	3.0 km NE
SR17	Residential	2RP616780	722415	7384928	3.8 km W
SR18	Residential	1HT424	729626	7384531	Within MLA
SR19	Residential	2HT138	732684	7377515	1.4 km SE
SR20	Residential	2HT138	732671	7377581	1.4 km SE
SR21	Residential	2HT138	732614	7377700	1.4 km SE
SR22	Residential and Camp Accommodation	100RP882349	726499	7386357	Within MLA
SR23	Residential	47H406	734446	7383534	Within MLA
SR24	Residential	20H4017	735824	7384500	1.2 km NE
SR26	Residential	20SP217269	739747	7382306	5.1 km E
SR27	Residential	20SP217269	739278	7383145	4.5 km E
SR28	Residential	21SP217269	739157	7383337	4.4 km E
SR30	Residential	25SP217269	739319	7383894	4.6 km E
SR31	Residential	-	725109	7385743	1.1 km NW
SR32	Residential	-	725075	7386813	1.2 km NW

It is noted that SR07 represents the Dingo township. The following sensitive receptors are located within the Mining Lease Application (MLA) Area:

- SR09
- SR18
- SR23

At the time of report preparation, receptors SR09, SR14, SR15, SR18, SR19, SR20, SR21, SR23 and SR24 are owned or under purchase by Magnetic South, and will be excluded from the assessment.

The Capricorn Highway and the Blackwater-Gladstone rail network extend through the northern section of the MLA. A number of the sensitive receptors are located within 1 km of the highway and rail line.

The site location and sensitive receptors are shown in **Figure 2.1**.

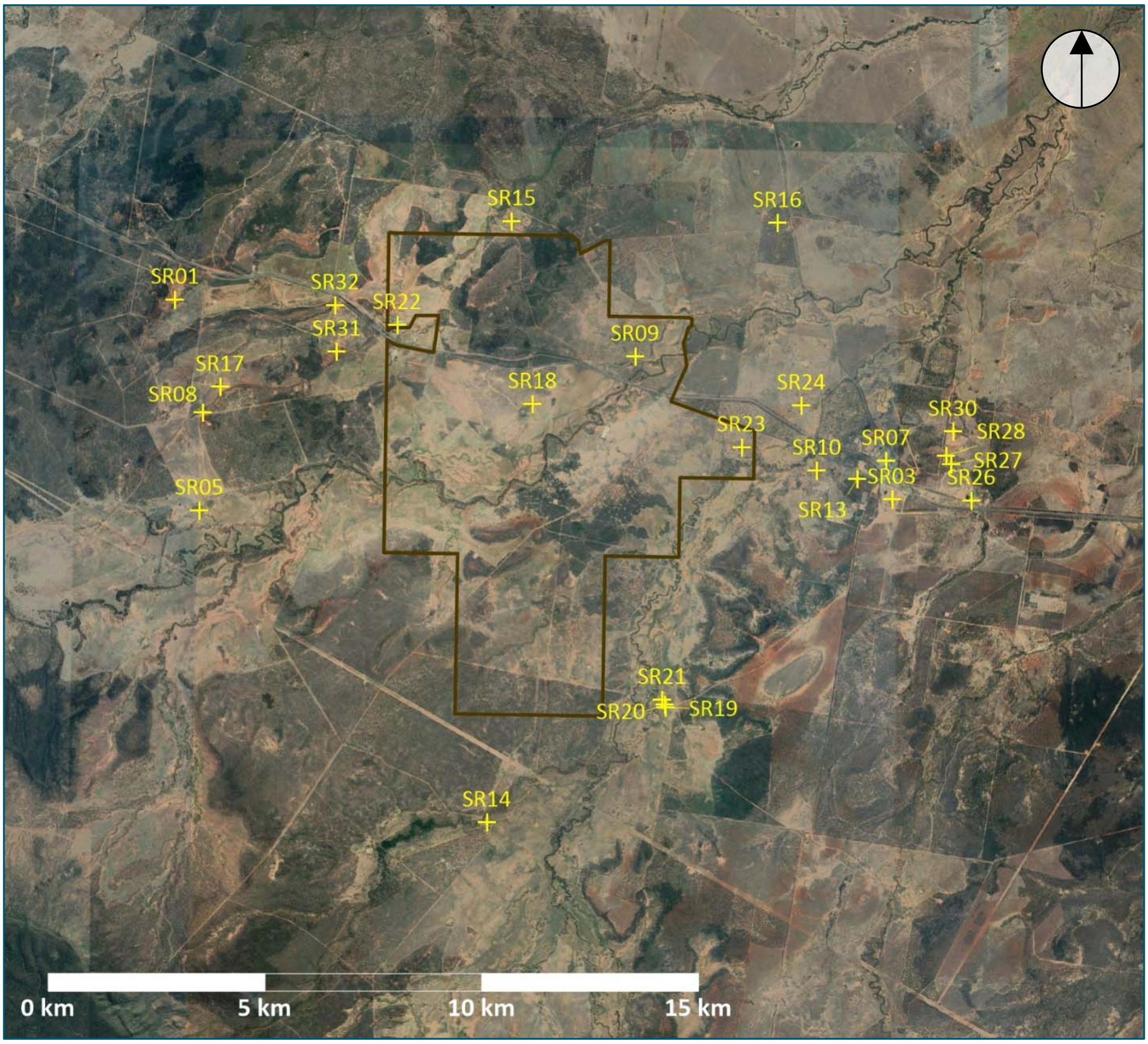


Figure 2.1 Site Location (MLA shown with brown line) & Sensitive Receptors

According to the Department of Natural Resources, Mines and Energy's MinesOnlineMaps system, the nearest mine to the Gemini Project is Bluff Mine, which is located approximately 15 km west of the Gemini Project's proposed ROM pad. There are a number of other mines further to the west, but no other mines within 50 km to the north, south or east.

3. Proposed Development

3.1 Project Description

The Gemini Project is a greenfield, open-cut metallurgical coal mine producing Pulverised Coal Injection (PCI) coal and coking coal for export to the international steel making industry. The Project term is anticipated to be 25 years from grant of the Mining Lease (ML) with this term including initial construction, mine operation and rehabilitation activities.

Mine construction activities are scheduled to commence in July 2021 subject to granting of the Project ML and EA. It is anticipated that it will take approximately six months to establish the necessary infrastructure to commence overburden removal and 18 months to commence coal production.

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, wash bay, laydown area, sewage, effluent and liquid waste storage, and a heli-pad.
- 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]).
- 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 an access road from the Capricorn Highway to the MIA and accommodation facility, and an access road to the TLO.
- 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 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.
- 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.

The proposed mine layout is shown in **Figure 3.1**.

Figure 3.1 Proposed Mine Layout

3.2 Projected Equipment Numbers

To give an indication of the amount of equipment used, the proposed haul truck numbers for the open cut mining operations are presented in **Table 3.1**.

Table 3.1 Haul Truck Fleet in Each Mining Year

Mining Year	Waste Haul Trucks	Coal Haul Trucks
1	6	0
2	12	1
3	12	2
4	13	2
5	14	2
6	15	2
7	15	2
8	15	2
9	15	2
10	15	2
11	15	2
12	15	2
13	15	2
14	15	2
15	17	3
16	17	3
17	17	3
18	17	3
19	10	3

It is noted that these haul truck numbers are the actual number of trucks in use at any one time, with an additional number of trucks being out of operation for maintenance etc. Further details on the types and numbers of equipment are provided in **Section 6.4**.

The major items of equipment at the ROM pad include a Coal Handling Preparation Plant (CHPP) and a front end loader (FEL). The rail loadout facility is also included in the model, including conveyors, conveyor drives, rail loadout bin and train locomotives.

4. Existing Noise Environment

4.1 Overview and Locations

Attended noise measurements and noise logging were undertaken at the following locations:

- Location A – Accommodation Facility: Located in an open-field, approximately 360 metres northeast of the railway line and 440 metres northeast of the Capricorn highway (726505.61 E, 7386445.61 N). This is the same location as SR22 (refer **Figure 2.1**).
- Location B – Roadhouse: Located in an open-field location, approximately 220 metres southwest of the Capricorn Highway (738095.59 E, 7382329.42 N). This is approximately the same location as SR03 (refer **Figure 2.1**).
- Location C – Residence: Located in an open-field position, approximately 200 metres northeast of the homestead (732865.98 E, 7377627.44 N). This is approximately the same location as sensitive receptors S19, SR20 and SR21 (refer **Figure 2.1**).

Aerial photos of the measurement locations are included in **Figures B.1**, **B.2** and **B.3** in **Appendix B**.

The noise monitoring was undertaken in general accordance with Australian Standard AS1055 *Acoustics – Description and measurement of environmental noise* and the DES Noise Measurement Manual 2013.

4.2 Weather

Data from the Bureau of Meteorology (Blackwater Airport) indicates that weather for the duration of the noise monitoring period was generally fine and warm with rainfall only recorded for Saturday 08/06/2019 (16.6 mm), Sunday 09/06/2019 (5.4 mm) and Tuesday 11/06/2019 (0.2 mm). Overall, the noise monitoring data has been deemed acceptable for use in this report.

4.3 Attended Noise Measurements

Attended noise measurements were undertaken at Locations A, B and C. The measurements were undertaken over separate 15-minute periods using a field and laboratory calibrated Larson Davis LD831 sound level meter. The microphone height was approximately 1.5m above natural ground level and was located in the free field at each location. Weather during the time of monitoring was generally cool, calm and clear. The conditions were as follows:

- Daytime: Approximately 11 to 15°C with a 2 to 3 m/s breeze and 1/8 cloud cover.
- Night time: Approximately 8 to 10°C, with a 0 to 3 m/s breeze and 1/8 cloud cover.

The measured noise levels are summarised in **Table 4.1**.

Table 4.1 Attended Noise Measurement Results

Location	Date & Time	Period (Minutes)	Results & Notes
A	19/06/2019 11:39pm	15	Statistical noise levels: L_{10} 61 dBA, L_{eq} 55 dBA, L_{90} 21 dBA Coal trains: 54 to 66 dBA Train horn: 58 dBA Distant cattle noise: 24 to 27 dBA Capricorn highway traffic: 45 to 52 dBA
B	19/06/2019 10:03pm	15	Statistical noise levels: L_{10} 61 dBA, L_{eq} 56 dBA, L_{90} 36 dBA Coal trains: 53 to 64 dBA Train horn: 78 to 79 dBA Capricorn highway traffic: 30 to 61 dBA
C	19/06/2019 10:52pm	15	Statistical noise levels: L_{10} 27 dBA, L_{eq} 27 dBA, L_{90} 19 dBA Cattle noise (Distant): 21 to 33 dBA Cattle noise (Closer): 37 to 43 dBA Birds: 33 dBA
A	20/06/2019 08:16am	15	Statistical noise levels: L_{10} 53 dBA, L_{eq} 50 dBA, L_{90} 41 dBA Birds: 39 to 42 dBA Highway trucks: 47 to 56 dBA Capricorn highway traffic: 37 to 50 dBA
B	20/06/2019 09:38am	15	Statistical noise levels: L_{10} 51 dBA, L_{eq} 49 dBA, L_{90} 46 dBA Wind through trees/rustling leaves: 47 to 48 dBA Crows: 54 to 58 dBA Birds: 46 to 51 dBA Truck leaving parking area: 47 to 55 dBA Capricorn highway traffic: 45 to 53 dBA

Note: * The reported noise levels, excluding the statistical noise levels, are the instantaneous levels read from the sound level meter, and generally represent the range in noise levels or maximum noise levels for a particular noise source.

4.4 Noise Logging

Noise logging was undertaken over the following time periods:

- Location A – Accommodation Facility: The measurement period was Friday 7th to Wednesday 19th June 2019.
- Location B – Roadhouse: The measurement period was Friday 7th to Wednesday 19th June 2019.
- Location C – Residence: The measurement period was Friday 7th to Monday 17th June 2019.

Logging was undertaken using field and laboratory calibrated Larson Davis LD831 environmental noise loggers. Noise logging was undertaken in the free-field at each location.

The measured noise levels at Locations A, B and C are shown in **Figure C.1** to **C.6** in **Appendix C**. The statistical results from the noise logging have been summarised in **Tables C.1**, **C.2** and **C.3** in **Appendix C**.

The noise logger at Location C had its wind protector removed when the logger was collected. This could have adversely affected the results with wind noise resulting in increased noise levels. However, the background noise levels remained consistently low throughout the measurement period, including background noise levels below 20 dBA L_{90}, and therefore the background noise data is still considered to be of use for this review.

The background noise levels were affected by insect noise at Locations A and C. At Location B, insect noise was minimal. As the insect noise is likely a seasonal influence, the noise level data has been filtered to remove the insect noise from Location A and C. The resulting background noise levels, calculated using the lowest 10th percentile method, are shown in **Table 4.2**.

Table 4.2 Background Noise Level with Insect Noise Removed

Period	Background Noise Level (Less Insect Noise) L_{90} dBA		
	Location A	Location B	Location C
Day (7am to 6pm)	33	35	25
Evening (6pm to 10pm)	23	37	29
Night (10pm to 7am)	20	27	22

5. Acoustic Criteria

5.1 Overview

Noise and vibration criteria are required to assess the potential impacts of the proposed Gemini Project operations on sensitive receptors.

The relevant Department of Environment and Science (DES) noise and vibration criteria have been considered and are listed as follows:

- Environmental Protection Act 1994
- Environmental Protection (Noise) Policy 2019
- Guideline "Planning For Noise Control"
- Guideline "Noise and Vibration from Blasting"

5.2 Environmental Protection Act

In Queensland, the environment is protected under the *Environmental Protection Act 1994* (EP Act).

Section 3 of the EP Act states that the object of the Act is to protect Queensland's environment while allowing for development that improves the total quality of life, both now and in the future, in a way that maintains the ecological processes on which life depends (ecologically sustainable development).

Section 12 of the EP Act defines noise as including *"vibration of any frequency, whether emitted through air or another medium"* and thus includes underwater noise.

Section 319 of the EP Act relates to General Environmental Duty and states that a person must not carry out any activity that causes, or is likely to cause, environmental harm unless the person takes all reasonable and practicable measures to prevent or minimise the harm.

Section 14(1) of the EP Act defines environmental harm as any adverse effect, or potential adverse effect (whether temporary or permanent and of whatever magnitude, duration or frequency) on an environmental value, and includes environmental nuisance.

Section 15 of the EP Act defines environmental nuisance as an unreasonable interference or likely interference with an environmental value caused by (a) ... noise.

Section 440 of the EP Act relates to the offence of causing a nuisance, and section 440Q relates to the offence of contravening a noise standard. In both cases, the sections state it does not apply to an environmental nuisance of the variety mentioned in schedule 1, part 1 of the EP Act.

The EP Act refers to the Environmental Protection Policies as being subordinate legislation to the Act.

5.3 Environmental Protection (Noise) Policy

5.3.1 Overview

In respect of the acoustic environment, the object of the Act is achieved by the Environmental Protection (Noise) Policy 2019 (EPP (Noise)). This policy identifies environmental values to be enhanced or protected, states acoustic quality objectives, and provides a framework for making decisions about the acoustic environment.

5.3.2 Acoustic Quality Objectives

The EPP (Noise) contains a range of acoustic quality objectives for a range of receptors. The objectives are in the form of noise levels, and are defined for various periods of the day, and use a number of acoustic parameters.

Schedule 1 of the EPP(Noise) includes the following acoustic quality objectives to be met at residential dwellings:

- Outdoors
    - Daytime and Evening: 50 dBA $L_{Aeq,adj,1hr}$, 55 dBA $L_{A10,adj,1hr}$ and 65 dBA $L_{A1,adj,1hr}$
- Indoors
    - Daytime and Evening: 35 dBA $L_{Aeq,adj,1hr}$, 40 dBA $L_{A10,adj,1hr}$ and 45 dBA $L_{A1,adj,1hr}$
    - Night: 30 dBA $L_{Aeq,adj,1hr}$, 35 dBA $L_{A10,adj,1hr}$ and 40 dBA $L_{A1,adj,1hr}$

Based on the previously published DES Guideline "Planning For Noise Control" (refer **Section 5.4**) the noise reduction provided by a typical residential building façade is 7 dBA with windows open.

Based on a façade reduction of 5 dBA (5 dBA reduction in noise levels from outside a house to inside a house when windows are fully open), the indoor noise objectives noted above could be converted to the following external objectives (with windows open) for monitoring:

- Daytime and Evening: 40 dBA $L_{Aeq,adj,1hr}$, 45 dBA $L_{A10,adj,1hr}$ and 50 dBA $L_{A1,adj,1hr}$
- Night: 35 dBA $L_{Aeq,adj,1hr}$, 40 dBA $L_{A10,adj,1hr}$ and 45 dBA $L_{A1,adj,1hr}$

A sensitive receptor is defined as "an area or place where noise is measured".

5.3.3 Background Creep

The current 2019 version of the EPP(Noise) no longer contains criteria for background creep, but states that background creep should be prevented or minimised, to the extent that it is reasonable to do so.

Background creep is defined as "a gradual increase in the total amount of background noise in the area or place as measured under the document called the 'Noise measurement manual' published on the department's website". This is understood to require consideration of cumulative impacts, including other developments.

5.4 Guideline – Planning for Noise Control

DES had previously published a guideline titled "Planning for Noise Control". The Planning for Noise Control guideline is currently listed as being "under review" according to the DES website. As such, it is not proposed to utilise the noise criteria contained within the document.

The document did contain some guidance on noise assessment, measurement and modelling, including the following:

- "Noise levels are calculated at the noise sensitive places for a range of typical operating scenarios and conditions that are representative of the proposed activity, including worst-case meteorological conditions."
- A method for determining the minimum background noise level using the lowest tenth percentile methodology is provided.

5.5 Guideline – Noise & Vibration from Blasting

The DES Guideline "Noise and vibration from blasting" contains criteria and procedures that are applicable to noise and vibration emitted from blasting. It applies to activities such as mining, quarries, construction and other operations which involve the use of explosives for fragmenting rock.

The criteria address human comfort and are below typical limits for prevention of structural damage. The criteria apply at residential and commercial receivers. The criteria are presented in **Table 5.1**.

Table 5.1 Blasting Vibration and Airblast Criteria

Issue	Criteria
Airblast	Air blast overpressure of 115 dB (linear peak) for nine (9) out of ten (10) consecutive blasts initiated and not greater than 120 dB (linear peak) at any time.
Vibration	5 mm/s peak particle velocity for nine (9) out of ten (10) consecutive blasts and not greater than 10 mm/s peak particle velocity at any time.

5.6 Proposed Criteria

5.6.1 Noise Emissions

In accordance with the EPP(Noise) and based on the calculated external limits as discussed in **Section 5.3.2**, the resulting noise limits are presented in **Table 5.2**.

Table 5.2 Proposed Noise Limits

Period	Noise Limit $L_{Aeq,adj,1hr}$ dBA
Day (7am to 6pm)	40
Evening (6pm to 10pm)	40
Night (10pm to 7am)	35

5.6.2 Blasting

It is proposed to adopt the blasting criteria from the Guideline “Noise and vibration from blasting”. The criteria are presented in **Table 5.3**.

Table 5.3 Proposed Blasting Vibration and Airblast Criteria

Issue	Criteria
Airblast	Air blast overpressure of 115 dB (linear peak) for nine (9) out of ten (10) consecutive blasts initiated and not greater than 120 dB (linear peak) at any time.
Vibration	5 mm/s peak particle velocity for nine (9) out of ten (10) consecutive blasts and not greater than 10 mm/s peak particle velocity at any time.

6. Noise Assessment

6.1 Model Description

Noise modelling was carried out using the SoundPLAN v8.2 computer program using the CONCAWE algorithms, which is widely used and accepted for noise modelling and is approved by DES.

The SoundPLAN program was used to develop a three-dimensional digital terrain noise model of the Gemini Project and the surrounding area including the location of sensitive receptors. The model incorporates terrain data for the proposed Gemini Project mine and the surrounding natural topography.

6.2 Meteorology

The mining noise levels at residential receptors can vary significantly depending upon the meteorology and the mining activities. Meteorology has a significant effect on the noise levels, particularly due to wind speed and direction and vertical temperature gradients, which include temperature inversions.

It is possible to measure noise variations of the order of 15 to 20 dBA due to changes in meteorology. Assessment is required under worst-case meteorological conditions according to the Planning for Noise Control guideline.

As per the air quality report (D16063-3_AQ_Gemini_V1.0, dated 02/10/2019), the winds are generally light to moderate and occur almost exclusively from the eastern quadrants with an average wind speed of 2.02 m/s. The distribution of winds is predominantly from the south-east. Winds are weaker during evening hours (6 pm to 6 am), and stronger during daylight hours (6 am to 6 pm).

The SoundPLAN model can model with a wind direction towards every receiver simultaneously, i.e. a worst-case scenario. However, in this instance, DES has requested modelling with specific wind directions, and thus ASK has modelled with wind from the south-east (SE) and west (W) directions.

The SoundPLAN model has been setup to predict noise levels under adverse day and night meteorological conditions. The conditions used in the noise model are shown in **Table 6.1**. It should be noted that noise emissions are not modelled under neutral (i.e. calm) or favourable (i.e. wind blowing towards the mine) conditions.

Table 6.1 Meteorological Scenarios

Parameter	Day Meteorological Scenarios			Night Meteorological Scenarios		
	Scenario D1	**Scenario D2**	**Scenario D3**	**Scenario N1**	**Scenario N2**	**Scenario N3**
Pasquill Stability Class	D	D	D	F	F	F
Temperature (°C)	25	25	25	10	10	10
Wind Speed (m/s)	2	2	2	2	2	2
Wind direction	Towards receivers	SE	W	Towards receivers	SE	W
Relative Humidity (%)	40	40	40	70	70	70

6.3 Noise Source Data

The model uses the sound power level (L_w) of each noise source to predict noise emissions. The sound power levels used in the model were based on noise source data obtained from previous mining projects or published sources. The sound power levels for the mobile and fixed equipment proposed for the Gemini Project are presented in **Table 6.2**.

Table 6.2 Noise Source Sound Power Levels

Equipment	Data Source	Octave Band Sound Power Level $L_{W,eq}$ dBZ								Overall $L_{W,eq}$	
		63	125	250	500	1k	2k	4k	8k	dBZ	dBA
Hitachi EX5600	1	129	124	114	119	111	106	104	99	131	118
Hitachi EX1900	1,2	127	121	112	116	109	103	101	97	128	116
CAT 793	1,2	115	125	120	118	113	111	104	96	127	120
CAT 777	1,2	110	112	110	111	111	109	101	96	118	115
D11	3	111	119	117	119	113	114	105	93	124	120
D10	3	111	119	117	119	113	114	105	93	124	120
CAT 994 (FEL)	1	103	110	113	109	109	104	98	94	117	113
CAT 777 (Water Cart)	1,2	110	112	110	111	111	109	101	96	119	115
CAT 16M (Grader)	1,2	108	115	112	104	104	102	98	90	118	110
Drill MD6420	2	109	111	111	110	110	109	106	101	118	115
CHPP	1,2	125	119	113	113	110	107	101	93	127	115
Conveyor Drive	2	98	97	98	100	99	94	87	78	106	102
Conveyor per 1m	2	75	74	75	77	76	71	64	55	83	79
Rail Loadout Bin	2	105	102	104	105	105	107	104	95	113	112
Train Slow Travel whilst Loading	2	110	105	104	103	104	104	101	94	114	110

The sources of data used to compile the sound power level data in **Table 6.2** are presented in **Table 6.3**.

Table 6.3 Source of Data for Equipment Sound Power Levels

Source #	Data Source
1	ASK database, based on sound power level calculated from measurements at another coal mine for the same/similar equipment.
2	Data for these sources was extracted from another similar coal mine project. Generally this data is similar to noise data for similar equipment at other mine sites and is considered suitable for noise modelling purposes.
3	Data for the tracked dozers was based on measurements at another coal mine and decreased by 5 dBA based the tracked dozers being limited to first gear only in reverse.

6.4 Modelling Scenarios

Mining noise emissions from the Gemini Project have been predicted for the following three mine year scenarios:

- Year 2
- Year 8
- Year 15

These years were selected to give a representation of mine noise levels near the beginning, middle and end of the project.

Modelling of the nominated mine year scenarios has included mine ground elevations, equipment numbers and equipment locations for each mine year based on information provided by Magnetic South Pty Ltd.

The mobile equipment numbers for the modelled mine years are presented in **Table 6.4**.

Table 6.4 Mobile Equipment Fleet in Modelled Mining Years

Equipment Type	Model #	Number of Items		
		Year 2	Year 8	Year 15
Excavator	EX5600	3	3	3
Excavator	EX1900	1	1	1
OB haul trucks	Cat 793	12	15	17
Coal haul trucks	Cat 777	1	2	3
Track Dozer	Cat D11	4	6	4
Track Dozer	Cat D10	3	3	3
Grader	Cat 16M	2	2	2
Water Cart	Cat 777	2	2	2
Drill	Cat MD6420	2	2	2
Front end loader	Cat 994	1	1	1

The locations of the equipment included in noise modelling as advised by Magnetic South Pty Ltd are provided in **Appendix D**. The location of equipment in the noise model has generally been located where it will spend the majority of time operating. Overburden trucks and dozers have generally been placed at or near the top of the dumps, except for Year 8, when waste will predominantly be dumped in-pit.

The following additional notes are provided regarding the modelled scenarios:

- Coal haul trucks will not operate during the night (10pm to 7am), and as such, have only been modelled during the day scenarios, not the night scenarios.
- The rail loadout facility will only operate when a train is being loaded, which is expected to occur on average four times per week. As such, the rail loadout facility noise sources, including conveyor system, rail loadout bin and slow-moving train being loaded, is modelled as part of a separate scenario, i.e. models of the mine only and the mine with the rail loadout facility.

The overall sound power levels of the equipment modelled in the night scenarios, excluding the rail loadout sources, are presented in **Table 6.5**.

Table 6.5 Total Scenario Sound Power Levels

Mining Year	Total Octave Band Sound Power Level $L_{W,eq}$ dBA
Year 2	133
Year 8	134
Year 15	134

6.5 Predicted Noise Levels & Assessment

6.5.1 L_{Aeq} Noise Levels

The predicted noise levels at nearby sensitive receptors for the three mining year scenarios are presented in **Table 6.6**, **Table 6.7** and **Table 6.8** for the Year 2, 8 and 15 mining years.

The results are compared against the proposed noise limits of 35 dBA L_{eq} and 40 dBA L_{eq} for the night and daytime/evening respectively, as per **Table 5.2**. Where the result exceeds the limit, the cell is shaded pink. Where the result does not exceed, the level below the criterion is included in brackets.

The predicted noise levels are also shown graphically as noise contours in **Appendix E**, as follows:

- **Figure E.1** Year 2 Scenario D1 Mine and Rail Loadout Noise Levels
- **Figure E.2** Year 8 Scenario D1 Mine and Rail Loadout Noise Levels
- **Figure E.3** Year 15 Scenario D1 Mine and Rail Loadout Noise Levels
- **Figure E.4** Year 2 Scenario N1 Mine and Rail Loadout Noise Levels
- **Figure E.5** Year 8 Scenario N1 Mine and Rail Loadout Noise Levels
- **Figure E.6** Year 15 Scenario N1 Mine and Rail Loadout Noise Levels

Note: Noise contours have not been prepared for the D2, D3, N2 and N3 scenarios, or for scenarios without the rail loadout, as they would have less noise impact than the results included in the figures.

Based on the tabulated results, no exceedances are recorded during day/evening operations, but the following night exceedances are predicted:

- Year 2:
  - SR 10: 2 dBA
  - SR 22: 1 dBA
- Year 8:
  - SR 10: 3 dBA

It is noted that receptor SR10 is located to the east of the Gemini Project, whilst receptor SR22 is located within the MLA.

Overall, the maximum predicted exceedance is 3 dBA at receptor SR10.

6.5.2 L_{Amax}, L_{A01} and L_{A10} Noise Levels

Noise levels have not been predicted in terms of L_{Amax}, L_{A01} and L_{A10} noise parameters because most mine noise source data is available in terms of the L_{Aeq} parameter. Were L_{Amax}, L_{A01} and L_{A10} noise limits to be specified for the project, they would be 15, 10 and 5 dBA higher than the L_{Aeq} noise limits respectively, as per the Sleep disturbance limit of 50 dBA L_{Amax} (equating to an indoor limit of 45 dBA L_{Amax} plus 5 dBA), and the Acoustic Quality Objectives in **Section 5.3.2**.

It is ASK's experience that L_{Amax}, L_{A01} and L_{A10} noise emissions from a coal mine would generally comply with the L_{Amax}, L_{A01} and L_{A10} noise limits if the L_{Aeq} noise level complies with the L_{Aeq} noise limit, and therefore no further assessment is proposed for the L_{Amax}, L_{A01} and L_{A10} parameters.

It is noted that L_{A01} and L_{A10} noise limits cannot be accurately used for compliance during warmer months because the L_{A01} and L_{A10} noise levels are generally dominated by insect noise. It is not strictly possible to remove insect noise from the measured L_{A01} and L_{A10} noise levels, and therefore these parameters are not as useful for compliance monitoring as the L_{Aeq} parameter.

The L_{Amax} parameter can also be challenging for compliance monitoring as extraneous L_{Amax} events (e.g. birds, animals, farm activities) need to be removed from the noise monitoring data.

6.6 Cumulative Noise Impacts

As described in **Section 2**, the nearest other existing mine is Bluff Mine to the west. The sensitive receptors that have the most potential to be impacted by the Gemini Project to the west are SR22, SR31 and SR32 with noise levels of up to 36 dBA, 33 dBA and 31 dBA L_{Aeq} respectively.

The Bluff Mine is over 12 km from these receptors (SR22, SR31 and SR32) and only 1 km from the township of Bluff. Given the requirement to comply with noise criteria in the township, it would be expected that Bluff mine noise levels at the receptors would be well below the 35 dBA noise limit, and would not significantly contribute to exceedances at these locations.

Table 6.6 Predicted Year 2 Noise Levels

Receptor	Predicted Noise Emission Levels, L_{eq} dBA																	
	Day Meteorological Scenarios									Night Meteorological Scenarios								
	Mine Only			Mine & Rail Loadout			Exceedance of 40 dBA Day Criterion			Mine Only			Mine & Rail Loadout			Exceedance of 35 dBA Night Criterion		
Scenario	D1	D2	D3	D1	D2	D3	D1	D2	D3	N1	N2	N3	N1	N2	N3	N1	N2	N3
SR01	23	24	15	24	24	15	(-16)	(-16)	(-25)	24	24	18	24	24	19	(-11)	(-11)	(-16)
SR03	31	23	31	31	23	31	(-9)	(-17)	(-9)	32	30	32	32	30	32	(-3)	(-5)	(-3)
SR05	26	25	17	26	25	17	(-14)	(-15)	(-23)	26	27	20	26	28	20	(-9)	(-7)	(-15)
SR07	31	24	31	31	24	31	(-9)	(-16)	(-9)	32	32	32	32	32	32	(-3)	(-3)	(-3)
SR08	24	25	15	24	25	15	(-16)	(-15)	(-25)	25	25	19	25	26	19	(-10)	(-9)	(-16)
SR10	36	29	36	36	29	36	(-4)	(-11)	(-4)	37	37	37	37	37	37	2	2	2
SR13	33	25	33	33	25	33	(-7)	(-15)	(-7)	34	33	34	34	33	34	(-1)	(-2)	(-1)
SR16	29	30	29	29	30	29	(-11)	(-10)	(-11)	30	30	30	30	30	30	(-5)	(-5)	(-5)
SR17	26	27	17	26	27	17	(-14)	(-13)	(-23)	27	27	21	27	27	21	(-8)	(-8)	(-14)
SR22	33	34	24	35	35	25	(-5)	(-5)	(-15)	35	35	29	36	36	30	1	1	(-5)
SR26	26	18	26	26	18	26	(-14)	(-22)	(-14)	27	25	27	27	25	27	(-8)	(-10)	(-8)
SR27	27	20	27	27	20	27	(-13)	(-20)	(-13)	28	28	28	28	28	28	(-7)	(-7)	(-7)
SR28	27	20	27	27	20	27	(-13)	(-20)	(-13)	28	28	28	28	28	28	(-7)	(-7)	(-7)
SR30	27	20	27	27	20	27	(-13)	(-20)	(-13)	28	29	28	28	29	28	(-7)	(-6)	(-7)
SR31	31	31	21	31	32	22	(-9)	(-8)	(-18)	32	32	26	33	33	26	(-2)	(-2)	(-9)
SR32	29	29	20	30	30	20	(-10)	(-10)	(-20)	30	30	24	31	31	25	(-4)	(-4)	(-10)

Table 6.7 Predicted Year 8 Noise Levels

Receptor	Predicted Noise Emission Levels, L_{eq} dBA																	
	Day Meteorological Scenarios									Night Meteorological Scenarios								
	Mine Only			Mine & Rail Loadout			Exceedance of 40 dBA Day Criterion			Mine Only			Mine & Rail Loadout			Exceedance of 35 dBA Night Criterion		
Scenario	**D1**	**D2**	**D3**	**D1**	**D2**	**D3**	**D1**	**D2**	**D3**	**N1**	**N2**	**N3**	**N1**	**N2**	**N3**	**N1**	**N2**	**N3**
SR01	21	22	12	21	22	12	(-19)	(-18)	(-28)	22	22	16	22	22	16	(-13)	(-13)	(-19)
SR03	32	24	32	32	24	32	(-8)	(-16)	(-8)	33	31	33	33	31	33	(-2)	(-4)	(-2)
SR05	24	23	15	24	23	15	(-16)	(-17)	(-25)	25	26	18	25	26	18	(-10)	(-9)	(-17)
SR07	32	24	32	32	24	32	(-8)	(-16)	(-8)	33	33	33	33	33	33	(-2)	(-2)	(-2)
SR08	22	23	13	23	23	13	(-17)	(-17)	(-27)	23	24	17	24	24	17	(-11)	(-11)	(-18)
SR10	37	30	37	37	30	37	(-3)	(-10)	(-3)	38	38	38	38	38	38	3	3	3
SR13	34	26	34	34	26	34	(-6)	(-14)	(-6)	35	35	35	35	35	35	(0)	(0)	(0)
SR16	28	29	28	28	29	28	(-12)	(-11)	(-12)	29	29	30	29	29	30	(-6)	(-6)	(-5)
SR17	24	25	15	24	25	15	(-16)	(-15)	(-25)	25	25	19	25	25	19	(-10)	(-10)	(-16)
SR22	32	32	22	34	34	23	(-6)	(-6)	(-17)	33	33	27	35	35	29	(0)	(0)	(-6)
SR26	27	18	27	27	18	27	(-13)	(-22)	(-13)	28	26	28	28	26	28	(-7)	(-9)	(-7)
SR27	28	20	28	28	20	28	(-12)	(-20)	(-12)	29	29	29	29	29	29	(-6)	(-6)	(-6)
SR28	28	20	28	28	20	28	(-12)	(-20)	(-12)	29	29	29	29	29	29	(-6)	(-6)	(-6)
SR30	27	20	27	27	20	27	(-13)	(-20)	(-13)	28	30	28	28	30	28	(-7)	(-5)	(-7)
SR31	29	30	19	30	30	20	(-10)	(-10)	(-20)	30	30	24	31	31	24	(-4)	(-4)	(-11)
SR32	27	28	17	28	29	18	(-12)	(-11)	(-22)	29	29	22	30	30	23	(-5)	(-5)	(-12)

Table 6.8 Predicted Year 15 Noise Levels

Receptor	Predicted Noise Emission Levels, L_{eq} dBA																	
	Day Meteorological Scenarios									Night Meteorological Scenarios								
	Mine Only			Mine & Rail Loadout			Exceedance of 40 dBA Day Criterion			Mine Only			Mine & Rail Loadout			Exceedance of 35 dBA Night Criterion		
Scenario	D1	D2	D3	D1	D2	D3	D1	D2	D3	N1	N2	N3	N1	N2	N3	N1	N2	N3
SR01	22	23	13	23	23	13	(-17)	(-17)	(-27)	23	23	18	23	23	18	(-12)	(-12)	(-17)
SR03	24	18	24	24	18	25	(-16)	(-22)	(-15)	25	28	25	25	28	25	(-10)	(-7)	(-10)
SR05	28	28	18	28	28	18	(-12)	(-12)	(-22)	28	29	22	28	29	22	(-7)	(-6)	(-13)
SR07	24	19	24	24	19	24	(-16)	(-21)	(-16)	24	27	24	25	27	25	(-10)	(-8)	(-10)
SR08	24	24	14	24	24	14	(-16)	(-16)	(-26)	25	25	19	25	25	19	(-10)	(-10)	(-16)
SR10	27	23	27	27	23	27	(-13)	(-17)	(-13)	28	29	28	28	29	28	(-7)	(-6)	(-7)
SR13	25	21	26	25	21	26	(-15)	(-19)	(-14)	26	28	26	26	28	26	(-9)	(-7)	(-9)
SR16	20	21	21	21	21	22	(-19)	(-19)	(-18)	21	21	21	21	22	21	(-14)	(-13)	(-14)
SR17	26	26	16	26	26	16	(-14)	(-14)	(-24)	27	27	21	27	27	21	(-8)	(-8)	(-14)
SR22	32	32	23	33	33	24	(-7)	(-7)	(-16)	33	33	29	35	35	30	(0)	(0)	(-5)
SR26	21	15	21	21	15	21	(-19)	(-25)	(-19)	21	24	21	22	24	22	(-13)	(-11)	(-13)
SR27	22	16	22	22	16	22	(-18)	(-24)	(-18)	22	25	22	22	25	22	(-13)	(-10)	(-13)
SR28	22	16	22	22	16	22	(-18)	(-24)	(-18)	22	25	22	22	25	22	(-13)	(-10)	(-13)
SR30	22	17	22	22	17	22	(-18)	(-23)	(-18)	22	25	22	22	25	22	(-13)	(-10)	(-13)
SR31	30	30	20	30	30	21	(-10)	(-10)	(-19)	31	31	26	32	32	26	(-3)	(-3)	(-9)
SR32	28	28	19	28	29	19	(-12)	(-11)	(-21)	29	29	24	30	30	25	(-5)	(-5)	(-10)

7. Blasting Assessment

7.1 Overview

It is anticipated that the existing vibration levels around the mine site and at the location of sensitive receptors will generally be negligible, except at locations which are close to roads, rail lines or near major items of fixed plant.

The only vibration source of significance from the mining of the Gemini Project would be blasting. Blasting activities within the pits have been assessed for both ground vibration and airblast. The relevant criteria for ground vibration and airblast have been presented and discussed in **Section 5.6.2**.

7.2 Predictions

Ground vibration and airblast levels caused by blasting activities have been predicted based on the formulas and methodology of Australian Standard AS2187.2 "Explosives - Storage Transport and Use - Use of Explosives", which predicts the peak particles velocity (PPV) in mm/s and the airblast over pressure (peak pressure) in dB.

7.2.1 Ground Vibration

In accordance with the criteria presented in **Section 5.6.2**, ground vibration levels are to achieve 5mm/s PPV for nine out of ten blasts and not greater than 10mm/s PPV at any time. Ground vibration can be calculated at various distances from a blast using the following formula from AS2187.2:

$$V = K (R / Q^{1/2})^{-B}$$

where: V = ground vibration as peak particle velocity (PPV) (mm/s)
K = site constant
R = distance between charge and point of measurement (m)
Q = effective charge mass per delay or maximum instantaneous charge (kg)
B = site exponent or attenuation rate

Ground vibration from blasting generally increases with an increase in charge mass and reduces with distance.

A site exponent (-B) (attenuation rate) of –1.6 has been estimated for the site based on ASK's experience with similar mining projects. The site constant (K) was assumed to be in the range 800 to 1600. The maximum instantaneous charge mass will be 900 kg as advised by Magnetic South Pty Ltd.

Table 7.1 contains the calculated ground vibration levels (mm/s) at various distances from the blast.

Table 7.1 Ground Vibration Levels at Various Distances from the Blast

Distance from Blast km	Vibration Level mm/s	
	K = 800	K = 1600
1.0	2.9	5.9
1.5	1.5	3.1
2.0	1.0	1.9
2.5	0.7	1.4
3.0	0.5	1.0
3.5	0.4	0.8
4.0	0.3	0.6
4.5	0.3	0.5
5.0	0.2	0.4
5.5	0.2	0.4
6.0	0.2	0.3
6.5	0.1	0.3
7.0	0.1	0.3
7.5	0.1	0.2
8.0	0.1	0.2
8.5	0.1	0.2
9.0	0.1	0.2
9.5	0.1	0.2
10.0	0.1	0.1

Table 7.1 shows that the 10 mm/s PPV criterion would not be exceeded at distances greater than 1.0 kilometre from the blast. The 5 mm/s PPV criterion would not be exceeded at distances greater than 1.5 kilometres from the blast.

The nearest sensitive receptor is approximately 1.9 kilometres away from the nearest pit within the proposed Gemini Project area. Therefore, ground vibration due to blasting is predicted to be compliant with the nominated criteria at all sensitive receptors.

Blast parameters will need to be reviewed to ensure that the nominated vibration criteria are met at all locations.

7.2.2 Airblast

In accordance with the criteria presented in **Section 5.6.2**, airblast pressure levels are to achieve 115 dBZ for nine out of ten blasts and not greater than 120 dBZ at any time. For blasting in an open-cut mine, the distance to the 120 dBZ L_{peak} contour line from the blast can be calculated using the following formula:

$$D_{120} = (k * h / \text{maximum } (B, S))^{2.5} * m^{1/3}$$

Where: D_{120} = distance to the 120 dBZ L_{peak} contour (m)

k = a site constant determined from the ratio S/B and S/h which requires local calibration
h = hole diameter (mm)
B = burden (mm)
S = stemming height (mm)
m = charge mass (kg)

The site constant, k, has been assumed to be equal to 180 based on ASK's experience with other mining projects.

The following blast information has been provided by Magnetic South Pty Ltd:

- h = 270 mm
- S = 8000 mm
- B = 8000 mm
- m = 900 kg

Table 7.2 contains the separation distances and the reduction of noise levels due to distance.

Table 7.2 Airblast Noise Levels at Various Distances from the Blast

Distance from Blast km	Airblast Level, dBZ
1.0	118.3
1.5	113.0
2.0	109.3
2.5	106.4
3.0	104.0
3.5	102.0
4.0	100.3
4.5	98.8
5.0	97.4
5.5	96.2
6.0	95.0
6.5	94.0
7.0	93.0
7.5	92.2
8.0	91.3
8.5	90.5
9.0	89.8
9.5	89.1
10.0	88.4

The distance to the 120 dBZ contour line is calculated to be 880 metres. The distance to the 115 dBZ contour line is calculated to be 1,290 metres.

Based on these calculations and blast parameters, the airblast criteria would not be exceeded at any sensitive receptors.

7.3 Assessment

Based on the blasting calculations presented within this section, the ground vibration and airblast levels from open cut operations within the Gemini Project are predicted to be acceptable at the nearest sensitive receptors based on the nominated criteria.

8. Noise Management Plan

8.1 Overview

Noise modelling has predicted noise level exceedances at some receptors as outlined in **Section 6**. The predicted noise levels are therefore expected to result in noise levels exceeding the EPP(Noise) Acoustic Quality Objectives inside these receptors.

To achieve the Acoustic Quality Objectives inside the receptors, the following opportunities are considered:

- Ceasing operations at times of the day that are predicted to result in exceedances.
- Ceasing operations under meteorological conditions that are predicted to result in exceedances.
- Moving mine equipment further from the receptors.
- Reducing quantity of mine equipment, i.e. lower production.
- Incorporating noise mitigation measures to equipment, particularly the mobile fleet.
- Providing acoustic or ventilation upgrades to the receptors.
- Relocating the receptors further from the mine.

The first four of the above opportunities could be considered by the mine, whereas the last two opportunities would require acceptance from the residents.

As disused in **Section 6.6**, receivers SR09, SR14, SR15, SR18, SR19, SR20, SR21, SR23 and SR24 are owned or are to be purchased by Magnetic South at the time of report preparation. The results in **Table 6.6**, **Table 6.7** and **Table 6.8** indicate there are no day/evening exceedances but the following night exceedances:

- Year 2:
  - SR 10: 2 dBA
  - SR 22: 1 dBA
- Year 8:
  - SR 10: 3 dBA

Noise management opportunities are discussed in the following sections of the report to achieve night time compliance.

8.2 Review of Noise Management Opportunities

8.2.1 Ceasing Operations in Various Time Periods

Based on the predictions noise level exceedances are only predict at night time scenarios for most of the receptors. Therefore, ceasing operations in particular time periods (e.g. night) can be considered in this assessment.

8.2.2 Ceasing Operations under Particular Meteorological Conditions

From **Table 6.6** to **Table 6.8,** it can be seen that modelled meteorological conditions affect the noise levels at the residence.

It would be possible to setup a real time noise monitors at highly affected receptors, so that the mine can alter operations according to measured noise levels, and thus react to meteorological conditions. However, it is ASK's experience that this form of reactive operation is difficult to plan for, and it is preferable to have operations that meet noise limits under most, if not all, meteorological conditions.

8.2.3 Moving Mine Equipment Further from the Receptors

Moving noisy equipment away from the most affected sensitive receptors can be considered to minimize noise effects.

8.2.4 Reduce Quantity of Mine Equipment, i.e. Lower Mine Output

If mine output was reduced, then the quantity of mine equipment could also be reduced, thereby resulting in lower noise emission levels.

A halving of equipment would be expected to provide a reduction of 3 dBA, assuming the shutdown equipment was spread around the mine operations. Similarly, reducing to a quarter of the equipment would be expected to provide a reduction of 6 dBA. If the equipment to be shutdown was the equipment located closest to the receptor, then the reduction could be greater.

8.2.5 Noise Mitigation of Equipment

Noise mitigation measures can be applied to equipment, including all the mobile equipment which is located near to the receptors. The noise reductions can be of the order of 3 to 8 dBA, and the costs can be of the order of a $250,000 to $750,000 per item of equipment.

8.2.6 Noise Mitigation between Equipment and Receptors

Noise mitigation measures can include bunding constructed between equipment and the receptors. Noise bunding is generally most effective when constructed near the source, e.g. adjacent a haul road, or near the receptors. Noise reduction via this technique is likely to be limited to less than 5 dBA even with quite significant bunding heights.

8.3 Mitigation Scenarios

Based on the results discussed in **Section 6.5** noise affected receptors are SR10 and SR22. The noise mitigation scenarios are outlined in **Table 8.1** for these receptors and focus on removing or relocating equipment.

Table 8.1 Example Mitigated Scenarios

Year	Scenario	Examples Scenarios and Resulting Noise Levels Under Adverse Conditions for Each Time Period	
		Day and Evening (7am to 10pm)	Night (10pm to 7am)
Year 2	Original	36 dBA at SR10 and 35 dBA at SR22, as per **Table 6.6**.	37 dBA at SR10 and 36 dBA at SR22, as per **Table 6.6**.
	Option 2A	No change to day/evening operations. Results as per Original scenario.	35 dBA at SR10 and 35 dBA at SR22, i.e. compliance achieved when 5 of 12 x OB haul trucks are removed.
Year 8	Original	37 dBA at SR10, as per **Table 6.7.**	38 dBA at SR10, as per **Table 6.7**.
	Option 8A	No change to day/evening operations. Results as per Original scenario.	35 dBA at SR10, i.e. compliance achieved when 1 of 6 x D11 dozers are removed from dump and 6 of 15 x OB haul trucks are removed.

It is proposed that the mine could operate compliantly by selecting operating to the optional scenarios in **Table 8.1**. The optional scenarios presented in **Table 8.1** should be considered examples only, and other acoustically equivalent scenarios could be developed.

8.4 Noise Monitoring

It is recommended that noise level compliance be confirmed by real time noise monitoring at the most noise affected receptor/s (i.e. SR10 and SR22, should they not be purchased by the mine operators), and that monitoring be commenced prior to mine operation.

The real time noise monitoring system should report one-third octave band noise levels (including L_{eq}, $L_{1,}$ L_{10} and L_{90}) over 15 minute periods, and should also provide audio recording/snapshots and 1 second time period noise levels. The system should have the capability to email, sms or otherwise transmit alerts to mine operators to enable the mine to react to potential exceedances, and should ideally also provide a web portal interface where mine operators can track the noise trends during night periods.

9. Recommendations and Conclusions

A noise and vibration impact assessment has been conducted for the proposed Gemini Project. Noise monitoring was conducted at three sensitive receptor locations. A noise model has been developed for proposed mining activities for mining years 2, 8 and 15 to predict noise emission levels at nearby sensitive receptors. Calculations have also been made to predict noise and vibration levels due to blasting.

From this assessment, the following conclusions are made:

- Noise criteria for the mine have been proposed in **Section 5.6**, which includes noise limits of 40 dBA $L_{Aeq,adj,1hr}$ in the day and evening and 35 dBA $L_{Aeq,adj,1hr}$ in the night. These limits are consistent with other coal mining projects.
- From the predicted noise levels in **Section 6.5**, no exceedances are predicted during the day/evening period, but minor exceedances of up to 3 dBA are predicted at receptors SR10 and SR22 during the night-time.
- Cumulative noise impacts are discussed in **Section 6.6**. Cumulative impacts from other mines are not expected to be an issue.
- Based on the blasting parameters and calculations in **Section 7**, the ground vibration and airblast levels from blasting are predicted to be acceptable at the nearest sensitive receptors.
- Given there are exceedances predicted, a noise management plan is included in **Section 8**.

Appendix A Glossary

Parameter or Term	Description
dB	The decibel (dB) is the unit measure of sound. Most noises occur in a range of 20 dB (quiet rural area at night) to 120 dB (nightclub dance floor or concert).
dBA	Noise levels are most commonly expressed in terms of the 'A' weighted decibel scale, dBA. This scale closely approximates the response of the human ear, thus providing a measure of the subjective loudness of noise and enabling the intensity of noises with different frequency characteristics (e.g. pitch and tone) to be compared.
Frequency	The number of vibrations, or complete cycles, that take place in one second. Measured in hertz (Hz), where one Hz equals one cycle per second. A young person with normal hearing will be able to perceive frequencies between approximately 20 and 20,000 Hz. With increasing age, the upper frequency limit tends to decrease.
dB, dB(linear) or dBZ	Noise levels are sometimes expressed in terms of the linear, Z or un-weighted decibel scale – they all take the same meaning. The value has no weighting applied to it and is the same as the dB level.
dBC	Noise levels are sometimes expressed in terms of the 'C' weighted decibel scale, dB(C). This scale is very similar to the dB, dB, dB(linear), dBZ un-weighted scale. The difference being that some negative weighting is applied below 250Hz and above 1kHz. The magnitude of the weighting is significantly less than the dBA scale.
Octave band	Ranges of frequencies where the highest frequency of the band is double the lowest frequency of the band. The band is usually specified by the centre frequency, i.e. 31.5, 63, 125, 250, 500 Hz, etc.
Day	The period between 7am and 6pm.
Evening	The period between 6pm and 10pm.
Night	The period between 10pm and 7am.
Free-field	The description of a noise receiver or source location which is away from any significantly reflective objects (e.g. buildings, walls).
Noise sensitive receiver or Noise sensitive receptor	The definition can vary depending on the project type or location, but generally defines a building or land area which is sensitive to noise. Generally it includes residential dwellings (e.g. houses, units, caravans, marina), medical buildings (e.g. hospitals, health clinics, medical centres), educational facilities (e.g. schools, universities, colleges),
L_1	The noise level exceeded for 1% of the measurement period.
L_{10}	The noise level exceeded for 10% of the measurement period. It is sometimes referred to as the average maximum noise level.
L_{90}	The noise level exceeded for 90% of the measurement period. This is commonly referred to as the background noise level.
minL_{90}	The background noise levels calculated using the 'lowest 10th percentile' of the L_{90} levels in each period of the day. This 'lowest 10th percentile' method is defined in the Queensland Department of Environment and Heritage Protection (EHP) guidelines.
L_{eq}	The equivalent continuous sound level, which is the constant sound level over a given time period, which is equivalent in total sound energy to the time-varying sound level, measured over the same time period.
$L_{eq,1hr}$	As for L_{eq} except the measurement intervals are defined as 1 hour duration.
$L_{eq,adj,T}$	The L_{eq} adjusted for tonal or impulsive noise characteristics and with a measurement interval of 'T' duration (e.g. 15 minutes, 1 hour).

Parameter or Term	Description
L_{Amax} or max L_{pA}	Maximum A-weighted sound pressure level.
Sound power level (L_W)	The sound power level of a noise source is its inherent noise, which does not vary with distance from the noise source. It is not directly measured with a sound level meter, but rather is calculated from the measured noise level and the distance at which the measurement was undertaken.

Appendix B Noise Monitoring Photos

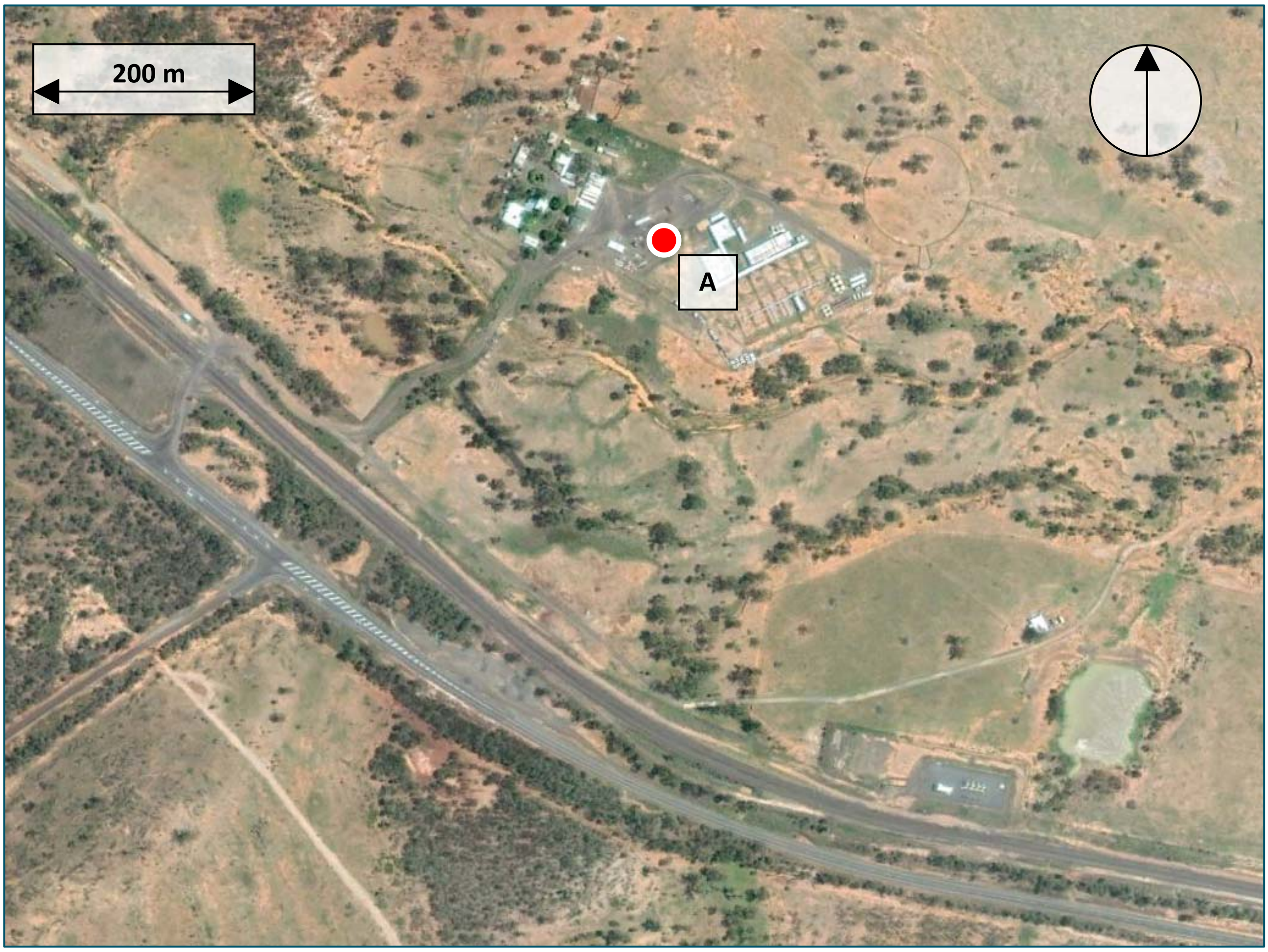


Figure B.1 Aerial Photo of Noise Monitoring Location A – Accommodation Facility

Figure B.2 Aerial Photo of Noise Monitoring Location B – Roadhouse

Figure B.3 Aerial Photo of Noise Monitoring Location C – Residence

Appendix C Noise Monitoring Results

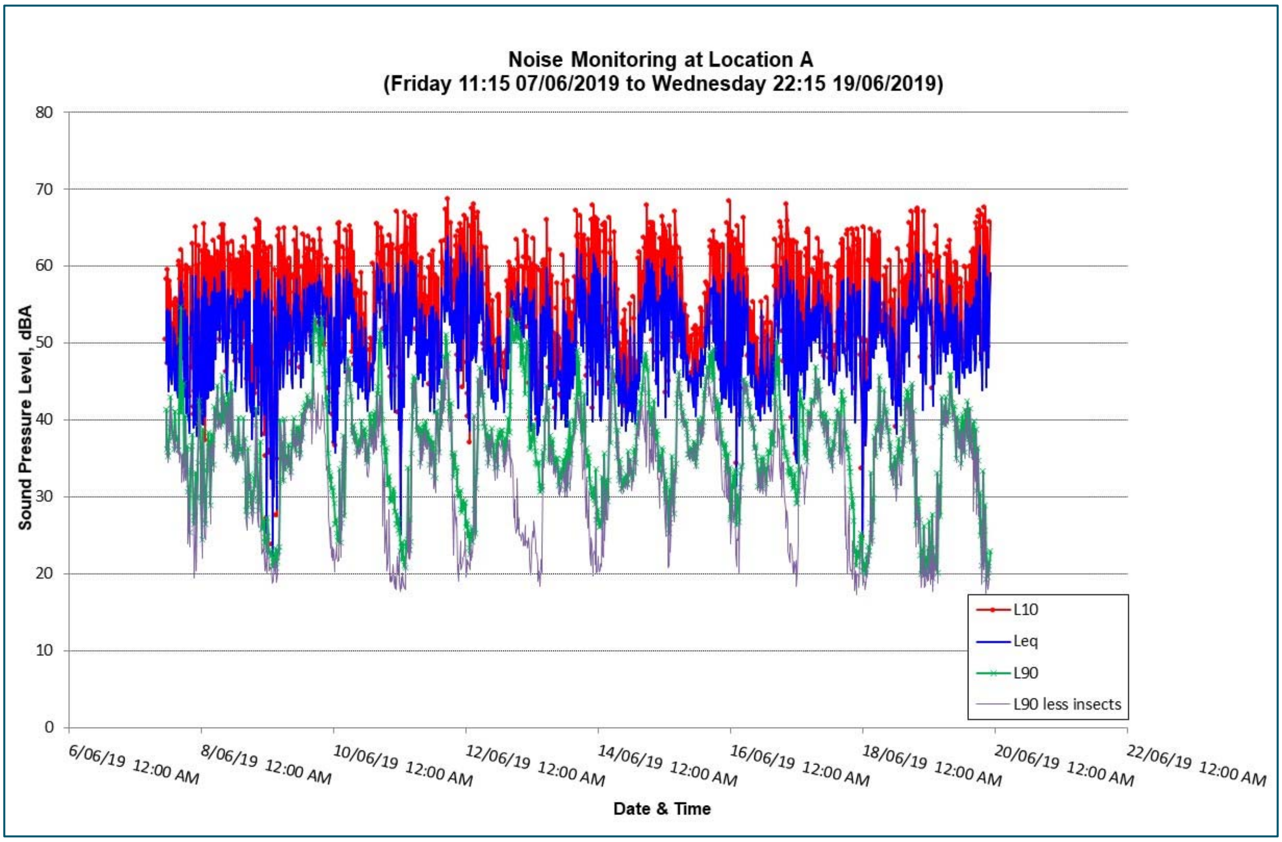


Figure C.1 Noise Monitoring Results at Location A – Accommodation Facility

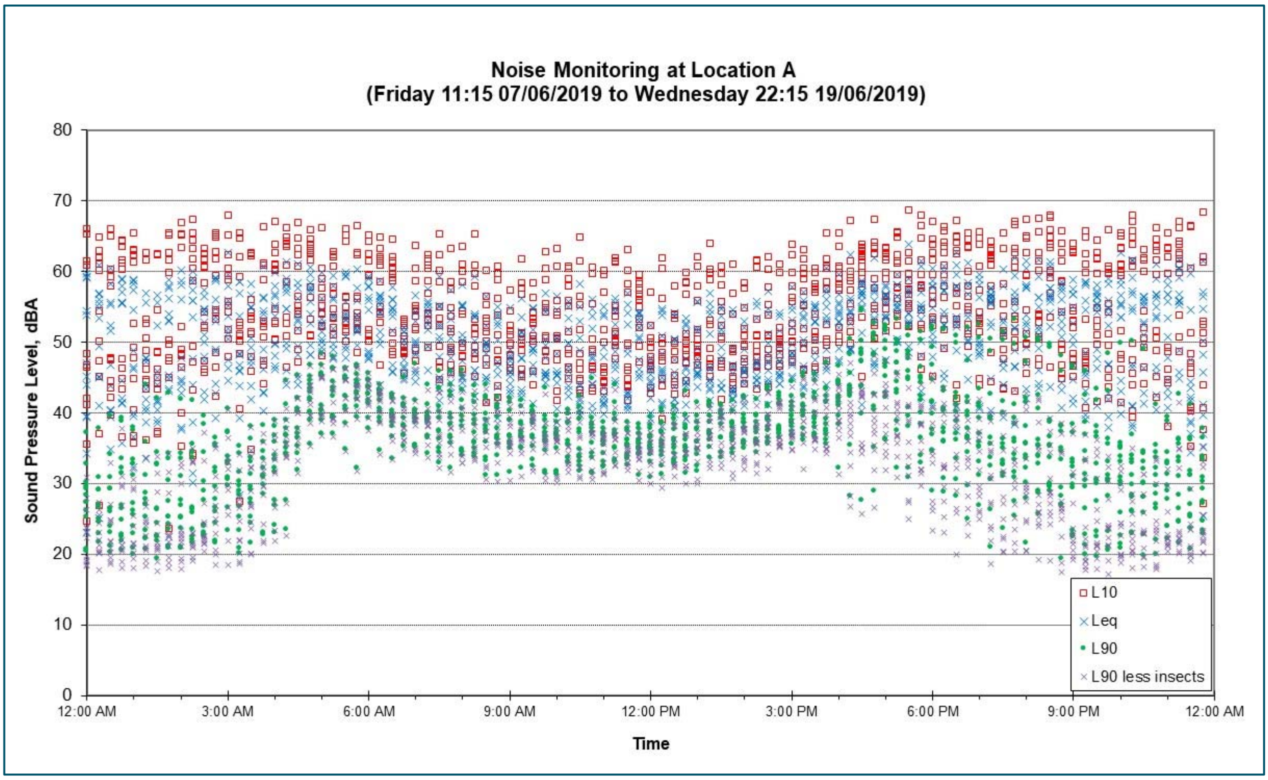


Figure C.2 24 Hour Noise Monitoring Results at Location A – Accommodation Facility

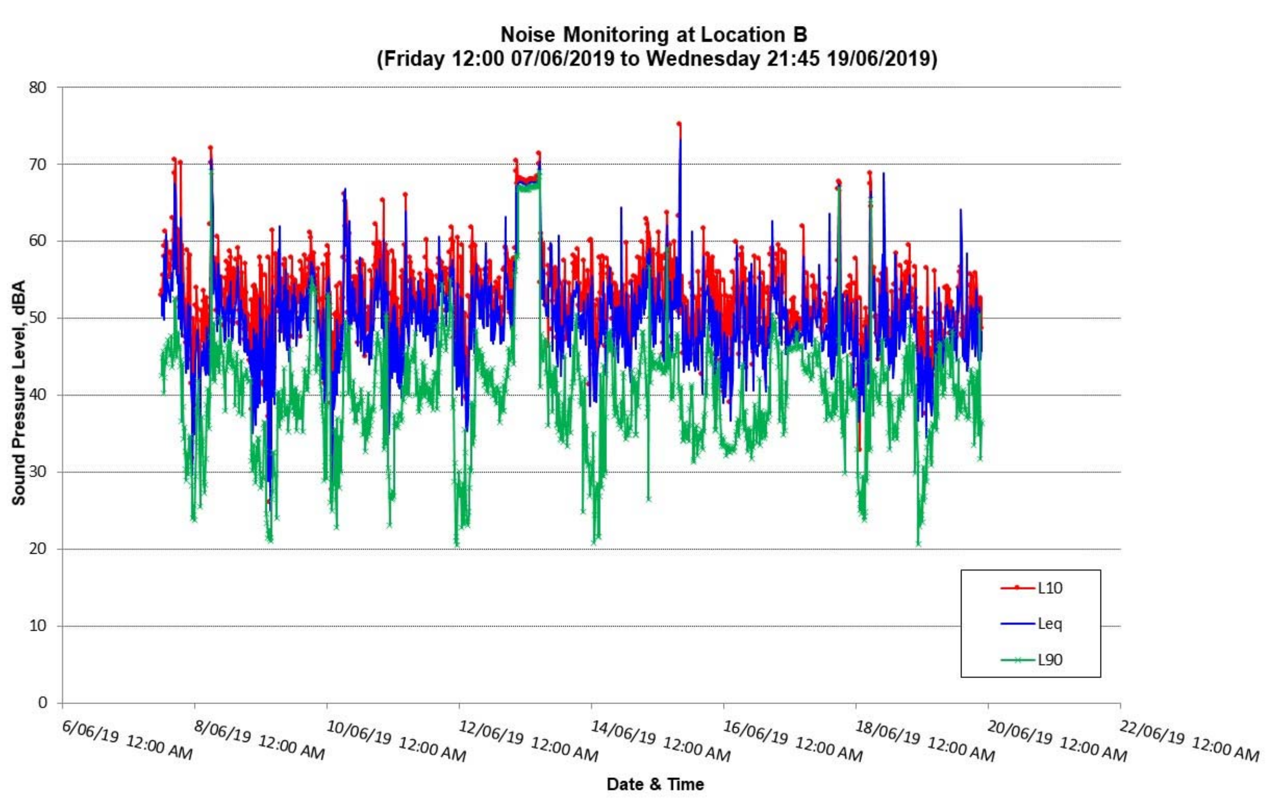


Figure C.3 Noise Monitoring Results at Location B – Roadhouse

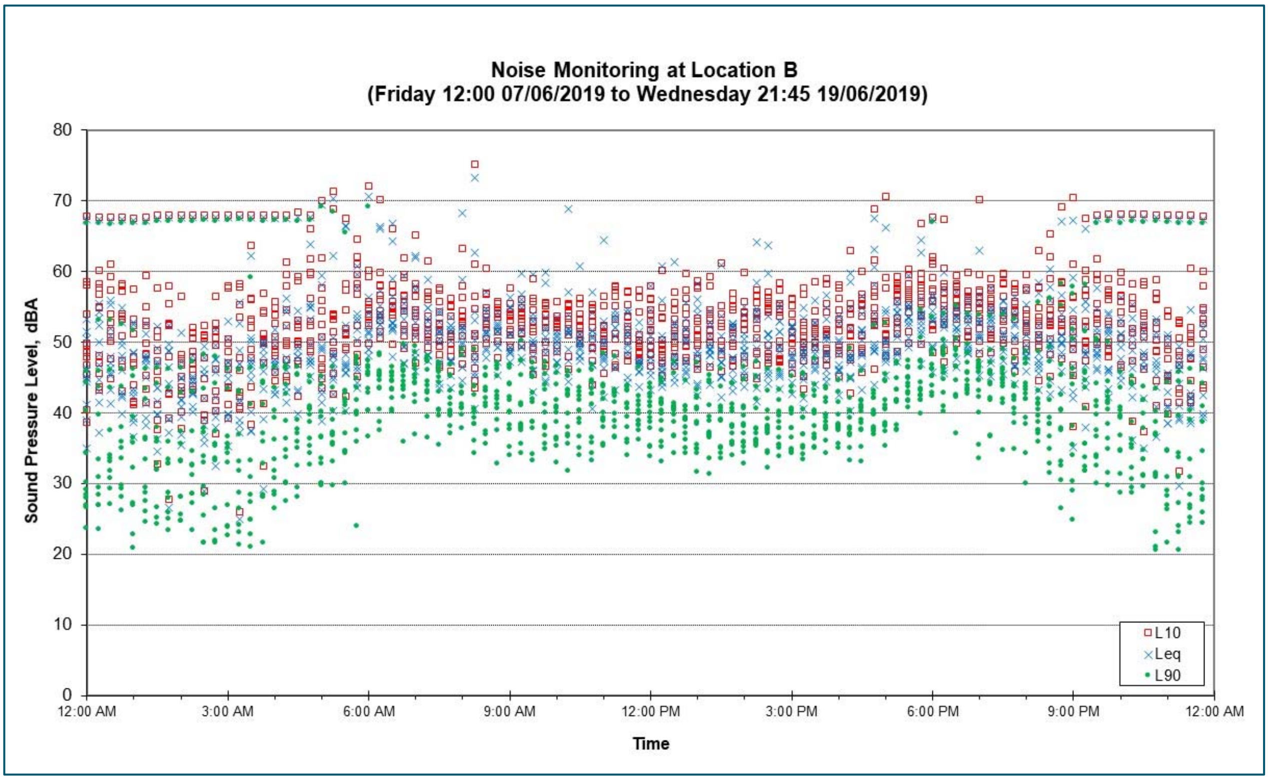


Figure C.4 24 Hour Noise Monitoring Results at Location B – Roadhouse

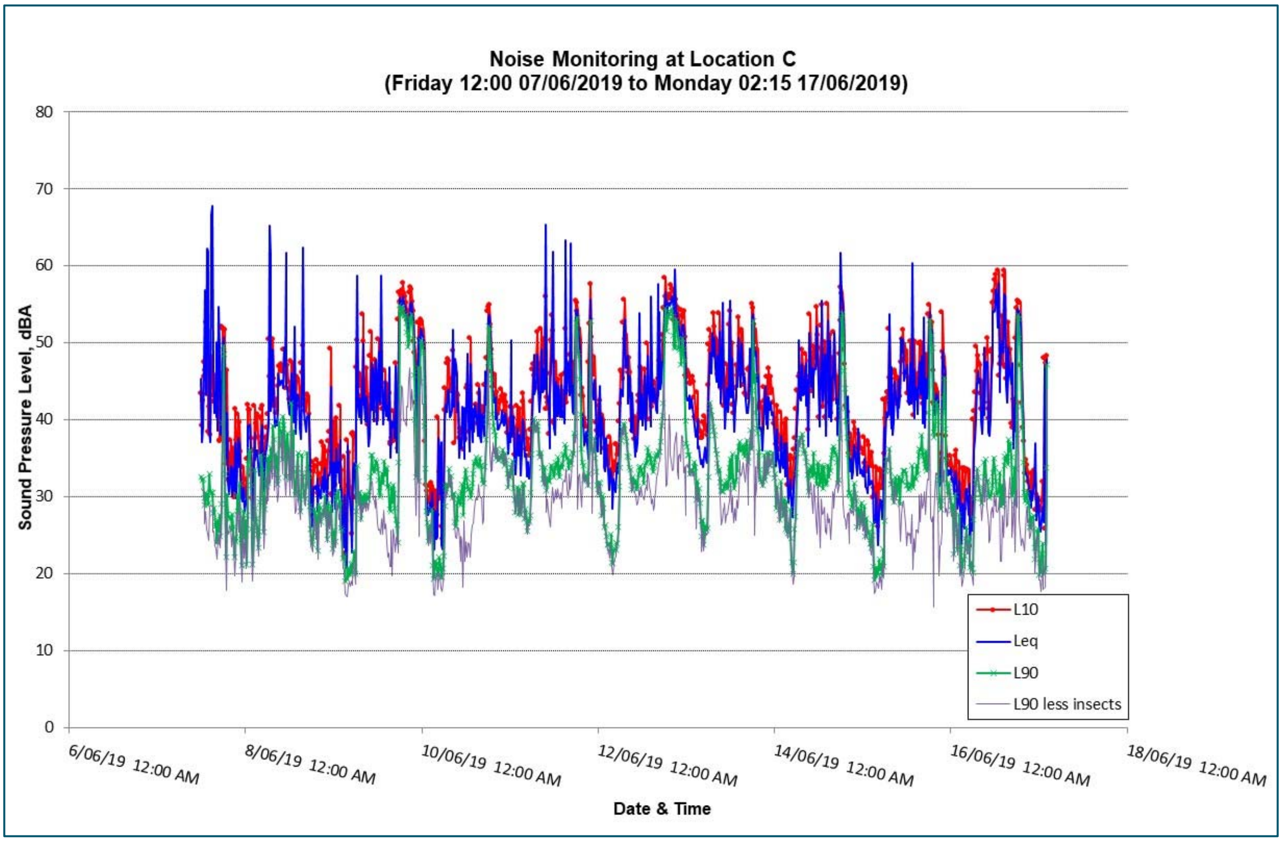


Figure C.5 Noise Monitoring Results at Location C – Residence

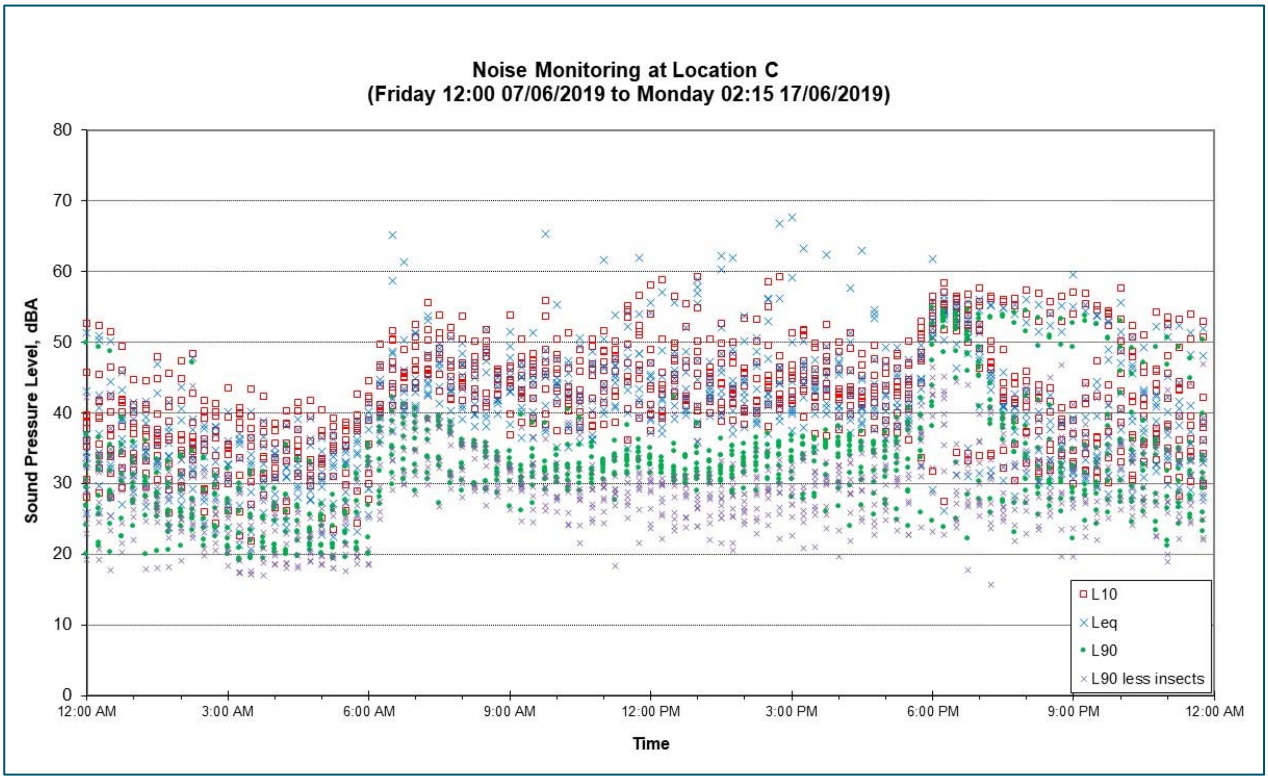


Figure C.6 24 Hour Noise Monitoring Results at Location C – Residence

Table C.1 Noise Monitoring Results at Location A – Accommodation Facility

Parameter	Noise Levels dBA [Maximum-Top 10%-(Average)-Bottom 10%-Minimum]		
	Day	Evening	Night
L_{max}	82-71-(64)-58-51	80-72-(65)-56-48	83-72-(65)-56-34
L_1	73-66-(58)-51-46	73-69-(62)-52-46	74-69-(61)-51-25
L_{10}	69-62-(53)-46-39	68-65-(56)-46-41	68-65-(55)-44-24
L_{eq}	64-56-(49)-43-38	63-59-(52)-43-38	63-59-(51)-41-22
L_{90}	55-45-(39)-34-28	53-48-(36)-27-19	50-43-(33)-23-19

Table C.2 Noise Monitoring Results at Location B – Roadhouse

Parameter	Noise Levels dBA [Maximum-Top 10%-(Average)-Bottom 10%-Minimum]		
	Day	Evening	Night
L_{max}	95-78-(68)-59-53	87-74-(65)-57-50	91-72-(62)-53-33
L_1	87-67-(60)-53-48	76-64-(58)-53-44	82-68-(56)-49-29
L_{10}	75-57-(53)-48-43	70-60-(55)-49-38	72-61-(52)-42-26
L_{eq}	73-55-(50)-45-40	68-57-(51)-46-35	71-59-(49)-39-25
L_{90}	55-46-(40)-35-31	67-51-(43)-34-25	69-47-(38)-26-21

Table C.3 Noise Monitoring Results at Location C – Residence

Parameter	Noise Levels dBA [Maximum-Top 10%-(Average)-Bottom 10%-Minimum]		
	Day	Evening	Night
L_{max}	94-76-(65)-56-48	93-60-(54)-44-38	89-61-(50)-39-29
L_1	82-63-(55)-48-42	62-57-(48)-37-31	80-52-(43)-33-25
L_{10}	59-51-(45)-40-34	58-56-(45)-33-27	58-47-(38)-30-22
L_{eq}	68-51-(44)-39-33	62-55-(43)-31-26	65-45-(36)-28-21
L_{90}	42-37-(33)-30-24	55-53-(39)-27-22	53-37-(29)-21-19

Appendix D Mining Equipment Locations

Figure D.1 Year 2 Equipment Locations

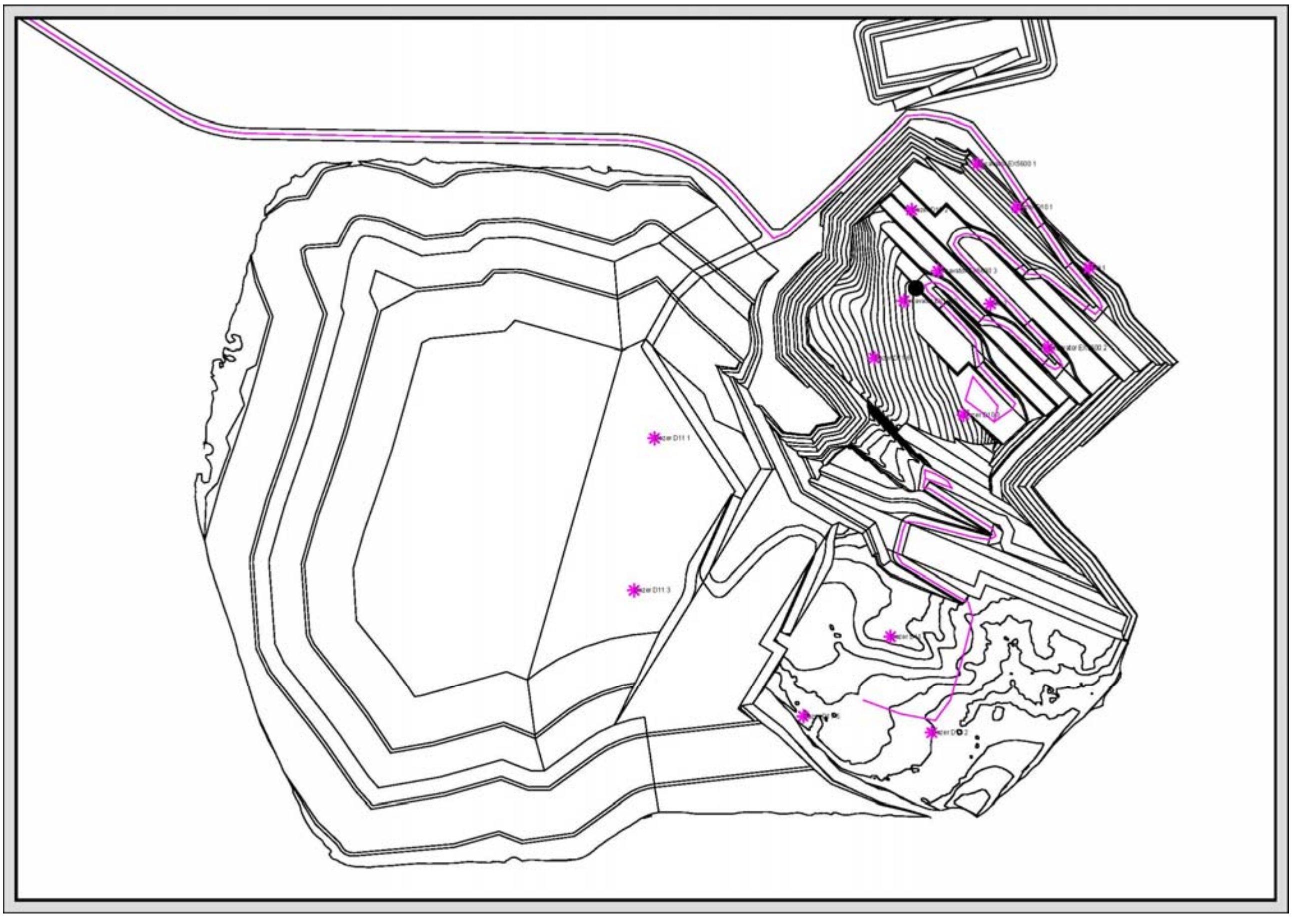


Figure D.2 Year 8 Equipment Locations

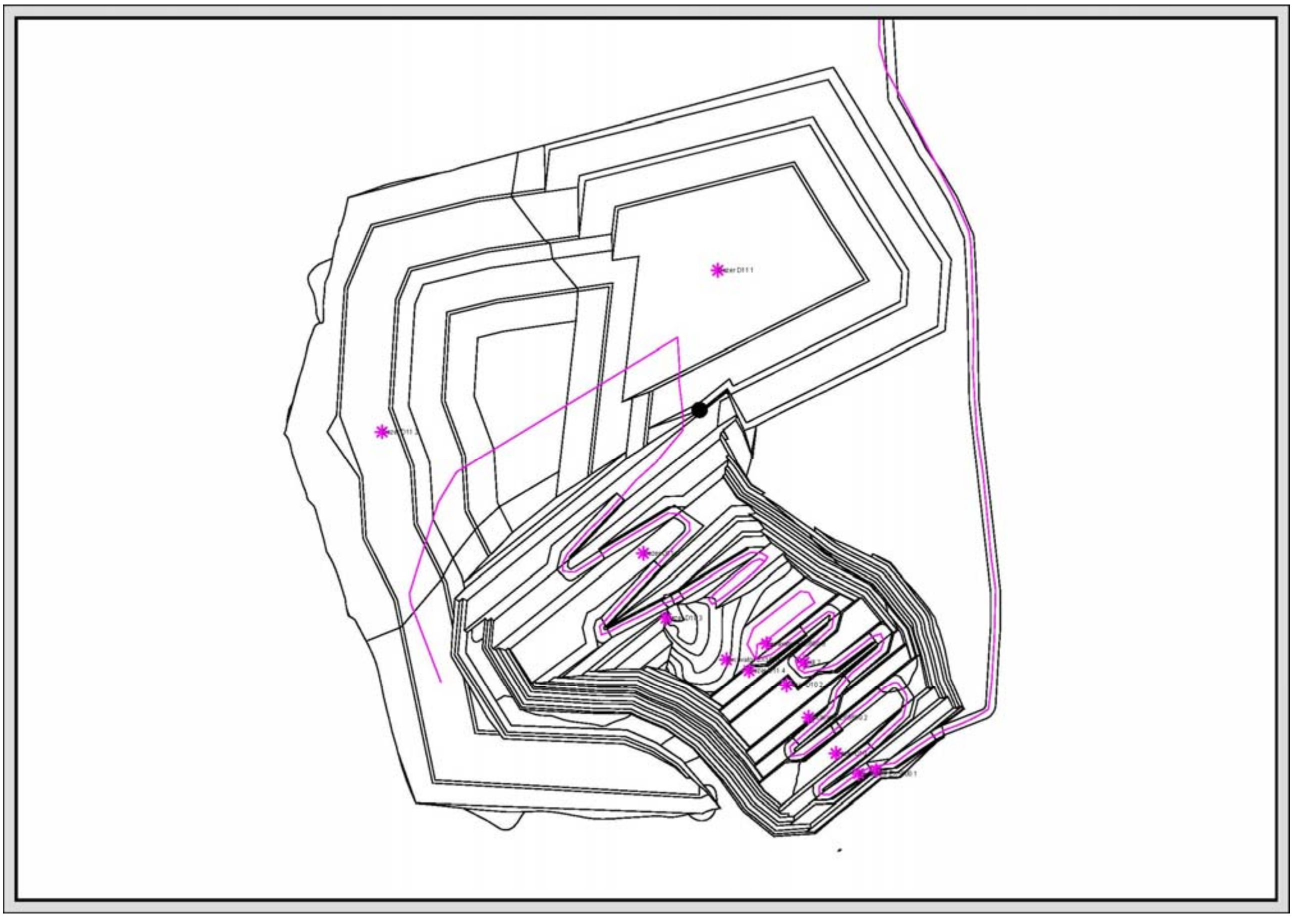
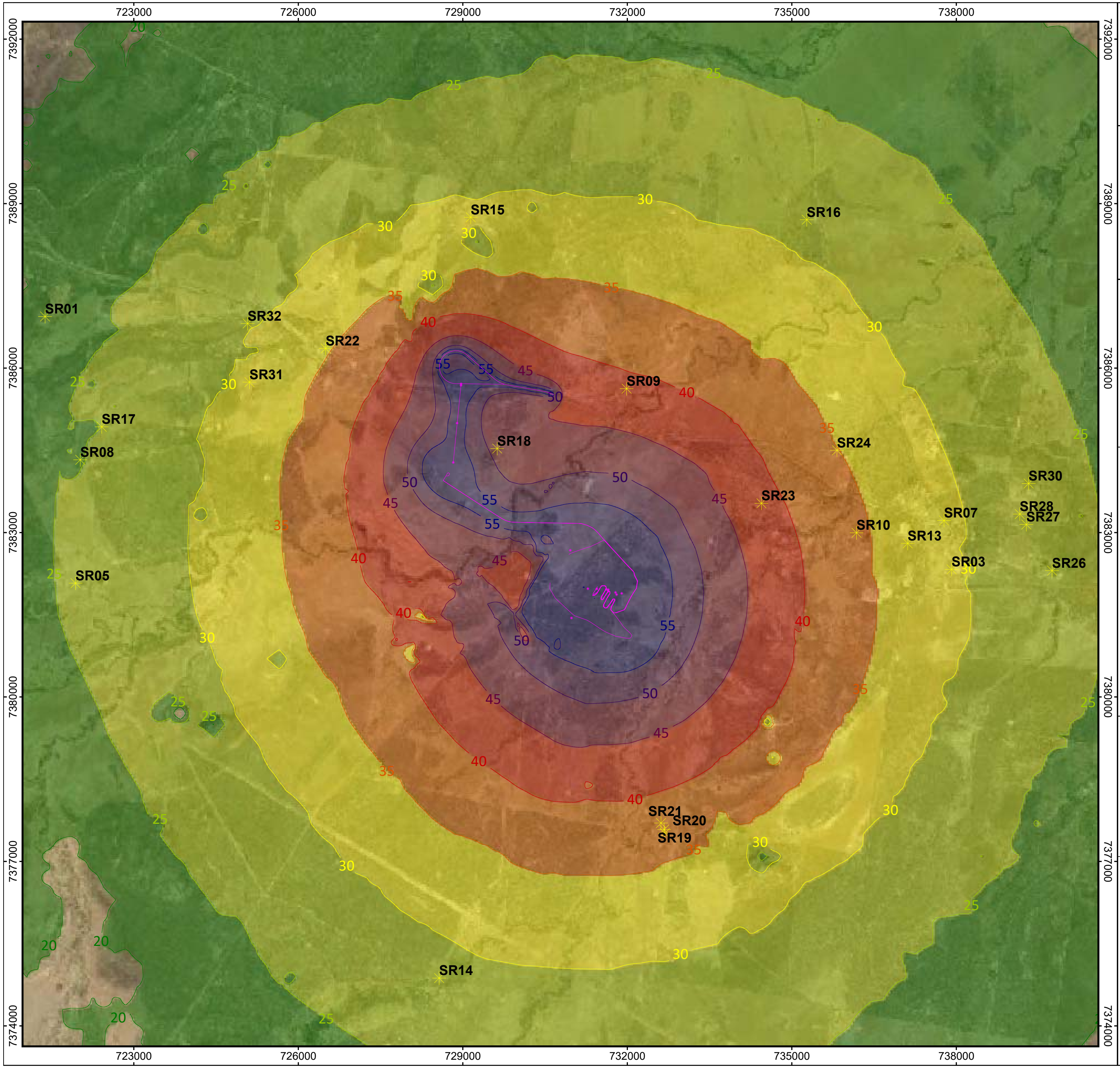


Figure D.3 Year 15 Equipment Locations

Appendix E Predicted Mining Noise Contours

The predicted mining noise level contour figures are as follows:

- **Figure E.1** Year 2 Scenario D1 Mine and Rail Loadout Noise Levels
- **Figure E.2** Year 8 Scenario D1 Mine and Rail Loadout Noise Levels
- **Figure E.3** Year 15 Scenario D1 Mine and Rail Loadout Noise Levels
- **Figure E.4** Year 2 Scenario N1 Mine and Rail Loadout Noise Levels
- **Figure E.5** Year 8 Scenario N1 Mine and Rail Loadout Noise Levels
- **Figure E.6** Year 15 Scenario N1 Mine and Rail Loadout Noise Levels



Gemini Project
Project Number: 197401.0181

Figure

E.1

Year 2 Mine and Rail Loadout Noise Contours Meteorology Scenario D1 (Day)

Date: 22/10/2020
Drawn By: PJ
Prepared For: Magnetic South Pty Ltd

Noise Levels Leq (1 hour)

Free Field dB(A)
Ground Contour Calculation Height = 1.8m

🟩 = 20
🟩 = 25
🟨 = 30
🟧 = 35
🟥 = 40
🟪 = 45
🟪 = 50
🟦 = 55

Signs and symbols

✳ Point receiver
• Point source
— Line source

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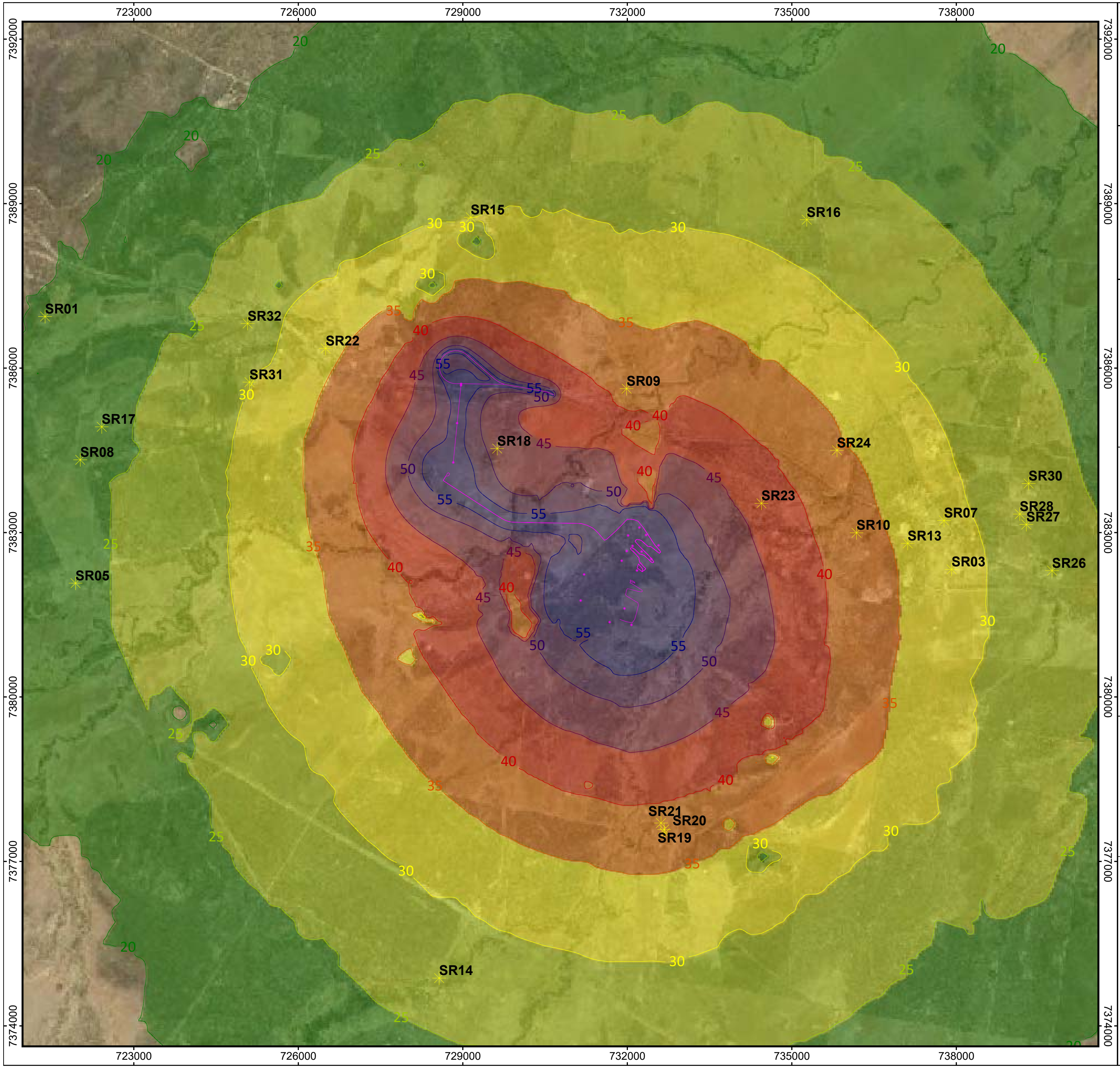

Gemini Project
Project Number: 197401.0181

Figure

E.2

Year 8 Mine and Rail Loadout Noise Contours Meteorology Scenario D1 (Day)

Date: 22/10/2020
Drawn By: PJ
Prepared For: Magnetic South Pty Ltd

Noise Levels Leq (1 hour)

Free Field dB(A)
Ground Contour Calculation Height = 1.8m

🟩 = 20
🟩 = 25
🟨 = 30
🟧 = 35
🟥 = 40
🟪 = 45
🟪 = 50
🟦 = 55

Signs and symbols

✳ Point receiver
• Point source
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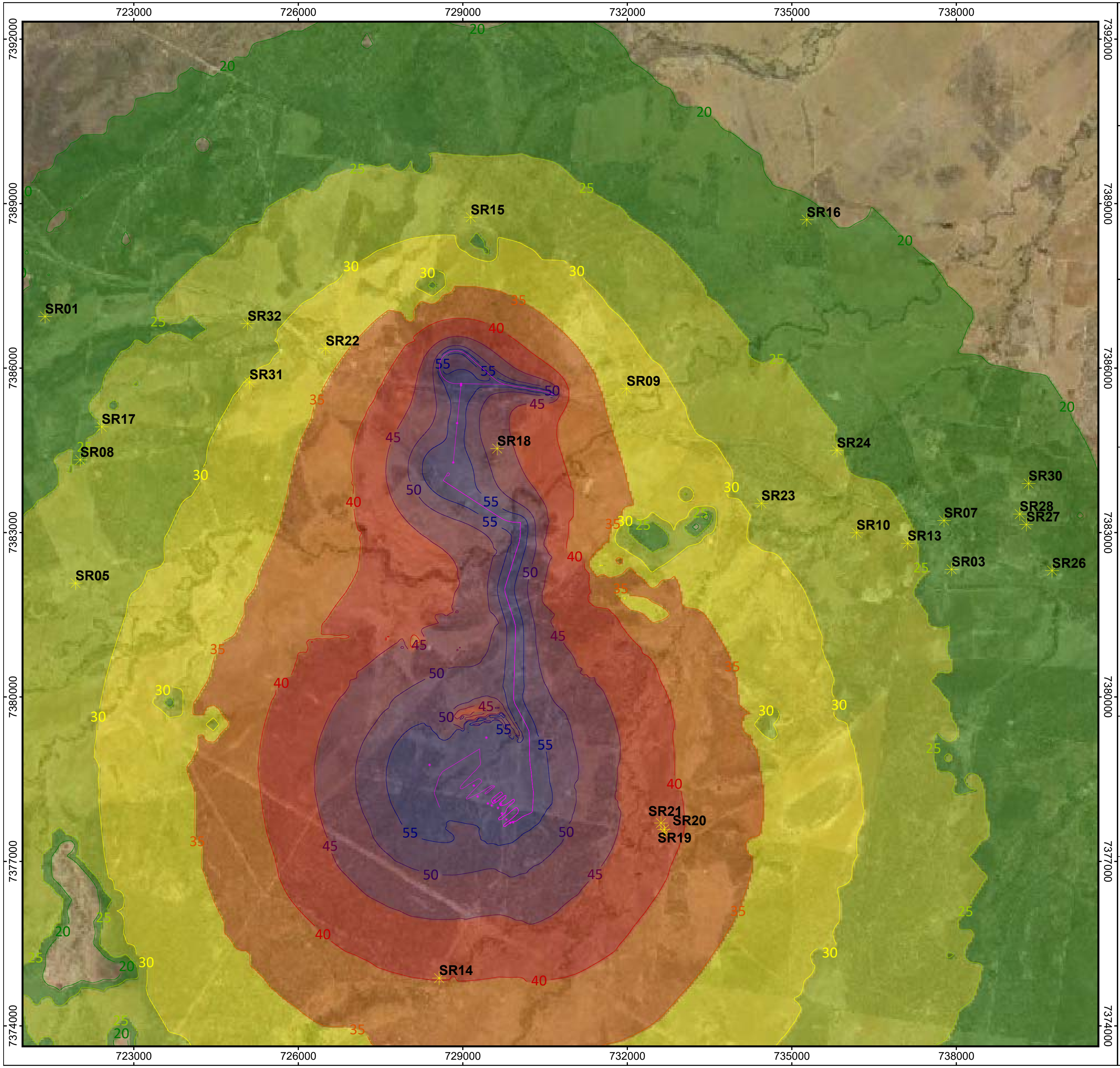

Gemini Project
Project Number: 197401.0181

Figure

E.3

Year 15 Mine and Rail Loadout Noise Contours Meteorology Scenario D1 (Day)

Date: 22/10/2020
Drawn By: PJ
Prepared For: Magnetic South Pty Ltd

Noise Levels Leq (1 hour)

Free Field dB(A)
Ground Contour Calculation Height = 1.8m

🟩	=	20
🟩	=	25
🟨	=	30
🟧	=	35
🟥	=	40
🟪	=	45
🟪	=	50
🟦	=	55

Signs and symbols

✳	Point receiver
•	Point source
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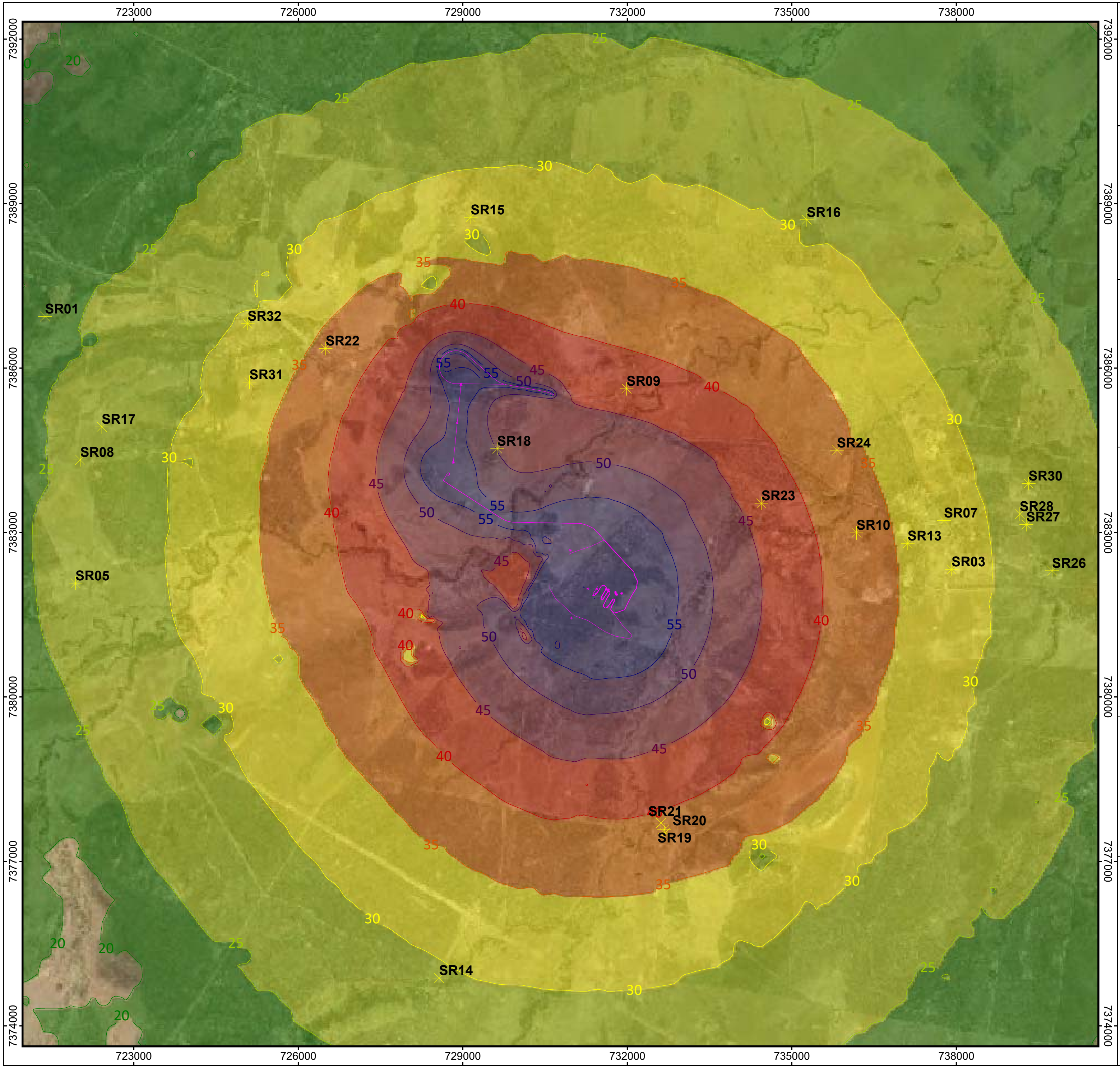

Gemini Project
Project Number: 197401.0181

Figure

E.4

Year 2 Mine and Rail Loadout Noise Contours
Meteorology Scenario N1 (Night)

Date: 22/10/2020
Drawn By: PJ
Prepared For: Magnetic South Pty Ltd

Noise Levels Leq (1 hour)
Free Field dB(A)
Ground Contour Calculation Height = 1.8m

🟩 = 20
🟩 = 25
🟨 = 30
🟧 = 35
🟥 = 40
🟪 = 45
🟪 = 50
🟦 = 55

Signs and symbols
✳ Point receiver
• Point source
— Line source

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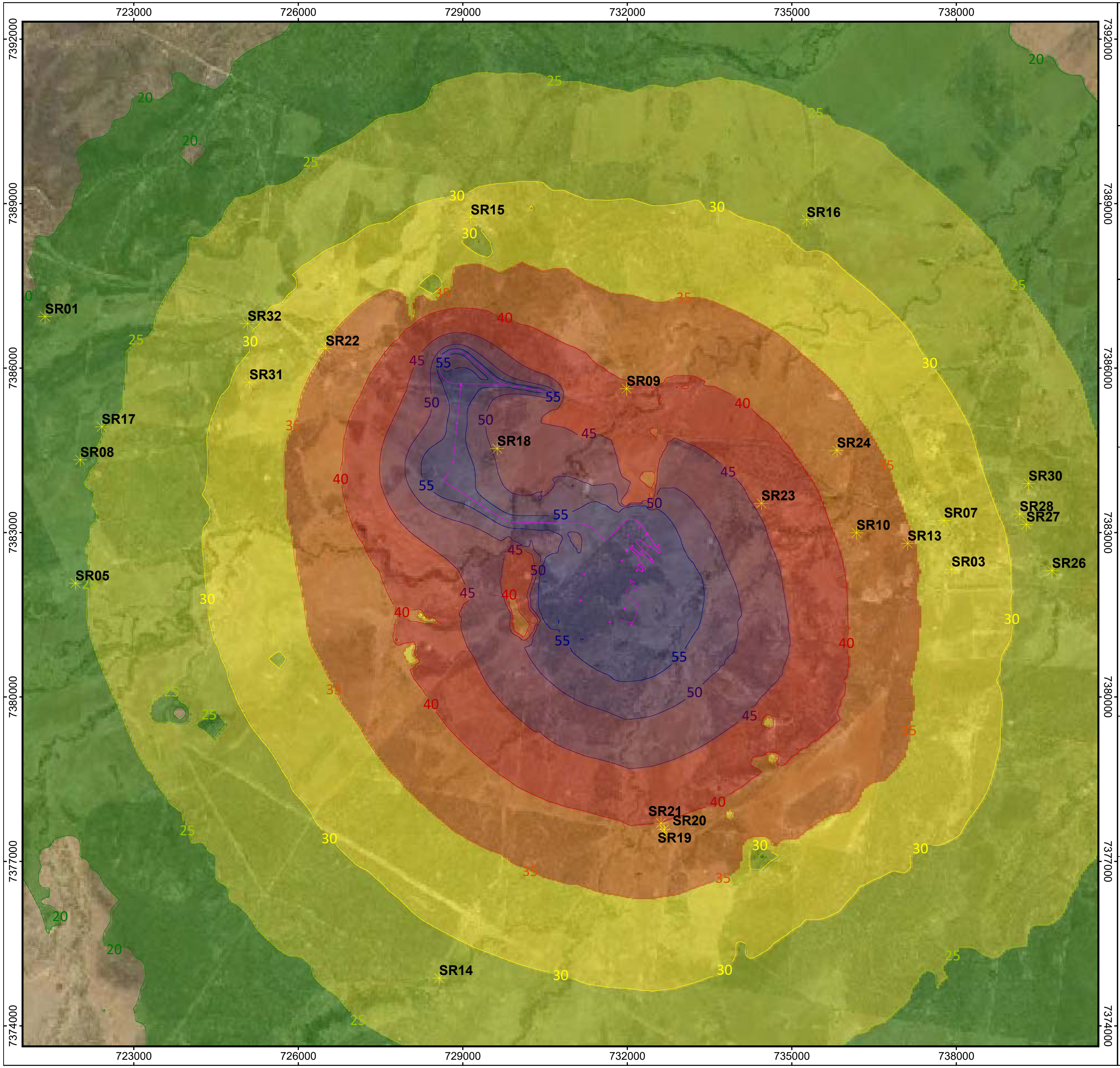

Gemini Project
Project Number: 197401.0181

Figure

E.5

Year 8 Mine and Rail Loadout Noise Contours Meteorology Scenario N1 (Night)

Date: 22/10/2020
Drawn By: PJ
Prepared For: Magnetic South Pty Ltd

Noise Levels Leq (1 hour)

Free Field dB(A)
Ground Contour Calculation Height = 1.8m

🟩 = 20
🟩 = 25
🟨 = 30
🟧 = 35
🟥 = 40
🟪 = 45
🟪 = 50
🟦 = 55

Signs and symbols

✳ Point receiver
• Point source
— Line source

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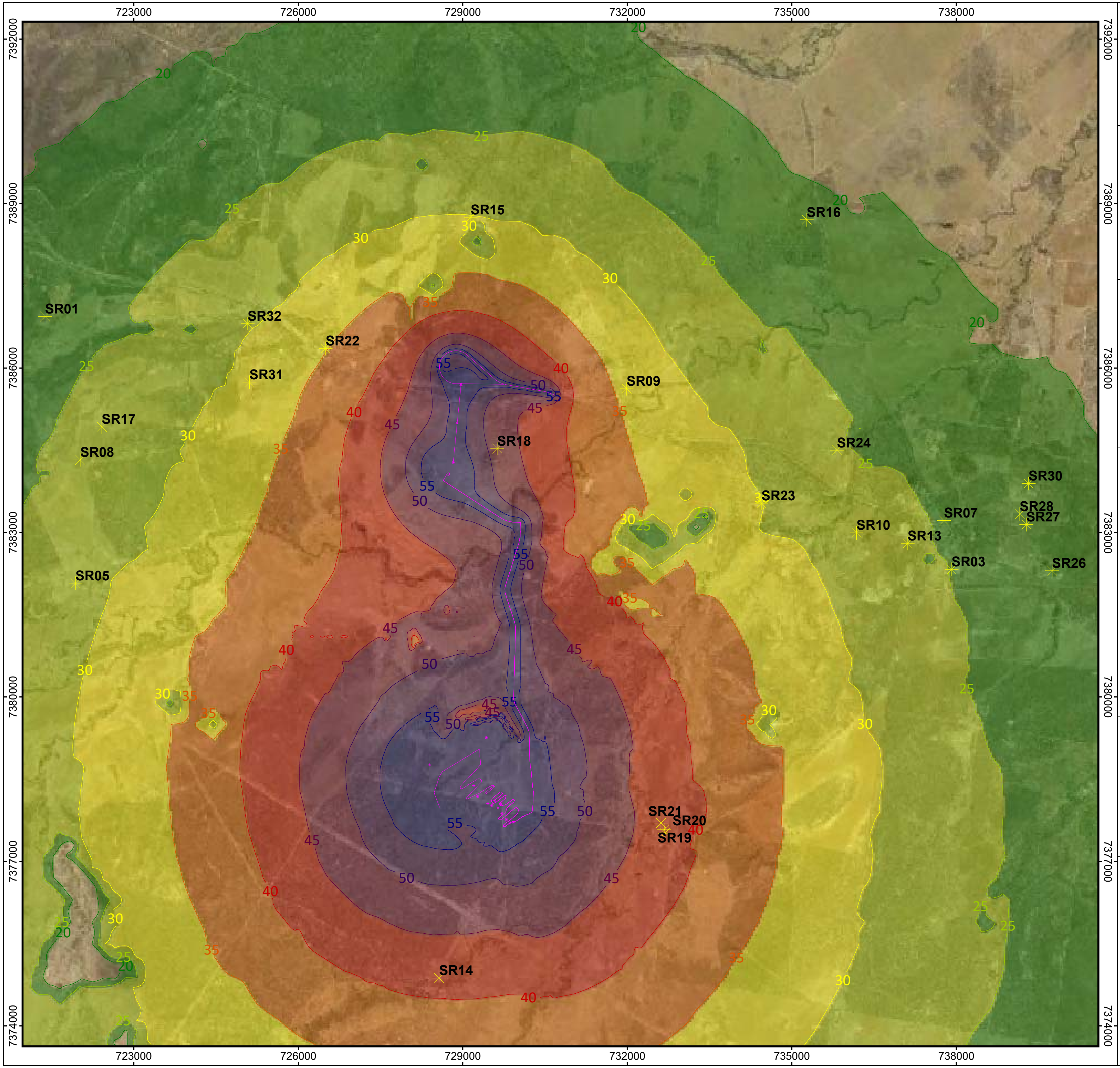

Gemini Project
Project Number: 197401.0181

Figure

E.6

Year 15 Mine and Rail Loadout Noise Contours
Meteorology Scenario N1 (Night)

Date: 22/10/2020
Drawn By: PJ
Prepared For: Magnetic South Pty Ltd

Noise Levels Leq (1 hour)

Free Field dB(A)
Ground Contour Calculation Height = 1.8m

🟩 = 20
🟩 = 25
🟨 = 30
🟧 = 35
🟥 = 40
🟪 = 45
🟪 = 50
🟦 = 55

Signs and symbols

✳ Point receiver
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Appendix N Land-Based Effluent Disposal Assessment

Land-Based Effluent Disposal Assessment Report

Proposed Gemini Mine

M31194

Prepared for
Magnetic South Pty Ltd

3 December 2020

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01	24 June 2020	Draft for client consideration	MF	AMW
02	03 July 2020	Final	MF	AMW
03	03 December 2020	Final updated irrigation area	MF	AMW

Table of Contents

1 Introduction 1

1.1 Background 1

2 Aim of Assessment 3

2.1 Objectives 3

2.2 Scope of Work 3

2.3 Fundamentals of MEDLI 3

3 Desktop Assessment 5

3.1 Preferred Irrigation Location 5

3.2 Climate 7

3.3 Topography, Drainage and Groundwater 7

3.4 Onsite Vegetation 9

3.5 Sensitive Receptors 10

4 Description of Wastewater 12

4.1 Wastewater Quantity 12

4.2 Wastewater Quality 12

5 Irrigation Area Soil Description 14

5.1 Soil Unit Description 14

5.2 Profile Description 15

5.3 Chemical and Physical Analysis 17

6 Desktop AS1547 Assessment 18

6.1 Selection Criteria 18

6.2 Design Criteria 20

7 MEDLI Modelling - Mine Construction Period 21

7.1 Extreme Impermeable Scenario 21

7.2 Extreme Permeable Scenario 22

8 MEDLI Model - Mine Operational Period 24

8.1 Extreme Impermeable Scenario 24

8.2 Extreme Permeable Scenario 25

9 Aerosols, Pathogens, Odour and Toxins 27

9.1 Aerosols and Pathogens 27

9.2 Odour 28

9.3 Toxins 28

10 Treatment Plant Sludge Management 30

10.1 Offsite Disposal 30

10.2 Reuse Options 30

11 Set Out and Management of Irrigation Area 32

11.1 Spray Irrigation Specifications 32

11.2 Buffer Distances 33

11.3 Management of Soil Sodicity 33
11.4 Maintaining Pasture 34
12 Conclusions and Recommendations 35
12.1 Mine Construction Phase 35
12.2 Mine Operational Phase 35
12.3 Location of Disposal Area 35
12.4 Managing Pathogen Exposure Risk 36
12.5 Managing Soil Sodicity 36
12.6 DES RFI Responses 36
12.7 Standard of Assessment and Limitations 36
13 References 37

Appendices

Appendix A Department of Environment & Science’s Request for Further Information
Appendix B Construction Period: Extreme Impermeable MEDLI Model Output Report
Appendix C Construction Period: Extreme Permeable MEDLI Model Output Report
Appendix D Operational Period: Extreme Impermeable MEDLI Model Output Report
Appendix E Construction Period: Extreme Permeable MEDLI Model Output Report
Appendix F Example of Irrigation Setout
Appendix G Response to DES’ RFI

Tables

Table 4-1 Wastewater Quality Estimations: Source ERA 63 Eligibility Criteria Standard Conditions 12
Table 4-2 Wastewater Quality Estimates – Secondary Treated Effluent: Source AS/NZ 1547 13
Table 5-1 Geoffrey SMU Description. Source – AARC:2019 14
Table 5-2 Chemical Properties of the Geoffrey SMU. Source – AARC: 2019 17
Table 5-3 Extractable nutrients and metals in Geoffrey SMU topsoil. Source: AARC – 2019. 17
Table 6-1 Selection Criteria for Irrigation Systems (Appendix K or AS/NZS 1547:2012) 19
Table 7-1 Mine Construction Period Extreme Impermeable MEDLI Input Parameters 21
Table 7-2 Mine Construction Period Extreme Permeable MEDLI Input Parameters 22
Table 8-1 Mine Operation Period Extreme Impermeable MEDLI Input Parameters 24
Table 8-2 Mine Operational Period – Extreme Permeable MEDLI Input Parameters 25
Table 9-1 Pathogen hazard log reduction targets for priority uses of recycled water from treated sewage (Source – National Guidelines for Water Recycling) 27
Table 9-2 Examples of how pathogen log reduction targets can be achieved for Municipal Irrigation systems (Source – National Guidelines for Water Recycling) 29

Table 11-1 Guide to permissible SAR of irrigation water to maintain a stable soil surface (Source – Salinity Management Handbook, Second Edition) 34

Figures

Figure 1-1 Location of Mining Lease Application (Source AARC: 2019) 2
Figure 3-1 Irrigation Investigation Area (located on western boundary) (Source AARC:2019) 6
Figure 3-2 Climate Data for the site 1950 - 2019 7
Figure 3-3 Topography and drainage of site and surrounds 8
Figure 3-4 Proximity of Potential Irrigation Area to Watercourses and Terrestrial Groundwater Dependent Ecosystems. 9
Figure 3-5 Proximity of irrigation area to adjacent Regional Ecosystems 10
Figure 3-6 Irrigation Investigation Area in respect to proposed accommodation facilities 11
Figure 5-1 Geoffrey SMU Vegetation (showing cleared and vegetated sections). Source – AARC:2019 14
Figure 5-2 Distribution of Soil Management Units 16
Figure 12-1 Example of Irrigation Area Size and Location 36

1 Introduction

Cardno were commissioned by Magnetic South Pty Ltd to investigate the disposal of wastewater from accommodation, offices and facilities at the proposed Gemini Mine site.

The wastewater from these sources will need to be treated and disposed of in a manner which is economical, practical and environmentally sustainable. In this case the most feasible method will involve a basic level of treatment followed by land-based disposal.

This report summarises the site background and constraints, justifies the chosen land-based disposal method and validates it with the use of the Model for Effluent Disposal Using Land Irrigation (MEDLI) version 2.0.

1.1 Background

The site is located within the Bowen Basin region of Central Queensland, approximately 3km west of Dingo and 15km east of Bluff. The location of the Mining Lease Application is provided in Figure 1-1.

The project is currently in the Environmental Impact Statement (EIS) phase, and therefore detailed design/operation information is yet to be developed. At this point in time, during the construction phase up to 280 workers are estimated, which will reduce to 140 workers during the operation phase.

During both construction and operation phases workers will generate domestic waste water from accommodation, offices and facilities. The wastewater will include that which is generated from the use of toilets (often classed as black water) as well as wastewater produced from showers, kitchen facilities and laundry (often classed as grey water). It is important to distinguish this domestic wastewater does not include Mine Water or Sediment Water which will be stored and handled in a separate manner.

1.1.1 Environmental Authority Requirements

Given that the wastewater systems at Gemini Mine will cater for more than 21 Equivalent Persons (EPs) (1 EP = 200 L/day), the activity triggers Environmental Relevant Activity (ERA) 63 for sewerage treatment. Therefore, the system requires an Environmental Authority (EA) from the Department of Environment and Science (DES).

An application for ERA 63 authority must provide supporting technical information in accordance with the DES *Guideline Application requirements for activities with impacts to land*. These guidelines encourage the applicant to:

- Design a sustainable system in accordance with Australian New Zealand Standard *AS/NZS 1547:2012 On-site domestic wastewater management*; and
- Undertake validation modelling of the system based on the local land and rainfall factors. The recommended model being the Model for Effluent Disposal using Land Irrigation (MEDLI) Version 2.0.

This report therefore centres around AS/NZS 1547:2012 and validation MEDLI 2.0 modelling of the irrigation site at the Gemini Mine.

1.1.2 Department of Environment and Science Request for Information

The requirement for an ERA 63 Environmental Authority has previously been raised by the Department of Environment and Science (DES) in a Request for Information (RFI) during the EIS process. The relevant parts of the RFI are attached in Appendix A.

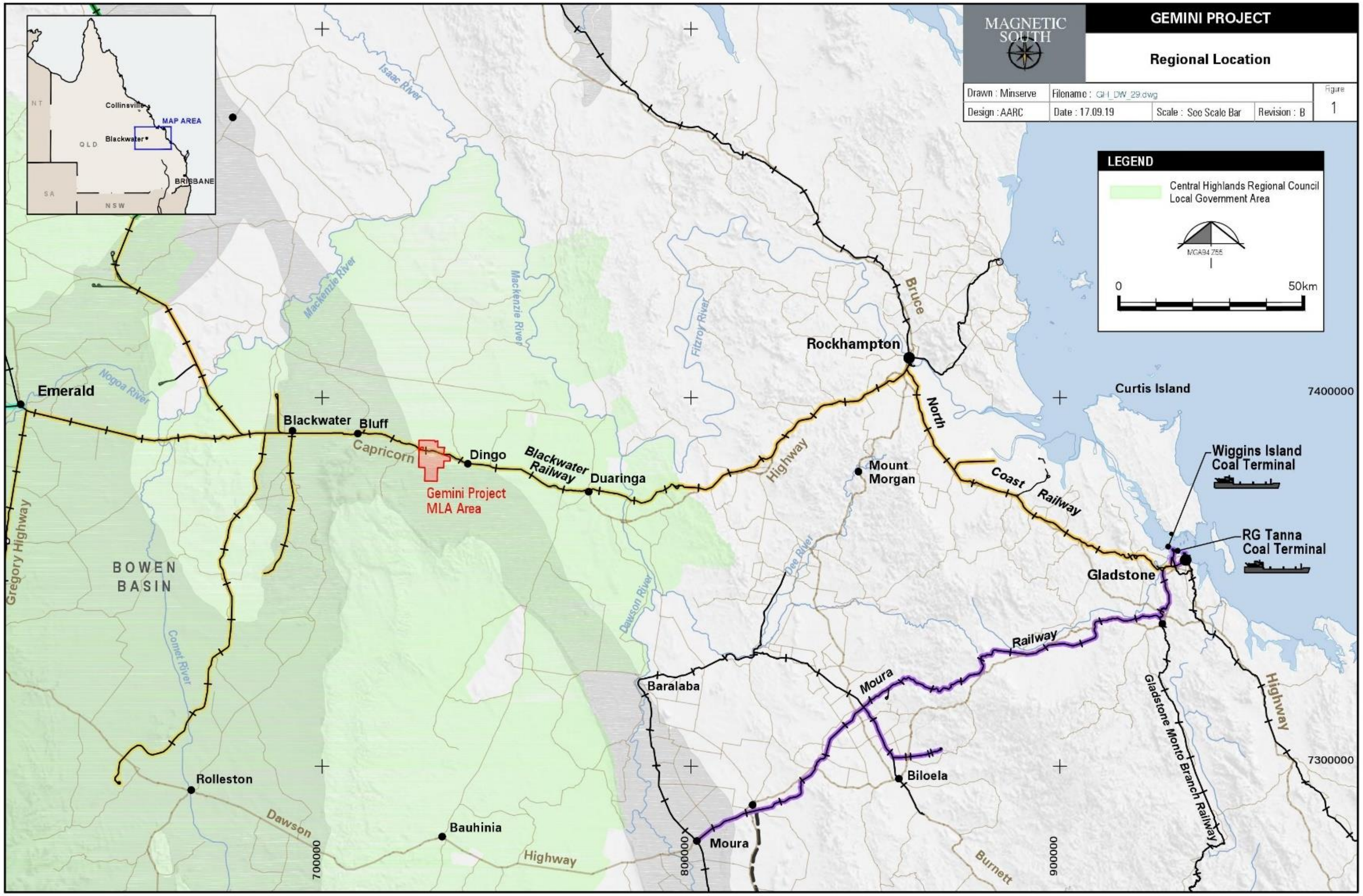


Figure 1-1 Location of Mining Lease Application (Source AARC: 2019)

2 Aim of Assessment

2.1 Objectives

The principal objective of the assessment was to address the RFI requests which relate to ERA 63 and the treatment/disposal of effluent on the Gemini Mine site. In essence, the RFI stipulates that the application needs to:

> Ensure that the land-based disposal system applies treated effluent over a suitable area, at a suitable rate to ensure that effluent does not run off, cause waterlogging, or cause high levels of nutrient leaching into the subsoil;

> Ensure that the water balance is correctly predicted to ensure that treated effluent storage tanks/ponds do not frequently overflow;

> Ensure that sensitive receivers are not overly exposed to health risks from the disposal system (i.e. ensuring treatment and exposure reduction methods are sufficient to minimise pathogen exposure); and

> Ensure that waste sludge is handled in a manner which complies with waste regulations and poses minimal risk to humans or the environment.

2.2 Scope of Work

The scope of this assessment is limited to assessing the suitability of land areas within the Gemini Mine site for effluent disposal via irrigation. The assessment consisted of:

> A desktop review of site topography, hydrology and soil type to select the most suitable effluent disposal area;

> Using AS1547: 2012 to estimate the irrigation rate and layout using soil condition assumptions obtained during the review;

> Review of existing soil data to assess soil characteristics of the intended effluent disposal area;

> Calculating expected wastewater quality and generation rates for the site;

> Obtaining site-specific climate data for the Dingo region (particularly rainfall/evaporation rates);

> Verifying the suitability of the subsurface irrigation system using software issued by DES: the Model for Effluent Disposal through Land Irrigation (MEDLI); and

> Providing recommendations to improve the performance of the irrigation system.

This report does not include provision for a Site Based Management Plan applicable to the ongoing operation of a wastewater disposal system. Prior to commissioning the treatment plant and disposal system a management plan detailing ongoing maintenance requirements, emergency response and contingency procedures will be required.

2.3 Fundamentals of MEDLI

Irrigation modelling systems offer a way of validating and refining irrigation systems designed in accordance with AS 1547:2012. Daily time step simulation models such as the Model for Effluent Irrigation using Land Disposal (MEDLI) Version 2.0 are generally considered a requirement by DES in order to obtain an ERA 63 EA.

2.3.1 MEDLI 2.0 Background

MEDLI Version 2.0 is a modelling program that simulates the complex dynamics of the effluent cycle on a daily time step, using historical daily climatic data. MEDLI 2.0 simulates the behaviour of water and nutrients in the soil column and the growth of irrigated pastures or crops in response to climatic conditions and nutrient and salt loadings. MEDLI 2.0 can be used to determine the required irrigation area, likely stresses on irrigated vegetation and the concentration of nutrients and salt in groundwater for given conditions. The model is based on historic climate information (temperature, rainfall, evaporation, and solar radiation), estimates of the effluent quality and quantity, and soil and groundwater properties. Modelling is designed to provide an overview of the proposed environmental impacts and to identify any significant areas of concern that may require further detailed investigations. Actual findings will depend on detailed information with respect to geology of the soils and groundwater, proposed irrigation methods and management practices in the field.

By undertaking effluent modelling, the process allows the identification of anticipated weaknesses in the wastewater disposal scheme, allowing the opportunity to explore alternative solutions until a suitable, and robust, design is found. By using MEDLI 2.0 in the feasibility process, effluent disposal essentially becomes a transparent issue allowing safety in design.

2.3.2 Modelling Objectives

A a successful model will generally have the following outcomes:

- Wet weather storage tank overflow events will be negligible in frequency and volume.
  - 90% reuse (irrigation) of effluent should occur (99.5% re-use is ideal);
  - No overflow events which equate to more than the top 1mm of the tank should occur; and
  - Overflow should be experienced less than 10 days per year;
- No surface runoff of irrigated effluent should occur;
- Less than 5kg/ha/year of nitrate is to be lost in deep drainage;
- Greater than 30 years of phosphorus adsorption capacity available in the soil;
- Build-up of salinity in the soil profile should not impede on the growth success of the grass; and
- Any pasture die-offs resulting from water stress, waterlogging, temperature stress or nitrogen stress are to be minimised as close to zero as possible.

3 Desktop Assessment

3.1 Preferred Irrigation Location

At this point in time it is assumed that all sources of domestic wastewater from the accommodation facilities and mine infrastructure area will be channelled to a single treatment plant and disposal area.

The area being investigated for treated effluent disposal is located towards the north east of the mining lease, just to the north of the Capricorn Highway and rail line (Figure 3-1). This area is being investigated because:

- It is within close proximity to the primary source of wastewater (the proposed mine camp), therefore minimising pumping requirements;
- It is at similar elevation to the primary source of wastewater (accommodation facilities), therefore minimising pumping requirements;
- It will be highly accessible from the proposed access roads;
- There is sufficient space to allow for placement of disposal area and still maintain large buffers from sensitive receivers such as waterways, ecosystems and the residents/mining camp; and
- The area has previously been cleared, and has been used for grazing purposes and therefore contains limited ecological value.

3.1.1 Flood Immunity

A review of the Central Highlands Regional Council Flood Hazard Overlay indicates that the investigation area and the greater proposed mine are located a substantial distance away from the defined flood event (DFE) overlay which is based on the 1% Annual Exceedance Probability (AEP) + climate change allowance.

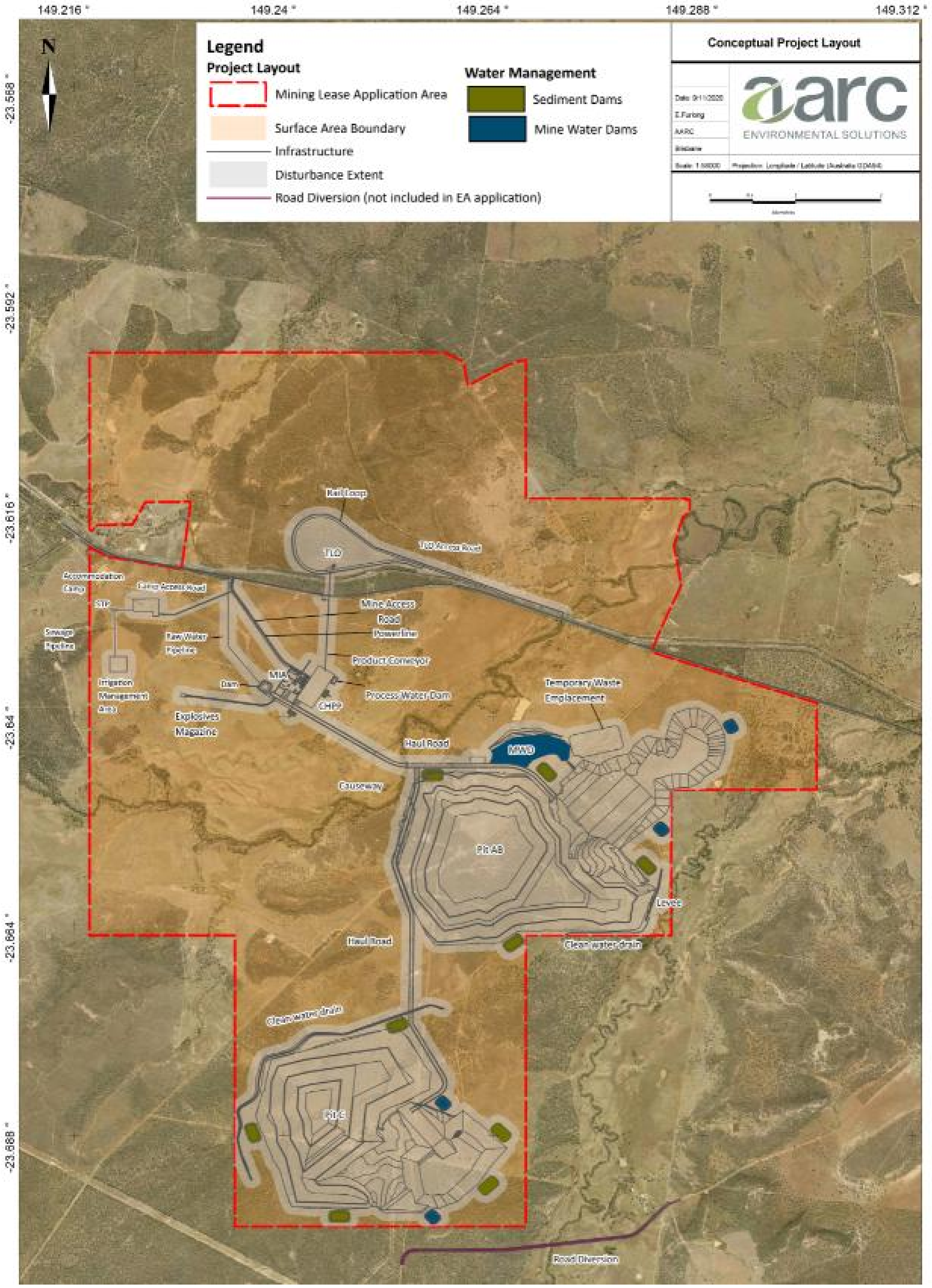
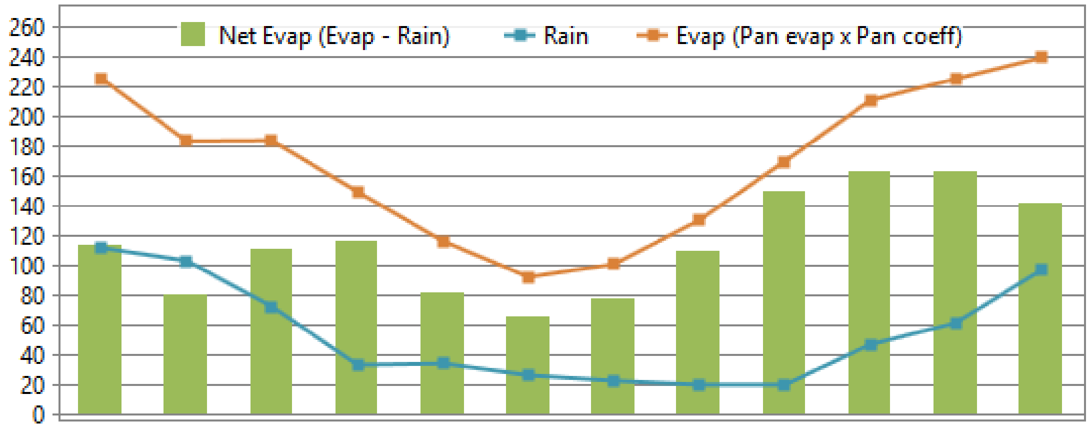


Figure 3-1 Irrigation Investigation Area (located on western boundary)

3.2 Climate

Climate data was obtained from the Queensland Government Scientific Information for Land Owners (SILO) for the closest grid point -24.65 149.20. SILO interpolates the data from the nearest climate stations. The data includes evaporation rates, rainfall and maximum and minimum temperatures for a period of 70 years from 1950 to 2019.

The site has a relatively dry climate, with evaporation rates exceeding rainfall throughout the year. A distinctive dry/wet season pattern is observed, whereby the winter period from April to September is traditionally dry, with higher rainfall (typically from storms) received over the summer months from September to January. Even during the wet season, the evaporation rates still exceed rainfall rates. The data has been summarised below in Figure 3-2.



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Rain	112.0	103.5	72.8	33.8	34.9	27.1	23.4	20.8	20.7	47.4	61.9	97.1	655.2
Evap	225.4	183.3	183.7	149.5	116.5	92.6	101.0	130.5	169.8	210.6	225.0	238.9	2026.9
Net Evap	113.4	79.8	110.9	115.7	81.6	65.6	77.7	109.8	149.1	163.2	163.1	141.8	1371.7
Net Evap/day	3.7	2.8	3.6	3.9	2.6	2.2	2.5	3.5	5.0	5.3	5.4	4.6	3.8

Figure 3-2 Climate Data for the site 1950 - 2019

3.3 Topography, Drainage and Groundwater

The investigation area is located in a relatively flat location, the slight gradient falls from a north to south direction. In terms of drainage, the area sits on the divide between the catchment of Stanley Creek towards the north and the catchment of Charlevue Creek to the south. The site itself lacks any mapped creeks or drainage lines, but two mapped drainage lines are situated to the east and west of the site. These are drainage lines which would only fall for brief periods following heavy rain.

The reasonably flat nature and distance from significant watercourses is ideal for effluent irrigation.

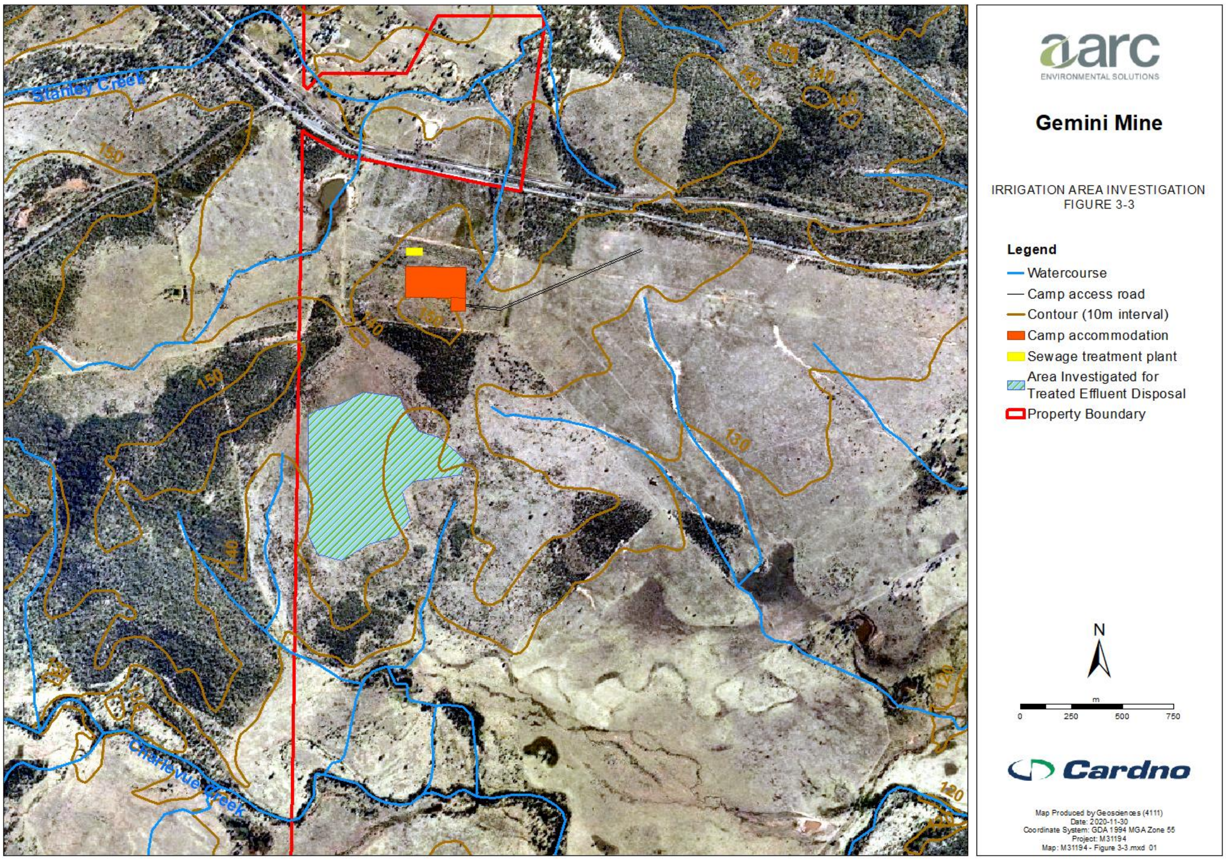


Figure 3-3 Topography and drainage of site and surrounds

A regional groundwater table is likely to be present at significant depth given that the site is quite elevated and near the top of its respective catchment. The closest registered bore (RN13010008) indicates that the regional groundwater table is present at approximately 46m below ground level as of the last measurement in February 2020.

Charlevue Creek, located approximately 1km south of the investigation area is an ephemeral creek. Ephemeral creeks tend to lose water slowly into the surrounding upper soil profile. This is often referred to as alluvial groundwater. The alluvial groundwater can persist for a period of weeks to months after the ephemeral stream has ceased flowing and can be drawn upon by plants and an ecosystem can develop around this. These are known as groundwater dependent ecosystems (GDEs). The QLD Government GDE mapping indicates there is some potential (with a low level of confidence) that a GDE may be present in the riparian zone around Charlevue Creek.

The irrigation scheme will need to be managed via use of an appropriate irrigation rate and set back distances to minimise any impact on groundwater and any potential GDEs.

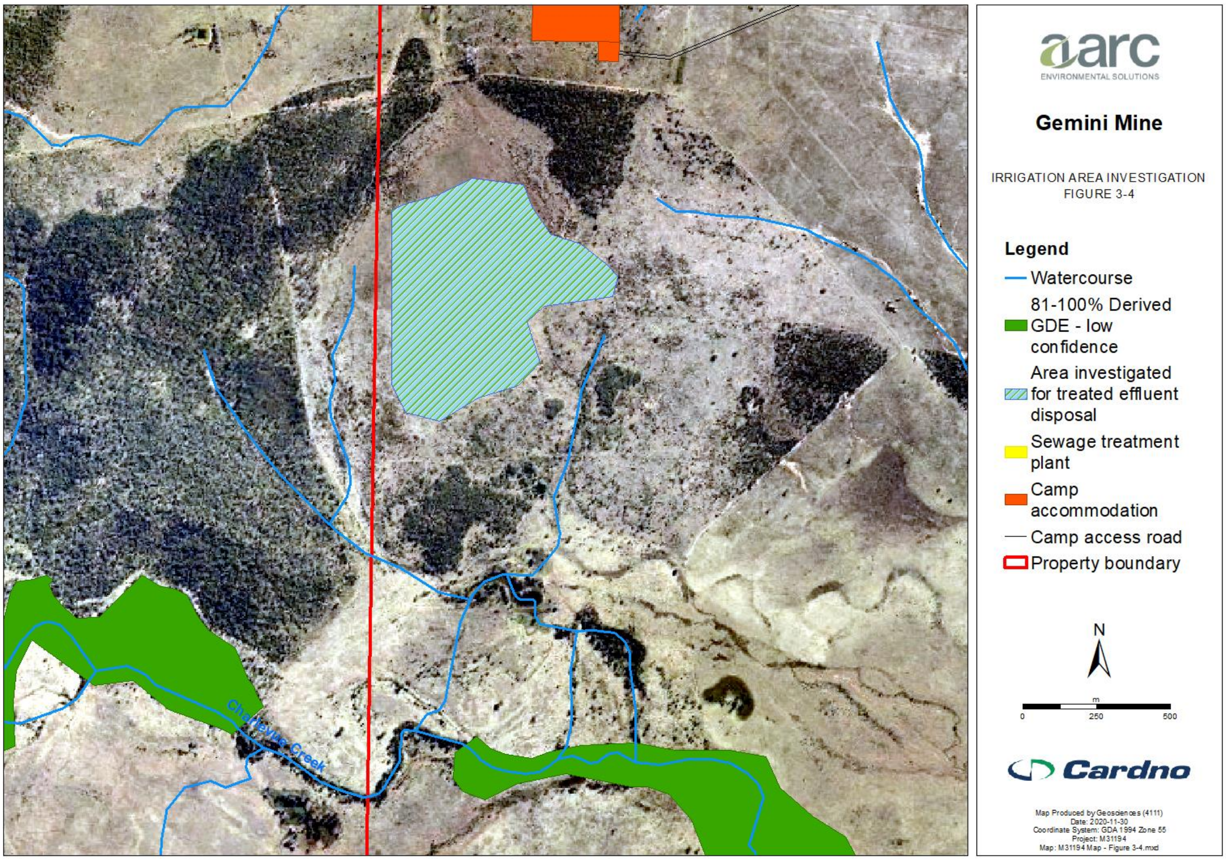


Figure 3-4 Proximity of Potential Irrigation Area to Watercourses and Terrestrial Groundwater Dependent Ecosystems.

3.4 Onsite Vegetation

The area being investigated for irrigation has been previously cleared for grazing purposes. The current coverage most likely consists of Buffel Grass. In accordance with the Queensland Regional Ecosystem (RE) mapping there are some pockets of remnant vegetation around the irrigation investigation area which contain least concern RE's. The irrigation scheme will need to be managed via appropriate irrigation rate and set back distances to minimise any impact on the REs.

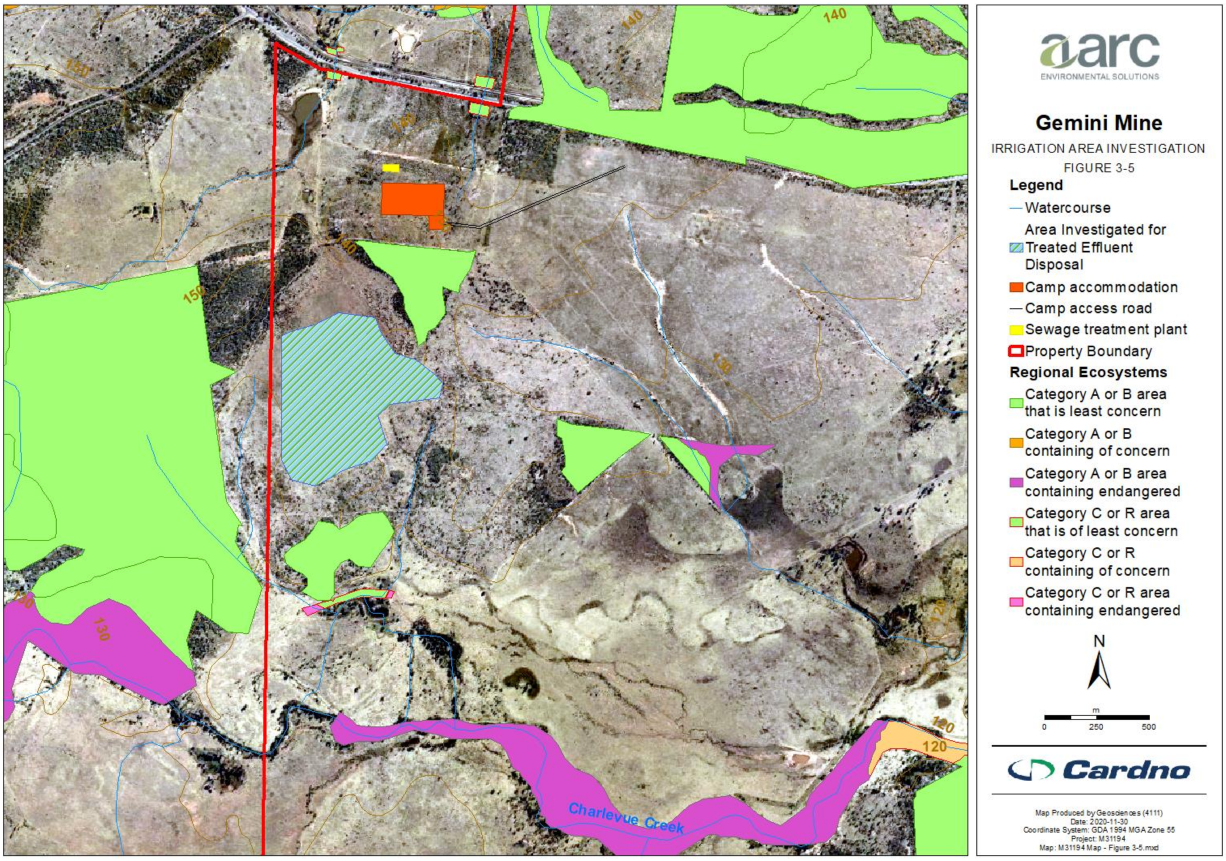


Figure 3-5 Proximity of irrigation area to adjacent Regional Ecosystems

3.5 Sensitive Receptors

Aside from the sensitive natural environmental receivers outlined above, other sensitive receptors include the nearby public or residents/workers at the mine. The investigation area is located approximately 1300m to the south of the Capricorn Highway and rail line, and approximately 500m south of the proposed accommodation facilities

The irrigation scheme will need to be managed via appropriate level of treatment and exposure reduction (i.e. irrigation area restriction, set back distances etc) distances to minimise any aerosol or odour exposure to sensitive receptors.

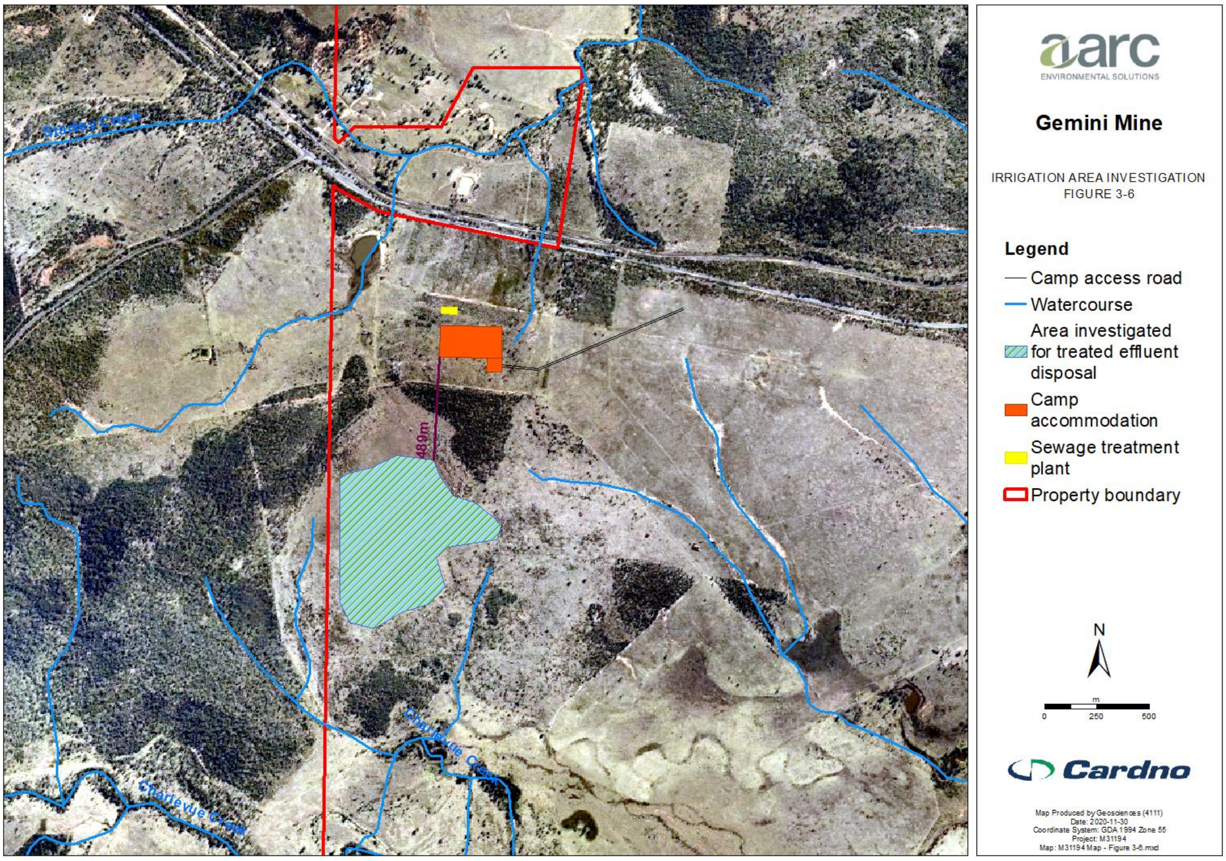


Figure 3-6 Irrigation Investigation Area in respect to proposed accommodation facilities

4 Description of Wastewater

Given that the mine, and any associated infrastructure and accommodation facilities have yet to be established, the wastewater quantity and quality had to be conservatively estimated.

4.1 Wastewater Quantity

4.1.1 Construction Period

A total of 280 construction workers are expected to be employed during the establishment/construction works before the mine becomes operational.

It is unlikely that all 280 workers will all be on site on a given day, and it is unlikely that all 280 workers will generate their entire volume of wastewater for a day (i.e. drinking/showering, washing/laundry) on site, as many may utilise off site accommodation facilities, particularly towards the start of the project.

- For the purpose of this exercise it has been conservatively estimated that all 280 workers will be on site, and each worker will generate the entire waste water volume that equates to 1 equivalent person (EP).
- The *Environmental Protection Regulation 2019* states that 1 EP = 200 L/day of effluent. With a total of 280 EPs the total daily wastewater volume is conservatively estimated at **56,000 L/day**.

4.1.2 Operational Period

When the mine is operational 140 workers are expected to be employed. Again, it is unlikely that all 140 workers will be on site on a given day.

- For the purpose of this exercise it has been conservatively estimated that all 140 workers will be on site, and each worker will generate the entire waste water volume that equates to 1 equivalent person (EP).
- The *Environmental Protection Regulation 2019* states that 1 EP = 200 L/day of effluent. With a total of 140 EPs the total daily wastewater volume is conservatively estimated at **28,000 L/day**.

4.2 Wastewater Quality

As the design of the mine and associated infrastructure progresses the most feasible/practical treatment plant will be decided upon, and from there the expected effluent quality can be estimated.

4.2.1 Key Contaminants

In the absence of specific information, conservative estimates have been provided in Table 4-1. These have been based on the long-term limits established in the *Eligibility Criteria and Standard Conditions for Sewage Treatment Works (ERA 63) – Version 2*. These limits also align with the quality which would be expected from a basic sewage treatment plant as per *Table A3.2 of the Australian Guidelines for Water Recycling: Managing Health and Environmental Risks (Phase 1)*.

Table 4-1 Wastewater Quality Estimations: Source ERA 63 Eligibility Criteria Standard Conditions

Quality Characteristics	Release Limit	Limit Type
Total nitrogen	30 mg/L	Maximum
Total phosphorus	10 mg/L	Maximum
Electrical conductivity	1600 µs/cm	Maximum
pH	5.0 – 8.5	Range
Total residual chlorine (if used for disinfection)	1 mg/L	Maximum
E. coli	<1000 cfu/100mL	Maximum

4.2.2 Other Contaminants

In addition to the above parameters, Australian New Zealand Standard 1547:2012 recommends that a secondary treated effluent is achieved for irrigation systems as per Table 4-2. These limits are primarily for operational purposes (i.e. to avoid clogging up pipes/fittings and soil pore spaces with solids and biofilms).

Table 4-2 Wastewater Quality Estimates – Secondary Treated Effluent: Source AS/NZ 1547

Quality Characteristics	Release Limit	Limit Type
Total Suspended Solids	20 mg/L	Maximum
Biochemical Oxygen Demand	30 mg/L	Maximum

5 Irrigation Area Soil Description

At this point in time the investigation area cannot be accessed to obtain site specific soil samples, therefore the soil conditions need to be interpolated from nearby soil data. Cardno refer to the *AARC Gemini Project Soil and Land Suitability Assessment.* This was a soil assessment for the greater mining lease site which describes and maps land suitability classes of the proposed mine area.

In summary, the irrigation investigation area is within the Soil Management Unit (SMU) defined as the Geoffrey SMU which covers approximately 2/3 of the mine lease (Figure 5-2). The following sections are extracted from the *AARC Gemini Project Soil and Land Suitability Assessment, July 2019*.

5.1 Soil Unit Description

The Geoffrey SMU 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 (AARC, 2019).

Australian Soil Classification: Brown Sodosol

Figure 5-1 Geoffrey SMU Vegetation (showing cleared and vegetated sections). Source – AARC:2019

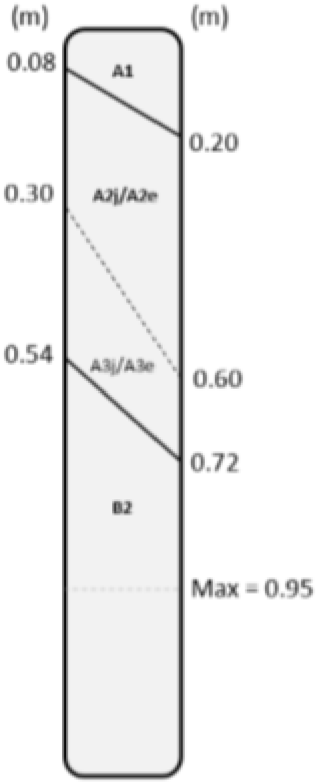
Table 5-1 Geoffrey SMU Description. Source – AARC:2019

Parameter	Soil Unit Description
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

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

5.2 Profile Description

The following is extracted from *AARC Gemini Project Soil and Land Suitability Assessment, July 2019*

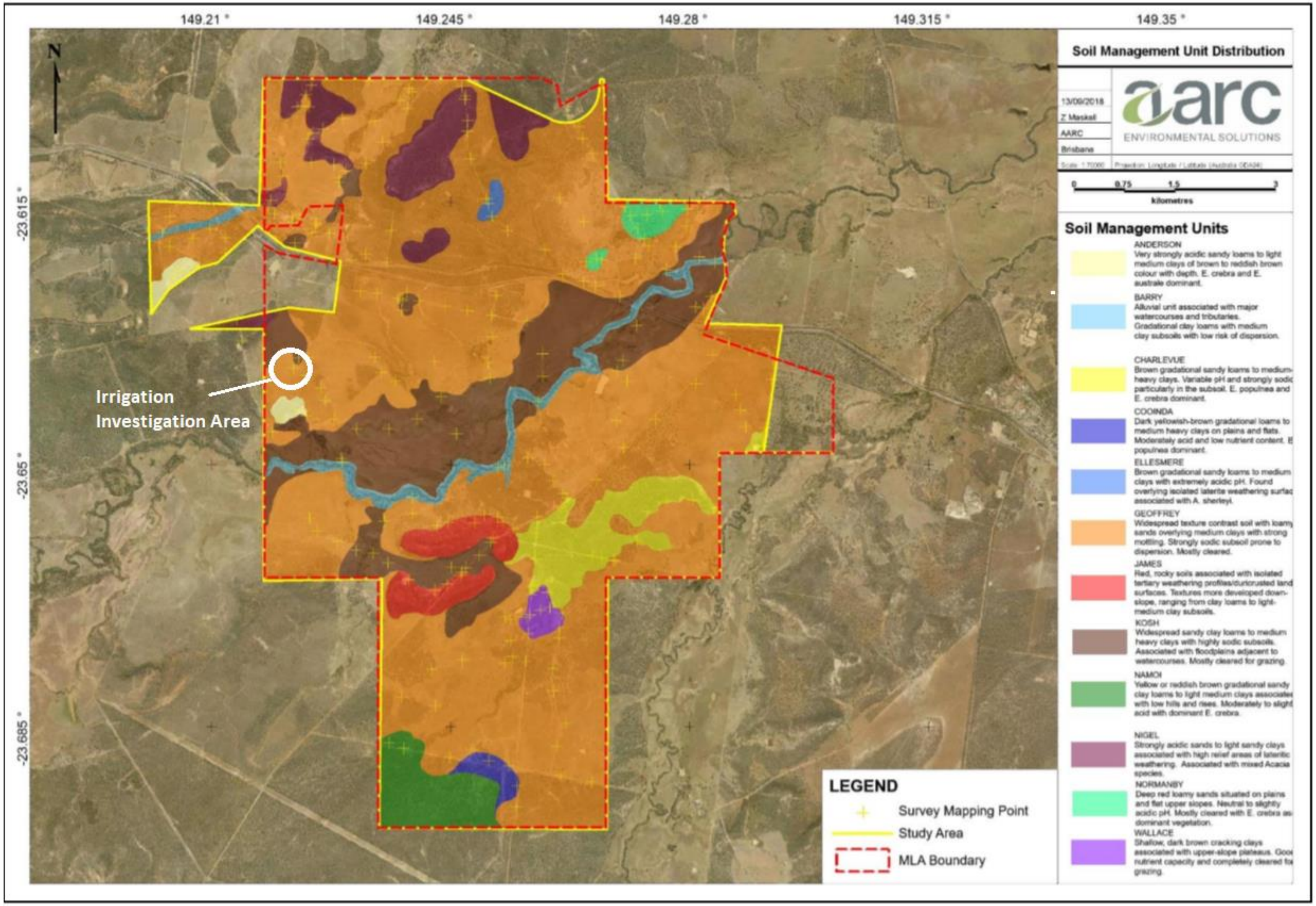


The **surface soil** (A1) is pale brown to brown sand to fine sandy loam with massive or grainy structure. This horizon has a field pH of 5.5 to 6.0.

The **mid-surface soil** (A2j/A2e) is brown 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** was not present at all sites. It is a sporadically or conspicuously bleached pale brown to pink sand to light sand. It has 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 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.



Soil Management Units

ANDERSON
Very strongly acidic sandy loams to light medium clays of brown to reddish brown colour with depth. E. crebra and E. australe dominant.

BARRY
Alluvial unit associated with major watercourses and tributaries. Gradational clay loams with medium clay subsoils with low risk of dispersion.

CHARLEVUE
Brown gradational sandy loams to medium-heavy clays. Variable pH and strongly sodic particularly in the subsoil. E. populnea and E. crebra dominant.

COOINDA
Dark yellowish-brown gradational loams to medium heavy clays on plains and flats. Moderately acid and low nutrient content. E populnea dominant.

ELLESMERE
Brown gradational sandy loams to medium clays with extremely acidic pH. Found overlying isolated laterite weathering surfac associated with A. sherleyi.

GEOFFREY
Widespread texture contrast soil with loamy sands overlying medium clays with strong mottling. Strongly sodic subsoil prone to dispersion. Mostly cleared.

JAMES
Red, rocky soils associated with isolated tertiary weathering profiles/duricrusted land surfaces. Textures more developed down-slope, ranging from clay loams to light-medium clay subsoils.

KOSH
Widespread sandy clay loams to medium heavy clays with highly sodic subsoils. Associated with floodplains adjacent to watercourses. Mostly cleared for grazing.

NAMOI
Yellow or reddish brown gradational sandy clay loams to light medium clays associate with low hills and rises. Moderately to slight acid with dominant E. crebra.

NIGEL
Strongly acidic sands to light sandy clays associated with high relief areas of lateritic weathering. Associated with mixed Acacia species.

NORMANBY
Deep red loamy sands situated on plains and flat upper slopes. Neutral to slightly acidic pH. Mostly cleared with E. crebra as dominant vegetation.

WALLACE
Shallow, dark brown cracking clays associated with upper-slope plateaus. Goo nutrient capacity and completely cleared fo grazing.

Figure 5-2 Distribution of Soil Management Units

5.3 Chemical and Physical Analysis

In summary the soil profile pH is moderately acidic in the upper loamy profile, with a sudden shift to weakly alkaline in the underlying clay profile. This seems to correlate with a significantly higher cation exchange capacity (CEC) at depth. Along with the increased CEC at depth was also a general increase in salts, as is evident in the higher EC, chloride and sodicity in the bottom clay layer. The ratio of calcium to magnesium in the bottom clay layer was extremely low. The low Ca/Mg ratio in combination with a high level of sodicity makes this bottom clay layer susceptible to dispersion upon wetting. (AARC, 2019)

Table 5-2 Chemical Properties of the Geoffrey SMU. Source – AARC: 2019

<table>
<tr><th colspan="10">Representative Site: DP1</th></tr>
<tr><th rowspan="2">Depth (m)</th><th colspan="2">pH</th><th colspan="2">EC</th><th>Cl</th><th colspan="2">ESP%</th><th rowspan="2">Moisture (%)</th><th rowspan="2">Emerson Class No.</th></tr>
<tr><th>#</th><th>Rate</th><th>d S/m</th><th>Rate</th><th>Mg/kg</th><th>%</th><th>Rate</th></tr>
<tr><td>0-0.1</td><td>5.8</td><td>Moderately acid</td><td>0.026</td><td>Very low</td><td>20</td><td>1.0</td><td>Non-sodic</td><td>2.7</td><td>4</td></tr>
<tr><td>0.2-0.3</td><td>5.6</td><td>Moderately acid</td><td>0.006</td><td>Very low</td><td><10</td><td>1.8</td><td>Non-sodic</td><td>0.8</td><td>4</td></tr>
<tr><td>0.5-0.6</td><td>6.0</td><td>Moderately acid</td><td>0.004</td><td>Very low</td><td><10</td><td>8.2</td><td>Sodic</td><td>0.8</td><td>4</td></tr>
<tr><td>0.8-0.9</td><td>8.1</td><td>Moderately alkaline</td><td>0.137</td><td>Low</td><td>110</td><td>22.1</td><td>Strongly sodic</td><td>9.0</td><td>1</td></tr>
<tr><th rowspan="2">Depth (m)</th><th colspan="2">CEC</th><th colspan="4">Exchangeable Cations (meq/100g)</th><th colspan="3" rowspan="2">Ca/Mg Ratio</th></tr>
<tr><th>meq / 100g</th><th>Rate</th><th>Ca</th><th>Mg</th><th>K</th><th>Na</th></tr>
<tr><td>0-0.1</td><td>1.7</td><td>Very low</td><td>0.7</td><td>0.7</td><td>0.3</td><td><0.1</td><td colspan="3">1.0</td></tr>
<tr><td>0.2-0.3</td><td>0.8</td><td>Very low</td><td>0.2</td><td>0.2</td><td>0.2</td><td><0.1</td><td colspan="3">1.0</td></tr>
<tr><td>0.5-0.6</td><td>0.4</td><td>Very low</td><td>0.1</td><td>0.2</td><td><0.1</td><td><0.1</td><td colspan="3">0.5</td></tr>
<tr><td>0.8-0.9</td><td>8.8</td><td>Low</td><td>0.9</td><td>5.9</td><td><0.2</td><td>2.0</td><td colspan="3"><0.2</td></tr>
<tr><td colspan="3">Percentage in Topsoil</td><td>41.18%</td><td>41.18%</td><td>17.65%</td><td>1.00%</td><td colspan="3">-</td></tr>
</table>

Topsoil nutrients were generally quite limited, with nitrate, phosphorus and potassium, boron and sulphate at lower than guideline recommendations for suitable plant growth medium. Metals such as manganese and zinc are within the desirable range, though iron is elevated and copper was below reportable levels. The low level of nutrients in the topsoil are likely due to the low CEC and leaching capacity of the sand, paired with the low nutrient content of the parent material. (AARC, 2019)

Table 5-3 Extractable nutrients and metals in Geoffrey SMU topsoil. Source: AARC – 2019.

<table>
<tr><th colspan="6">Extractable Nutrients</th><th colspan="4">Extractable Metals</th></tr>
<tr><th>NO3+</th><th>SO^4+</th><th>Organic matter</th><th>P</th><th>K</th><th>B</th><th>Cu</th><th>Fe</th><th>Mn</th><th>Zn</th></tr>
<tr><td>3</td><td><10</td><td>1.8</td><td>8</td><td><200</td><td>0.2</td><td><1.00</td><td>166</td><td>16.0</td><td>2.16</td></tr>
</table>

6 Desktop AS1547 Assessment

6.1 Selection Criteria

To determine the suitability of a site/system for spray irrigation, a comparison against Appendix K of AS 1547:2012 has been presented in Table 6-1 on the following page. Overall, it can be seen that the nature of the soil and the site is generally supportive of spray irrigation, though the sodicity in the lower soil profile will need to be managed to ensure the soil does not become dispersive.

Table 6-1 Selection Criteria for Irrigation Systems (Appendix K or AS/NZS 1547:2012)

	Slope Gradient	Soil Depth	Soil Category Number	Depth to seasonal water table	Duration of continuous seasonal soil saturation	Dispersive (sodic) soil	High content of stones, cobbles, or boulders	Climatic factors
Recommendation	Steep slopes can cause greater run-off during wet weather (< 10%).	A minimum of 0.6 m desirable.	Categories 1 and 2 may lead to nutrients reaching groundwater. Categories 4-6 may require large irrigation fields.	>1.2 m depth.	Prolonged saturation of upper soil impedes treatment and hinders adsorption.	Soil may lose permeability during life of system.	Unless extremely stony or covered in boulders, not relevant as delivery pipes need not be dug in soil in straight line.	Best in climates where intense rainfall events are uncommon and evapotranspiration exceeds rainfall in most months.
Conditions apparent on site	Site < 4% grade	Soil profile >1.5 m deep.	Mixed soil categories present Upper profile likely Category 3 (loam based), lower profile likely Category 5-6 (clay based)	Groundwater approx. 30 m below ground.	Saturation generally not an issue given the dry climate	Sodicity present in the bottom clay layer	Gravel and stone not observed in nearby soil samples	Climate suitable. Net evapotranspiration far exceeds rainfall year-round.

6.2 Design Criteria

The following sections provide design criteria for standard surface spray irrigation systems in accordance with Appendix L and Appendix M of AS 1547:2012.

6.2.1 Irrigation Trigger

Irrigation schemes can be scheduled using either a soil moisture deficit standard, a set daily irrigation rate.

A soil moisture trigger allows for large volumes to be irrigated in dry conditions (i.e. much of the winter dry season), but minimal or no irrigation can occur during wet conditions (i.e. frequent periods in the summer wet season). The use of a soil moisture trigger requires large wet weather storage volumes, but can lessen the irrigation area required.

A set daily irrigation rate, provides the same daily irrigation rate which will take place despite weather conditions. Given that irrigation will occur every day, minimal wet weather storage is required (it is generally reserved only for truly waterlogged/flooded days). The disadvantage of a set daily irrigation rate is that the rate needs to be kept quite low, so as to not overload the soil profile in the wetter months. This typically results in the need for a larger irrigation area than would be required for a soil moisture trigger scheme.

The site has a moisture deficit throughout the majority of the year (evaporation exceeds rainfall), there is unlikely to be a major difference in irrigation area between a moisture deficit or a set irrigation scheme. Given that a set irrigation rate scheme requires minimal wet weather storage requirements and is simpler to operate, a set irrigation scheme was considered to be warranted for this site.

6.2.2 Design Irrigation Rate

AS 1547:2012 assumes a secondary treated effluent will be irrigated (BOD 20 mg/L & TSS 30 mg/L). AS 1547:2012 uses this quality assumption to deem a suitable irrigation rate based on soil permeability.

The limiting soil profile is the subsoil which is likely to consist of a heavy clay. In a heavy clay (category 6 soil) AS 1547:2012 recommends an irrigation rate no higher than 2mm day.

This irrigation rate was set as a daily maximum within the MEDLI model. The MEDLI model was then used to test how the soil/plant responded. In some cases, the daily maximum can be raised if the model responds well. In this case the maximum rate remained at 2mm/day, and this is discussed in further detail in Section 7.

7 MEDLI Modelling - Mine Construction Period

Typically, a MEDLI model will be based on site specific soil data. In the absence of site-specific soil data, the advice from the Queensland Government MEDLI team was to produce extreme soil scenario models in order to undertake a sensitivity analysis. The two most extreme models are:

- An extremely permeable soil (sand). Sandy soils are susceptible to nutrient leaching below the root zone if they are irrigated too intensely.
- An extremely impermeable soil (clay). Clay soils are susceptible to waterlogging. This results in surface runoff, and in addition to this, a waterlogged profile allows for nutrient leaching below the root zone.

7.1 Extreme Impermeable Scenario

The simulation was carried out from 1950 – 2019. Daily climate information for -24.65 149.20 (including rainfall, pan evaporation, maximum and minimum temperatures and solar radiation) was obtained from the SILO database (maintained by DES). Given the wastewater is sourced from a small new and confined network, the model assumed no wet weather infiltration into the network occurs.

The key model inputs were as follows in Table 7-1.

Table 7-1 Mine Construction Period Extreme Impermeable MEDLI Input Parameters

Parameter	Proposed System
Effluent quantity	56 m^3/day
Wet Weather Storage Tank Volume/Capacity	168 m^3 (3 days)
Tank System Sludge Accumulation	0.0 kg dwt/year
Average Rainfall	655.2 mm/yr
Soil Evaporation	2026.9 mm/yr
Effluent Irrigation Area	3.8 ha
Irrigation Application	Daily maximum of 2mm depth
Total Nitrogen entering the tank system	30 mg/L
Total Phosphorous entering the tank system	10 mg/L
Salinity	1600 µs/cm
Pasture Type	Rhodes Grass
Soil Type – Extreme Impermeable Model	Default MEDLI 2.0 Grey Clay

7.1.2 Hydraulic Balance Results

The modelling outputs indicated that by using the above irrigation scheme 100% of the treated effluent could be reused (irrigated) with no overflow events occurring.

7.1.3 Nutrient Balance Results

Nitrogen (N)

The nitrogen balance indicated that the average load of nitrogen added to the soil was 161.48 kg/ha/year. The average load of nitrogen removed by plant uptake was 206.90 kg/ha/year. This indicates there was a net average removal of nitrogen from the irrigation area. As is naturally expected, there are still a limited number of occasions when more nitrogen is added than removed (i.e. heavy rain periods), and during those occasions some nitrate is leached into the groundwater table. On average 0.17 kg/ha/year of nitrate would leach via deep drainage. This is well within the accepted limit of 5 kg/ha/year.

Phosphorous (P)

The phosphorus balance indicated that the average load of phosphorus added to the soil was 53.83 kg/ha/year. The average load of phosphorus removed by plant uptake was 42.18 kg/ha/year. This indicates a slight net average addition of phosphorus to the irrigation area. This is typically expected as most plants have a demand for nitrogen which far exceeds the demand for phosphorus.

Given that a small net addition of phosphorus occurs in most land based effluent disposal systems, the soil phosphorus adsorption capacity is relied on. It is generally considered acceptable if the phosphorus adsorption capacity life reaches 30 years or more. The model confirmed that the above scenario can achieve 46 years life capacity.

Salinity

Modelling using Rhodes Grass (considered to be moderately salt-tolerant) indicated the resulting salinity would be too low to impact upon the health of the grass. Grass health is important to maintain to ensure that nitrogen and phosphorus uptake is maximised.

7.1.4 Waterlogging

This model is limited by waterlogging, as clay soils have limited permeability. By spreading out the effluent over an area of 3.8 ha and a maximum daily irrigation rate of 2mm/day, waterlogging was entirely eliminated. If irrigation is applied at any greater intensity the model is subject to a waterlogging outlier event that would have occurred in 1983 due to a heavy prolonged rainfall event.

7.1.5 Surface Runoff Water Quality

In a similar fashion to waterlogging, the model is subject to effluent runoff if effluent is irrigated any more intensely than 2mm/day maximum over 3.8ha.

It must be noted that the model cannot account for site specific conditions such as any rainwater ponding or run-on. Once an irrigation area has been established, it must be designed to ensure that pooling does not occur, and run-on from any uphill areas is diverted around the irrigation area.

7.1.6 Model Summary

The MEDLI 2.0 model supports the irrigation of effluent in a clay soil over 3.8 ha at no more than 2mm/day. If the soil is irrigated any more intensely than this, it is prone to waterlogging and runoff.

For further detail, the MEDLI output report is provided in **Appendix B**.

7.2 Extreme Permeable Scenario

The simulation was carried out from 1950 – 2019. Daily climate information for -24.65 149.20 (including rainfall, pan evaporation, maximum and minimum temperatures and solar radiation) was obtained from the SILO database (maintained by DES). Given the wastewater is sourced from a small new and confined network, the model assumed no wet weather infiltration into the network occurs.

The key model inputs were as follows in Table 7-2.

Table 7-2 Mine Construction Period Extreme Permeable MEDLI Input Parameters

Parameter	Proposed System
Effluent quantity	56 m3/day.
Wet Weather Storage Tank Volume/Capacity	168 m3 (3 days)
Tank System Sludge Accumulation	0.0 kg dwt/year
Average Rainfall	655.2 mm/yr

Soil Evaporation	2026.9 mm/yr
Effluent Irrigation Area	3 ha
Irrigation Application	Daily maximum of 2mm depth
Total Nitrogen entering the tank system	30 mg/L
Total Phosphorous entering the tank system	10 mg/L
Salinity	1600 µs/cm
Pasture Type	Rhodes Grass
Soil Type – Extreme Impermeable Model	Default MEDLI 2.0 Sand

7.2.2 Hydraulic Balance Results

The modelling outputs indicated that by using the above irrigation scheme, with 375 KL effluent storage provided, 100% of the treated effluent could be reused (irrigated) with no overflow events occurring.

7.2.3 Nutrient Balance Results

Nitrogen (N)

The nitrogen balance indicated that the average load of nitrogen added to the soil was 204.54 kg/ha/year. The average load of nitrogen removed by plant uptake was 226.31 kg/ha/year. This indicates there was a slight net average removal of nitrogen from the irrigation area. As is naturally expected, there are still a limited number of occasions when more nitrogen is added than removed (i.e. heavy rain periods), and during those occasions some nitrate is leached into the groundwater table. On average 1.29 kg/ha/year of nitrate would leach via deep drainage. This is well within the accepted limit of 5 kg/ha/year.

Phosphorous (P)

The phosphorus balance indicated that the average load of phosphorus added to the soil was 68.18 kg/ha/year. The average load of phosphorus removed by plant uptake was 53.22 kg/ha/year. This indicates a slight net average addition of phosphorus to the irrigation area. This is typically expected as most plants have a demand for nitrogen which far exceeds demand for phosphorus.

Given that a small net addition of phosphorus occurs in most land based effluent disposal systems, the soil phosphorus adsorption capacity is relied on. It is generally considered acceptable if the phosphorus adsorption capacity life reaches 30 years or more. The model confirmed that the above scenario can achieve 30.18 years life capacity.

Salinity

Modelling using Rhodes Grass (considered to be moderately salt tolerant) indicated the resulting salinity would be too low to impact upon the health of the grass. Grass health is important to maintain to ensure that nitrogen and phosphorus uptake is maximised.

7.2.4 Surface Runoff Water Quality

The model indicated no surface runoff of the irrigated effluent would occur. However, the model cannot account for site specific conditions such as any rainwater ponding or run-on. Once an irrigation area has been established, it must be designed to ensure that pooling does not occur, and run-on from any uphill areas is diverted around the irrigation area.

7.2.5 Model Summary

The MEDLI 2.0 model supports the irrigation of effluent in a sand soil over 3.0 ha at no more than 2mm/day. If the soil is irrigated any more intensely than this, it is prone to overwhelming the soil phosphorus adsorption capacity. For further detail, the MEDLI output report is provided in **Appendix C**.

8 MEDLI Model - Mine Operational Period

Typically, a MEDLI model will be based on site specific soil data. In the absence of site-specific soil data, the advice from the Queensland Government MEDLI team was to produce extreme soil scenario models as a sensitivity analysis. The two most extreme models are:

- An extremely permeable soil (sand). Sandy soils are susceptible to nutrient leaching below the root zone if they are irrigated too intensely.
- An extremely impermeable soil (clay). Clay soils are susceptible to waterlogging. This results in surface runoff, and in addition to this, a waterlogged profile allows for nutrient leaching below the root zone.

8.1 Extreme Impermeable Scenario

The simulation was carried out from 1950 – 2019. Daily climate information for -24.65 149.20 (including rainfall, pan evaporation, maximum and minimum temperatures and solar radiation) was obtained from the SILO database (maintained by DES). Given the wastewater is sourced from a small new and confined network, the model assumed no wet weather infiltration into the network occurs.

The key model inputs were as follows in Table 8-1.

Table 8-1 Mine Operation Period Extreme Impermeable MEDLI Input Parameters

Parameter	Proposed System
Effluent quantity	28 m3/day.
Wet Weather Storage Tank Volume/Capacity	84 m3 (3 days)
Tank System Sludge Accumulation	0.0 kg dwt/year
Average Rainfall	655.2 mm/yr
Soil Evaporation	2026.9 mm/yr
Effluent Irrigation Area	1.9 ha
Irrigation Application	Daily maximum of 2mm depth
Total Nitrogen entering the tank system	30 mg/L
Total Phosphorous entering the tank system	10 mg/L
Salinity	1600 µs/cm
Pasture Type	Rhodes Grass
Soil Type – Extreme Impermeable Model	Default MEDLI 2.0 Grey Clay

8.1.2 Hydraulic Balance Results

The modelling outputs indicated that by using the above irrigation scheme, with 84 KL effluent storage provided, 100% of the treated effluent could be reused (irrigated) with no overflow events occurring.

8.1.3 Nutrient Balance Results

Nitrogen (N)

The nitrogen balance indicated that the average load of nitrogen added to the soil was 161.48 kg/ha/year. The average load of nitrogen removed by plant uptake was 206.90 kg/ha/year. This indicates there was a slight net average removal of nitrogen from the irrigation area. As is naturally expected, there are still a limited number of occasions when more nitrogen is added than removed (i.e. heavy rain periods), and during those occasions some nitrate is leached into the groundwater table. On average 0.17 kg/ha/year of nitrate would leach via deep drainage. This is well within the accepted limit of 5 kg/ha/year.

Phosphorous (P)

The phosphorus balance indicated that the average load of phosphorus added to the soil was 53.83 kg/ha/year. The average load of phosphorus removed by plant uptake was 42.18 kg/ha/year. This indicates a slight net average addition of phosphorus to the irrigation area. This is typically expected as most plants have a demand for nitrogen which far exceeds demand for phosphorus.

Given that a small net addition of phosphorus occurs in most land based effluent disposal systems, the soil phosphorus adsorption capacity is relied on. It is generally considered acceptable if the phosphorus adsorption capacity life reaches 30 years or more. The model confirmed that the above scenario can achieve 46.27 years life capacity.

Salinity

Modelling using Rhodes Grass (considered to be moderately salt tolerant) indicated the resulting salinity would be too low to impact upon the health of the grass. Grass health is important to maintain to ensure that nitrogen and phosphorus uptake is maximised.

8.1.4 Waterlogging

This model is limited by waterlogging, as clay soils have limited permeability. By spreading out the effluent over an area of 1.9 ha and a maximum daily irrigation rate of 2mm/day, waterlogging was entirely eliminated. If irrigation is applied at any greater intensity the model is subject to a waterlogging outlier event that would have occurred in 1983 due to a heavy prolonged rainfall event.

8.1.5 Surface Runoff Water Quality

In a similar fashion to waterlogging, the model is subject to effluent runoff if effluent is irrigated any more intensely than 2mm/day maximum over 1.9ha.

It must be noted that the model cannot account for site specific conditions such as any rainwater ponding or run-on. Once an irrigation area has been established, it must be designed to ensure that pooling does not occur, and run-on from any uphill areas is diverted around the irrigation area.

8.1.6 Model Summary

The MEDLI 2.0 model supports the irrigation of effluent in a clay soil over 1.9 ha at no more than 2mm/day. If the soil is irrigated any more intensely than this, it is prone to waterlogging.

For further detail, the MEDLI output report is provided in **Appendix D**.

8.2 Extreme Permeable Scenario

The simulation was carried out from 1950 – 2019. Daily climate information for Dingo (including rainfall, pan evaporation, maximum and minimum temperatures and solar radiation) was obtained from the SILO database (maintained by DES). Given the wastewater is sourced from a small new and confined network, the model assumed no wet weather infiltration into the network occurs.

The key model inputs were as follows in Table 8-2.

Table 8-2 Mine Operational Period – Extreme Permeable MEDLI Input Parameters

Parameter	Proposed System
Effluent quantity	28 m^3/day.
Wet Weather Storage Tank Volume/Capacity	84 m^3 (3 days)
Tank System Sludge Accumulation	0.0 kg dwt/year
Average Rainfall	655.2 mm/yr

Soil Evaporation	2026.9 mm/yr
Effluent Irrigation Area	1.5 ha
Irrigation Application	Daily maximum of 2mm depth
Total Nitrogen entering the tank system	30 mg/L
Total Phosphorous entering the tank system	10 mg/L
Salinity	1600 µs/cm
Pasture Type	Rhodes Grass
Soil Type – Extreme Impermeable Model	Default MEDLI 2.0 Grey Clay

8.2.2 Hydraulic Balance Results

The modelling outputs indicated that by using the above irrigation scheme, with 84 KL effluent storage provided, 100% of the treated effluent could be reused (irrigated) with no overflow events occurring.

8.2.3 Nutrient Balance Results

Nitrogen (N)

The nitrogen balance indicated that the average load of nitrogen added to the soil was 204.54 kg/ha/year. The average load of nitrogen removed by plant uptake was 226.31 kg/ha/year. This indicates there was a slight net average removal of nitrogen from the irrigation area. As is naturally expected, there are still a limited number of occasions when more nitrogen is added than removed (i.e. heavy rain periods), and during those occasions some nitrate is leached into the groundwater table. On average 1.29 kg/ha/year of nitrate would leach via deep drainage. This is well within the accepted limit of 5 kg/ha/year.

Phosphorous (P)

The phosphorus balance indicated that the average load of phosphorus added to the soil was 68.18 kg/ha/year. The average load of phosphorus removed by plant uptake was 53.22 kg/ha/year. This indicates a slight net average addition of phosphorus to the irrigation area. This is typically expected as most plants have a demand for nitrogen which far exceeds demand for phosphorus.

Given that a small net addition of phosphorus occurs in most land based effluent disposal systems, the soil phosphorus adsorption capacity is relied on. It is generally considered acceptable if the phosphorus adsorption capacity life reaches 30 years or more. The model confirmed that the above scenario can achieve 30.18 years life capacity.

Salinity

Modelling using Rhodes Grass (considered to be moderately salt tolerant) indicated the resulting salinity would be too low to impact upon the health of the grass. Grass health is important to maintain to ensure that nitrogen and phosphorus uptake is maximised.

8.2.4 Surface Runoff Water Quality

The model indicated no surface runoff of the irrigated effluent would occur. However, the model cannot account for site specific conditions such as any rainwater ponding or run-on. Once an irrigation area has been established, it must be designed to ensure that pooling does not occur, and run-on from any uphill areas is diverted around the irrigation area.

8.2.5 Model Summary

The MEDLI 2.0 model supports the irrigation of effluent in a sand soil over 1.5 ha at no more than 2mm/day. If the soil is irrigated any more intensely than this, it is prone to overwhelming the soil phosphorus adsorption capacity.

For further detail, the MEDLI output report is provided in **Appendix E**.

9 Aerosols, Pathogens, Odour and Toxins

9.1 Aerosols and Pathogens

A spray irrigation system will likely be the most simple and practical method of irrigation for this site. Spray irrigation systems disperse effluent through the air, which can result in fine mist, otherwise termed as aerosols. The aerosols can contain pathogens which can be carried for some distance on the wind.

There are a range of measures which can be put into effect to minimise the exposure risk to the public and staff from exposure to aerosols. The *National Guidelines for Water Recycling: Managing Health and Environmental Risks (Phase 1) 2006* contain guidance based on achieving pathogen hazard log reduction targets. If these hazard reduction targets can be achieved for the given scenario, the human health risk is considered to be negligible. The appropriate targets for a municipal system such as this have been extracted and presented below in Table 9-1 below. The reduction targets are as follows:

- Viruses – 5.0 log reductions.
- Protozoa – 3.5 log reductions.
- Bacteria – 4.0 log reductions.

Hazard log reduction targets can be achieved via treatment alone, or in combination with exposure reduction measures. These are discussed in further detail in Section 9.1 and Section 9.2.

Table 9-1 Pathogen hazard log reduction targets for priority uses of recycled water from treated sewage (Source – National Guidelines for Water Recycling)

Activity	**Route of exposure**	**Exposure (litres) x freq (per year)**	**Log reduction**		
			Cryptosporidium	*Rotavirus*	*Campylobacter*
Commercial food crops	Ingestion – Lettuce – Other produce **Total**	0.005 x 70 0.001 x 140 **0.49**	**4.8**	**6.1**	**5.0**
		Dual reticulation			
Garden irrigation	Ingestion of sprays Ingestion – Low S – High **Total**	0.0001 x 90 0.001 x 90 0.1 x 1 **0.2**	**4.4**	**5.8**	**4.6**
Garden food crops	Ingestion – Lettuce – Other produce **Total**	0.005 x 7 0.001 x 50 **0.09**	**4.0**	**5.3**	**4.2**
Internal uses					
Toilet flushing	Ingestion of sprays	0.00001 x 1100	3.1	4.5	3.3
Washing machine	Ingestion of sprays	0.00001 x 100	2.1	3.5	2.3
Cross-connections	Ingestion	1 x 0.365	4.7	6.1	4.8
Total internal use (no garden use)		0.38	4.7	6.1	4.8
Total residential use (garden + internal)		0.67	4.9	6.3	5.1
Municipal Irrigation	Ingestion of sprays	0.001 x 50	3.7	5.2	4.0
Dual reticulation plus municipal irrigation	Ingestion water and sprays	0.72	5.0	6.4	5.1
Fire fighting	Ingestion water and sprays	0.02 x 50	5.1	6.5	5.3

Log reduction calculations:

Cryptosporidium = Log (number of organisms in sewage x exposure (L) x frequency / 1.6 x 10^{-2})

Rotavirus = Log (number of organisms in sewage x exposure (L) x frequency / 2.5 x 10^{-3})

Campylobacter = Log (number of organisms in sewage x exposure (?) x frequency / 3.8 x 10^{-2})

9.1.2 Treatment Pathogen Log Reductions

Hazard log reductions can be achieved by using various treatment processes, either singly or in combination. Section 3.4.2 of the *National Guidelines for Water Recycling: Managing Health and Environmental Risks (Phase 1) 2006* provides detail on the log reductions which can be achieved via various treatment technology.

9.1.3 Exposure Pathogen Log Reductions

Hazard log reductions can be achieved by using various exposure control processes, either singly or in combination. Section 3.4.3 of the *National Guidelines for Water Recycling: Managing Health and Environmental Risks (Phase 1) 2006* provides detail on the log reductions which can be achieved using various exposure control measures.

9.1.4 Recommended Combination of Treatment and Exposure Reduction

The *National Guidelines for Water Recycling: Managing Health and Environmental Risks (Phase 1) 2006* provide examples of how log reductions using treatment (section 9.2) and exposure control (section 9.3) can be achieved. The three examples which are relative to municipal irrigation are provided below in Table 9-2. The options are presented in order of highest level of treatment, to lowest level of treatment. The lower the level of treatment, the higher the level of exposure reductions measures are required.

Given that the site is large in size and relatively isolated, it would be feasible to implement a range of exposure reduction measures such as buffers, restriction of public access or spray drift control. If these exposure reduction measures are utilised this would warrant only aiming for secondary treatment quality.

Further recommendations on appropriate buffer distances are provided in Section 11.2.

9.2 Odour

Odour can be released by the sewage treatment plant and the irrigation field. Odour is spread in a similar manner to that of aerosols and can be dealt with in a similar manner.

Odour can be reduced by aiming for a higher level of treatment, otherwise set back distances tend to be highly effective in addition to aerosol reduction measures (i.e. using aerosol limiting spray methods). Timing also plays a part in minimising odour drift, such as avoiding irrigation when prevalent wind direction is towards nearby residents/accommodation facilities. Irrigation can also be best timed during the day when residents/staff are at work. Avoid irrigating in periods such as cold still winter nights when temperature inversions commonly occur and “trap” odours towards the ground.

9.3 Toxins

Aside from nutrients and pathogens, wastewater can contain other toxins. Domestic sources of wastewater can contain heavy metals, pesticides and pharmaceuticals. These tend to only pose a direct risk to humans if the treated wastewater is intended for re-use to supplement a drinking water supply. In such cases the wastewater must be treated to an extremely high level to address these risks.

In this case the only risk posed by toxins is via aerosol exposure which could result in dermal contact or inhalation. This would generally need to occur via prolonged period to result in any noticeable effects. The most effective way to minimise health risks from toxins is to reduce the production of aerosols during irrigation, implement access restrictions to the irrigation area, and ensure buffer zones are implemented as per Section 11.2

Table 9-2 Examples of how pathogen log reduction targets can be achieved for Municipal Irrigation systems (Source – National Guidelines for Water Recycling)

Log reduction targets (Virus, Protozoa, Bacteria) [a]	Indicative treatment process	Log reductions achievable by treatment (V, P, B)	On-site preventative measures	Exposure reduction [b]	Water quality objectives [c]
Municipal use – open use, sports grounds, golf courses, dust suppression, etc *or* unrestricted access and application					
5.0 3.5 4.0	Advanced treatment required; for example: Secondary, coagulation, filtration and disinfection Secondary, membrane filtration, UV light	5.0 3.5 4.0	No specific measures		To be determined on case-by-case basis depending on technologies Could include turbidity criteria for filtration, disinfectant Ct or dose (UV) *E. coli* < 1 per 100ml
Municipal use, with restricted access and application					
5.0 3.5 4.0	Secondary treatment with disinfection	2.0 - 3.0 1.0 >6.0	Restrict public access during irrigation **and one** of the following: No access after irrigation, until dry (1-4 hours) Minimum 25-30m buffer to nearest point of public access Spray drift control; for example, through low-throw sprinklers (180º inward throw), vegetation screening, or anemometer switching	2.0 1.0 1.0 1.0	▪ BOD < 20mg/L[d] ▪ SS < 30mg/L[d] ▪ Disinfectant residual (e.g. minimum chlorine residual) or UV dose[e] ▪ *E. coli* < 100cfu/100mL
Municipal use, with enhanced restrictions on access and application					
5.0 3.5 4.0	▪ Secondary treatment with > 25 days lagoon detention or primary treatment with > 50 days lagoon detention ▪ Secondary treatment	1.0 – 3.0 1.0 – 3.0 3.0 – 4.0 0.5 – 2.0 0.5 – 1.0 1.0 – 3.0	Restrict public access during irrigation **and combinations** of: ▪ No access after irrigation, until dry (1-4 hours) ▪ Minimum 25-30m buffer to nearest point of public access ▪ Spray drift control, e.g. through low throw sprinklers (180º inward throw), vegetation screening or anemometer switching	2.0 1.0 1.0 1.0	▪ BOD < 20mg/L[d] ▪ SS < 30mg/L[d] ▪ *E. coli* < 1000 cfu/100mL (disinfection may be required to achieve this concentration)

B = enteric bacteria; BOD = biochemical oxygen demand; cfu = colony forming unit; Ct = disinfectant concentration x time; P = enteric protozoa; SS = suspended solid; V = enteric virus; UV = ultraviolet.

a Log reduction targets are minimum reductions required from raw sewage based on 95th percentiles from Table 3.7 of guideline.

b Exposure reductions are those achievable by on-site measures as listed in Table 3.3 of guideline.

c Water quality objectives represent medians for numbers of *E. coli* and means for other parameters.

d BOD and SS are an indication of secondary treatment effectiveness.

e Aim is to demonstrate reliability of disinfection and ability to consistently achieve microbial quality.

f Log reductions for public in the vicinity of commercial food crop irrigation areas should comply with total log reductions required for municipal use.

10 Treatment Plant Sludge Management

In addition to producing treated effluent, sewage treatment plants produce waste in the form of sludge. The sludge also needs to be disposed of, or recycled/reused if possible.

10.1 Offsite Disposal

The default option available for the management of sewage treatment plant sludge is to dewater it and dispose the dried sludge as waste. Dewatering technology is often an add on to a standard treatment plant (i.e. press belts, centrifuges, drying beds etc). The water which is extracted in the drying process is added back into the treatment plant while the dried sludge is disposed of typically at a landfill as a regulated waste.

10.2 Reuse Options

There is potential to re-use dried sludge, instead of disposing of it as a waste. In the event this option is considered, the following information has been provided for assistance.

10.2.1 End of Waste Code for Biosolids

The Waste and Contaminated Land Assessment division of DES produced the *End of Waste Code for Biosolids (ENEW07359617)* (EOWC) under the *Waste Reduction and Recycling Act 2011* to encourage the recycling and reuse of biosolids (i.e. dewatered sludge). Biosolid reuse can have a number of benefits, such as reducing landfill disposal costs for regulated waste, and the ability to sell waste to consumers. The EOWC sets out the quality criteria needed for biosolids to be re-classified as a 'resource' (instead of waste) and thus suitable for recycling or reuse.

Biosolids are classified as a 'resource' if they are generated from a sewage treatment plant, meet the quality characteristic requirements given in EOWC Table 2 (Biosolids Classification Requirements) and Table 3 (Contaminant Limits), and have been treated for at least one pathogen reduction requirement and one vector reduction requirement for Table 4 (Biosolids Stabilisation Requirements). Depending on the results, biosolids can be classified into one of four categories:

- Unrestricted Use – where EOWC Table 3 Grade A standards and Table 2 Unrestricted Use biological criteria are met. Unrestricted use biosolids can be used as fertiliser or soil ameliorant on home lawns and gardens, public contact sites, urban landscaping, agriculture, forestry, and soil and site rehabilitation.
- Restricted Use 1 – where EOWC Grade B standards and Table 2 Restricted Use 1 biological criteria are met. Reuse is allowed as above, except for home lawns and gardens.
- Restricted Use 2 – where Grade C standards plus at least one pathogen reduction requirement and one vector reduction requirement for stabilisation Grade B of Table 4 are met. Resource use is allowed for agriculture, forestry, and soil and site rehabilitation.
- Non-compliant – where biosolids do not meet the criteria, and are thus classed as regulated waste and must be disposed of accordingly.

10.2.2 Sampling Requirements

Sampling requirements are as follows:

- At least 1 sample must be collected for every 120 dry tonnes of biosolids.
- Samples collected must be representative of the material.
- Sampling must be conducted by an appropriately qualified person, with samples sent to a NATA-accredited lab.
- A range of contaminants must be tested for. These include
  - Certain per- and poly-fluoroalkyl substances (PFAS) types.
  - Pathogens including bacteria, viruses and helminths.
  - Heavy metals.
  - Pesticides.

  - PCBs.
  - BHC.

10.2.3 Known Catch Points

Site Suitability Assessment

For an area to accept dried sludge as a resource, a site suitability assessment must be undertaken to determine the existing soil nutrient and contaminant levels, and determine if the soil has the ability to assimilate them without exceeding the soil limits presented in Table 6 of the EOWC.

The emergence of PFAS as a major contaminant of concern in recent years has presented a significant hurdle which can be challenging to overcome. Specific PFAS soil limits are presented in Table 7 of the EOWC and the limits are extremely low. PFAS are a common group of chemicals which are present in human bodies and human waste. There is significant likelihood that the sludge may contain concentrations of PFAS which can quickly cause receiving soil to exceed the targets in Table 7 of the EOWC. For this reason, it is important to characterise the PFAS concentrations of the sludge early on, to determine if the PFAS levels will make sludge reuse a viable option.

Resource User Agreement

If the sludge can be reused, it cannot be stored for more than 30 days without an Environmental Authority (EA) for site rehabilitation. It also can’t be stored within buffer zones of sensitive areas like water bores, farm dams and driveways (shown in Table 7of the EOWC). It is therefore important that an agreement is in place from an accepting party before the sludge is moved to their site.

Consultation with neighbours prior to resource supply must occur, with records kept. The resource user must comply with all resource application guidelines in the Code.

10.2.4 Records

When supplying the resource to a resource user:

- The resource supplier must make the user aware, in writing, of any restrictions relating to the resource classification (for example, if it is not in the unrestricted category it cannot be used on home lawns and gardens).
- Keep records of details relating to use e.g. application rates, GPS locations, dates and times.
- The supplier must keep monitoring/sampling/classification records for at least 5 years in case they are requested by DES. Any records requested will need to be supplied to DES within 10 business days.
- The supplier must also record tracking details of the resource provided; the purchaser’s address, where the resource will be applied, information provided to the purchaser etc as per the EOWC.

11 Set Out and Management of Irrigation Area

11.1 Spray Irrigation Specifications

The following spray irrigation recommendations are adopted from AS/NZS 1547:2012.

- An example of an irrigation field using many sprinklers with small spray radius (minimal aerosols) is provided in **Appendix F.**
  - If during detailed design the irrigation area if confirmed to be well away from any sensitive receivers (accommodation facilities and public) fewer sprinklers with larger spray radius can likely be used.

11.1.1 Designated Disposal Area

Irrigation systems shall be located in a designated area to enhance evapotranspiration and its amenity and shall:

- Not be used for purposes that compromise the effectiveness of the system or access for future maintenance purposes;
- Be used only for effluent application;
- Have boundaries clearly delineated by appropriate vegetation or fence other type of border (keeping stock out of the irrigation area is particularly important to minimise damage);
- Have no run-off or seepage of effluent beyond the designated area;
- Have no casual access by humans or animals;
- Allow no spray to reach areas normally occupied by humans or animals.

11.1.2 Irrigation System

Spray- irrigation systems shall:

- Distribute the effluent evenly in the designated area;
- Control the droplet size, throw and plume height of the sprinkler system so that the risk of aerosol dispersion and likelihood of wind draft distributing any effluent beyond the designated area are negligible;
- Have warnings, complying with AS 1319 or AS/NZS 1319, at the boundaries of the designated area in at least two places, clearly visible to property users, with wording such as “Recycled Water – Avoid Contact – DO NOT DRINK”;
- Meet the applicable treatment standard (i.e. secondary standard); and
- Be provided with a buffer area to ensure that any potential spray drift is adsorbed within appropriate setback distances.

11.1.3 Spray

Spray heads shall:

- Distribute the effluent through coarse spray heads suitable for use with effluent;
- Distribute the effluent evenly; and
- Not produce fine mist of aerosols.

11.1.4 Pump System

The pump system shall:

- Have a separate effluent chamber that has a storage volume to match the electrical starting requirements of the irrigation pump motor and to copy with the design flow:
- Have performance characteristics that match the hydraulic characteristics or the irrigation system;
- Be capable of discharging at least 50% more than the maximum 30-minute flow rate; and
- A minimum pump chamber volume of 200L.

11.1.5 Pipework

The pipes and fittings shall:

- Be rated to withstand at least 150% of the shut-off head of the pump;
- Be semi-flexible and robust; and
- Be permanently buried and fixed

11.1.6 Solids, soil and water

The following measures shall be taken to prevent malfunction of the irrigation system.

- In-line filters shall be provided on the pump discharge to protect pipework from any effluent solids carried over from the wastewater treatment unit into the irrigation lines and to facilitate system servicing;
- Vacuum release valves shall be provided to prevent ingress of soil into the irrigation lines under the effects of negative pipeline pressures. Air release valves shall be fitted at high points in the pipeline. In both cases these valves shall be fitted with boxes to protect the valve and to provide access for maintenance; and
- All surface boxes shall be provided with purple coloured lids to indicate their use for wastewater.

11.2 Buffer Distances

The QLD Government Technical Guideline for Disposal of Effluent via Irrigation provide the following distances for reducing the risk associated with land disposal schemes using effluent irrigation:

- Natural waterways >100 m
- Residential facility or public amenities >50 m
- Domestic water bore > 250 m
- Drinking water catchment and aquatic ecosystems with high ecological value > 250 m
- Town water supply bore > 1000m
- Groundwater bore used for potable water supply >250 m; and
- Groundwater table at a depth >3 m.

Section 12.3 contains an example of how this can be achieved.

11.3 Management of Soil Sodicity

It is important to note that the subsurface soil is likely to contain elevated levels of sodicity (high percentage of sodium in the soil). Sodic soils tend to disperse readily when in contact with water, particularly if the water is fresh and lacks other ions (particularly calcium) which can counter balance the effects of sodium. Over time dispersion can reduce the permeation of water and air into the soil profile.

The MEDLI model does not have the ability to account for changes to the soil profile resulting from dispersion, therefore additional measures need to be taken to prevent it from occurring. The Department of Environment and Resource Management - *Salinity Management Handbook Second Edition 2011* provides a range of management measures which can be used to manage salinity and sodicity in soils. In an effluent irrigation scenario such as this, with a predominantly low permeable clay profile the most reasonable and practical measures include:

- Management of the soil profile to minimise dispersion; and/or
- Management of the irrigation water to minimise dispersion.

11.3.1 Management of Soil

It is possible to balance the soil Sodium Adsorption Ratio (SAR) by addition of calcium (typically gypsum) into the soil profile which results in better surface soil aggregation and consequently reduced waterlogging and crusting, and can improve drainage.

In this case, gypsum would be added to the upper loamy soil profile (which is not sodic) with the aim of leaching the calcium into the underlying sodic clay profile. This should work relatively well as the upper profile is relatively permeable. Gypsum has a relatively low solubility, and it is estimated that on average only

1 tonne/ha/year of pure gypsum can be dissolved (Ayers & Westcot 1976). Due to the impurities in gypsum, unevenness of distribution and loss from surface runoff, the general recommendation is 2-6 t/ha every year.

The alternative is to apply gypsum via the irrigation water as discussed in Section 11.3.2. This method can be much more effective at dissolving the gypsum.

11.3.2 Management of Irrigation Water

It is possible to lessen the potential for dispersion by controlling the Sodium Adsorption Ratio (SAR) of the irrigated effluent. The following table is extracted from the *Salinity Management Handbook Second Edition 2011*. In summary it is recommended that the SAR of the irrigated effluent is maintained below 5 for clays, which can generally be achieved by addition of calcium (typically gypsum) to balance out the ratio of sodium. Sometimes acids such as sulfuric or phosphoric acid are also added in small doses to the irrigation water to aid in the dissolution of gypsum.

The specific dosing rates would need to be calculated during the commissioning of the sewage treatment plant when the SAR of the irrigation water can be accurately measured.

Table 11-1 Guide to permissible SAR of irrigation water to maintain a stable soil surface (Source – Salinity Management Handbook, Second Edition)

Clay content (%)	Soil texture	Permissible irrigation water SAR* Clay mineralogy expressed as CCR (mole$_c$, kg)				
		< 0.35 non-cracking**	0.35 – 0.55 non-cracking	0.55 – 0.75 cracking**	0.75 – 0.95 strongly cracking	> 0.95 very strongly cracking
< 15	Sand, sandy loam	> 20	> 20	> 20	> 20	> 20
15 – 24	Loam, silty loam	20	11	10	10	8
25 – 34	Clay loam	13	11	8	5	6
35 – 44	Light clay	11	8	5	5	5
45 – 54	Medium clay	10	5	5	5	5
55 – 64	Medium-heavy clay	5	5	5	4	4
65 – 74	Heavy clay	-	4	4	4	4
75 - 85	Heavy clay	-	-	4	5	5

* Values calculated assuming surface soil EC equal to undisturbed soil in Lockyer Valley, modified from Shaw and Thorburn (1985) at 2000mm rainfall.

Shaw RJ, Thorburn PJ (1985) *Prediction of leaching fraction from soil properties, irrigation water and rainfall*. *Irrigation Science* **6**, 73–83.

** Cracking or non-cracking applies only if clay content is greater than about 35%.

11.4 Maintaining Pasture

The MEDLI model assumes that when the grass is mowed, that the grass clippings are removed from the area so that the nutrients within the grass clippings are removed with them. There are a couple of ways to achieve this, by either using a mower with a catcher, or by removing the grass clippings after mowing has been completed (i.e. manually or via leaf blower etc)

The MEDLI model indicates that mowing would only be required approximately 3 times per year to maintain sufficient growth and subsequent nutrient uptake. The grass can be mowed more frequently to maintain aesthetics if required.

12 Conclusions and Recommendations

The conclusions below are based on using default worst case scenario soils (sand and clay) in MEDLI. The irrigation areas and rates are likely to be conservative, and can be refined once site-specific soil data can be obtained.

12.1 Mine Construction Phase

During construction a conservative volume of **56m^3** per day of secondary treated effluent with quality as per Table 4-1 and Table 4-2 is expected to be generated. This effluent can be irrigated over **3.8 ha** at no more than **2mm/day** in either an extremely impermeable or extremely permeable soil without nutrient leaching or runoff issues arising. If **168m^3** of wet weather storage (3 days) is provided in tanks, no overflow events will occur.

12.2 Mine Operational Phase

During operation a conservative volume of **28m^3** per day of secondary treated effluent with quality as per Table 4-1 and Table 4-2 is expected to be generated. This effluent can be irrigated over **1.9 ha** at no more than **2mm/day** in either an extremely impermeable or extremely permeable soil without nutrient leaching or runoff issues arising. If **84m^3** of wet weather storage (3 days) is provided in tanks, no overflow events will occur.

12.3 Location of Disposal Area

The irrigation disposal area can be located anywhere within the investigation area, using whichever shape is most practical. One example is provided below in Figure 12-1. Using a square set out, approximately 195m x 195m is required to cover 3.8 ha. The example of an irrigation area in Figure 12-1 has been produced using a GPS location of -23.6334 S, 149.2193 E for the north west corner.

The example location achieves >200m buffer from nearby remnant vegetation, and mapped watercourses. It is also situated >500m away from the proposed mine accommodation facilities and even further from the public road/rail line so as to limit any aerosol or odour exposure.

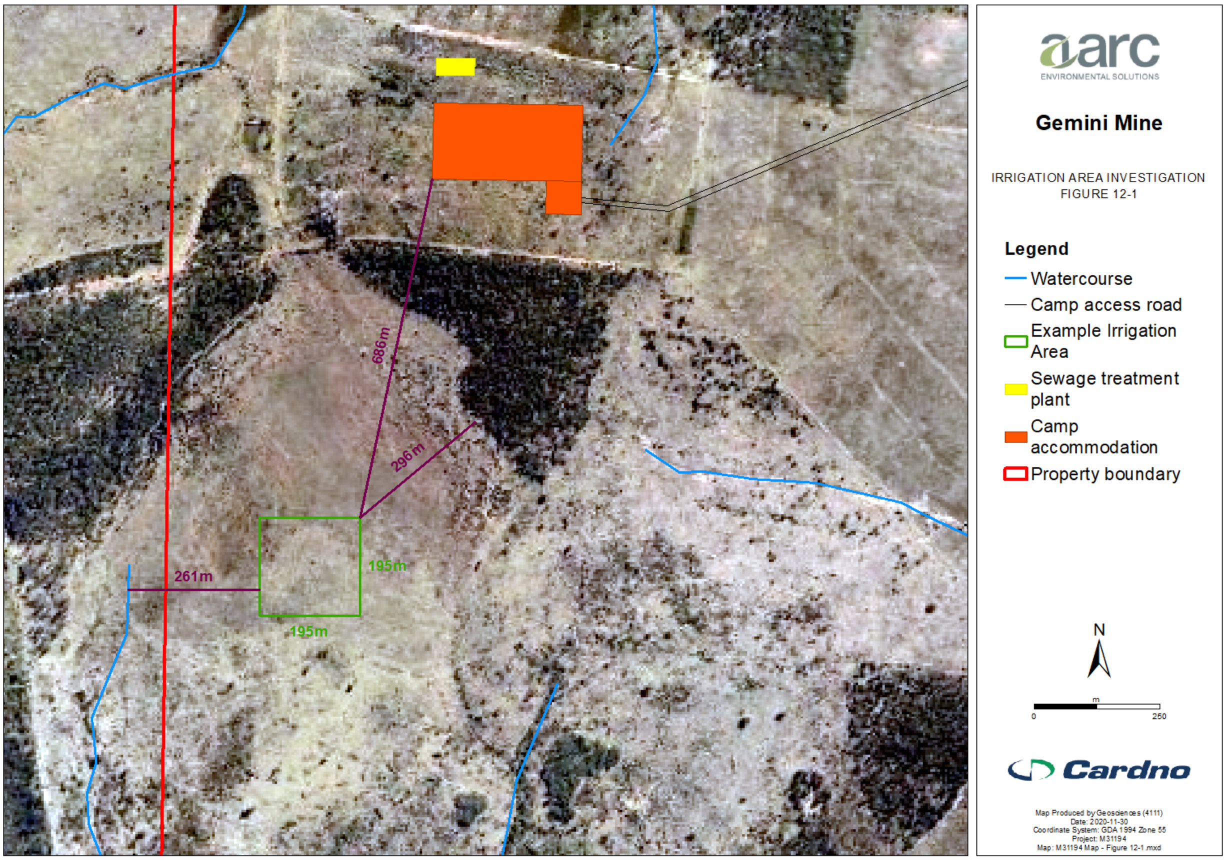


Figure 12-1 Example of Irrigation Area Size and Location

12.4 Managing Pathogen Exposure Risk

It will likely be reasonable and practical to restrict public/staff access to the irrigation area, and restrict the irrigation application method as per the last row in Table 9-2. As a result, the risk of pathogen exposure to the public/staff is low enough to negate the requirement for any additional treatment or disinfection.

12.5 Managing Soil Sodicity

The underlying soil profile at ~0.7m depth is likely to consist of a sodic clay layer. Sodic soils need to be managed to prevent them becoming dispersive, which leads to reduction in pore spaces and waterlogging issues. Management options will need to centre around balancing the Sodium Adsorption Ratio (SAR) in the soil via direct addition of gypsum to the soil profile, or via the irrigated effluent as per Section 11.3.

12.6 DES RFI Responses

For specific detail as to how each RFI item has been addressed in this report refer to Appendix G.

12.7 Standard of Assessment and Limitations

This Land-Based Effluent Disposal Assessment Report has been undertaken in general accordance with the current “industry standard” for wastewater management set out in AS/NZS 1547:2012 *On-site Domestic Wastewater Management.*

The agreed scope of this desktop assessment has been limited for the current purposes of the Client. As no soil testing on site could be completed at the time of reporting due to access restrictions, this investigation was based on the results of previous soil sampling completed at the site for AARC’s (July 2019) report *Gemini Project Soil and Land Suitability Assessment* prepared for Magnetic South Pty Ltd.

13 References

- AARC Environmental Solutions Pty Ltd (July 2019) *Gemini Project Soil and Land Suitability Assessment*. Prepared for Magnetic South Pty Ltd. Provided by the client.
- AARC Environmental Solutions Pty Ltd (October 2019) *Project Description and Background – Gemini Project.* Prepared as part of the EA Application and provided by the client.
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- *Environmental Protection (Water and Wetland Biodiversity) Policy 2019.* Available: https://www.legislation.qld.gov.au/view/html/inforce/current/sl-2019-0156#
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- Central Highlands Regional Council Planning Scheme Flood Hazard Overlay Map.
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- National Resource Management Ministerial Council, Environment Protection and Heritage Council and Australian Health Ministers Conference (2006) Australian Guidelines for Water Recycling: Managing Health and Environmental Risks (Phase 1). Available: www.awa.asn.au/Documents/water-recycling-guidelines-health-environmental-21.pdf
- *Tennakoon. S, and Ramsay. I, 2020. Technical Guideline for disposal of effluent via irrigation. Brisbane: Queensland Department of Environment and Science.*

APPENDIX

A

DEPARTMENT OF ENVIRONMENT & SCIENCE'S REQUEST FOR FURTHER INFORMATION

DEPARTMENT OF ENVIRONMENT AND SCIENCE – REQUEST FOR INFORMATION

The principal objective of this assessment was to provide a report responding to DES's RFI and combining all treatment and disposal recommendations. The following information has been requested by DES:

- Justification of any predicted storage overflows in terms of environmental impact;
- Runoff assessments for proposed and future effluent disposal rates. It is understood the construction phase will accommodate up to 280 equivalent persons and the operational phase up to 140 equivalent persons;
- Management measures to be implemented to ensure irrigation does not exceed water holding capacity of the soil or the uptake capacity of the crop, resulting in water logging, surface runoff or excessive deep drainage;
- Capacity of the vegetation and soils in the irrigation area to assimilate salts on a long-term, sustainable basis;
- The irrigation application method and scheduling;
- Risks of human exposure from irrigation of effluent or aerosol drift;
- Risks of aerosol drift to off-sife locations and odour nuisance;
- Buffer zones from sensitive receptors to the irrigation area and sewage treatment plant;
- Model scenarios including 140 persons and 280 persons;
- Consideration to contingencies following a sewage treatment plant failure event and maintenance issues;
- Effluent sources and type:
  - Type of treatment applied: treatment process, design details including size/volumes, peak design capacity;
  - Quantity, description of average and maximum wastewater flows in dry versus wet weather periods;
  - Average and maximum concentrations of key contaminants including total nitrogen, total phosphorus, electrical conductivity/total dissolved salts and sodium/sodium absorption ratio; and
  - A risk assessment of other contaminants including heavy metals, pharmaceuticals, toxins and pathogens including E. coli.
- The location of effluent discharge (irrigation scheme) and a layout plan showing:
  - Property boundaries;
  - Proposed irrigation area boundary;
  - Location of any wet weather storage infrastructure;
  - Sampling and discharge points including GPS coordinates and elevation;
  - Topography including drainage lines, water courses or any waters;
  - Any sensitive receiving environments such as sensitive/high ecological value areas in close vicinity to the irrigation scheme;
  - Any buffer distances to sensitive receivers.
- Historic climate data to support the proposed irrigation scheme, preferably obtained from Silo DataDrill;
- A description and risk assessment of the frequency of inundation in the area. The sewage treatment plant and any other high-risk areas should be located above the Q100 floodplain;
- A description of soil characteristics of the proposed effluent irrigation area including erodibility, texture, structure, impermeable layers, any evidence of rising water table, nitrogen and phosphorus content, exchange sodium percentage and background concentrations of any contaminants;
- A description of the proposed vegetation for the irrigation area; species of plant cover and management of plant biomass (expected to be cutting and removal from the irrigation area);
- The presence of groundwater or temporary perched water tables, levels over time and background water quality;
- Impacts to groundwater of the proposed treated effluent release;

- The proposed irrigation regime, method and infrastructure required, and management of any potential aerosol drift generated;
- Wet weather storage management and contingency plans;
- Water balance method MEDLI modelling to determine suitable wet weather storage volume, size and locations of effluent irrigation areas based on volume of wastewater generated; and
- A description of any waste treatment processes proposed and the anticipated end products of these processes, including the quality of irrigation water and waste residues including sludge.

APPENDIX

B

CONSTRUCTION PERIOD: EXTREME IMPERMEABLE MEDLI MODEL OUTPUT REPORT

Enterprise: **Gemini Construction - Extreme Impermeable**

Description:
Clay Based Model

Client: **Gemini Mine**

MEDLI User: CARDNO\mark.farrey

Scenario Details:
Construction - Extreme Impermeable - Clay Soil
-168KL Storage (3 days)
- 2mm/day max irrigation
- 3.8ha irrigation area
- Rhodes Grass

Climate Data: Gemini -23.65_149.20, -23.65°, 149.2°

Run Period: 01/01/1950 to 31/12/2019 70 years, 0 days

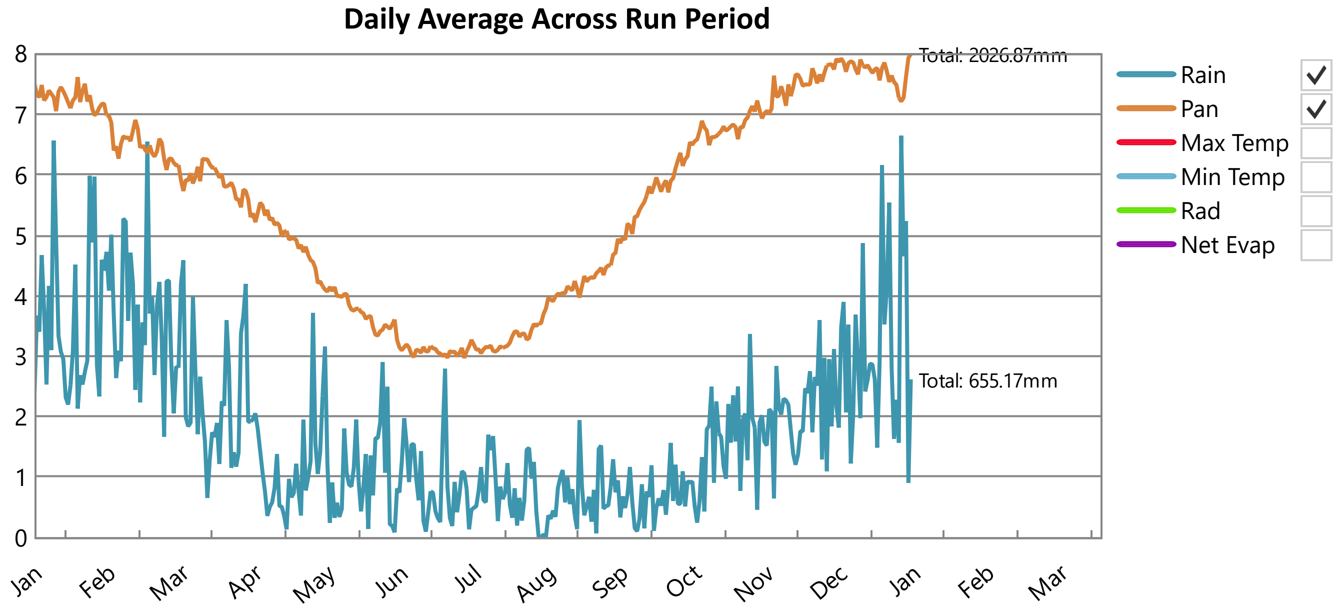
Climate Statistics:

	5th ▾ Percentile	50th Percentile	95th ▾ Percentile
Rainfall (mm/year)	308	632	1107
Pan Evaporation (mm/year)	1792	2046	2219

Climate Data:

■ Chart ☐ Table

☐ Monthly ■ Daily



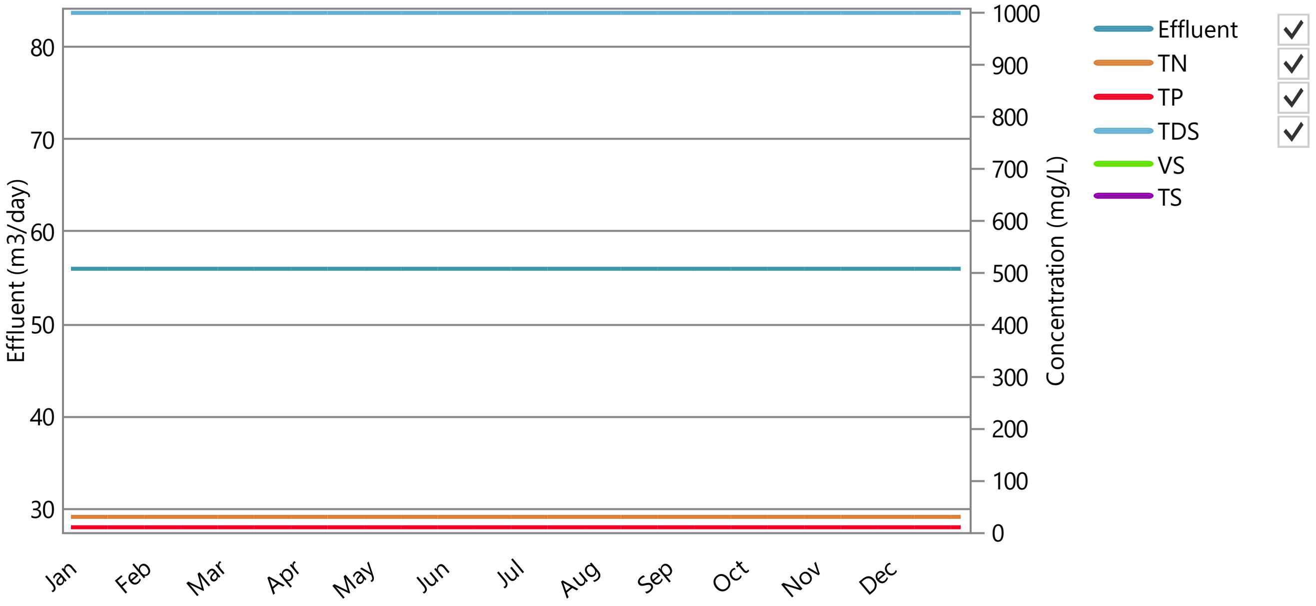
DESCRIPTION

Effluent type: New Sewage Treatment Plant

Wastestream before any recycling or pretreatment

Average daily quantity and flow-weighted average quality:

■ Chart ☐ Table



Wastestream after any recycling and pretreatment if applicable

Effluent quantity: **20453.60 m3/year** or 56.00 m3/day (Min-Max: 56.00 - 56.00)

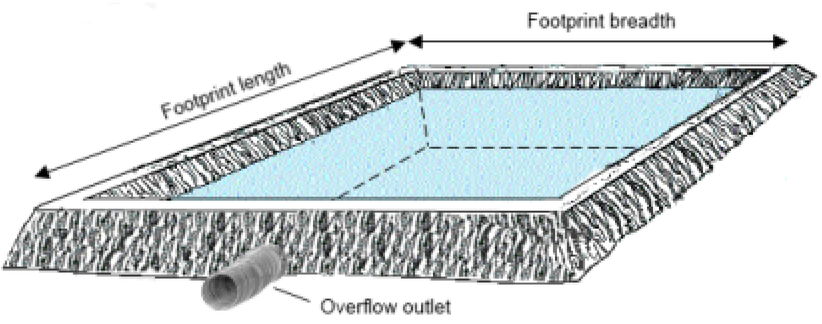
Flow-weighted average (minimum - maximum) daily effluent quality entering pond system:

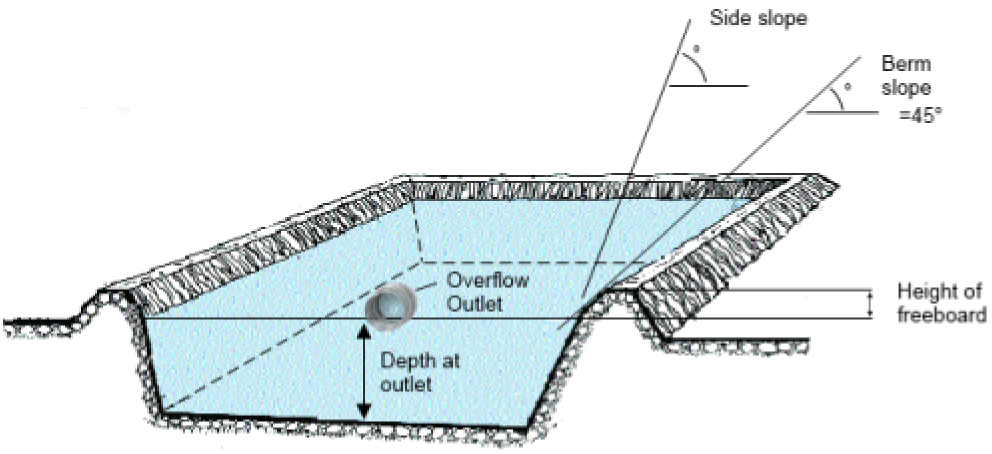
	Concentration (mg/L)	Load (kg/year)
Total Nitrogen	30.00 (30.00 - 30.00)	613.61 (613.20 - 614.88)
Total Phosphorus	10.00 (10.00 - 10.00)	204.54 (204.40 - 204.96)
Total Dissolved Salts	1000.00 (1000.00 - 1000.00)	20453.60 (20440.00 - 20496.00)
Volatile Solids	0.00 (0.00 - 0.00)	0.00 (0.00 - 0.00)
Total Solids	0.00 (0.00 - 0.00)	0.00 (0.00 - 0.00)

Pond system: 1 closed storage tank

Pond system details:

	Pond 1
Maximum pond volume (m3)	168.00
Minimum allowable pond volume (m3)	0.00
Pond depth at overflow outlet (m)	3.00
Maximum water surface area (m2)	56.00
Pond footprint length (m)	7.48
Pond footprint width (m)	7.48
Pond catchment area (m2)	56.00
Average active volume (m3)	0.00





Irrigation pump limits:

Minimum pump rate limit (ML/day)	0.00
Maximum pump rate limit (ML/day)	1000000.00

Shandying water:

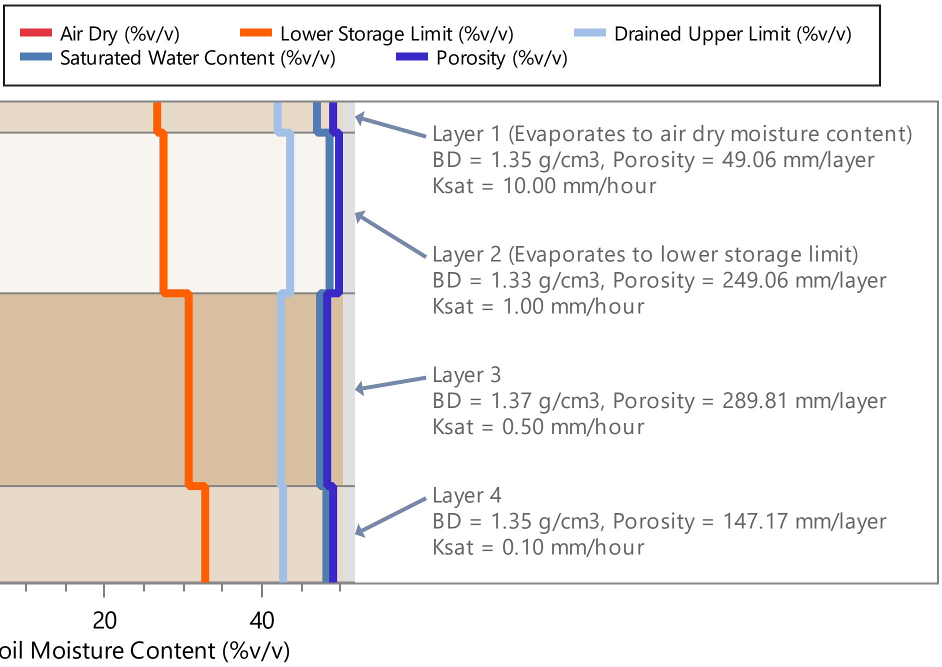
Annual allocation of fresh water available for shandying (m3/year)	0.00
Maximum rate of application of fresh water (ML/day)	0.00
Nitrogen concentration (mg/L)	0.00
Salinity (dS/m)	0.00
Minimum shandy water is used	False

Land: Gemini Clay

Area (ha): 3.80

Soil Type: Grey Clay, 1500.00 mm defined profile depth

Profile Porosity (mm)	735.09
Profile saturation water content (mm)	719.00
Profile drained upper limit (or field capacity) (mm)	642.50
Profile lower storage limit (or permanent wilting point) (mm)	446.80
Profile available water capacity (mm)	195.70
Profile limiting saturated hydraulic conductivity (mm/hour)	0.10
Surface saturated hydraulic conductivity (mm/hour)	10.00
Runoff curve number II (coefficient)	75.00
Soil evaporation U (mm)	6.00
Soil evaporation Cona (mm/sqrt day)	3.50



Plant Data: Continuous Kikuyu 1 Pasture

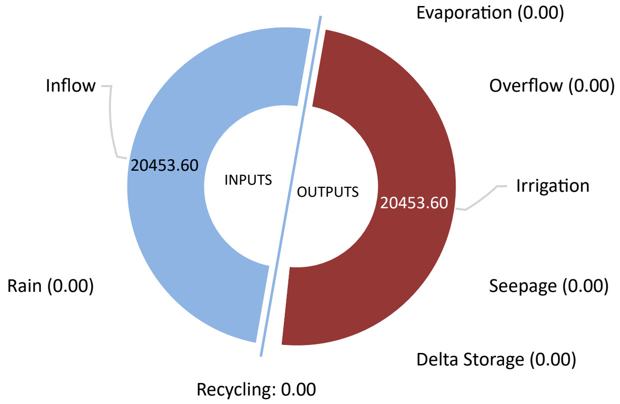
Average monthly cover (fraction) (minimum - maximum)	0.87 (0.82 - 0.91)
Maximum crop factor at 100% cover (mm/mm) (Maximum crop coefficient 0.8 x Pan coefficient 1)	0.80
Total plant cover (both green and dead) left after harvest (fraction)	1.00
Maximum potential root depth in defined soil profile (mm)	1200.00
Salt tolerance	Moderately tolerant
Salinity threshold EC sat. ext. (dS/m)	3.00
Proportion of yield decrease per dS/m increase (fraction/dS/m)	0.03

PERFORMANCE

Pond System Water Performance - Overflow: 1 closed storage tank

Capacity of wet weather storage pond: **168 m3**

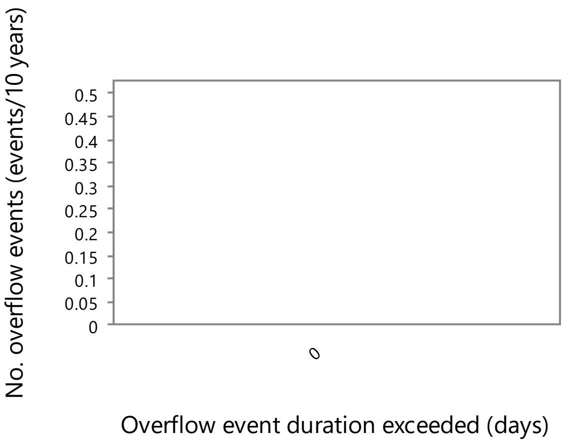
Pond System Water Balance (m3/year)

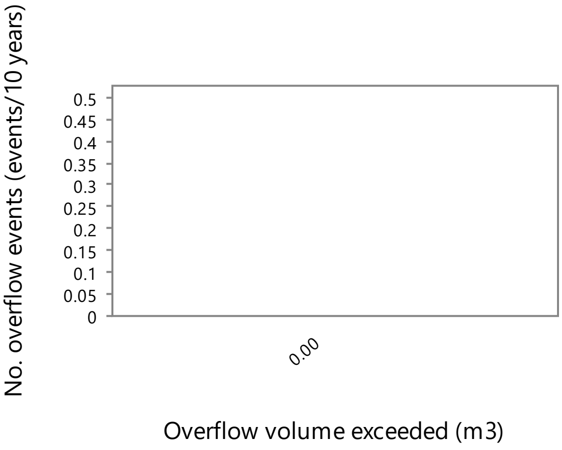


Name	Value
Rain	0.00
Inflow	20453.60
Recycling	0.00
Evaporation	0.00
Overflow	0.00
Irrigation	20453.60
Seepage	0.00
Delta Storage	0.00

Overflow Diagnostics

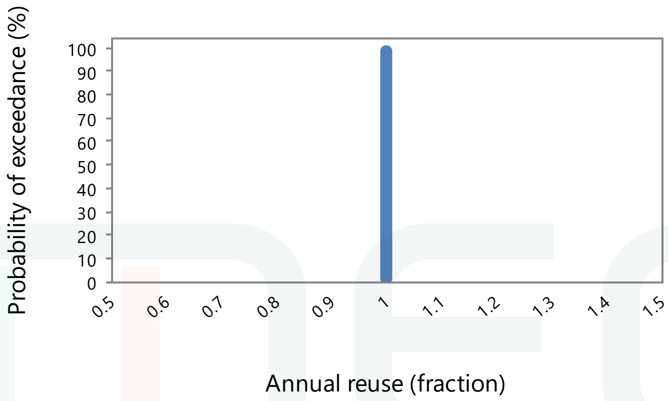
Volume of overflow (m3/year)	0.00
No. days pond overflows (days/year)	0.00
Average duration of overflow (days)	0.00
Effluent Reuse (Proportion of Inflow + Net Rain Gain that is Irrigated) (fraction)	1.00
Probability of at least 90% reuse (fraction)	1.00





Export plot

Export plot



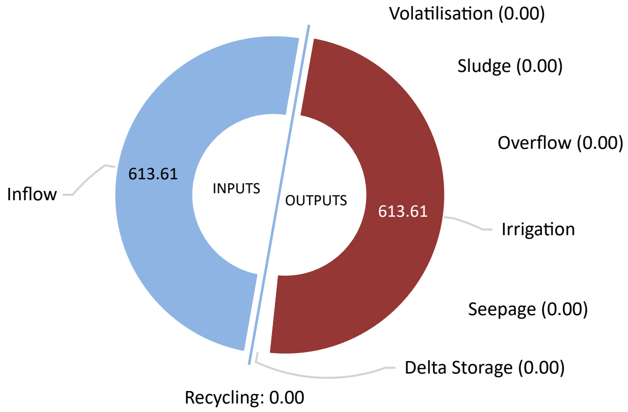
Export plot

PERFORMANCE

Pond System Performance - Nutrient: 1 closed storage tank

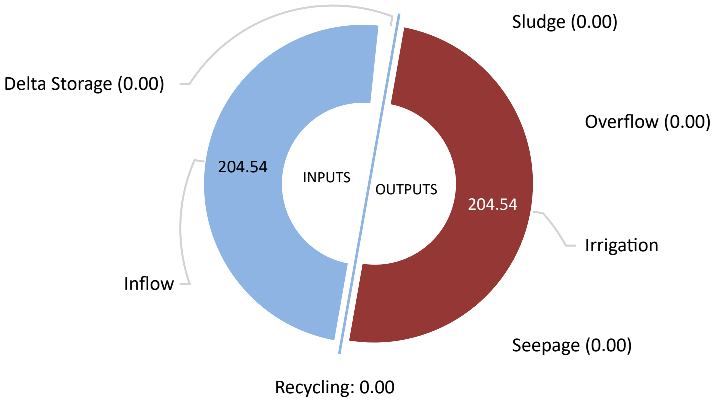
Pond System Nutrients and Salt Balance:

Nitrogen Balance (kg/year)



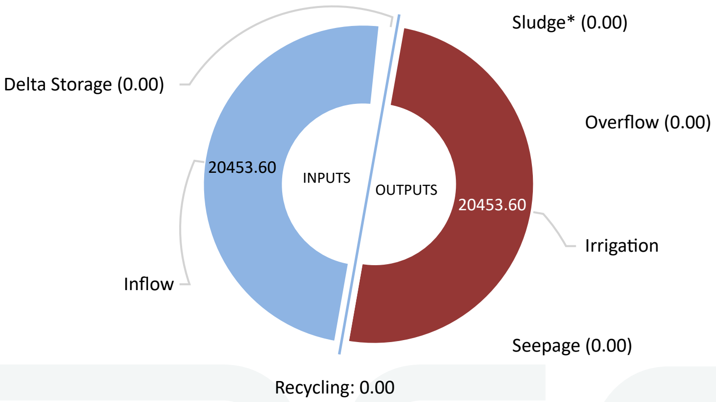
Name	Value
Inflow	613.61
Recycling	0.00
Volatilisation	0.00
Sludge	0.00
Overflow	0.00
Irrigation	613.61
Seepage	0.00
Delta Storage	0.00

Phosphorus Balance (kg/year)



Name	Value
Inflow	204.54
Recycling	0.00
Sludge	0.00
Overflow	0.00
Irrigation	204.54
Seepage	0.00
Delta Storage	0.00

Salt Balance (kg/year)



Name	Value
Inflow	20453.60
Recycling	0.00
Sludge*	0.00
Overflow	0.00
Irrigation	20453.60
Seepage	0.00
Delta Storage	0.00

* Salt removal in sludge is not calculated from the pond salt balance. However if salt could be assumed to be present in the sludge at the same concentration as in the pond supernatant (up to a maximum of salt added in inflow) - then salt accumulation in the sludge could be 0.00 kg/year

Pond System Sludge Accumulation: 0.00 kg dwt/year

Pond System Performance - Nutrient: 1 closed storage tank

Pond Nutrient Concentrations and Salinity:

Average across simulation period	Pond 1
Average nitrogen concentration of pond liquid (mg/L)	30.00
Average phosphorus concentration of pond liquid (mg/L)	10.00
Average salinity of pond liquid (dS/m)	1.56

Value on final day of simulation period	Pond 1
Final nitrogen concentration of pond liquid (mg/L)	N.D.*
Final phosphorus concentration of pond liquid (mg/L)	N.D.*
Final salinity of pond liquid (dS/m)	N.D.*

* Not determined. Pond is empty.

PERFORMANCE

Irrigation Performance:

Water Use: (assumes 100% Irrigation Efficiency)

Pond water irrigated (m3/year)	20453.60
Average Shandy water irrigation (m3/year) (minimum - maximum)	0.00 (0.00 - 0.00)
Total water irrigated (m3/year)	20453.60
Proportion of irrigation events requiring shandying (fraction of events)	0.00
Proportion of years shandying water allocation of 0 m3/year is exceeded (fraction of years)	0.00
Average exceedance as a proportion of annual shandy water allocation (fraction of allocation) (minimum - maximum)	0.00 (0.00 - 0.00)

Irrigation Quality:

Average nitrogen concentration of irrigation water - before ammonia loss during irrigation (mg/L)	30.00
Average nitrogen concentration of irrigation water - after ammonia loss during irrigation (mg/L)	30.00
Average phosphorus concentration of irrigation water (mg/L)	10.00
Average salinity of irrigation water (dS/m)	1.56

Irrigation Diagnostics:

Proportion of Days irrigation occurs (fraction)	1.00

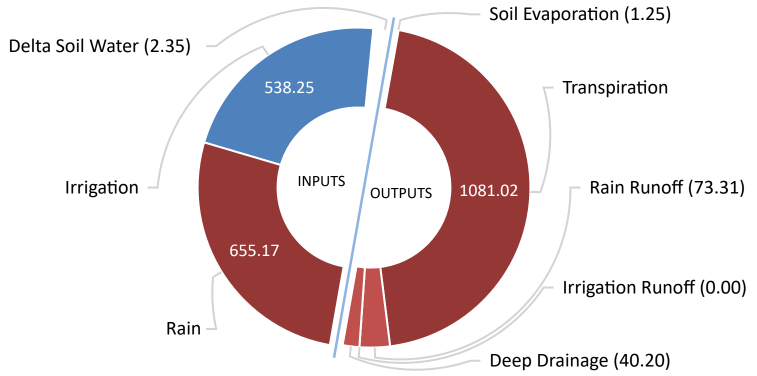
PERFORMANCE

Land Performance - Soil Water

Paddock: Gemini Clay, 3.8 ha
Soil Type: Grey Clay, 166.00 mm PAWC at maximum root depth

Land Water Balance (mm/year):

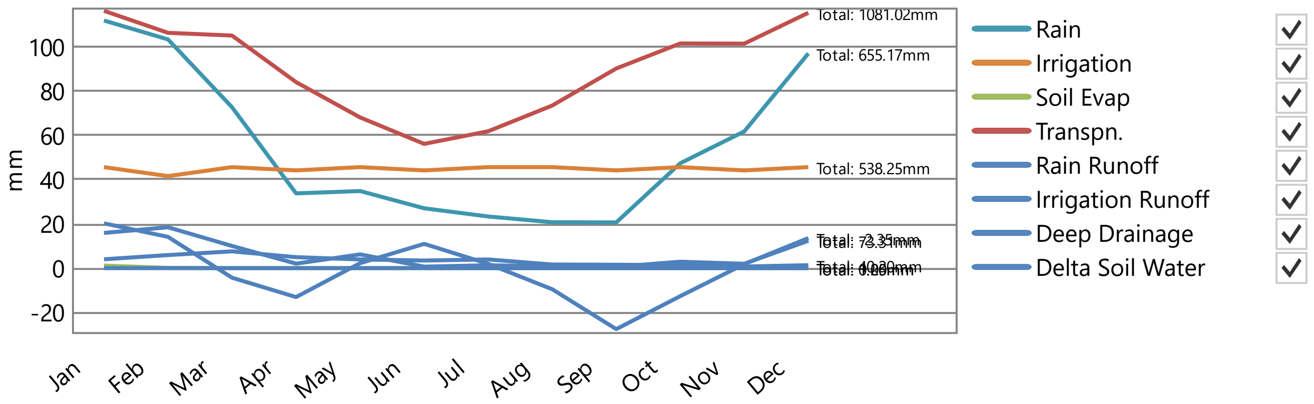
▣ mm/year ☐ % Total inputs



Name	Value
Rain	655.17
Irrigation	538.25
Soil Evaporation	1.25
Transpiration	1081.02
Rain Runoff	73.31
Irrigation Runoff	0.00
Deep Drainage	40.20
Delta Soil Water	-2.35

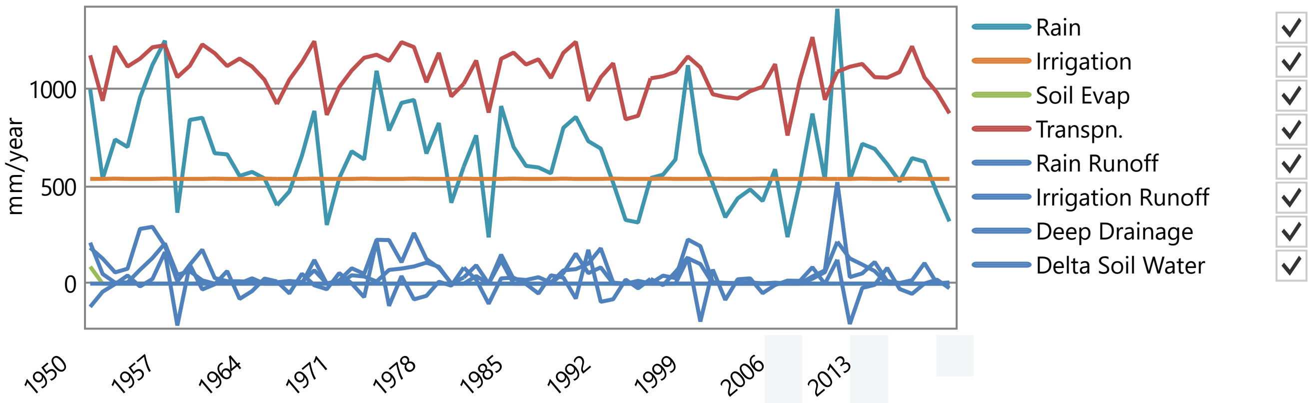
Average Monthly Totals (mm):

▣ Chart ☐ Table



Average Annual Totals (mm/year):

▣ Chart ☐ Table



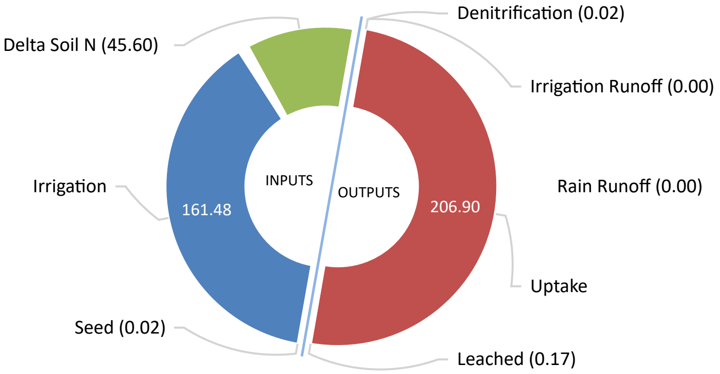
PERFORMANCE

Land Performance - Soil Nutrient

Paddock: Gemini Clay, 3.8 ha **Soil Type**: Grey Clay

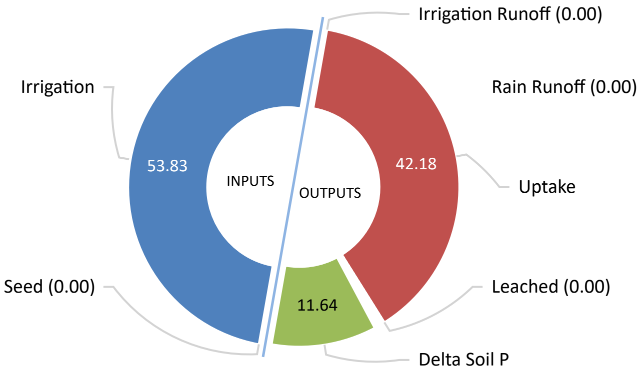
Irrigation ammonium volatilisation losses (kg/ha/year): 0.00
Proportion of total nitrogen in irrigated effluent as ammonium (fraction): 0.25

Land Nitrogen Balance (kg/ha/year)



Name	Value
Seed	0.02
Irrigation	161.48
Denitrification	0.02
Irrigation Runoff	0.00
Rain Runoff	0.00
Uptake	206.90
Leached	0.17
Delta Soil N	-45.60

Land Phosphorus Balance (kg/ha/year)



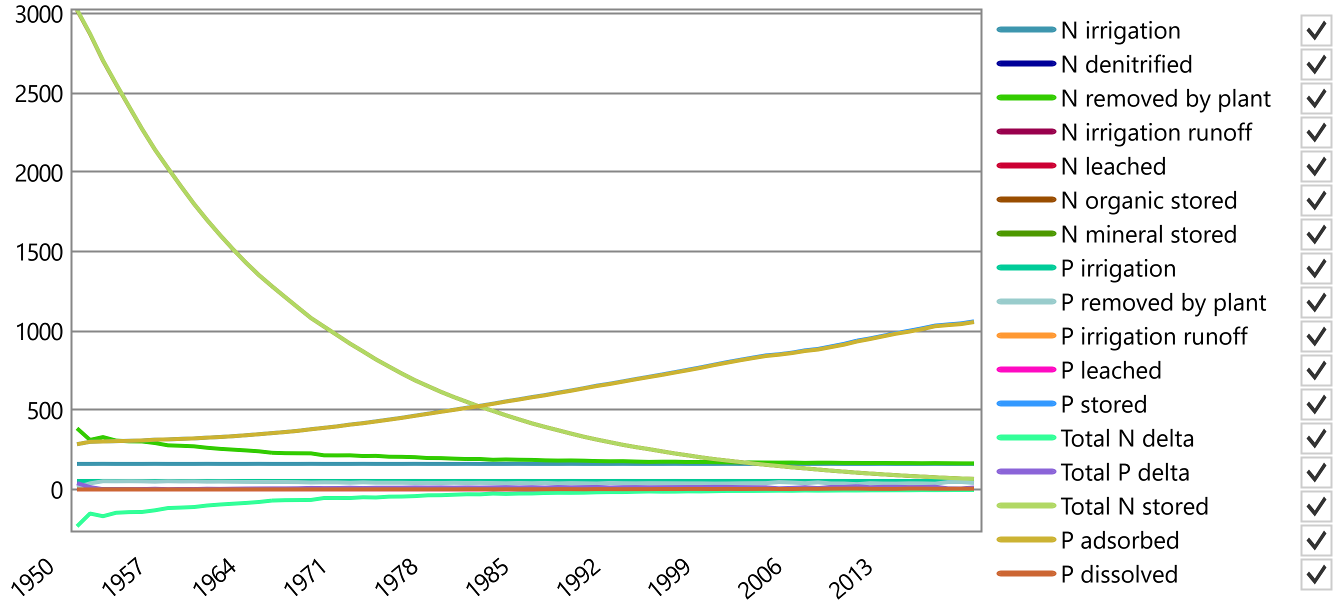
Name	Value
Seed	1.29E-03
Irrigation	53.83
Irrigation Runoff	0.00
Rain Runoff	0.00
Uptake	42.18
Leached	4.04E-03
Delta Soil P	11.64

PERFORMANCE

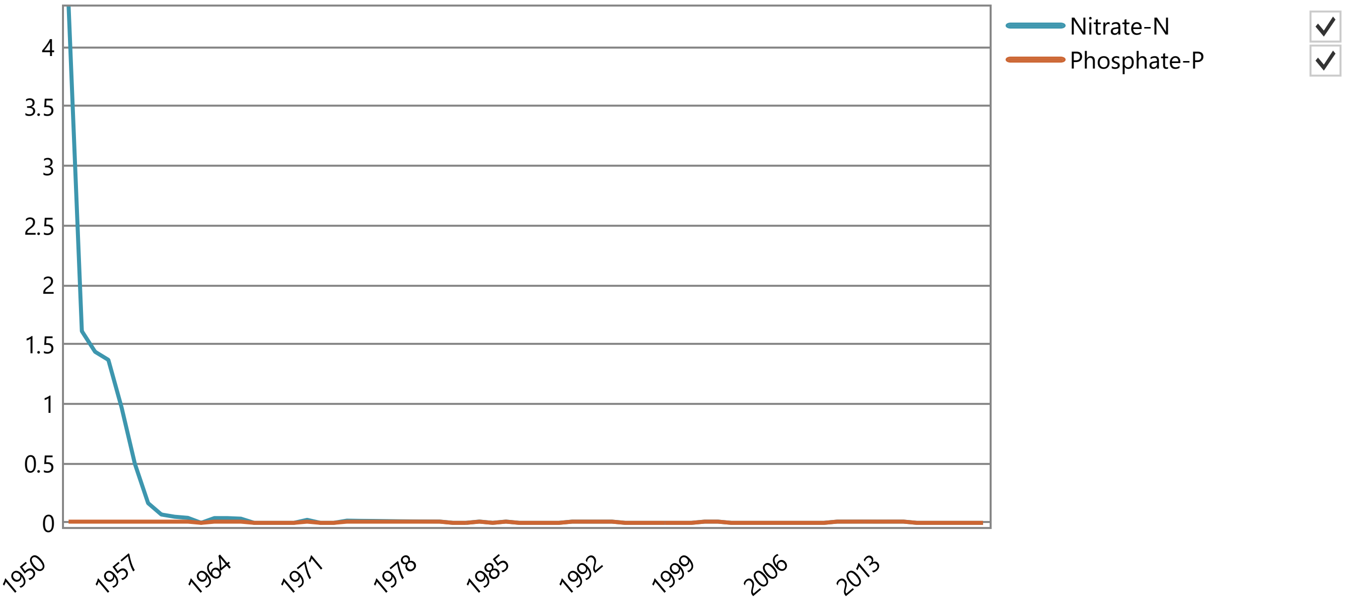
Land Performance - Soil Nutrient

Paddock: **Gemini Clay, 3.8 ha** **Soil Type**: **Grey Clay**

Annual Nutrient Totals (kg/ha):



Annual Nutrient Leaching Concentration (mg/L):



PERFORMANCE

Plant Performance and Nutrients

Paddock: **Gemini Clay, 3.8 ha** **Soil Type**: **Grey Clay**

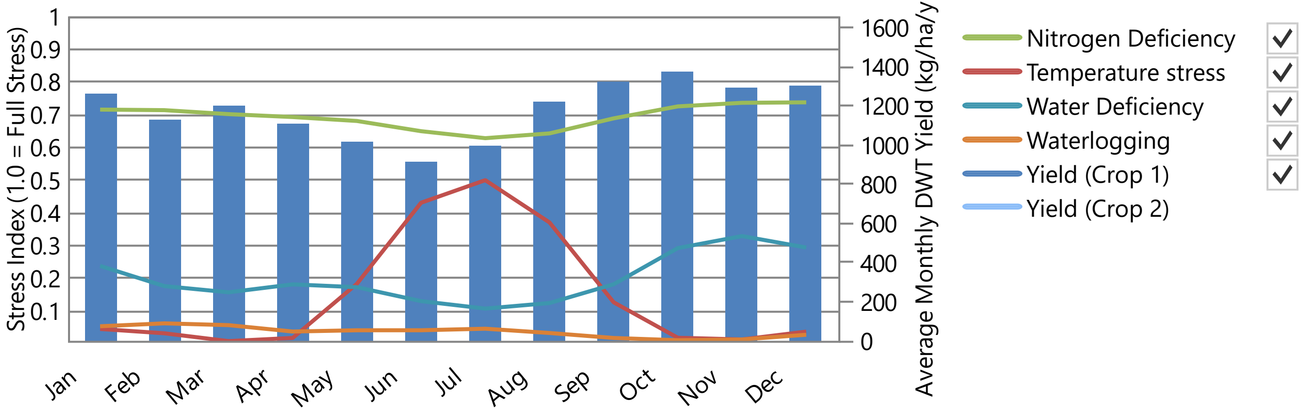
Plant: **Continuous Kikuyu 1 Pasture**

Average annual shoot dry matter yield (kg/ha/year)	14169.27 (11233.69 - 20218.65)
Average monthly plant (green) cover (fraction) (minimum - maximum)	0.87 (0.82 - 0.91)
Average monthly root depth (mm) (minimum - maximum)	1199.08 (1189.67 - 1200.00)

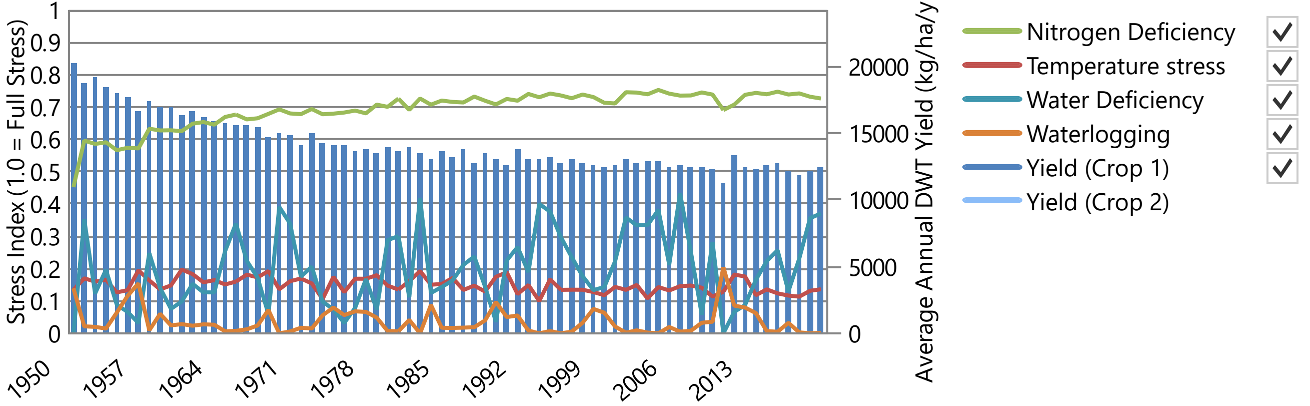
Nutrient Uptake (minimum - maximum):

Average annual net nitrogen removed by plant uptake (kg/ha/year)	206.90 (164.39 - 385.60)
Average annual net phosphorus removed by plant uptake (kg/ha/year)	42.18 (13.85 - 52.02)
Average annual shoot nitrogen concentration (fraction dwt)	0.02 (0.01 - 0.02)
Average annual shoot phosphorus concentration (fraction dwt)	0.003 (0.001 - 0.004)

Average Monthly Yield (kg/ha/year) and Plant Stresses



Average Annual Yield (kg/ha/year) and Plant Stresses



No. of harvests/year: 2.56 (normal)

No. days without crop/year (days/year): 0.00

PERFORMANCE

Land Performance

Paddock: Gemini Clay, 3.8 ha **Soil Type**: Grey Clay

Plant: Continuous Kikuyu 1 Pasture

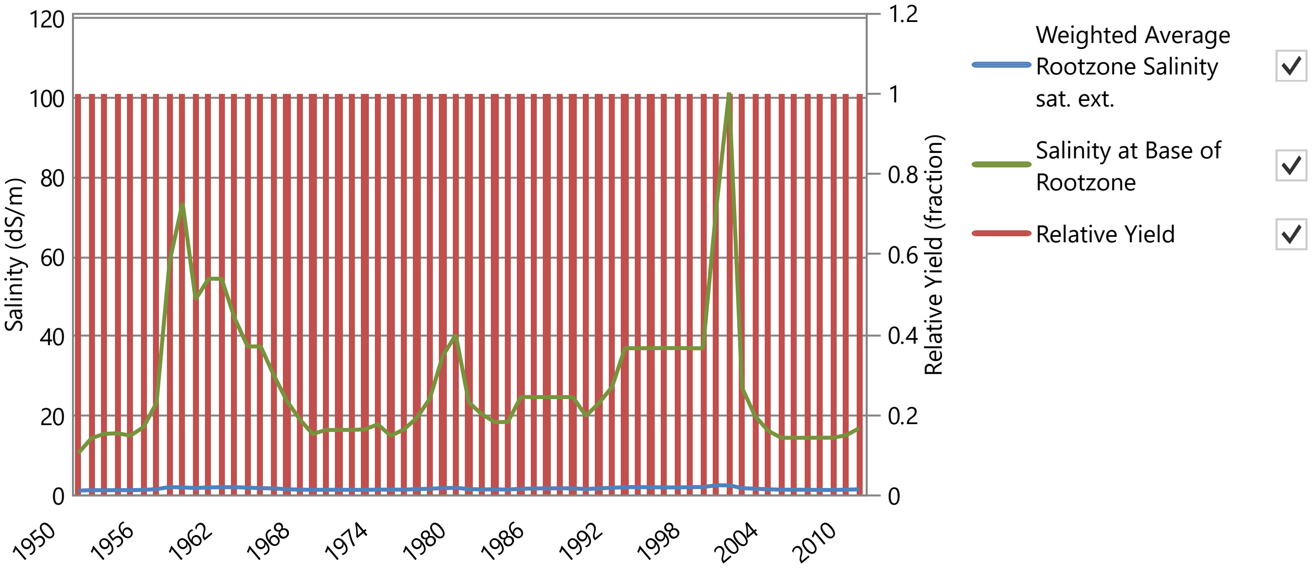
Salt tolerance	Moderately tolerant
Salinity threshold EC sat. ext. (dS/m)	3.00
Proportion of yield decrease per dS/m increase (fraction/dS/m)	0.03
No. years assumed for leaching to reach steady-state (years)	10.00

Soil Salinity:

Salinity of infiltrated water (Average salinity of rainwater = 0.03 dS/m) (dS/m)	0.77
Salt added by rainfall (kg/ha/year)	111.72
Average annual effluent salt added & leached at steady state (kg/ha/year)	5494.24
Average leaching fraction based on 10 year running averages (fraction)	0.21
Average water-uptake-weighted rootzone salinity sat. ext. (dS/m)	1.71
Salinity of the soil solution (at drained upper limit) at base of rootzone (dS/m)	28.22
Relative crop yield expected due to salinity (fraction)	1.00
Proportion of years that crop yields would be expected to fall below 90% of potential due to salinity (fraction)	0.00

Average Annual Rootzone Salinity and Relative Yield: ■ Chart ☐ Table

All values based on 10 year running averages

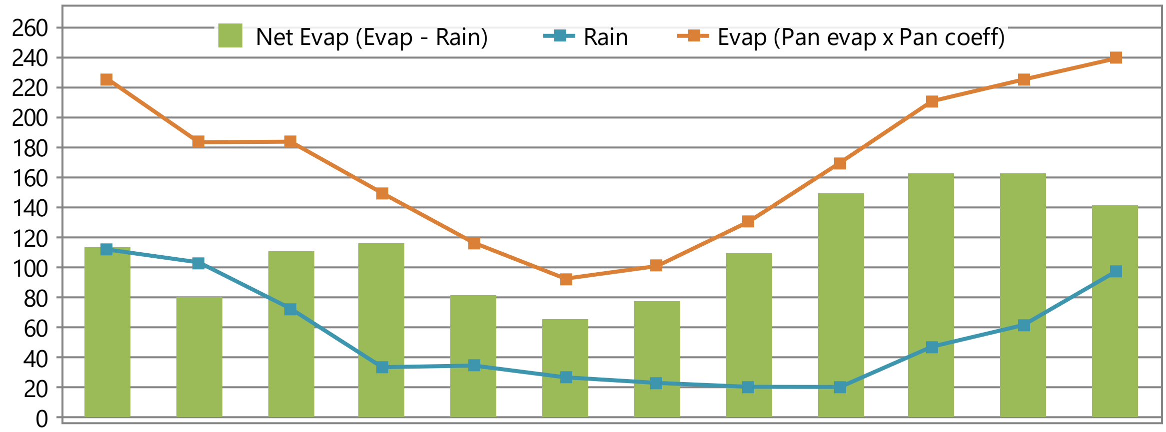


Sustainability Diagnostics: Gemini Construction - Extreme Impermeable

Averaged Historical Climate Data Used in Simulation (mm)

Location: Gemini -23.65_149.20, -23.65°, 149.2°

Run Period: 01/01/1950 to 31/12/2019 70 years, 0 days



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Rain	112.0	103.5	72.8	33.8	34.9	27.1	23.4	20.8	20.7	47.4	61.9	97.1	655.2
Evap	225.4	183.3	183.7	149.5	116.5	92.6	101.0	130.5	169.8	210.6	225.0	238.9	2026.9
Net Evap	113.4	79.8	110.9	115.7	81.6	65.6	77.7	109.8	149.1	163.2	163.1	141.8	1371.7
Net Evap/day	3.7	2.8	3.6	3.9	2.6	2.2	2.5	3.5	5.0	5.3	5.4	4.6	3.8

Sustainability Diagnostics: Gemini Construction - Extreme Impermeable

Pond System: 1 closed storage tank

New Sewage Treatment Plant - 20453.60 m3/year or 56.00 m3/day generated on average

Effluent entering pond system after any pretreatment and recycling

Average (Minimum-Maximum) influent quality calculated for 365.24 non-zero flow days, after any pretreatment and recycling.

Constituent	Concentration (mg/L)	Load (kg/year)
Total Nitrogen	30.00 (30.00 - 30.00)	613.61 (613.20 - 614.88)
Total Phosphorus	10.00 (10.00 - 10.00)	204.54 (204.40 - 204.96)
Total Dissolved Salts	1000.00 (1000.00 - 1000.00)	20453.60 (20440.00 - 20496.00)
Volatile Solids	0.00 (0.00 - 0.00)	0.00 (0.00 - 0.00)
Total Solids	0.00 (0.00 - 0.00)	0.00 (0.00 - 0.00)

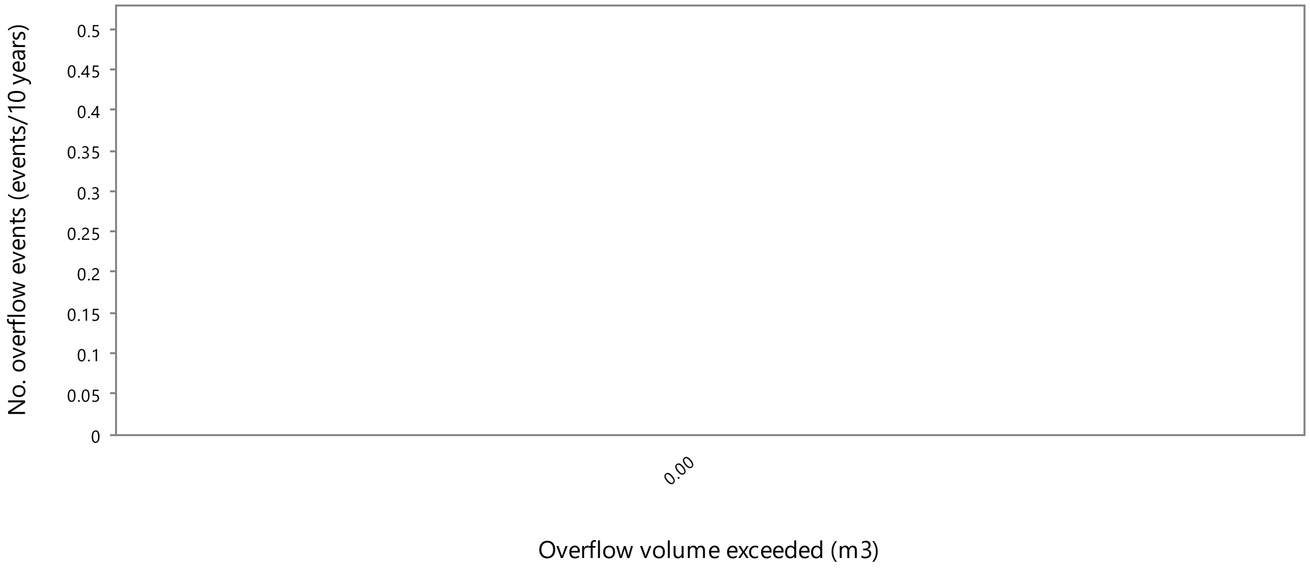
Last pond (Wet weather store): 168.00 m3

Theoretical hydraulic retention time (days)	3.00
Average volume of overflow (m3/year)	0.00
No. overflow events per year exceeding threshold* of 0.06 m3 (no./year)	0.00
Average duration of overflow (days)	0.00
Effluent Reuse (Proportion of Inflow + Net Rain Gain that is Irrigated) (fraction)	1.00
Probability of at least 90% effluent reuse (fraction)	1.00
Average salinity of last pond (dS/m)	1.56
Salinity of last pond on final day of simulation (dS/m)	1.56
Ammonia loss from pond system water area (kg/m2/year)	0.00

* The threshold is the volume equivalent to the top 1 mm depth of water of a full pond

Overflow exceedance:

☒ Chart ☐ Table



Export plot

Sustainability Diagnostics: Gemini Construction - Extreme Impermeable

Irrigation Information

Irrigation: 3.8 ha total area (assumed 100% irrigation efficiency)

	Quantity/year	Quantity/ha/year
Total irrigation applied (m3)	20453.60	5382.53
Total nitrogen applied (kg)	613.61	161.48
Total phosphorus applied (kg)	204.54	53.83
Total salts applied (kg)	20453.60	5382.53

Shandying

Annual allocation of fresh water for shandying (m3/year)	0.00
Average Shandy water irrigation (m3/year) (minimum - maximum)	0.00 (0.00 - 0.00)
Average exceedance as a proportion of annual shandy water allocation (% of allocation) (minimum - maximum)	0.00 (0.00 - 0.00)
Proportion of irrigation events requiring shandying (fraction of events)	0.00
Minimum shandy water is used	False

Irrigation Issues

Proportion of Days irrigation occurs (fraction)	1.00

Sustainability Diagnostics: Gemini Construction - Extreme Impermeable

Paddock Land: Gemini Clay: 3.8 ha

Irrigation: New Irrigation Method with 0% ammonium loss during irrigation

Irrigation triggered every 1 days
Irrigate a fixed amount of 2.00 mm each day
Irrigation window from 1/1 to 31/12 including the days specified
A minimum of 0 days must be skipped between irrigation events

Soil Water Balance (mm): Grey Clay, 166.00 mm PAWC at maximum root depth

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Rain	112.0	103.5	72.8	33.8	34.9	27.1	23.4	20.8	20.7	47.4	61.9	97.1	655.2
Irrigation	45.7	41.6	45.7	44.2	45.7	44.2	45.7	45.7	44.2	45.7	44.2	45.7	538.3
Soil Evap	1.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.2
Transpn.	116.4	106.4	105.2	84.1	68.2	56.2	61.9	73.5	90.3	101.6	101.6	115.5	1081.0
Rain Runoff	15.9	18.5	10.0	2.0	6.2	0.7	1.3	0.8	0.6	2.9	2.0	12.4	73.3
Irr. Runoff	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Drainage	4.0	5.9	7.6	5.0	3.9	3.4	3.9	1.6	1.5	1.3	0.7	1.3	40.2
Delta	20.3	14.1	-4.3	-13.1	2.2	11.0	1.9	-9.6	-27.6	-12.7	1.8	13.6	-2.4

Soil Nitrogen Balance

Average annual effluent nitrogen added (kg/ha/year)	161.48
Average annual soil nitrogen removed by plant uptake (kg/ha/year)	206.90
Average annual soil nitrogen removed by denitrification (kg/ha/year)	0.02
Average annual soil nitrogen leached (kg/ha/year)	0.17
Average annual nitrate-N loading to groundwater (kg/ha/year)	0.17
Soil organic-N kg/ha (Initial - Final)	3208.00 - 66.51
	50.68 - 0.05
Average nitrate-N concentration of deep drainage (mg/L)	0.43
Max. annual nitrate-N concentration of deep drainage (mg/L)	4.35

Soil Phosphorus Balance

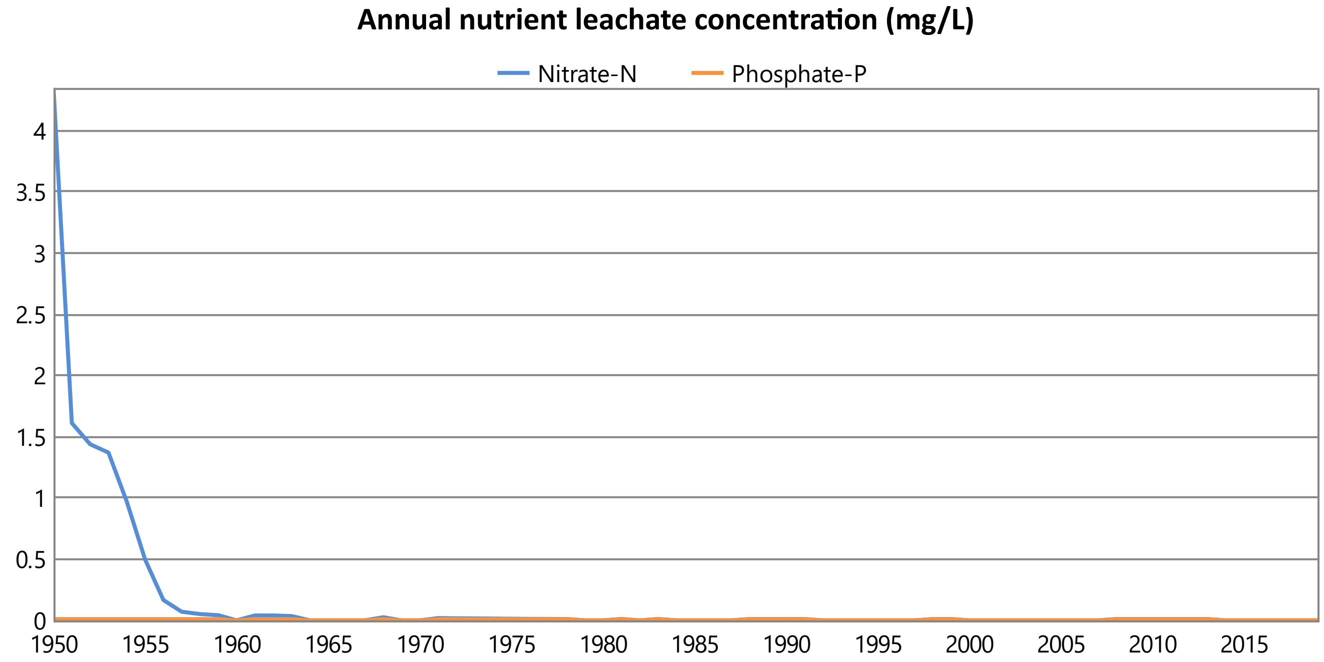
Average annual effluent phosphorus added (kg/ha/year)	53.83
Average annual soil phosphorus removed by plant uptake (kg/ha/year)	42.18
Average annual soil phosphorus leached (kg/ha/year)	4.04E-03
Dissolved phosphorus (kg/ha) (Initial - Final)	0.06 - 4.71
Adsorbed phosphorus (kg/ha) (Initial - Final)	245.27 - 1055.46
Average phosphate-P concentration in rootzone (mg/L)	0.49
Average phosphate-P concentration of deep drainage (mg/L)	0.01
Max. annual phosphate-P concentration of deep drainage (mg/L)	0.01
Design soil profile storage life based on average infiltrated water phosphorus concn. of 4.81 mg/L (years)	46.27

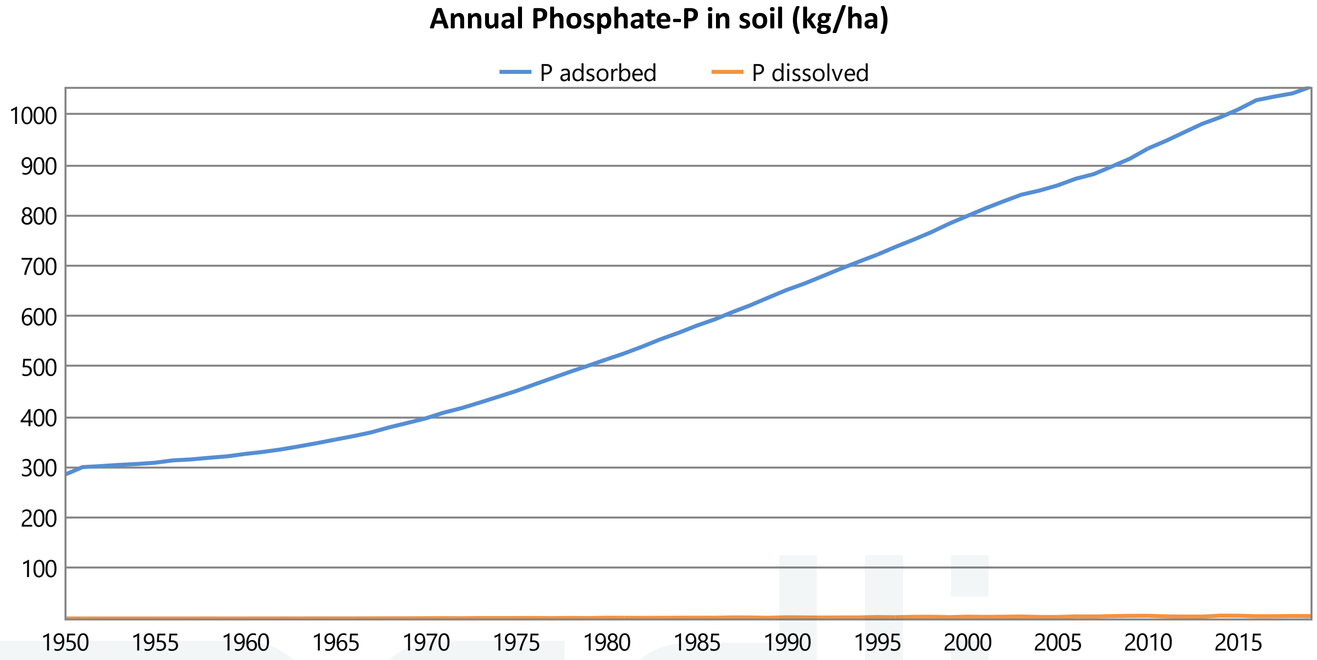
DIAGNOSTICS

Sustainability Diagnostics: Gemini Construction - Extreme Impermeable

Paddock Land: Gemini Clay: 3.8 ha

Irrigation: New Irrigation Method with 0% ammonium loss during irrigation





Sustainability Diagnostics: Gemini Construction - Extreme Impermeable

Paddock Plant Performance: Gemini Clay: 3.8 ha

Average Plant Performance (Minimum - Maximum): Continuous Kikuyu 1 Pasture

Average annual shoot dry matter yield (kg/ha/year)	14169.27 (11233.69 - 20218.65)
Average monthly plant (green) cover (fraction)	0.87 (0.82 - 0.91)
Average monthly crop factor (fraction)	0.70 (0.66 - 0.73)
Total plant cover (both green and dead) left after harvest (fraction)	1.00
Average monthly root depth (mm)	1199.08 (1189.67 - 1200.00)
Average number of normal harvests per year (no./year)	2.56 (2.00 - 4.00)
Average number of normal harvests for last five years only (no./year)	2.20
Average number of crop deaths per year (no./year)	0.00 (0.00 - 0.00)
Average number of crop deaths for last five years only (no./year)	0.00
Average annual nitrogen deficiency index (0 = no stress, 1 = full stress) (coefficient)	0.69 (0.45 - 0.75)
Average January temperature stress index (0 = no stress, 1 = full stress) (coefficient)	0.04 (0.00 - 0.17)
Average July temperature stress index (0 = no stress, 1 = full stress) (coefficient)	0.50 (0.23 - 0.77)
Average monthly water stress index (0 = no stress, 1 = full stress) (coefficient)	0.20 (0.11 - 0.33)
Average monthly waterlogging index (0 = no stress, 1 = full stress) (coefficient)	0.04 (0.01 - 0.06)
No. days without crop/year (days)	0.00

Soil Salinity - Plant salinity tolerance: Moderately tolerant

Assumes 1.0 dS/m Electrical Conductivity = 640 mg/L Total Dissolved Salts

All values based on 10 year running averages

Salinity of infiltrated water (Average salinity of rainwater = 0.03 dS/m) (dS/m)	0.77
Salt added by rainfall (kg/ha/year)	111.72
Average annual effluent salt added & leached at steady state (kg/ha/year)	5494.24
Average leaching fraction based on 10 year running averages (fraction)	0.21
Average water-uptake-weighted rootzone salinity sat. ext. (dS/m)	1.71
Salinity of the soil solution (at drained upper limit) at base of rootzone (dS/m)	28.22
Relative crop yield expected due to salinity (fraction)	1.00
Proportion of years that crop yields would be expected to fall below 90% of potential due to salinity (fraction)	0.00

Run Messages

Messages generated when the scenario was run:

Full run chosen

APPENDIX

C

CONSTRUCTION PERIOD: EXTREME PERMEABLE MEDLI MODEL OUTPUT REPORT

Enterprise: Gemini Construction - Extreme Permeable

Description:
Sand Based Model

Client: Gemini Mine

MEDLI User: CARDNO\mark.farrey

Scenario Details:
Construction - Extreme Permeable Model - Sand Soil
-168KL Storage (3 days)
-2mm/day max irrigation
-3ha irrigation area
-Rhodes Grass

Climate Data: Gemini -23.65_149.20, -23.65°, 149.2°

Run Period: 01/01/1950 to 31/12/2019 70 years, 0 days

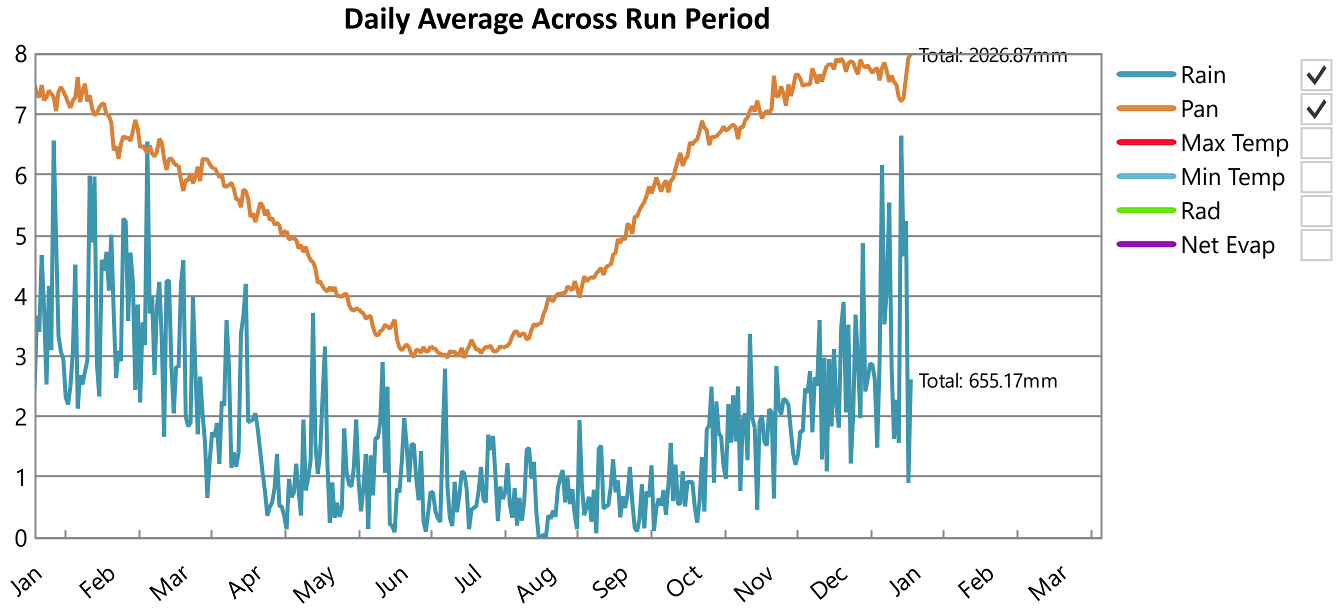
Climate Statistics:

	5th ▾ **Percentile**	**50th Percentile**	95th ▾ **Percentile**
Rainfall (mm/year)	308	632	1107
Pan Evaporation (mm/year)	1792	2046	2219

Climate Data:

☒ Chart ☐ Table

☐ Monthly ☒ Daily



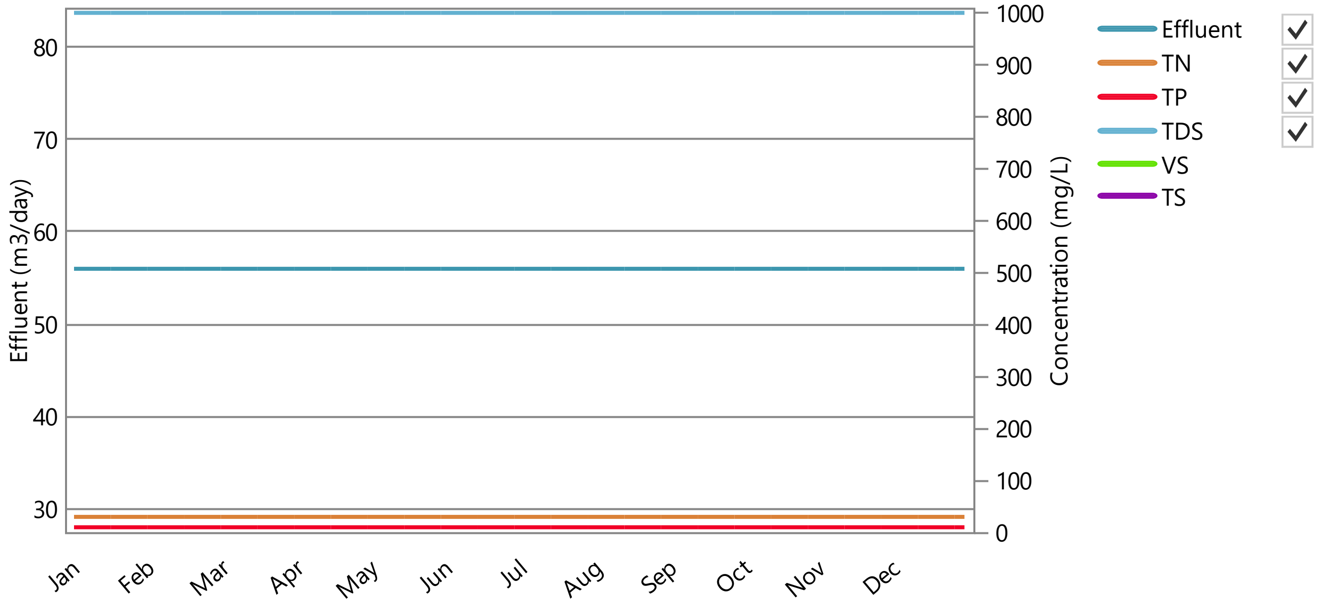
DESCRIPTION

Effluent type: New Sewage Treatment Plant

Wastestream before any recycling or pretreatment

Average daily quantity and flow-weighted average quality:

■ Chart ☐ Table



Wastestream after any recycling and pretreatment if applicable

Effluent quantity: 20453.60 m3/year or 56.00 m3/day (Min-Max: 56.00 - 56.00)

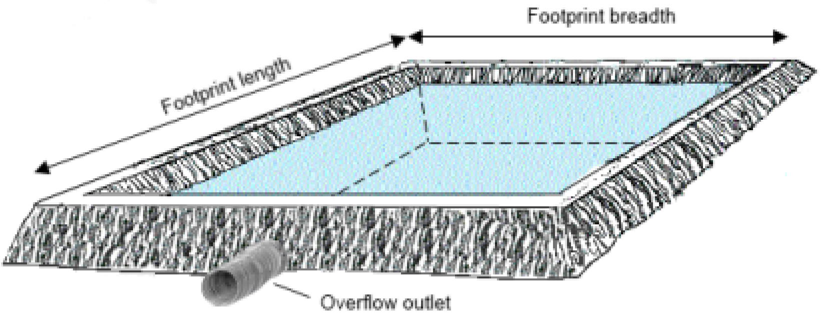
Flow-weighted average (minimum - maximum) daily effluent quality entering pond system:

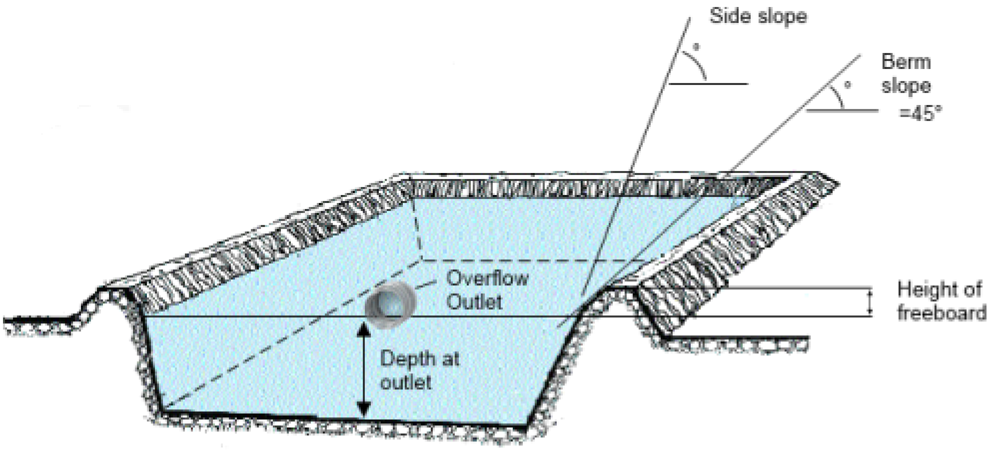
	Concentration (mg/L)	Load (kg/year)
Total Nitrogen	30.00 (30.00 - 30.00)	613.61 (613.20 - 614.88)
Total Phosphorus	10.00 (10.00 - 10.00)	204.54 (204.40 - 204.96)
Total Dissolved Salts	1000.00 (1000.00 - 1000.00)	20453.60 (20440.00 - 20496.00)
Volatile Solids	0.00 (0.00 - 0.00)	0.00 (0.00 - 0.00)
Total Solids	0.00 (0.00 - 0.00)	0.00 (0.00 - 0.00)

Pond system: 1 closed storage tank

Pond system details:

	Pond 1
Maximum pond volume (m3)	168.00
Minimum allowable pond volume (m3)	0.00
Pond depth at overflow outlet (m)	3.00
Maximum water surface area (m2)	56.00
Pond footprint length (m)	19.48
Pond footprint width (m)	19.48
Pond catchment area (m2)	379.60
Average active volume (m3)	0.00





Irrigation pump limits:

Minimum pump rate limit (ML/day)	0.00
Maximum pump rate limit (ML/day)	100000000.00

Shandying water:

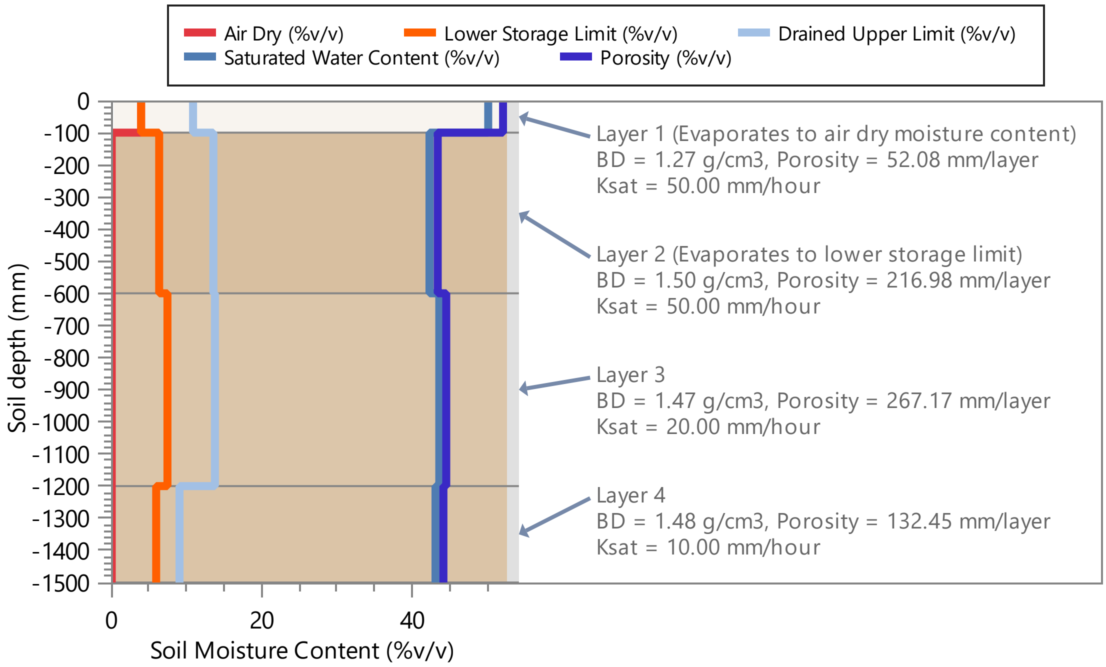
Annual allocation of fresh water available for shandying (m3/year)	0.00
Maximum rate of application of fresh water (ML/day)	0.00
Nitrogen concentration (mg/L)	0.00
Salinity (dS/m)	0.00
Minimum shandy water is used	False

Land: Gemini Sand

Area (ha): 3.00

Soil Type: Sand, 1500.00 mm defined profile depth

Profile Porosity (mm)	668.68
Profile saturation water content (mm)	652.50
Profile drained upper limit (or field capacity) (mm)	189.00
Profile lower storage limit (or permanent wilting point) (mm)	99.00
Profile available water capacity (mm)	90.00
Profile limiting saturated hydraulic conductivity (mm/hour)	10.00
Surface saturated hydraulic conductivity (mm/hour)	50.00
Runoff curve number II (coefficient)	70.00
Soil evaporation U (mm)	10.00
Soil evaporation Cona (mm/sqrt day)	4.50



Layer 1 (Evaporates to air dry moisture content)
BD = 1.27 g/cm3, Porosity = 52.08 mm/layer
Ksat = 50.00 mm/hour

Layer 2 (Evaporates to lower storage limit)
BD = 1.50 g/cm3, Porosity = 216.98 mm/layer
Ksat = 50.00 mm/hour

Layer 3
BD = 1.47 g/cm3, Porosity = 267.17 mm/layer
Ksat = 20.00 mm/hour

Layer 4
BD = 1.48 g/cm3, Porosity = 132.45 mm/layer
Ksat = 10.00 mm/hour

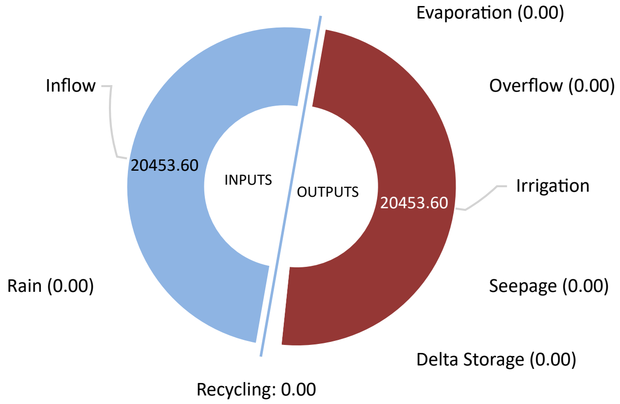
Plant Data: Continuous Rhodes Grass Pasture

Average monthly cover (fraction) (minimum - maximum)	0.70 (0.66 - 0.76)
Maximum crop factor at 100% cover (mm/mm) (Maximum crop coefficient 0.9 x Pan coefficient 1)	0.90
Total plant cover (both green and dead) left after harvest (fraction)	1.00
Maximum potential root depth in defined soil profile (mm)	1200.00
Salt tolerance	Tolerant
Salinity threshold EC sat. ext. (dS/m)	7.00
Proportion of yield decrease per dS/m increase (fraction/dS/m)	0.03

Pond System Water Performance - Overflow: 1 closed storage tank

Capacity of wet weather storage pond: **168 m3**

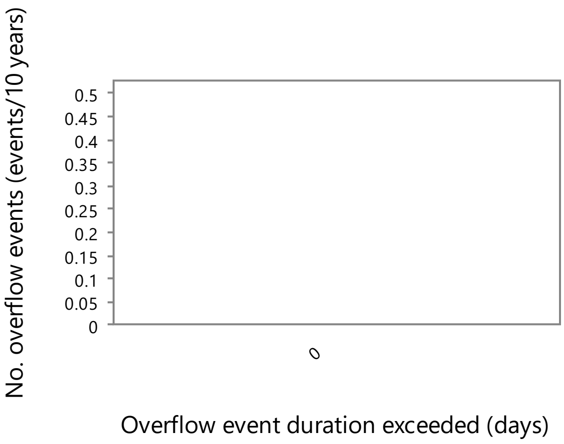
Pond System Water Balance (m3/year)

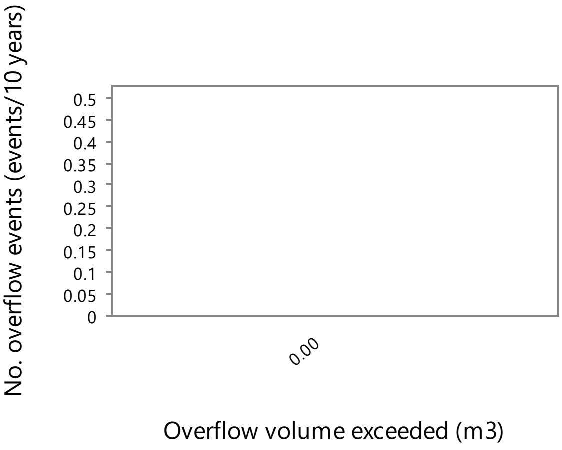


Name	Value
Rain	0.00
Inflow	20453.60
Recycling	0.00
Evaporation	0.00
Overflow	0.00
Irrigation	20453.60
Seepage	0.00
Delta Storage	0.00

Overflow Diagnostics

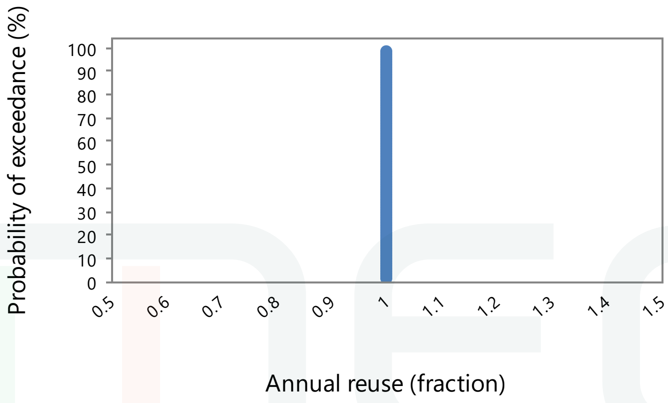
Volume of overflow (m3/year)	0.00
No. days pond overflows (days/year)	0.00
Average duration of overflow (days)	0.00
Effluent Reuse (Proportion of Inflow + Net Rain Gain that is Irrigated) (fraction)	1.00
Probability of at least 90% reuse (fraction)	1.00





Export plot

Export plot

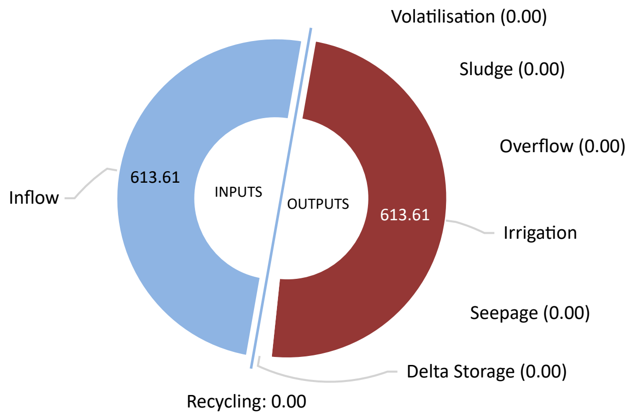


Export plot

Pond System Performance - Nutrient: 1 closed storage tank

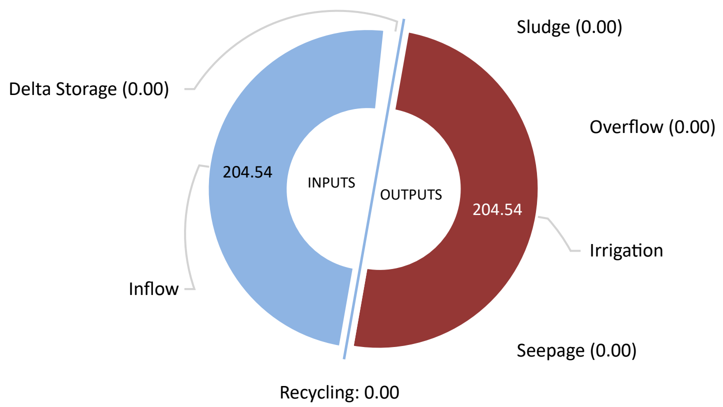
Pond System Nutrients and Salt Balance:

Nitrogen Balance (kg/year)



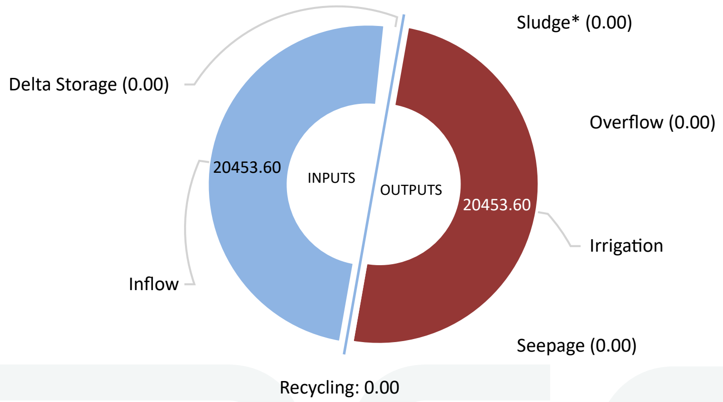
Name	Value
Inflow	613.61
Recycling	0.00
Volatilisation	0.00
Sludge	0.00
Overflow	0.00
Irrigation	613.61
Seepage	0.00
Delta Storage	0.00

Phosphorus Balance (kg/year)



Name	Value
Inflow	204.54
Recycling	0.00
Sludge	0.00
Overflow	0.00
Irrigation	204.54
Seepage	0.00
Delta Storage	0.00

Salt Balance (kg/year)



Name	Value
Inflow	20453.60
Recycling	0.00
Sludge*	0.00
Overflow	0.00
Irrigation	20453.60
Seepage	0.00
Delta Storage	0.00

* Salt removal in sludge is not calculated from the pond salt balance. However if salt could be assumed to be present in the sludge at the same concentration as in the pond supernatant (up to a maximum of salt added in inflow) - then salt accumulation in the sludge could be 0.00 kg/year

Pond System Sludge Accumulation: 0.00 kg dwt/year

Pond System Performance - Nutrient: 1 closed storage tank

Pond Nutrient Concentrations and Salinity:

Average across simulation period	Pond 1
Average nitrogen concentration of pond liquid (mg/L)	30.00
Average phosphorus concentration of pond liquid (mg/L)	10.00
Average salinity of pond liquid (dS/m)	1.56

Value on final day of simulation period	Pond 1
Final nitrogen concentration of pond liquid (mg/L)	N.D.*
Final phosphorus concentration of pond liquid (mg/L)	N.D.*
Final salinity of pond liquid (dS/m)	N.D.*

* Not determined. Pond is empty.

Irrigation Performance:

Water Use: (assumes 100% Irrigation Efficiency)

Pond water irrigated (m3/year)	20453.60
Average Shandy water irrigation (m3/year) (minimum - maximum)	0.00 (0.00 - 0.00)
Total water irrigated (m3/year)	20453.60
Proportion of irrigation events requiring shandying (fraction of events)	0.00
Proportion of years shandying water allocation of 0 m3/year is exceeded (fraction of years)	0.00
Average exceedance as a proportion of annual shandy water allocation (fraction of allocation) (minimum - maximum)	0.00 (0.00 - 0.00)

Irrigation Quality:

Average nitrogen concentration of irrigation water - before ammonia loss during irrigation (mg/L)	30.00
Average nitrogen concentration of irrigation water - after ammonia loss during irrigation (mg/L)	30.00
Average phosphorus concentration of irrigation water (mg/L)	10.00
Average salinity of irrigation water (dS/m)	1.56

Irrigation Diagnostics:

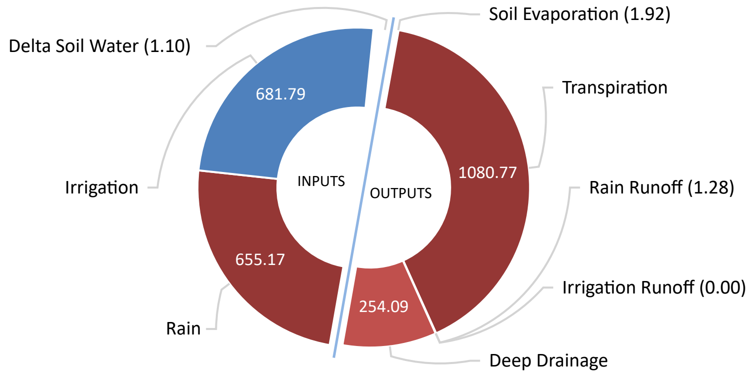
Proportion of Days irrigation occurs (fraction)	1.00

Land Performance - Soil Water

Paddock: Gemini Sand, 3 ha
Soil Type: Sand, 80.70 mm PAWC at maximum root depth

Land Water Balance (mm/year):

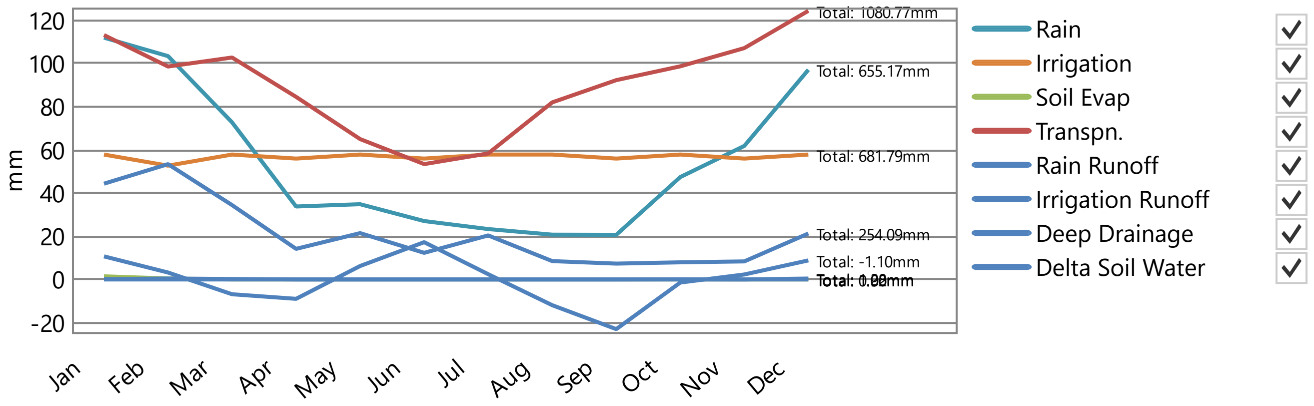
☑ mm/year ☐ % Total inputs



Name	Value
Rain	655.17
Irrigation	681.79
Soil Evaporation	1.92
Transpiration	1080.77
Rain Runoff	1.28
Irrigation Runoff	0.00
Deep Drainage	254.09
Delta Soil Water	-1.10

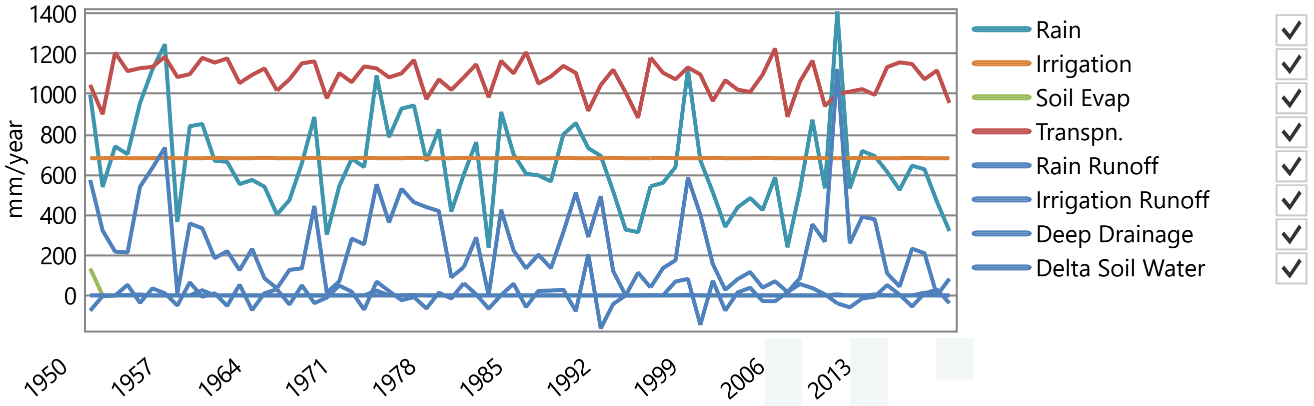
Average Monthly Totals (mm):

☑ Chart ☐ Table



Average Annual Totals (mm/year):

☑ Chart ☐ Table

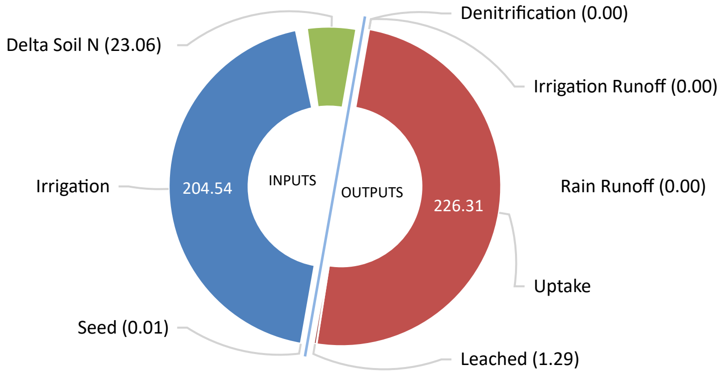


Land Performance - Soil Nutrient

Paddock: **Gemini Sand, 3 ha** **Soil Type**: **Sand**

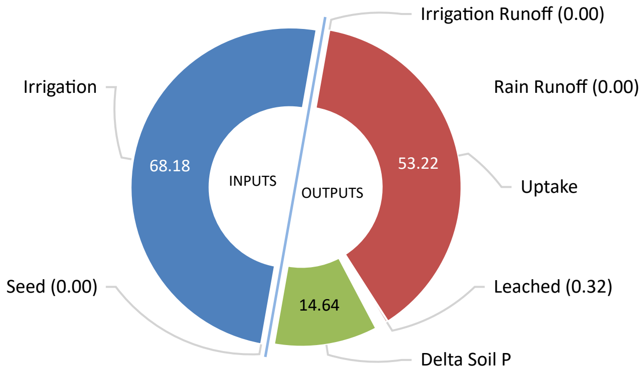
Irrigation ammonium volatilisation losses (kg/ha/year): 0.00
Proportion of total nitrogen in irrigated effluent as ammonium (fraction): 0.25

Land Nitrogen Balance (kg/ha/year)



Name	Value
Seed	0.01
Irrigation	204.54
Denitrification	3.27E-03
Irrigation Runoff	0.00
Rain Runoff	0.00
Uptake	226.31
Leached	1.29
Delta Soil N	-23.06

Land Phosphorus Balance (kg/ha/year)



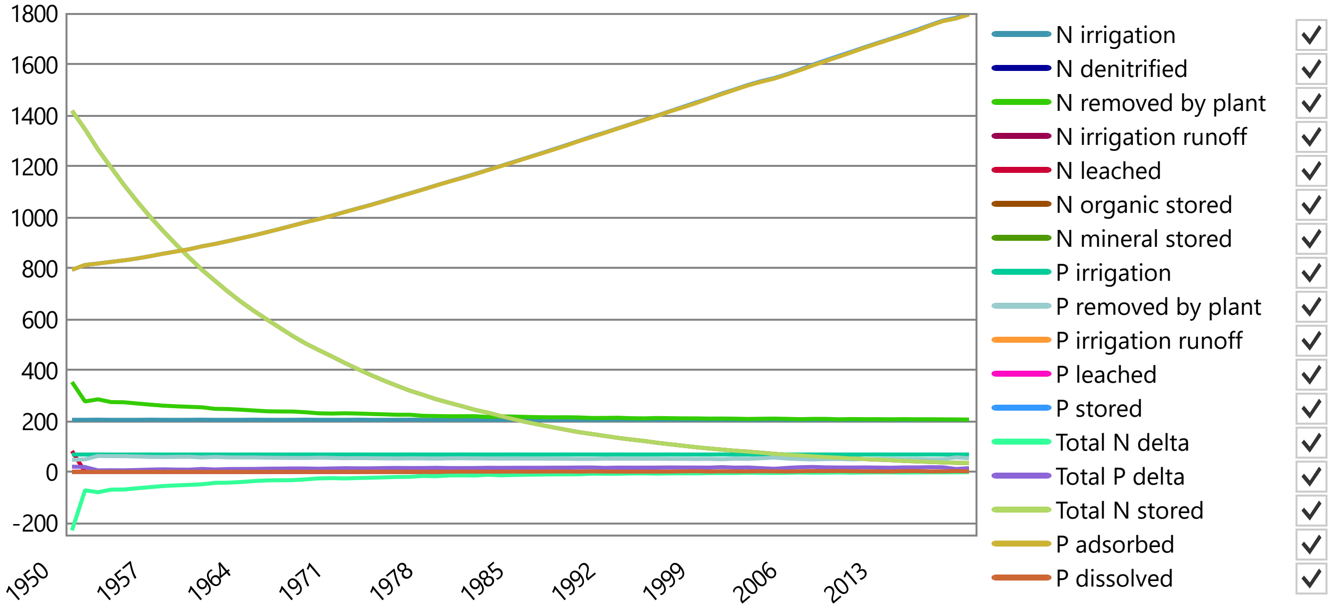
Name	Value
Seed	1.29E-03
Irrigation	68.18
Irrigation Runoff	0.00
Rain Runoff	0.00
Uptake	53.22
Leached	0.32
Delta Soil P	14.64

PERFORMANCE

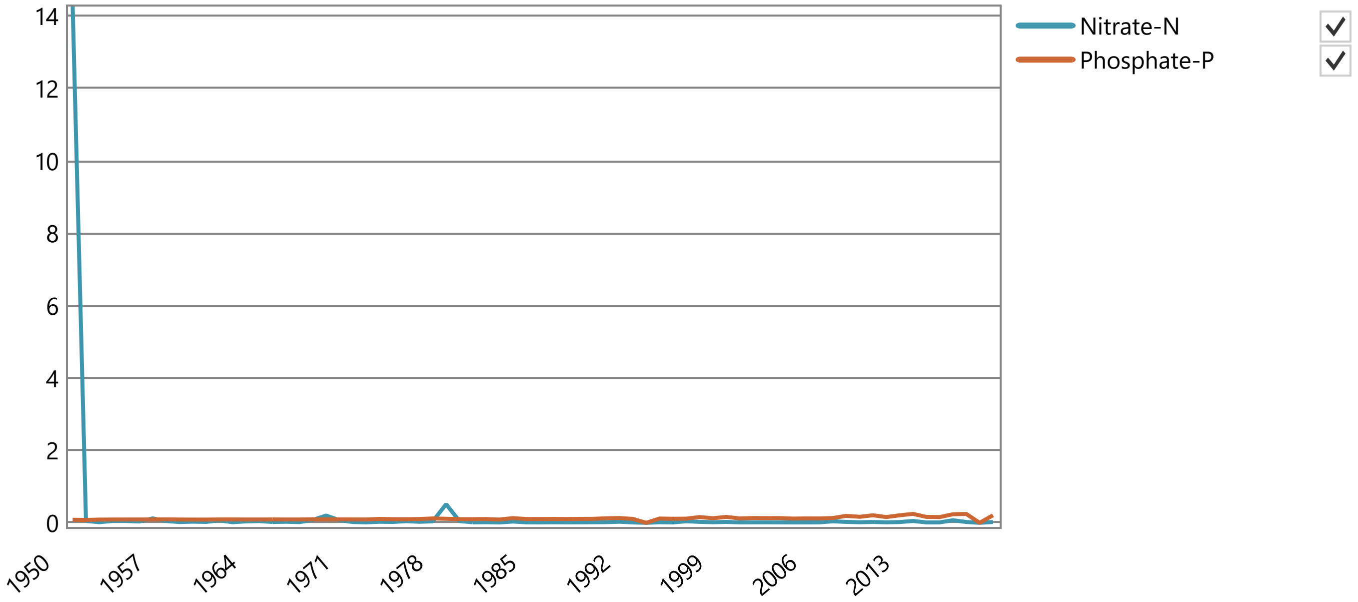
Land Performance - Soil Nutrient

Paddock: **Gemini Sand, 3 ha** **Soil Type**: **Sand**

Annual Nutrient Totals (kg/ha):



Annual Nutrient Leaching Concentration (mg/L):



Plant Performance and Nutrients

Paddock: Gemini Sand, 3 ha **Soil Type: Sand**

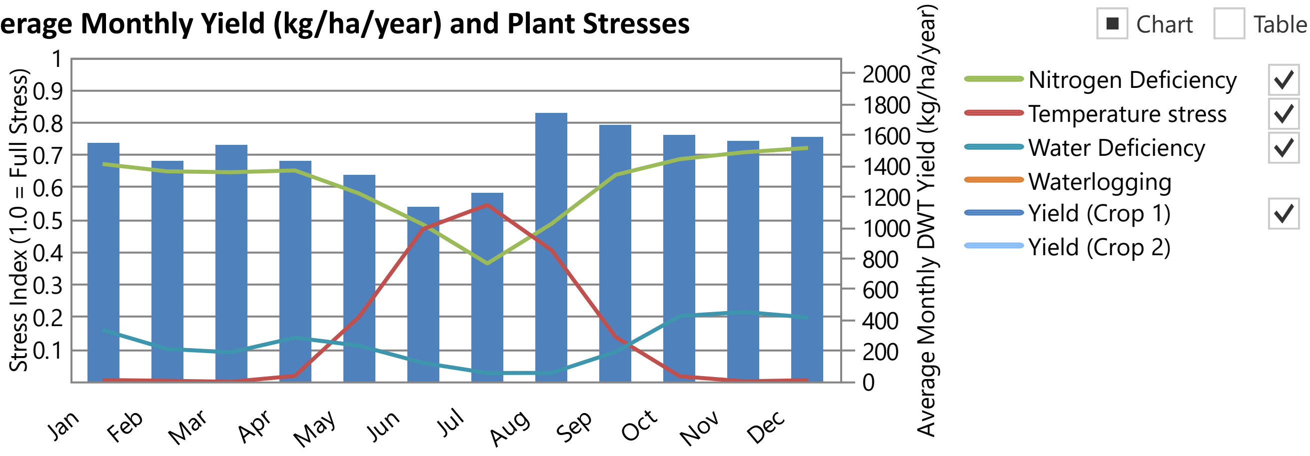
Plant: Continuous Rhodes Grass Pasture

Average annual shoot dry matter yield (kg/ha/year)	17859.55 (16257.55 - 23931.03)
Average monthly plant (green) cover (fraction) (minimum - maximum)	0.70 (0.66 - 0.76)
Average monthly root depth (mm) (minimum - maximum)	1198.88 (1189.54 - 1200.00)

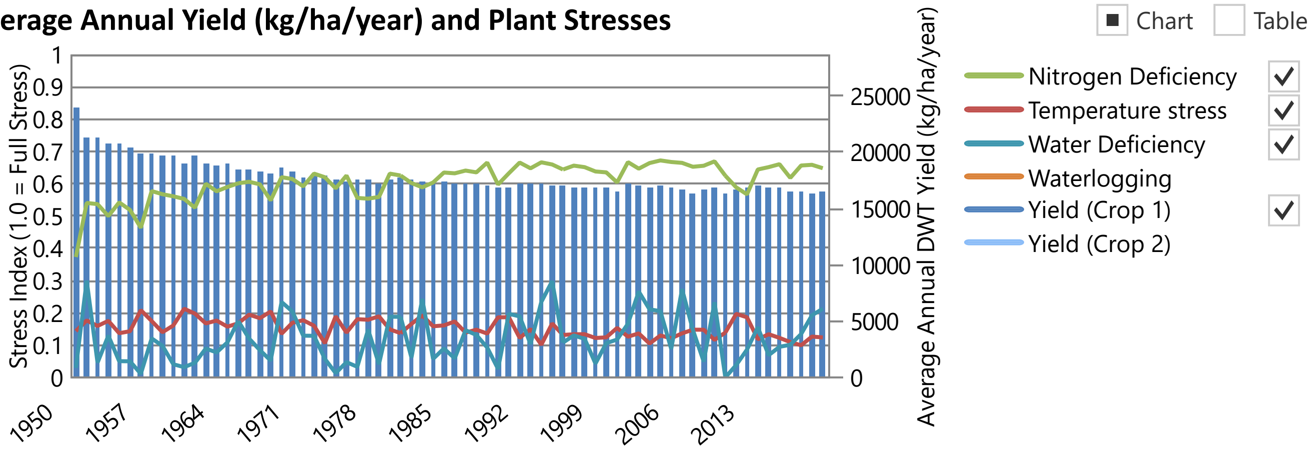
Nutrient Uptake (minimum - maximum):

Average annual net nitrogen removed by plant uptake (kg/ha/year)	226.31 (205.32 - 352.89)
Average annual net phosphorus removed by plant uptake (kg/ha/year)	53.22 (47.24 - 62.41)
Average annual shoot nitrogen concentration (fraction dwt)	0.01 (0.01 - 0.02)
Average annual shoot phosphorus concentration (fraction dwt)	0.003 (0.002 - 0.003)

Average Monthly Yield (kg/ha/year) and Plant Stresses



Average Annual Yield (kg/ha/year) and Plant Stresses



No. of harvests/year: 3.11 (normal)

No. days without crop/year (days/year): 0.00

Land Performance

Paddock: Gemini Sand, 3 ha **Soil Type**: Sand

Plant: Continuous Rhodes Grass Pasture

Salt tolerance	Tolerant
Salinity threshold EC sat. ext. (dS/m)	7.00
Proportion of yield decrease per dS/m increase (fraction/dS/m)	0.03
No. years assumed for leaching to reach steady-state (years)	10.00

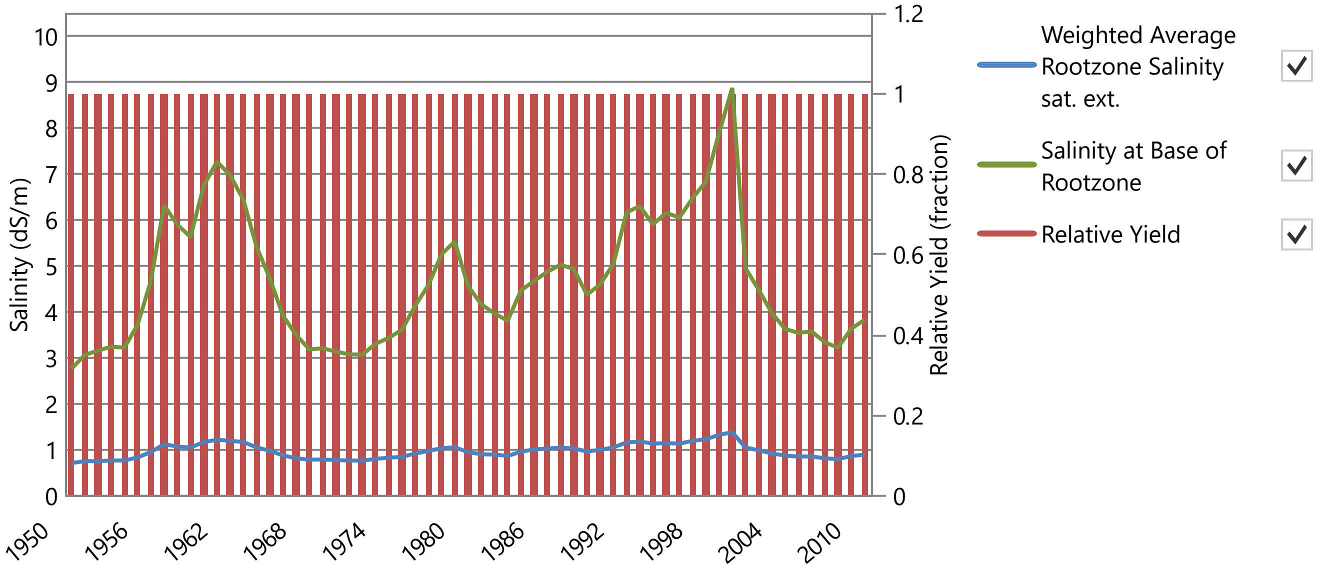
Soil Salinity:

Salinity of infiltrated water (Average salinity of rainwater = 0.03 dS/m) (dS/m)	0.82
Salt added by rainfall (kg/ha/year)	125.55
Average annual effluent salt added & leached at steady state (kg/ha/year)	6943.41
Average leaching fraction based on 10 year running averages (fraction)	0.39
Average water-uptake-weighted rootzone salinity sat. ext. (dS/m)	0.97
Salinity of the soil solution (at drained upper limit) at base of rootzone (dS/m)	4.68
Relative crop yield expected due to salinity (fraction)	1.00
Proportion of years that crop yields would be expected to fall below 90% of potential due to salinity (fraction)	0.00

Average Annual Rootzone Salinity and Relative Yield:

■ Chart ☐ Table

All values based on 10 year running averages

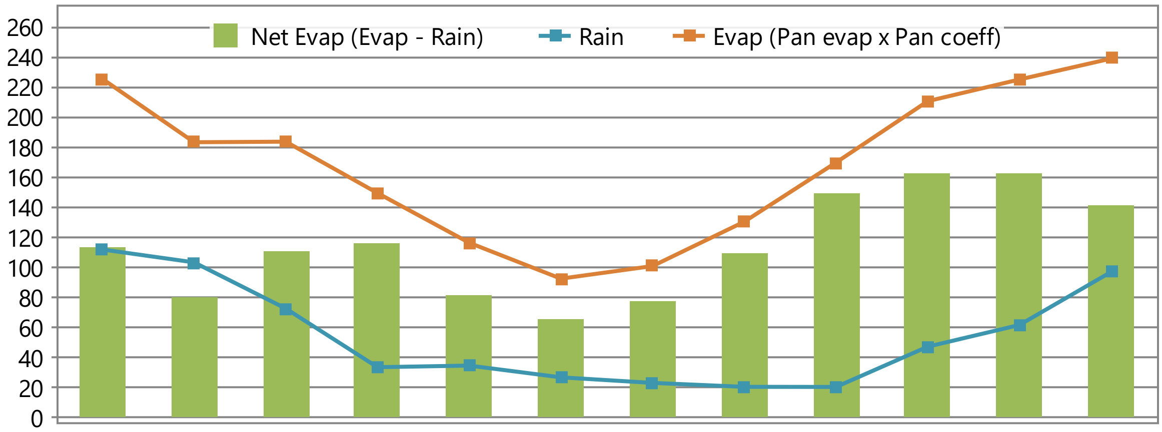


Sustainability Diagnostics: Gemini Construction - Extreme Permeable

Averaged Historical Climate Data Used in Simulation (mm)

Location: Gemini -23.65_149.20, -23.65°, 149.2°

Run Period: 01/01/1950 to 31/12/2019 70 years, 0 days



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Rain	112.0	103.5	72.8	33.8	34.9	27.1	23.4	20.8	20.7	47.4	61.9	97.1	655.2
Evap	225.4	183.3	183.7	149.5	116.5	92.6	101.0	130.5	169.8	210.6	225.0	238.9	2026.9
Net Evap	113.4	79.8	110.9	115.7	81.6	65.6	77.7	109.8	149.1	163.2	163.1	141.8	1371.7
Net Evap/day	3.7	2.8	3.6	3.9	2.6	2.2	2.5	3.5	5.0	5.3	5.4	4.6	3.8

DIAGNOSTICS

Sustainability Diagnostics: Gemini Construction - Extreme Permeable

Pond System: 1 closed storage tank

New Sewage Treatment Plant - 20453.60 m3/year or 56.00 m3/day generated on average

Effluent entering pond system after any pretreatment and recycling

Average (Minimum-Maximum) influent quality calculated for 365.24 non-zero flow days, after any pretreatment and recycling.

Constituent	Concentration (mg/L)	Load (kg/year)
Total Nitrogen	30.00 (30.00 - 30.00)	613.61 (613.20 - 614.88)
Total Phosphorus	10.00 (10.00 - 10.00)	204.54 (204.40 - 204.96)
Total Dissolved Salts	1000.00 (1000.00 - 1000.00)	20453.60 (20440.00 - 20496.00)
Volatile Solids	0.00 (0.00 - 0.00)	0.00 (0.00 - 0.00)
Total Solids	0.00 (0.00 - 0.00)	0.00 (0.00 - 0.00)

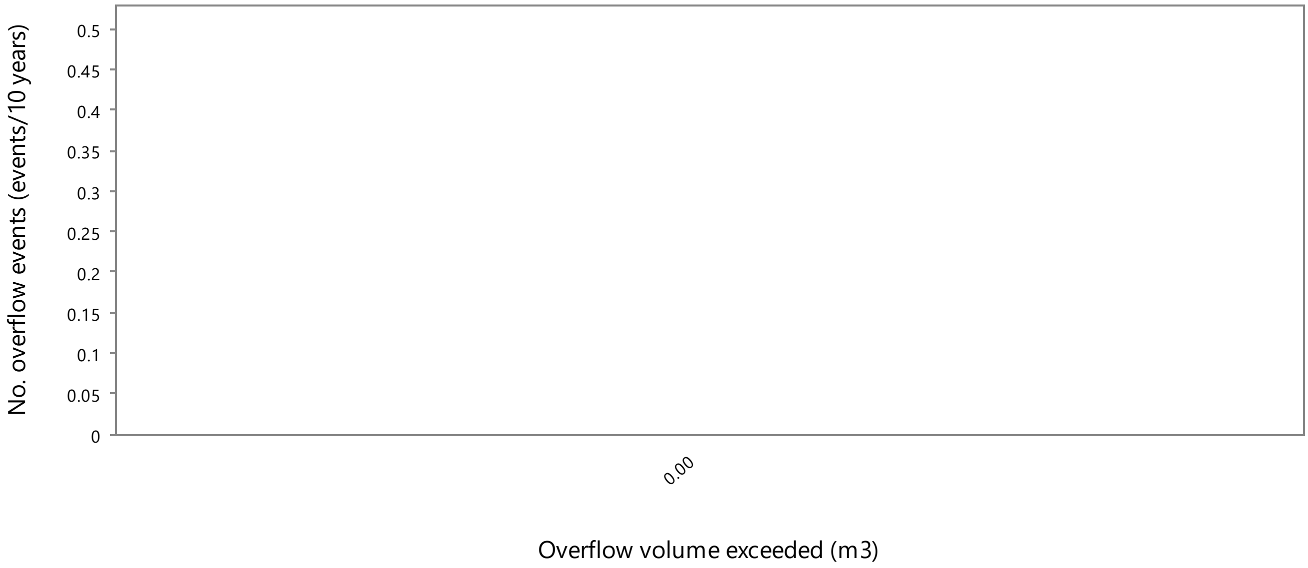
Last pond (Wet weather store): 168.00 m3

Theoretical hydraulic retention time (days)	3.00
Average volume of overflow (m3/year)	0.00
No. overflow events per year exceeding threshold* of 0.06 m3 (no./year)	0.00
Average duration of overflow (days)	0.00
Effluent Reuse (Proportion of Inflow + Net Rain Gain that is Irrigated) (fraction)	1.00
Probability of at least 90% effluent reuse (fraction)	1.00
Average salinity of last pond (dS/m)	1.56
Salinity of last pond on final day of simulation (dS/m)	1.56
Ammonia loss from pond system water area (kg/m2/year)	0.00

* The threshold is the volume equivalent to the top 1 mm depth of water of a full pond

Overflow exceedance:

■ Chart ☐ Table



Export plot

Sustainability Diagnostics: Gemini Construction - Extreme Permeable

Irrigation Information

Irrigation: 3 ha total area (assumed 100% irrigation efficiency)

	Quantity/year	Quantity/ha/year
Total irrigation applied (m3)	20453.60	6817.87
Total nitrogen applied (kg)	613.61	204.54
Total phosphorus applied (kg)	204.54	68.18
Total salts applied (kg)	20453.60	6817.87

Shandying

Annual allocation of fresh water for shandying (m3/year)	0.00
Average Shandy water irrigation (m3/year) (minimum - maximum)	0.00 (0.00 - 0.00)
Average exceedance as a proportion of annual shandy water allocation (% of allocation) (minimum - maximum)	0.00 (0.00 - 0.00)
Proportion of irrigation events requiring shandying (fraction of events)	0.00
Minimum shandy water is used	False

Irrigation Issues

Proportion of Days irrigation occurs (fraction)	1.00

Sustainability Diagnostics: Gemini Construction - Extreme Permeable

Paddock Land: Gemini Sand: 3 ha

Irrigation: New Irrigation Method with 0% ammonium loss during irrigation

Irrigation triggered every 1 days
Irrigate a fixed amount of 2.00 mm each day
Irrigation window from 1/1 to 31/12 including the days specified
A minimum of 0 days must be skipped between irrigation events

Soil Water Balance (mm): Sand, 80.70 mm PAWC at maximum root depth

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Rain	112.0	103.5	72.8	33.8	34.9	27.1	23.4	20.8	20.7	47.4	61.9	97.1	655.2
Irrigation	57.9	52.7	57.9	56.0	57.9	56.0	57.9	57.9	56.0	57.9	56.0	57.9	681.8
Soil Evap	1.5	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.9
Transpn.	113.2	98.6	102.8	84.6	65.0	53.4	58.4	82.0	92.3	98.7	107.2	124.4	1080.8
Rain Runoff	0.1	0.4	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	1.3
Irr. Runoff	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Drainage	44.4	53.4	34.5	14.2	21.5	12.3	20.4	8.5	7.3	7.9	8.4	21.3	254.1
Delta	10.7	3.2	-6.8	-9.0	6.2	17.3	2.4	-11.9	-23.0	-1.4	2.3	8.8	-1.1

Soil Nitrogen Balance

Average annual effluent nitrogen added (kg/ha/year)	204.54
Average annual soil nitrogen removed by plant uptake (kg/ha/year)	226.31
Average annual soil nitrogen removed by denitrification (kg/ha/year)	3.27E-03
Average annual soil nitrogen leached (kg/ha/year)	1.29
Average annual nitrate-N loading to groundwater (kg/ha/year)	1.29
Soil organic-N kg/ha (Initial - Final)	1494.50 - 34.57
	154.21 - 0.01
Average nitrate-N concentration of deep drainage (mg/L)	0.51
Max. annual nitrate-N concentration of deep drainage (mg/L)	14.29

Soil Phosphorus Balance

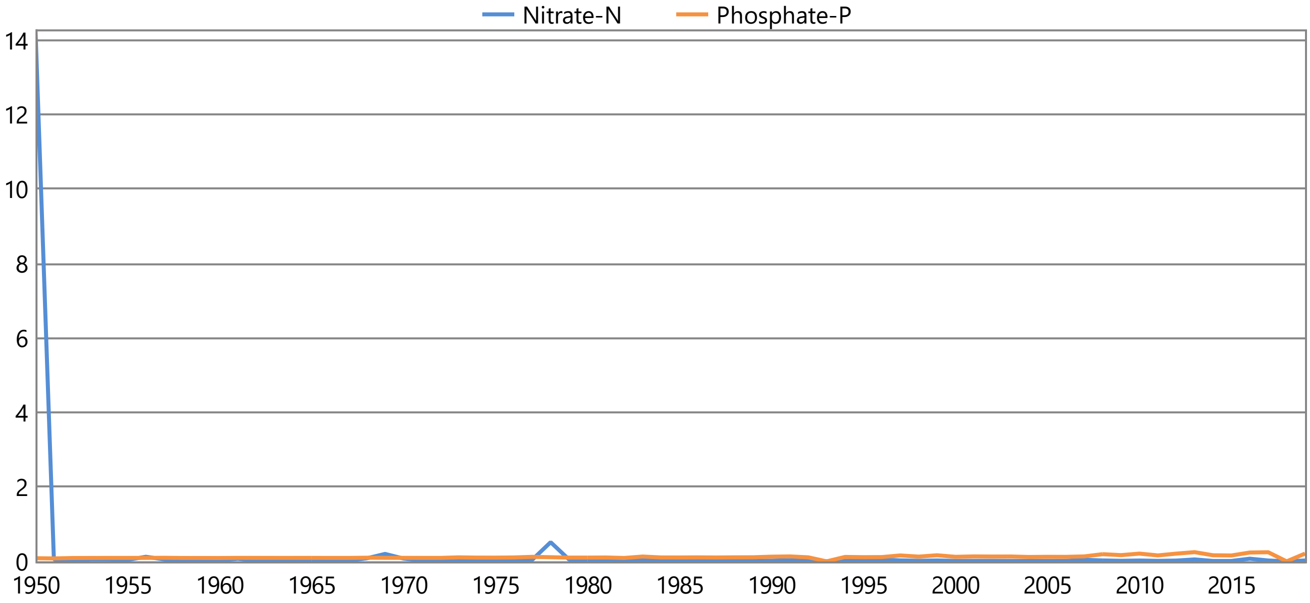
Average annual effluent phosphorus added (kg/ha/year)	68.18
Average annual soil phosphorus removed by plant uptake (kg/ha/year)	53.22
Average annual soil phosphorus leached (kg/ha/year)	0.32
Dissolved phosphorus (kg/ha) (Initial - Final)	0.19 - 2.02
Adsorbed phosphorus (kg/ha) (Initial - Final)	773.25 - 1796.48
Average phosphate-P concentration in rootzone (mg/L)	0.95
Average phosphate-P concentration of deep drainage (mg/L)	0.13
Max. annual phosphate-P concentration of deep drainage (mg/L)	0.25
Design soil profile storage life based on average infiltrated water phosphorus concn. of 5.10 mg/L (years)	30.18

Sustainability Diagnostics: Gemini Construction - Extreme Permeable

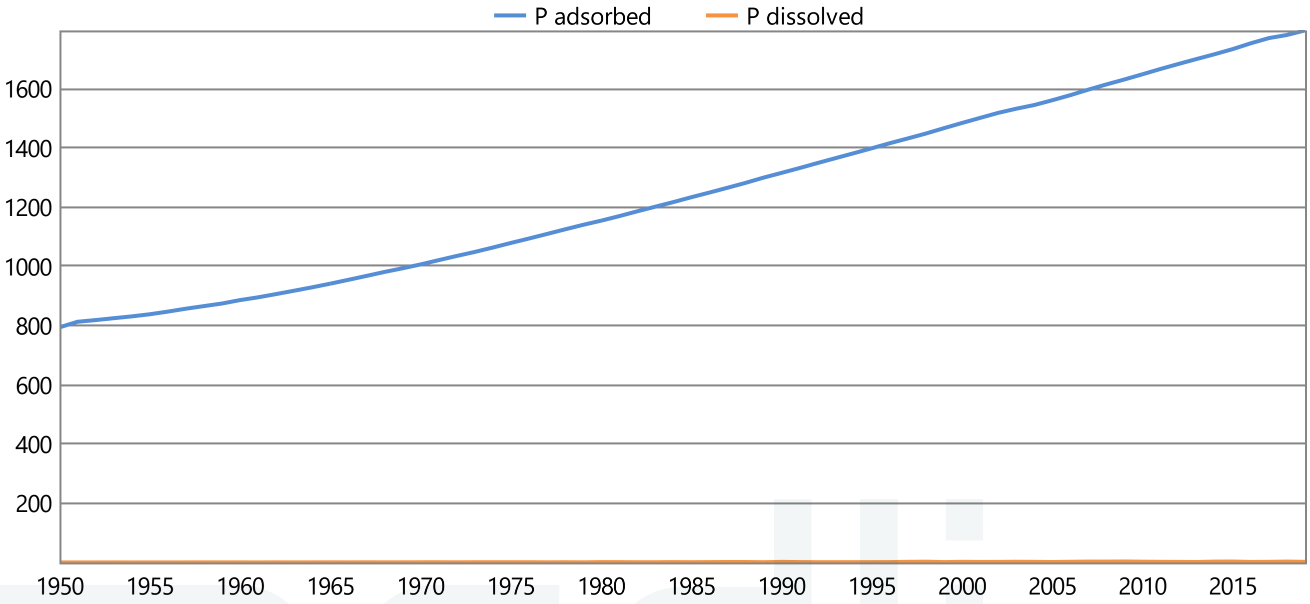
Paddock Land: Gemini Sand: 3 ha

Irrigation: New Irrigation Method with 0% ammonium loss during irrigation

Annual nutrient leachate concentration (mg/L)



Annual Phosphate-P in soil (kg/ha)



Sustainability Diagnostics: Gemini Construction - Extreme Permeable

Paddock Plant Performance: Gemini Sand: 3 ha

Average Plant Performance (Minimum - Maximum): Continuous Rhodes Grass Pasture

Average annual shoot dry matter yield (kg/ha/year)	17859.55 (16257.55 - 23931.03)
Average monthly plant (green) cover (fraction)	0.70 (0.66 - 0.76)
Average monthly crop factor (fraction)	0.63 (0.60 - 0.68)
Total plant cover (both green and dead) left after harvest (fraction)	1.00
Average monthly root depth (mm)	1198.88 (1189.54 - 1200.00)
Average number of normal harvests per year (no./year)	3.11 (2.00 - 4.00)
Average number of normal harvests for last five years only (no./year)	3.00
Average number of crop deaths per year (no./year)	0.00 (0.00 - 0.00)
Average number of crop deaths for last five years only (no./year)	0.00
Average annual nitrogen deficiency index (0 = no stress, 1 = full stress) (coefficient)	0.61 (0.37 - 0.67)
Average January temperature stress index (0 = no stress, 1 = full stress) (coefficient)	0.01 (0.00 - 0.05)
Average July temperature stress index (0 = no stress, 1 = full stress) (coefficient)	0.55 (0.25 - 0.83)
Average monthly water stress index (0 = no stress, 1 = full stress) (coefficient)	0.12 (0.03 - 0.22)
Average monthly waterlogging index (0 = no stress, 1 = full stress) (coefficient)	0.00 (0.00 - 0.00)
No. days without crop/year (days)	0.00

Soil Salinity - Plant salinity tolerance: Tolerant

Assumes 1.0 dS/m Electrical Conductivity = 640 mg/L Total Dissolved Salts

All values based on 10 year running averages

Salinity of infiltrated water (Average salinity of rainwater = 0.03 dS/m) (dS/m)	0.82
Salt added by rainfall (kg/ha/year)	125.55
Average annual effluent salt added & leached at steady state (kg/ha/year)	6943.41
Average leaching fraction based on 10 year running averages (fraction)	0.39
Average water-uptake-weighted rootzone salinity sat. ext. (dS/m)	0.97
Salinity of the soil solution (at drained upper limit) at base of rootzone (dS/m)	4.68
Relative crop yield expected due to salinity (fraction)	1.00
Proportion of years that crop yields would be expected to fall below 90% of potential due to salinity (fraction)	0.00

DIAGNOSTICS

Run Messages

Messages generated when the scenario was run:

Full run chosen

APPENDIX

D

OPERATIONAL PERIOD: EXTREME IMPERMEABLE MEDLI MODEL OUTPUT REPORT

Enterprise: **Gemini Operation - Extreme Impermeable**

Description:
Clay Based Model

Client: **Gemini Mine**

MEDLI User: CARDNO\mark.farrey

Scenario Details:
Operation - Extreme Impermeable - Clay Soil
-84KL Storage (3 days)
- 2mm/day max irrigation
- 1.9ha irrigation area
- Rhodes Grass

Climate Data: Gemini -23.65_149.20, -23.65°, 149.2°

Run Period: 01/01/1950 to 31/12/2019   70 years, 0 days

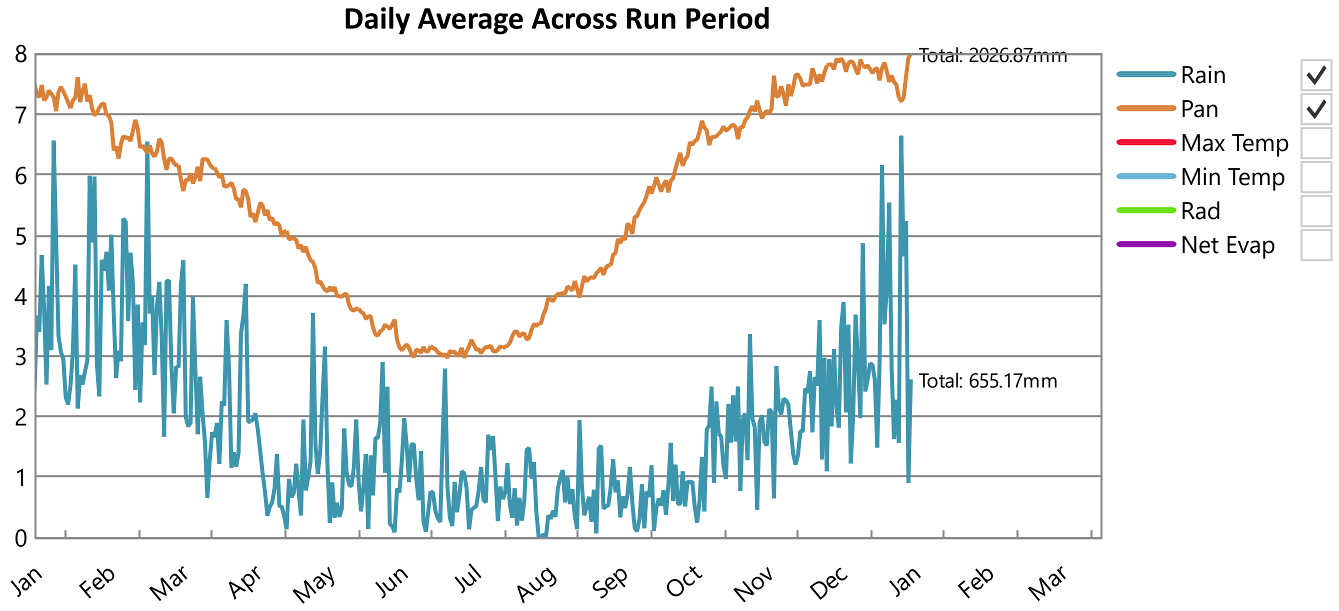
Climate Statistics:

	5th ▼ Percentile	50th Percentile	95th ▼ Percentile
Rainfall (mm/year)	308	632	1107
Pan Evaporation (mm/year)	1792	2046	2219

Climate Data:

■ Chart ☐ Table

☐ Monthly ■ Daily

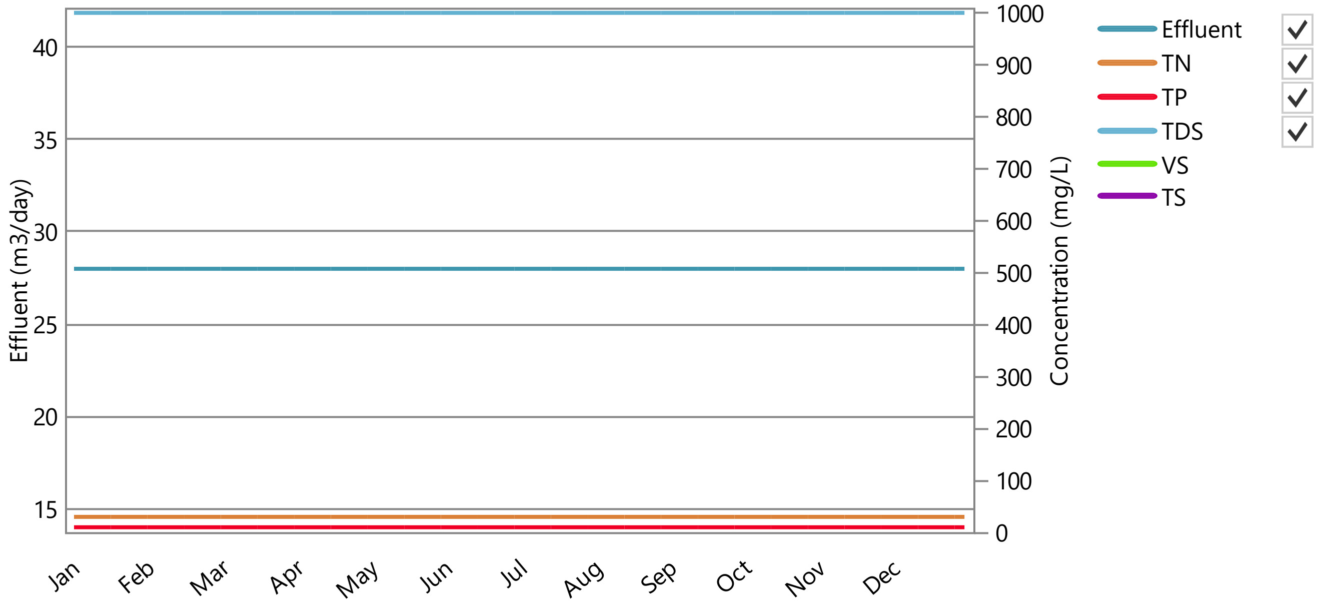


Effluent type: New Sewage Treatment Plant

Wastestream before any recycling or pretreatment

Average daily quantity and flow-weighted average quality:

■ Chart ☐ Table



Wastestream after any recycling and pretreatment if applicable

Effluent quantity: 10226.80 m3/year or 28.00 m3/day (Min-Max: 28.00 - 28.00)

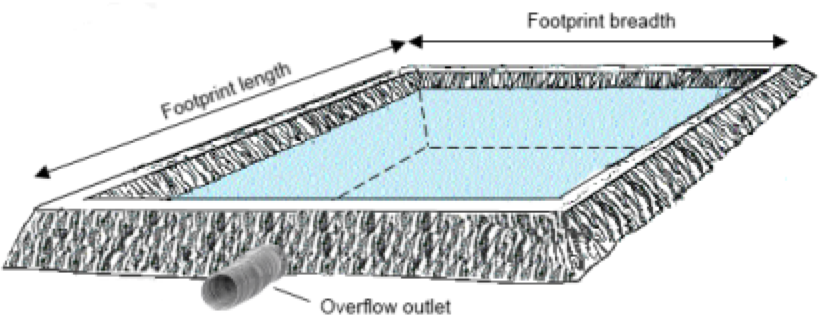
Flow-weighted average (minimum - maximum) daily effluent quality entering pond system:

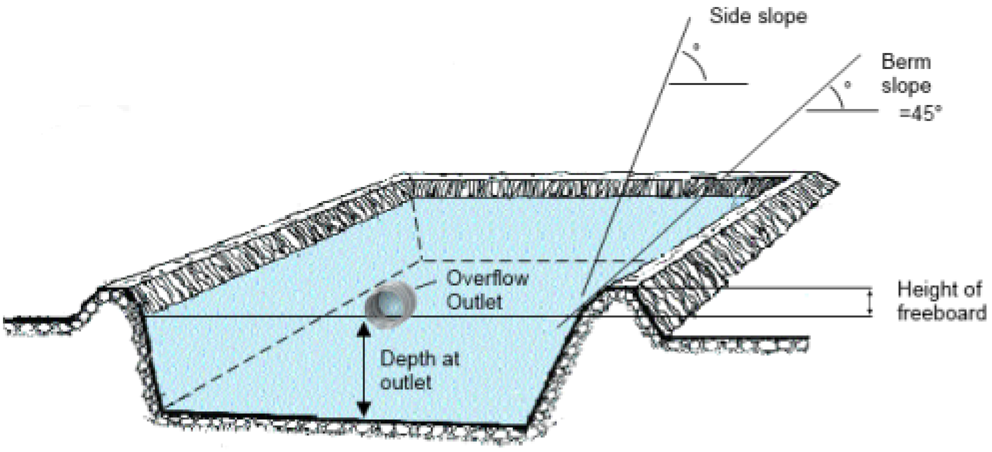
	Concentration (mg/L)	Load (kg/year)
Total Nitrogen	30.00 (30.00 - 30.00)	306.80 (306.60 - 307.44)
Total Phosphorus	10.00 (10.00 - 10.00)	102.27 (102.20 - 102.48)
Total Dissolved Salts	1000.00 (1000.00 - 1000.00)	10226.80 (10220.00 - 10248.00)
Volatile Solids	0.00 (0.00 - 0.00)	0.00 (0.00 - 0.00)
Total Solids	0.00 (0.00 - 0.00)	0.00 (0.00 - 0.00)

Pond system: 1 closed storage tank

Pond system details:

	Pond 1
Maximum pond volume (m3)	84.00
Minimum allowable pond volume (m3)	0.00
Pond depth at overflow outlet (m)	3.00
Maximum water surface area (m2)	28.00
Pond footprint length (m)	5.29
Pond footprint width (m)	5.29
Pond catchment area (m2)	28.00
Average active volume (m3)	0.00





Irrigation pump limits:

Minimum pump rate limit (ML/day)	0.00
Maximum pump rate limit (ML/day)	1000000.00

Shandying water:

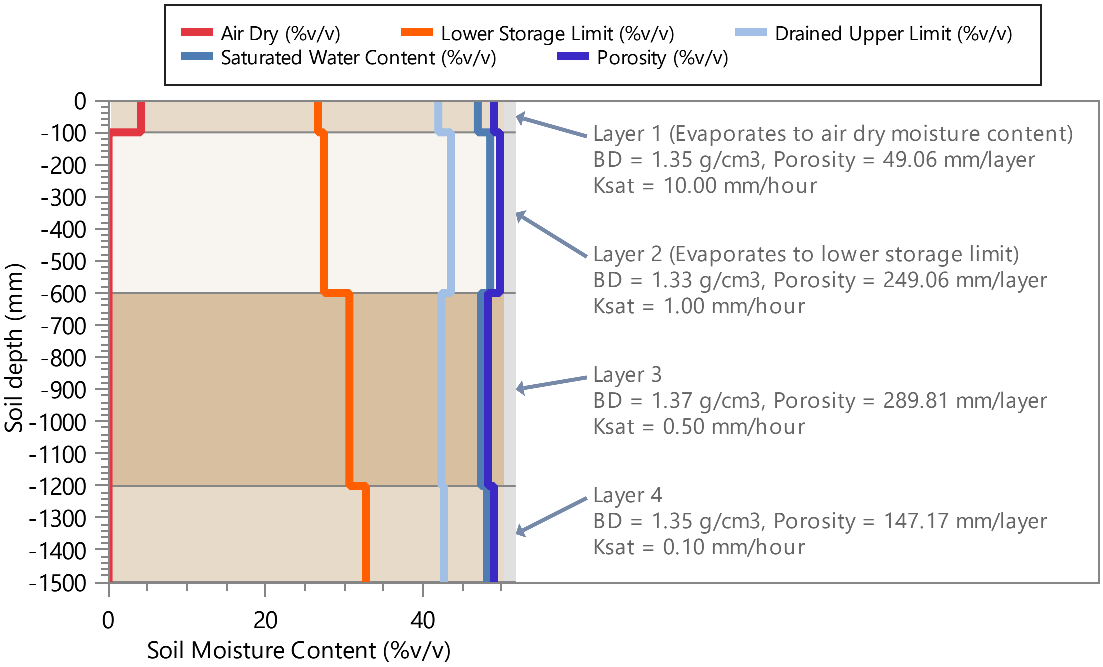
Annual allocation of fresh water available for shandying (m3/year)	0.00
Maximum rate of application of fresh water (ML/day)	0.00
Nitrogen concentration (mg/L)	0.00
Salinity (dS/m)	0.00
Minimum shandy water is used	False

Land: Gemini Clay

Area (ha): 1.90

Soil Type: Grey Clay, 1500.00 mm defined profile depth

Profile Porosity (mm)	735.09
Profile saturation water content (mm)	719.00
Profile drained upper limit (or field capacity) (mm)	642.50
Profile lower storage limit (or permanent wilting point) (mm)	446.80
Profile available water capacity (mm)	195.70
Profile limiting saturated hydraulic conductivity (mm/hour)	0.10
Surface saturated hydraulic conductivity (mm/hour)	10.00
Runoff curve number II (coefficient)	75.00
Soil evaporation U (mm)	6.00
Soil evaporation Cona (mm/sqrt day)	3.50



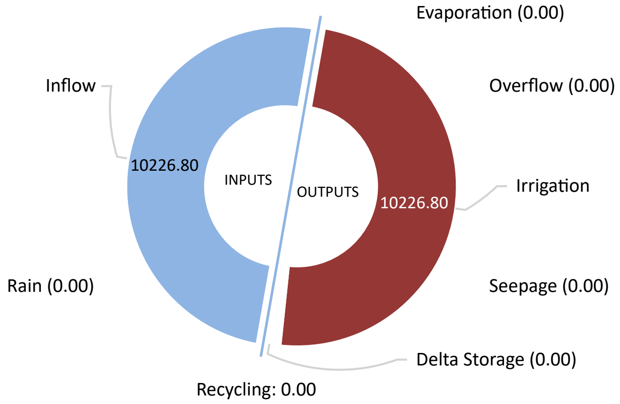
Plant Data: Continuous Kikuyu 1 Pasture

Average monthly cover (fraction) (minimum - maximum)	0.87 (0.82 - 0.91)
Maximum crop factor at 100% cover (mm/mm) (Maximum crop coefficient 0.8 x Pan coefficient 1)	0.80
Total plant cover (both green and dead) left after harvest (fraction)	1.00
Maximum potential root depth in defined soil profile (mm)	1200.00
Salt tolerance	Moderately tolerant
Salinity threshold EC sat. ext. (dS/m)	3.00
Proportion of yield decrease per dS/m increase (fraction/dS/m)	0.03

Pond System Water Performance - Overflow: 1 closed storage tank

Capacity of wet weather storage pond: **84 m3**

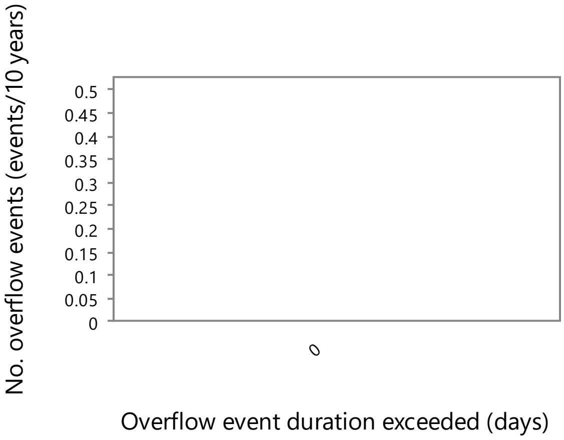
Pond System Water Balance (m3/year)

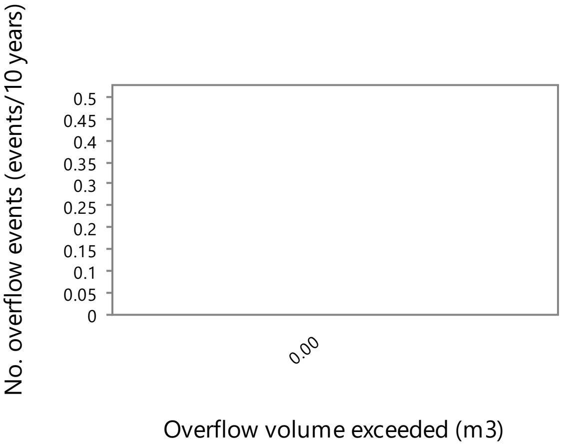


Name	Value
Rain	0.00
Inflow	10226.80
Recycling	0.00
Evaporation	0.00
Overflow	0.00
Irrigation	10226.80
Seepage	0.00
Delta Storage	0.00

Overflow Diagnostics

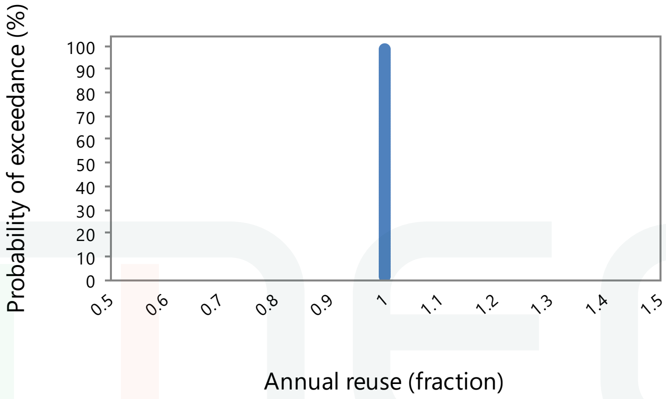
Volume of overflow (m3/year)	0.00
No. days pond overflows (days/year)	0.00
Average duration of overflow (days)	0.00
Effluent Reuse (Proportion of Inflow + Net Rain Gain that is Irrigated) (fraction)	1.00
Probability of at least 90% reuse (fraction)	1.00





Export plot

Export plot



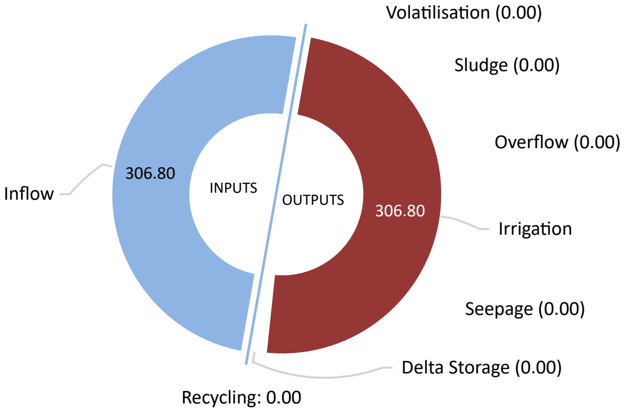
Export plot

PERFORMANCE

Pond System Performance - Nutrient: 1 closed storage tank

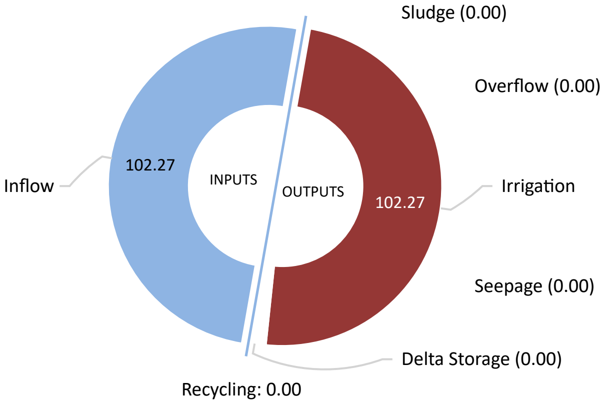
Pond System Nutrients and Salt Balance:

Nitrogen Balance (kg/year)



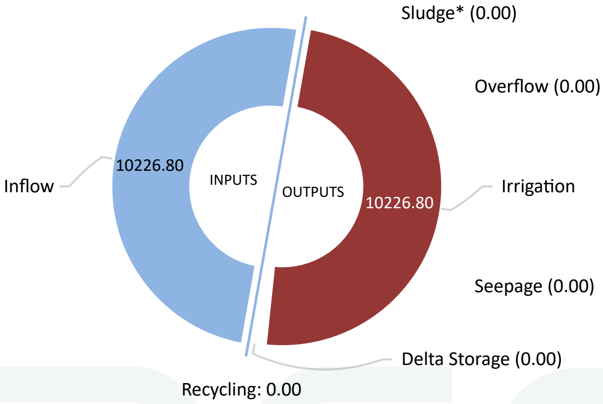
Name	Value
Inflow	306.80
Recycling	0.00
Volatilisation	0.00
Sludge	0.00
Overflow	0.00
Irrigation	306.80
Seepage	0.00
Delta Storage	0.00

Phosphorus Balance (kg/year)



Name	Value
Inflow	102.27
Recycling	0.00
Sludge	0.00
Overflow	0.00
Irrigation	102.27
Seepage	0.00
Delta Storage	0.00

Salt Balance (kg/year)



Name	Value
Inflow	10226.80
Recycling	0.00
Sludge*	0.00
Overflow	0.00
Irrigation	10226.80
Seepage	0.00
Delta Storage	0.00

* Salt removal in sludge is not calculated from the pond salt balance. However if salt could be assumed to be present in the sludge at the same concentration as in the pond supernatant (up to a maximum of salt added in inflow) - then salt accumulation in the sludge could be 0.00 kg/year

Pond System Sludge Accumulation: 0.00 kg dwt/year

Pond System Performance - Nutrient: 1 closed storage tank

Pond Nutrient Concentrations and Salinity:

Average across simulation period	Pond 1
Average nitrogen concentration of pond liquid (mg/L)	30.00
Average phosphorus concentration of pond liquid (mg/L)	10.00
Average salinity of pond liquid (dS/m)	1.56

Value on final day of simulation period	Pond 1
Final nitrogen concentration of pond liquid (mg/L)	30.00
Final phosphorus concentration of pond liquid (mg/L)	10.00
Final salinity of pond liquid (dS/m)	1.56

Irrigation Performance:

Water Use: (assumes 100% Irrigation Efficiency)

Pond water irrigated (m3/year)	10226.80
Average Shandy water irrigation (m3/year) (minimum - maximum)	0.00 (0.00 - 0.00)
Total water irrigated (m3/year)	10226.80
Proportion of irrigation events requiring shandying (fraction of events)	0.00
Proportion of years shandying water allocation of 0 m3/year is exceeded (fraction of years)	0.00
Average exceedance as a proportion of annual shandy water allocation (fraction of allocation) (minimum - maximum)	0.00 (0.00 - 0.00)

Irrigation Quality:

Average nitrogen concentration of irrigation water - before ammonia loss during irrigation (mg/L)	30.00
Average nitrogen concentration of irrigation water - after ammonia loss during irrigation (mg/L)	30.00
Average phosphorus concentration of irrigation water (mg/L)	10.00
Average salinity of irrigation water (dS/m)	1.56

Irrigation Diagnostics:

Proportion of Days irrigation occurs (fraction)	1.00

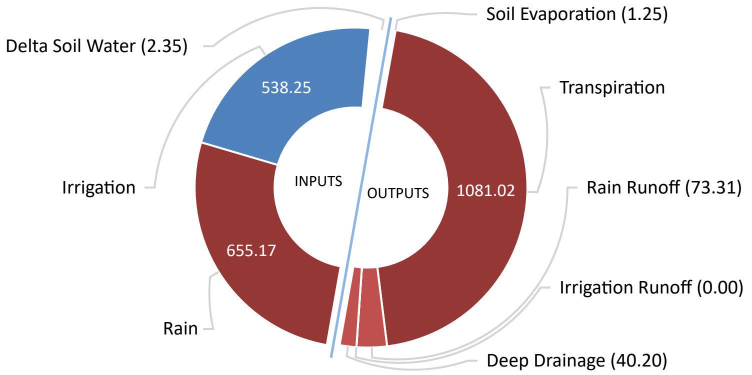
PERFORMANCE

Land Performance - Soil Water

Paddock: **Gemini Clay, 1.9 ha**
Soil Type: **Grey Clay**, **166.00 mm PAWC at maximum root depth**

Land Water Balance (mm/year):

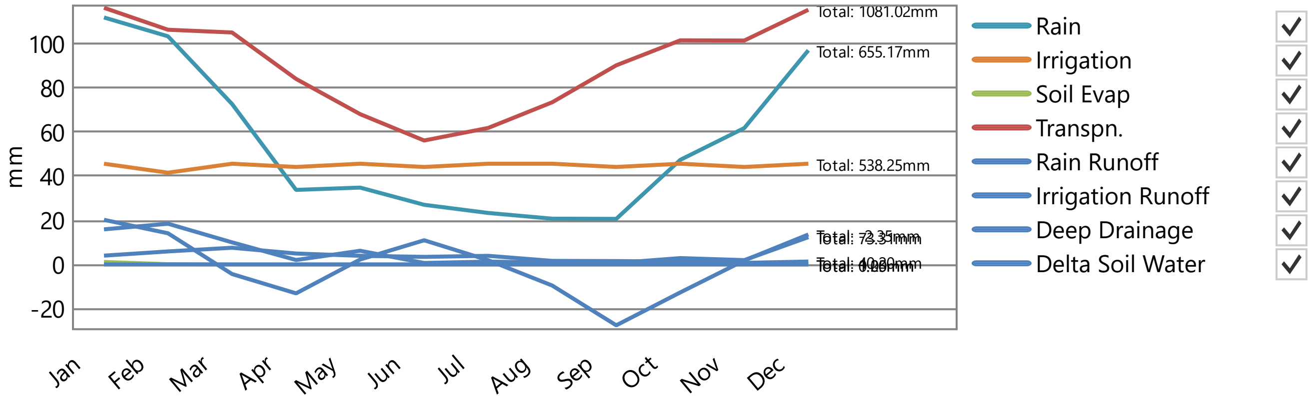
■ mm/year ☐ % Total inputs



Name	Value
Rain	655.17
Irrigation	538.25
Soil Evaporation	1.25
Transpiration	1081.02
Rain Runoff	73.31
Irrigation Runoff	0.00
Deep Drainage	40.20
Delta Soil Water	-2.35

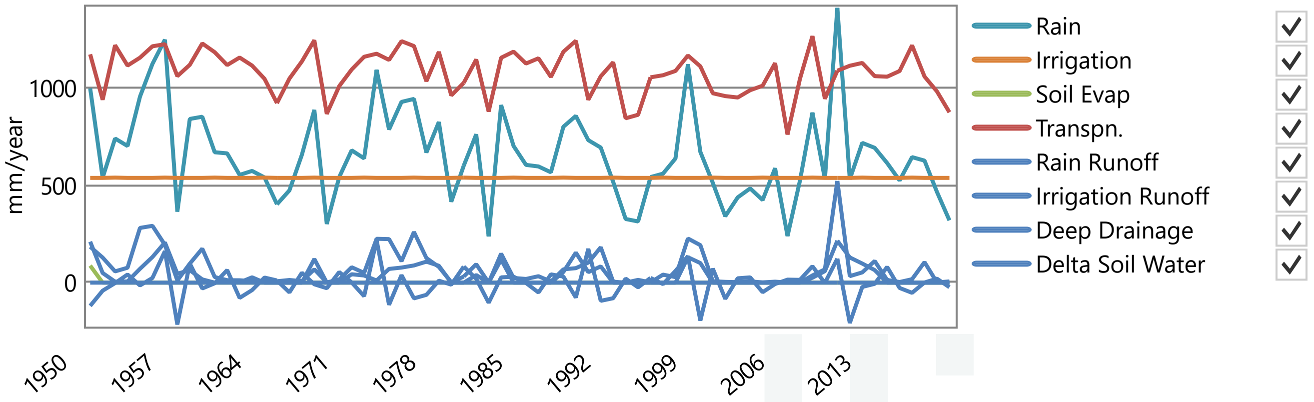
Average Monthly Totals (mm):

■ Chart ☐ Table



Average Annual Totals (mm/year):

■ Chart ☐ Table

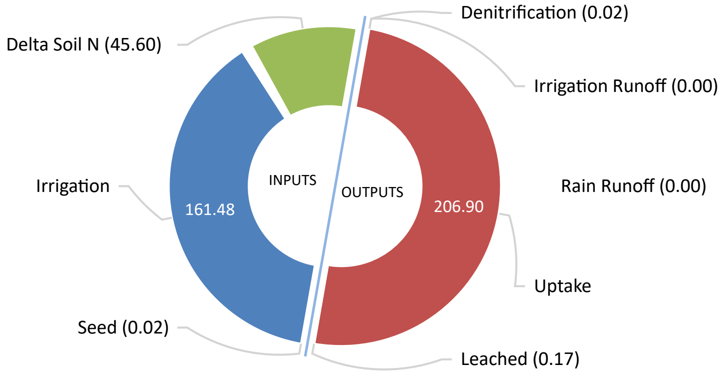


Land Performance - Soil Nutrient

Paddock: **Gemini Clay, 1.9 ha** **Soil Type**: **Grey Clay**

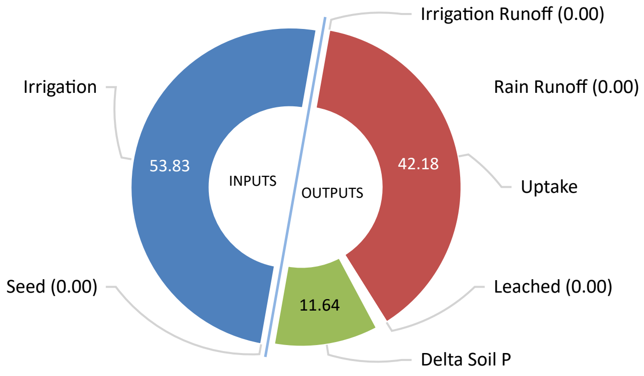
Irrigation ammonium volatilisation losses (kg/ha/year): 0.00
Proportion of total nitrogen in irrigated effluent as ammonium (fraction): 0.25

Land Nitrogen Balance (kg/ha/year)



Name	Value
Seed	0.02
Irrigation	161.48
Denitrification	0.02
Irrigation Runoff	0.00
Rain Runoff	0.00
Uptake	206.90
Leached	0.17
Delta Soil N	-45.60

Land Phosphorus Balance (kg/ha/year)



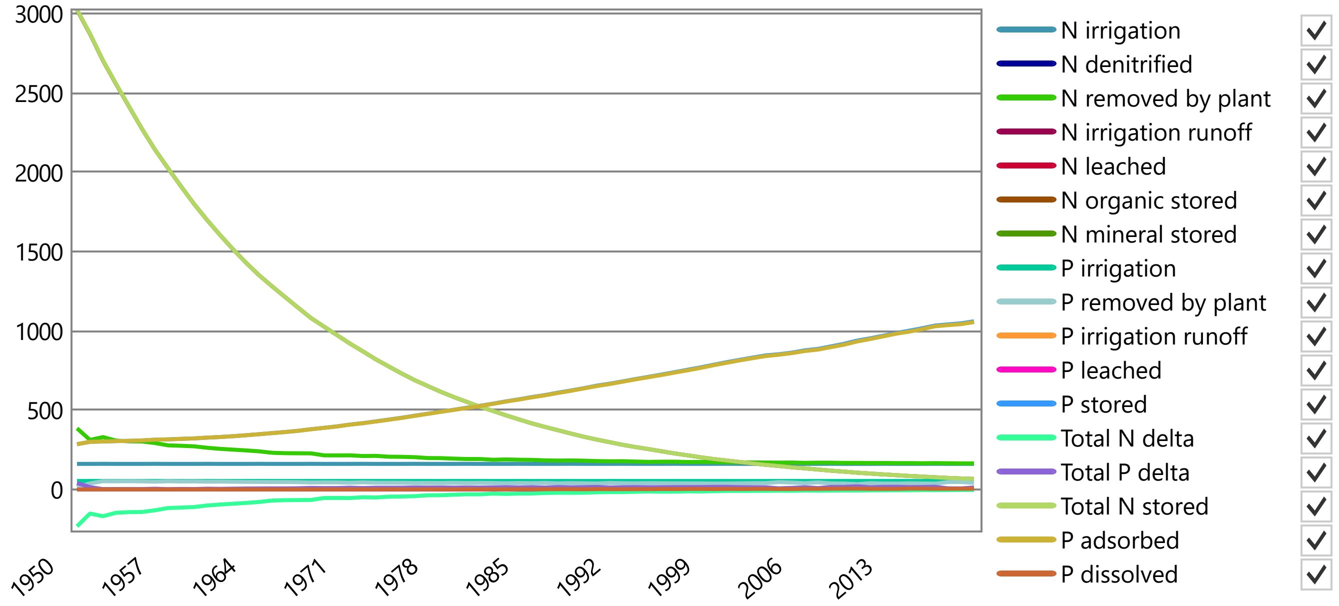
Name	Value
Seed	1.29E-03
Irrigation	53.83
Irrigation Runoff	0.00
Rain Runoff	0.00
Uptake	42.18
Leached	4.04E-03
Delta Soil P	11.64

PERFORMANCE

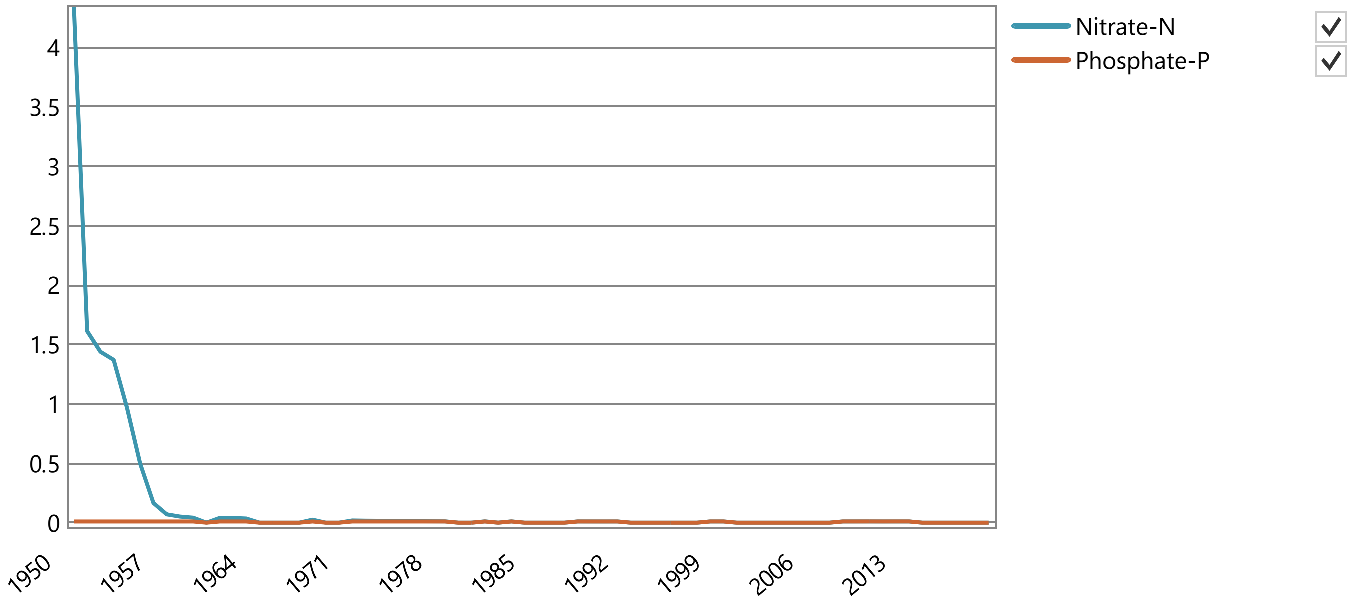
Land Performance - Soil Nutrient

Paddock: Gemini Clay, 1.9 ha **Soil Type**: Grey Clay

Annual Nutrient Totals (kg/ha):



Annual Nutrient Leaching Concentration (mg/L):



PERFORMANCE

Plant Performance and Nutrients

Paddock: Gemini Clay, 1.9 ha **Soil Type**: **Grey Clay**

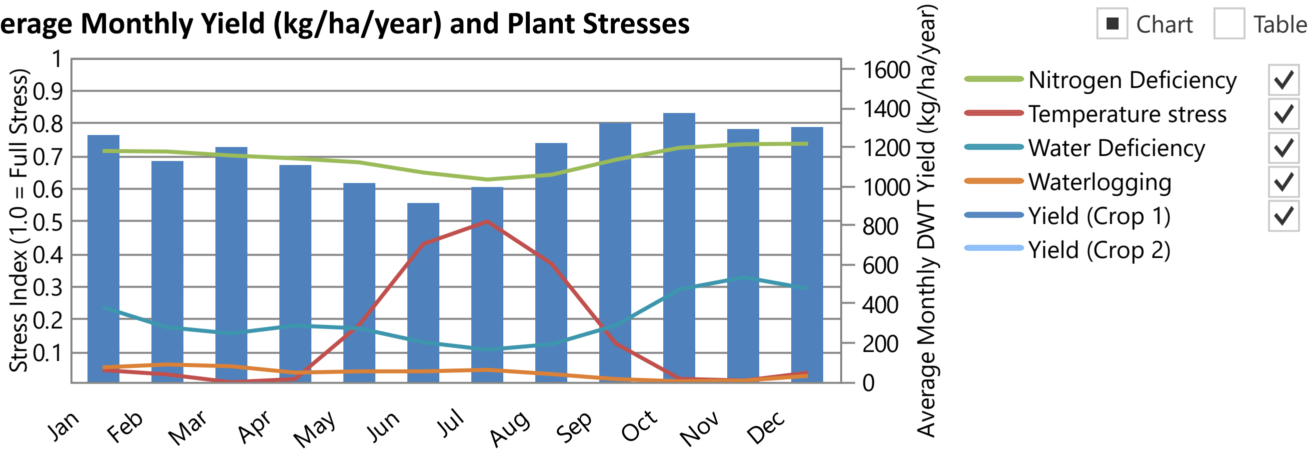
Plant: Continuous Kikuyu 1 Pasture

Average annual shoot dry matter yield (kg/ha/year)	14169.27 (11233.69 - 20218.65)
Average monthly plant (green) cover (fraction) (minimum - maximum)	0.87 (0.82 - 0.91)
Average monthly root depth (mm) (minimum - maximum)	1199.08 (1189.67 - 1200.00)

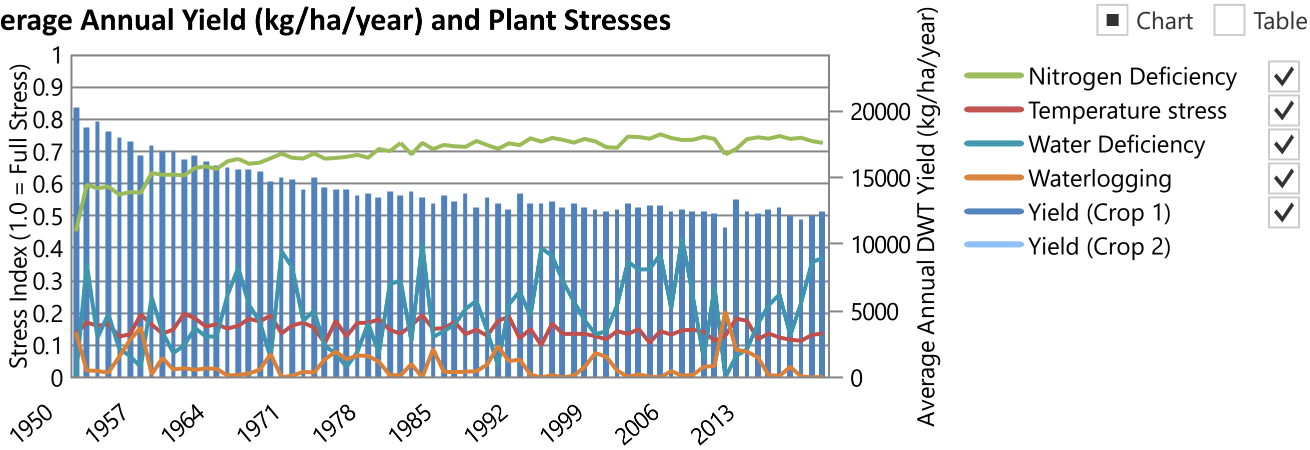
Nutrient Uptake (minimum - maximum):

Average annual net nitrogen removed by plant uptake (kg/ha/year)	206.90 (164.39 - 385.60)
Average annual net phosphorus removed by plant uptake (kg/ha/year)	42.18 (13.85 - 52.02)
Average annual shoot nitrogen concentration (fraction dwt)	0.02 (0.01 - 0.02)
Average annual shoot phosphorus concentration (fraction dwt)	0.003 (0.001 - 0.004)

Average Monthly Yield (kg/ha/year) and Plant Stresses



Average Annual Yield (kg/ha/year) and Plant Stresses



No. of harvests/year: 2.56 (normal)

No. days without crop/year (days/year): 0.00

Land Performance

Paddock: Gemini Clay, 1.9 ha **Soil Type: Grey Clay**

Plant: Continuous Kikuyu 1 Pasture

Salt tolerance	Moderately tolerant
Salinity threshold EC sat. ext. (dS/m)	3.00
Proportion of yield decrease per dS/m increase (fraction/dS/m)	0.03
No. years assumed for leaching to reach steady-state (years)	10.00

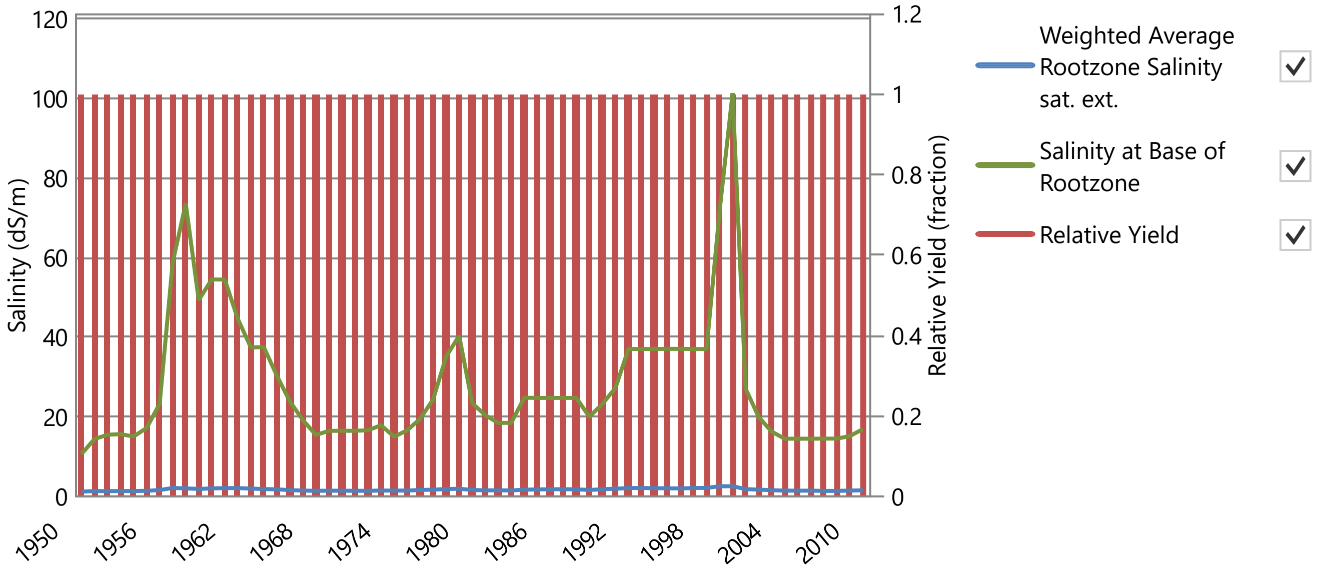
Soil Salinity:

Salinity of infiltrated water (Average salinity of rainwater = 0.03 dS/m) (dS/m)	0.77
Salt added by rainfall (kg/ha/year)	111.72
Average annual effluent salt added & leached at steady state (kg/ha/year)	5494.24
Average leaching fraction based on 10 year running averages (fraction)	0.21
Average water-uptake-weighted rootzone salinity sat. ext. (dS/m)	1.71
Salinity of the soil solution (at drained upper limit) at base of rootzone (dS/m)	28.22
Relative crop yield expected due to salinity (fraction)	1.00
Proportion of years that crop yields would be expected to fall below 90% of potential due to salinity (fraction)	0.00

Average Annual Rootzone Salinity and Relative Yield:

☒ Chart ☐ Table

All values based on 10 year running averages

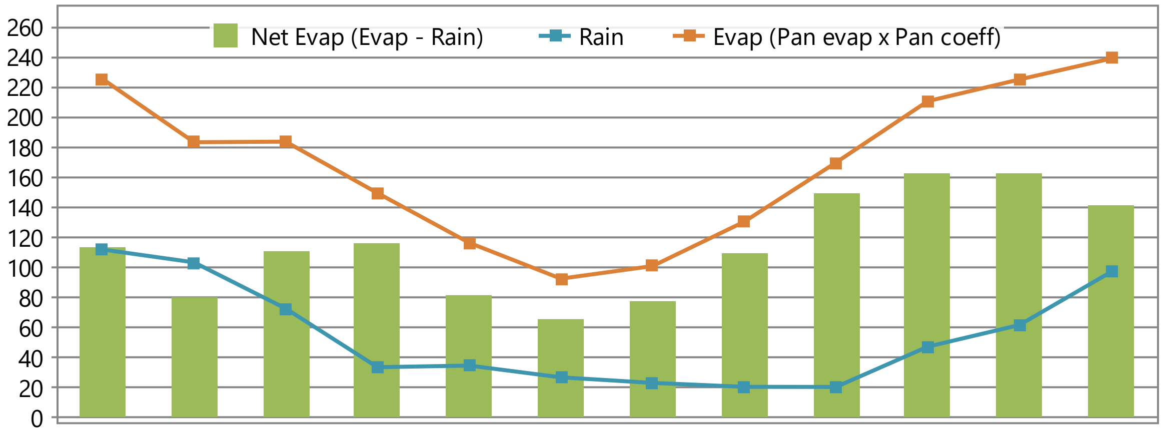


Sustainability Diagnostics: Gemini Operation - Extreme Impermeable

Averaged Historical Climate Data Used in Simulation (mm)

Location: Gemini -23.65_149.20, -23.65°, 149.2°

Run Period: 01/01/1950 to 31/12/2019 70 years, 0 days



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Rain	112.0	103.5	72.8	33.8	34.9	27.1	23.4	20.8	20.7	47.4	61.9	97.1	655.2
Evap	225.4	183.3	183.7	149.5	116.5	92.6	101.0	130.5	169.8	210.6	225.0	238.9	2026.9
Net Evap	113.4	79.8	110.9	115.7	81.6	65.6	77.7	109.8	149.1	163.2	163.1	141.8	1371.7
Net Evap/day	3.7	2.8	3.6	3.9	2.6	2.2	2.5	3.5	5.0	5.3	5.4	4.6	3.8

Sustainability Diagnostics: Gemini Operation - Extreme Impermeable

Pond System: 1 closed storage tank

New Sewage Treatment Plant - 10226.80 m3/year or 28.00 m3/day generated on average

Effluent entering pond system after any pretreatment and recycling

Average (Minimum-Maximum) influent quality calculated for 365.24 non-zero flow days, after any pretreatment and recycling.

Constituent	Concentration (mg/L)	Load (kg/year)
Total Nitrogen	30.00 (30.00 - 30.00)	306.80 (306.60 - 307.44)
Total Phosphorus	10.00 (10.00 - 10.00)	102.27 (102.20 - 102.48)
Total Dissolved Salts	1000.00 (1000.00 - 1000.00)	10226.80 (10220.00 - 10248.00)
Volatile Solids	0.00 (0.00 - 0.00)	0.00 (0.00 - 0.00)
Total Solids	0.00 (0.00 - 0.00)	0.00 (0.00 - 0.00)

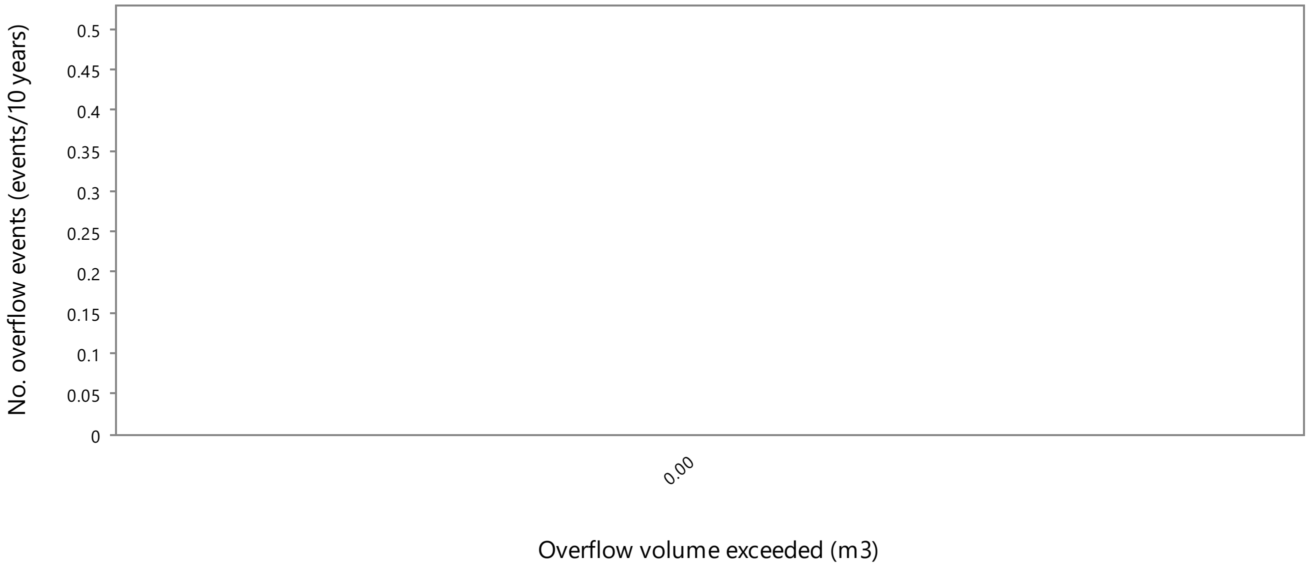
Last pond (Wet weather store): 84.00 m3

Theoretical hydraulic retention time (days)	3.00
Average volume of overflow (m3/year)	0.00
No. overflow events per year exceeding threshold* of 0.03 m3 (no./year)	0.00
Average duration of overflow (days)	0.00
Effluent Reuse (Proportion of Inflow + Net Rain Gain that is Irrigated) (fraction)	1.00
Probability of at least 90% effluent reuse (fraction)	1.00
Average salinity of last pond (dS/m)	1.56
Salinity of last pond on final day of simulation (dS/m)	1.56
Ammonia loss from pond system water area (kg/m2/year)	0.00

* The threshold is the volume equivalent to the top 1 mm depth of water of a full pond

Overflow exceedance:

■ Chart ☐ Table



Export plot

Sustainability Diagnostics: Gemini Operation - Extreme Impermeable

Irrigation Information

Irrigation: 1.9 ha total area (assumed 100% irrigation efficiency)

	Quantity/year	Quantity/ha/year
Total irrigation applied (m3)	10226.80	5382.53
Total nitrogen applied (kg)	306.80	161.48
Total phosphorus applied (kg)	102.27	53.83
Total salts applied (kg)	10226.80	5382.53

Shandying

Annual allocation of fresh water for shandying (m3/year)	0.00
Average Shandy water irrigation (m3/year) (minimum - maximum)	0.00 (0.00 - 0.00)
Average exceedance as a proportion of annual shandy water allocation (% of allocation) (minimum - maximum)	0.00 (0.00 - 0.00)
Proportion of irrigation events requiring shandying (fraction of events)	0.00
Minimum shandy water is used	False

Irrigation Issues

Proportion of Days irrigation occurs (fraction)	1.00

Sustainability Diagnostics: Gemini Operation - Extreme Impermeable

Paddock Land: Gemini Clay: 1.9 ha

Irrigation: New Irrigation Method with 0% ammonium loss during irrigation

Irrigation triggered every 1 days
Irrigate a fixed amount of 2.00 mm each day
Irrigation window from 1/1 to 31/12 including the days specified
A minimum of 0 days must be skipped between irrigation events

Soil Water Balance (mm): Grey Clay, 166.00 mm PAWC at maximum root depth

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Rain	112.0	103.5	72.8	33.8	34.9	27.1	23.4	20.8	20.7	47.4	61.9	97.1	655.2
Irrigation	45.7	41.6	45.7	44.2	45.7	44.2	45.7	45.7	44.2	45.7	44.2	45.7	538.3
Soil Evap	1.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.2
Transpn.	116.4	106.4	105.2	84.1	68.2	56.2	61.9	73.5	90.3	101.6	101.6	115.5	1081.0
Rain Runoff	15.9	18.5	10.0	2.0	6.2	0.7	1.3	0.8	0.6	2.9	2.0	12.4	73.3
Irr. Runoff	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Drainage	4.0	5.9	7.6	5.0	3.9	3.4	3.9	1.6	1.5	1.3	0.7	1.3	40.2
Delta	20.3	14.1	-4.3	-13.1	2.2	11.0	1.9	-9.6	-27.6	-12.7	1.8	13.6	-2.4

Soil Nitrogen Balance

Average annual effluent nitrogen added (kg/ha/year)	161.48
Average annual soil nitrogen removed by plant uptake (kg/ha/year)	206.90
Average annual soil nitrogen removed by denitrification (kg/ha/year)	0.02
Average annual soil nitrogen leached (kg/ha/year)	0.17
Average annual nitrate-N loading to groundwater (kg/ha/year)	0.17
Soil organic-N kg/ha (Initial - Final)	3208.00 - 66.51
	50.68 - 0.05
Average nitrate-N concentration of deep drainage (mg/L)	0.43
Max. annual nitrate-N concentration of deep drainage (mg/L)	4.35

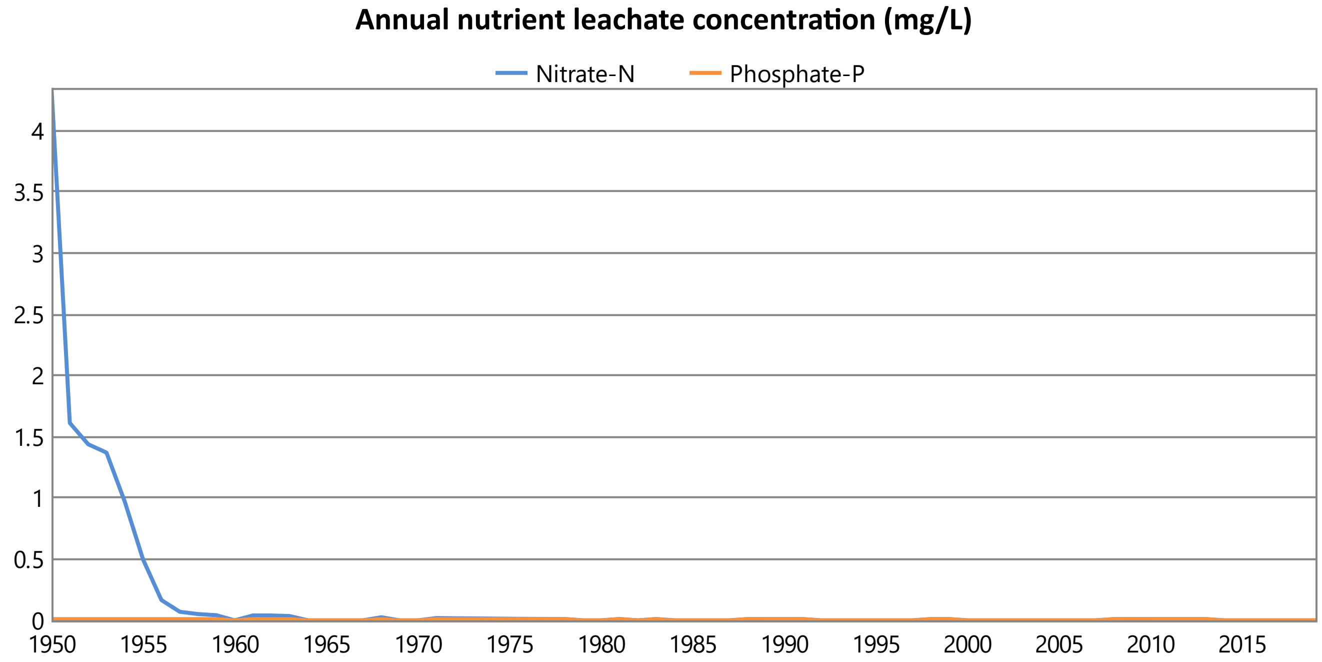
Soil Phosphorus Balance

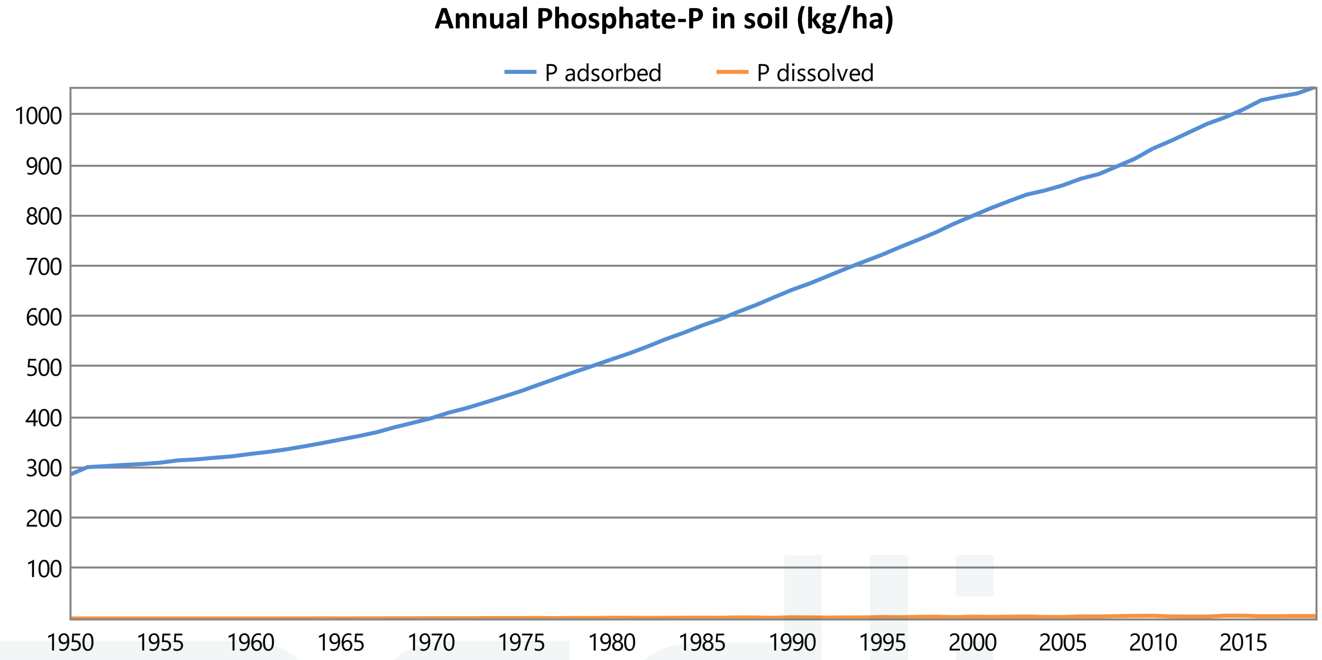
Average annual effluent phosphorus added (kg/ha/year)	53.83
Average annual soil phosphorus removed by plant uptake (kg/ha/year)	42.18
Average annual soil phosphorus leached (kg/ha/year)	4.04E-03
Dissolved phosphorus (kg/ha) (Initial - Final)	0.06 - 4.71
Adsorbed phosphorus (kg/ha) (Initial - Final)	245.27 - 1055.46
Average phosphate-P concentration in rootzone (mg/L)	0.49
Average phosphate-P concentration of deep drainage (mg/L)	0.01
Max. annual phosphate-P concentration of deep drainage (mg/L)	0.01
Design soil profile storage life based on average infiltrated water phosphorus concn. of 4.81 mg/L (years)	46.27

Sustainability Diagnostics: Gemini Operation - Extreme Impermeable

Paddock Land: Gemini Clay: 1.9 ha

Irrigation: New Irrigation Method with 0% ammonium loss during irrigation





Sustainability Diagnostics: Gemini Operation - Extreme Impermeable

Paddock Plant Performance: Gemini Clay: 1.9 ha

Average Plant Performance (Minimum - Maximum): Continuous Kikuyu 1 Pasture

Average annual shoot dry matter yield (kg/ha/year)	14169.27 (11233.69 - 20218.65)
Average monthly plant (green) cover (fraction)	0.87 (0.82 - 0.91)
Average monthly crop factor (fraction)	0.70 (0.66 - 0.73)
Total plant cover (both green and dead) left after harvest (fraction)	1.00
Average monthly root depth (mm)	1199.08 (1189.67 - 1200.00)
Average number of normal harvests per year (no./year)	2.56 (2.00 - 4.00)
Average number of normal harvests for last five years only (no./year)	2.20
Average number of crop deaths per year (no./year)	0.00 (0.00 - 0.00)
Average number of crop deaths for last five years only (no./year)	0.00
Average annual nitrogen deficiency index (0 = no stress, 1 = full stress) (coefficient)	0.69 (0.45 - 0.75)
Average January temperature stress index (0 = no stress, 1 = full stress) (coefficient)	0.04 (0.00 - 0.17)
Average July temperature stress index (0 = no stress, 1 = full stress) (coefficient)	0.50 (0.23 - 0.77)
Average monthly water stress index (0 = no stress, 1 = full stress) (coefficient)	0.20 (0.11 - 0.33)
Average monthly waterlogging index (0 = no stress, 1 = full stress) (coefficient)	0.04 (0.01 - 0.06)
No. days without crop/year (days)	0.00

Soil Salinity - Plant salinity tolerance: Moderately tolerant

Assumes 1.0 dS/m Electrical Conductivity = 640 mg/L Total Dissolved Salts

All values based on 10 year running averages

Salinity of infiltrated water (Average salinity of rainwater = 0.03 dS/m) (dS/m)	0.77
Salt added by rainfall (kg/ha/year)	111.72
Average annual effluent salt added & leached at steady state (kg/ha/year)	5494.24
Average leaching fraction based on 10 year running averages (fraction)	0.21
Average water-uptake-weighted rootzone salinity sat. ext. (dS/m)	1.71
Salinity of the soil solution (at drained upper limit) at base of rootzone (dS/m)	28.22
Relative crop yield expected due to salinity (fraction)	1.00
Proportion of years that crop yields would be expected to fall below 90% of potential due to salinity (fraction)	0.00

DIAGNOSTICS

Run Messages

Messages generated when the scenario was run:

Full run chosen

APPENDIX

E

CONSTRUCTION PERIOD: EXTREME PERMEABLE MEDLI MODEL OUTPUT REPORT

Enterprise: **Gemini Operation - Extreme Permeable**

Description:
Sand Based Model

Client: **Gemini Mine**

MEDLI User: CARDNO\mark.farrey

Scenario Details:
Operation - Extreme Permeable Model - Sand Soil
-84KL Storage (3 days)
-2mm/day max irrigation
-1.5ha irrigation area
-Rhodes Grass

Climate Data: **Gemini -23.65_149.20, -23.65°, 149.2°**

Run Period: **01/01/1950 to 31/12/2019** 70 years, 0 days

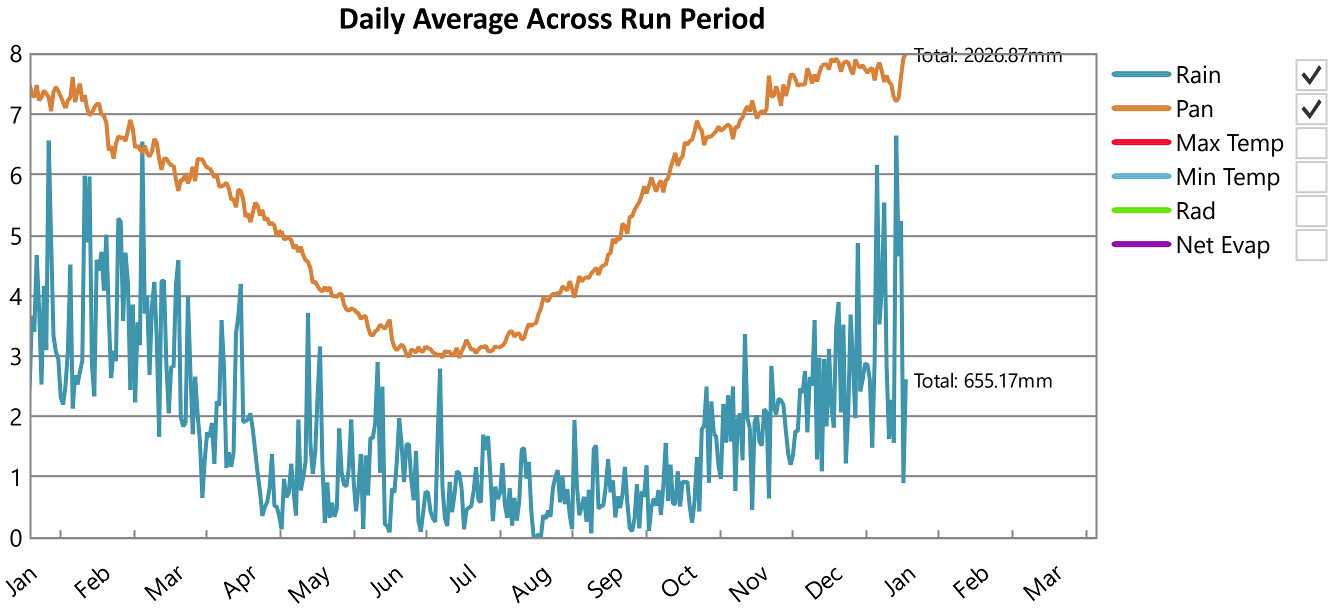
Climate Statistics:

	5th ▼ **Percentile**	**50th Percentile**	95th ▼ **Percentile**
Rainfall (mm/year)	308	632	1107
Pan Evaporation (mm/year)	1792	2046	2219

Climate Data:

☒ Chart ☐ Table

☐ Monthly ☒ Daily



Daily Average Across Run Period

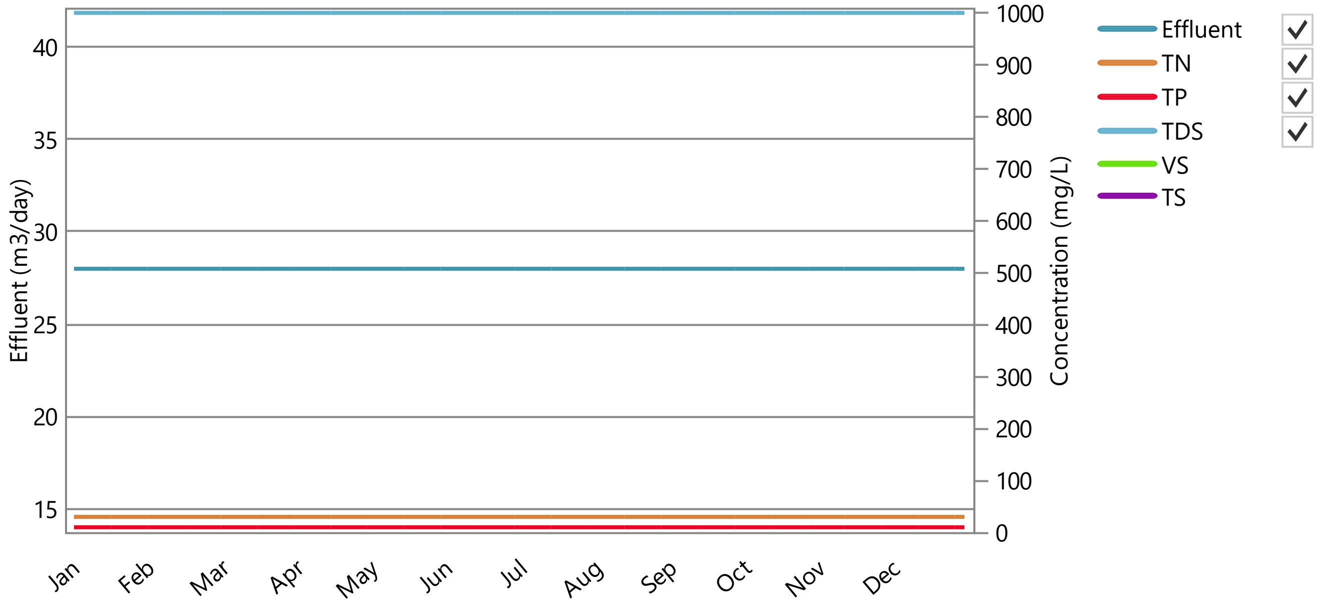
DESCRIPTION

Effluent type: New Sewage Treatment Plant

Wastestream before any recycling or pretreatment

Average daily quantity and flow-weighted average quality:

■ Chart ☐ Table



Wastestream after any recycling and pretreatment if applicable

Effluent quantity: 10226.80 m3/year or 28.00 m3/day (Min-Max: 28.00 - 28.00)

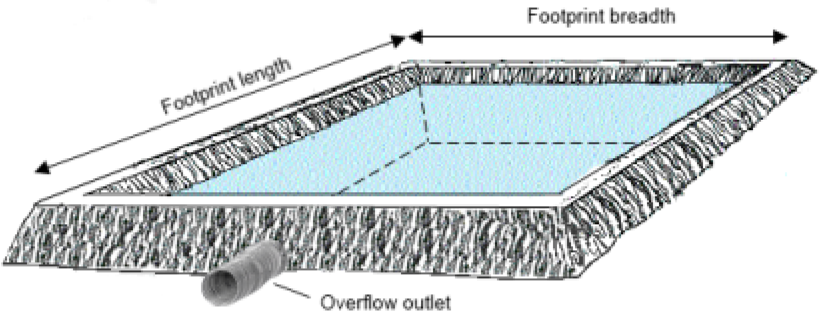
Flow-weighted average (minimum - maximum) daily effluent quality entering pond system:

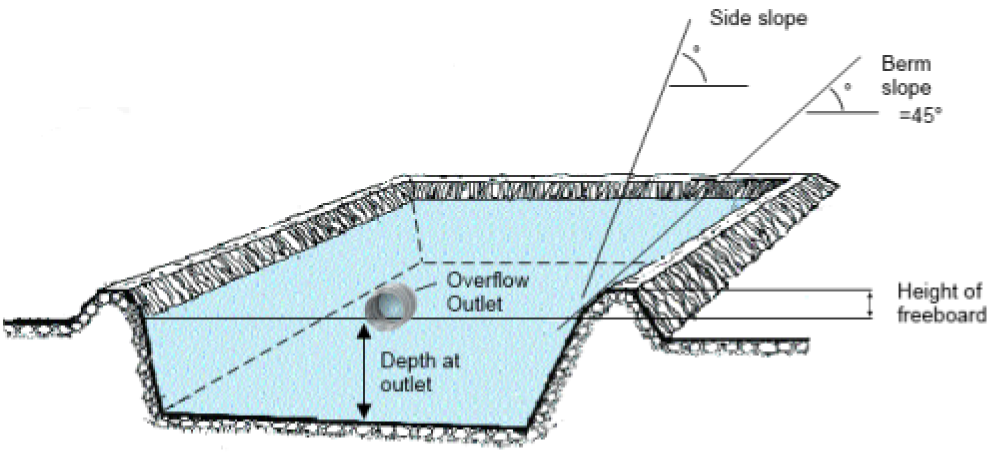
	Concentration (mg/L)	Load (kg/year)
Total Nitrogen	30.00 (30.00 - 30.00)	306.80 (306.60 - 307.44)
Total Phosphorus	10.00 (10.00 - 10.00)	102.27 (102.20 - 102.48)
Total Dissolved Salts	1000.00 (1000.00 - 1000.00)	10226.80 (10220.00 - 10248.00)
Volatile Solids	0.00 (0.00 - 0.00)	0.00 (0.00 - 0.00)
Total Solids	0.00 (0.00 - 0.00)	0.00 (0.00 - 0.00)

Pond system: 1 closed storage tank

Pond system details:

	Pond 1
Maximum pond volume (m3)	84.00
Minimum allowable pond volume (m3)	0.00
Pond depth at overflow outlet (m)	3.00
Maximum water surface area (m2)	28.00
Pond footprint length (m)	17.29
Pond footprint width (m)	17.29
Pond catchment area (m2)	298.99
Average active volume (m3)	0.00





Irrigation pump limits:

Minimum pump rate limit (ML/day)	0.00
Maximum pump rate limit (ML/day)	100000000.00

Shandying water:

Annual allocation of fresh water available for shandying (m3/year)	0.00
Maximum rate of application of fresh water (ML/day)	0.00
Nitrogen concentration (mg/L)	0.00
Salinity (dS/m)	0.00
Minimum shandy water is used	False

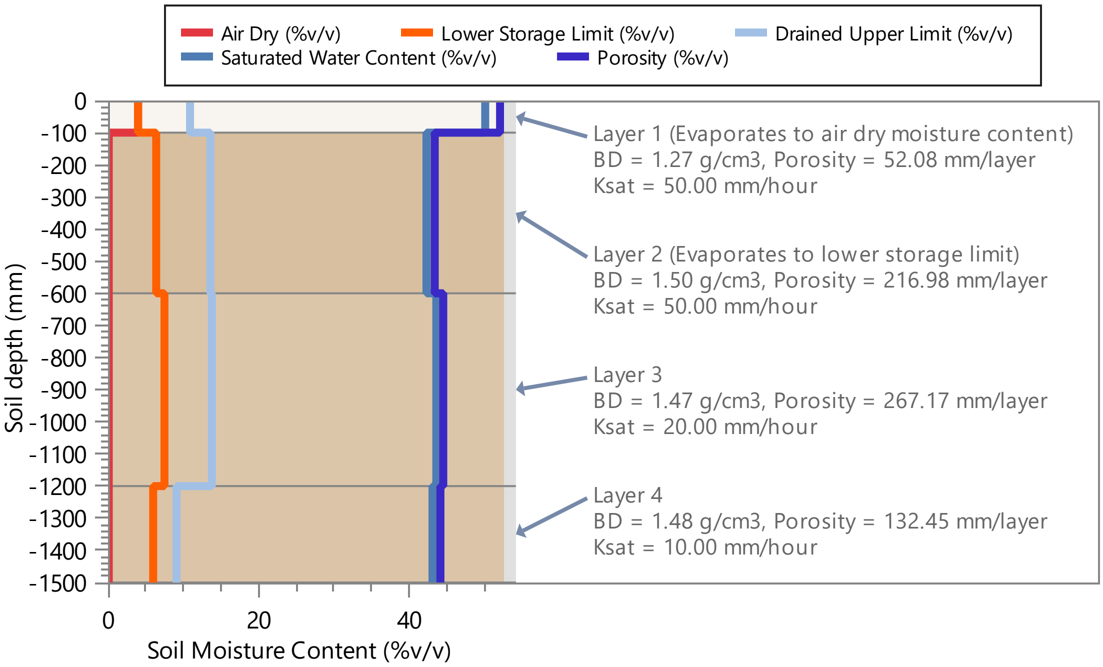
DESCRIPTION

Land: Gemini Sand

Area (ha): 1.50

Soil Type: Sand, 1500.00 mm defined profile depth

Profile Porosity (mm)	668.68
Profile saturation water content (mm)	652.50
Profile drained upper limit (or field capacity) (mm)	189.00
Profile lower storage limit (or permanent wilting point) (mm)	99.00
Profile available water capacity (mm)	90.00
Profile limiting saturated hydraulic conductivity (mm/hour)	10.00
Surface saturated hydraulic conductivity (mm/hour)	50.00
Runoff curve number II (coefficient)	70.00
Soil evaporation U (mm)	10.00
Soil evaporation Cona (mm/sqrt day)	4.50



Plant Data: Continuous Rhodes Grass Pasture

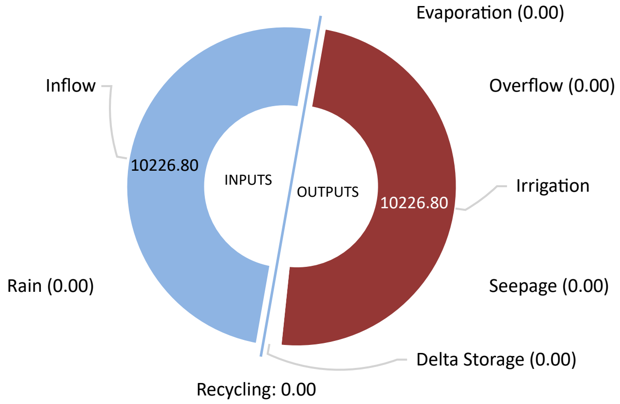
Average monthly cover (fraction) (minimum - maximum)	0.70 (0.66 - 0.76)
Maximum crop factor at 100% cover (mm/mm) (Maximum crop coefficient 0.9 x Pan coefficient 1)	0.90
Total plant cover (both green and dead) left after harvest (fraction)	1.00
Maximum potential root depth in defined soil profile (mm)	1200.00
Salt tolerance	Tolerant
Salinity threshold EC sat. ext. (dS/m)	7.00
Proportion of yield decrease per dS/m increase (fraction/dS/m)	0.03

PERFORMANCE

Pond System Water Performance - Overflow: 1 closed storage tank

Capacity of wet weather storage pond: **84 m3**

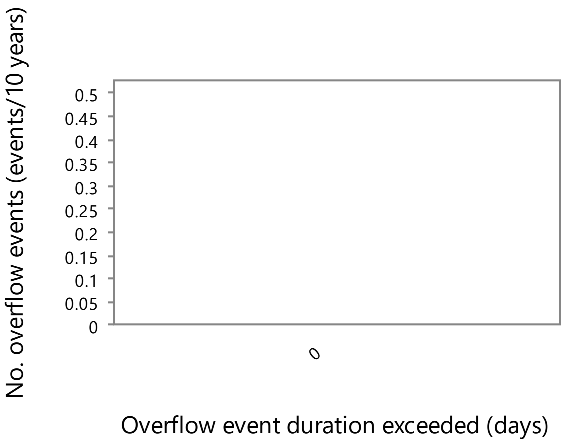
Pond System Water Balance (m3/year)

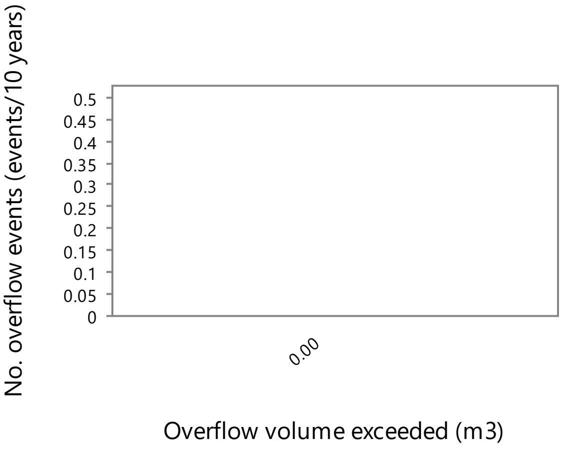


Name	Value
Rain	0.00
Inflow	10226.80
Recycling	0.00
Evaporation	0.00
Overflow	0.00
Irrigation	10226.80
Seepage	0.00
Delta Storage	0.00

Overflow Diagnostics

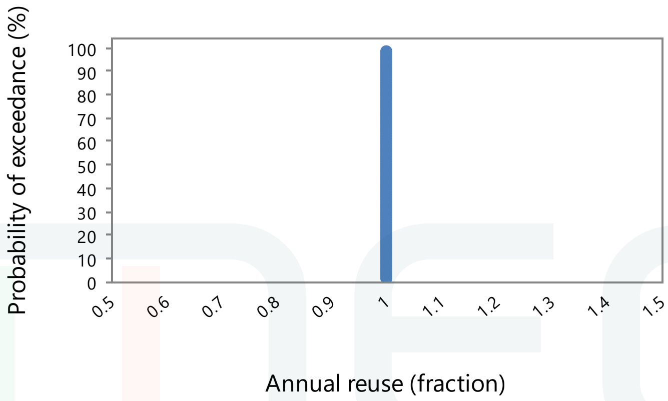
Volume of overflow (m3/year)	0.00
No. days pond overflows (days/year)	0.00
Average duration of overflow (days)	0.00
Effluent Reuse (Proportion of Inflow + Net Rain Gain that is Irrigated) (fraction)	1.00
Probability of at least 90% reuse (fraction)	1.00





Export plot

Export plot

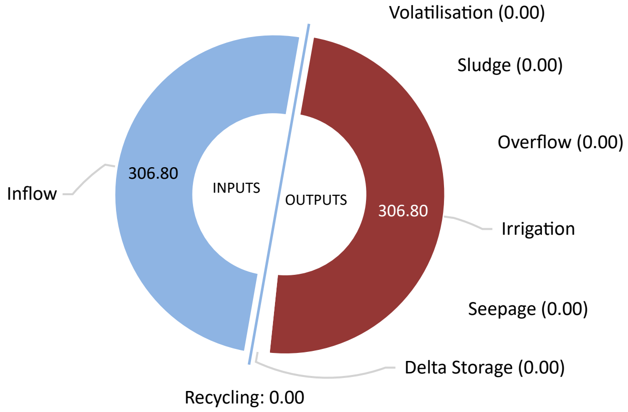


Export plot

Pond System Performance - Nutrient: 1 closed storage tank

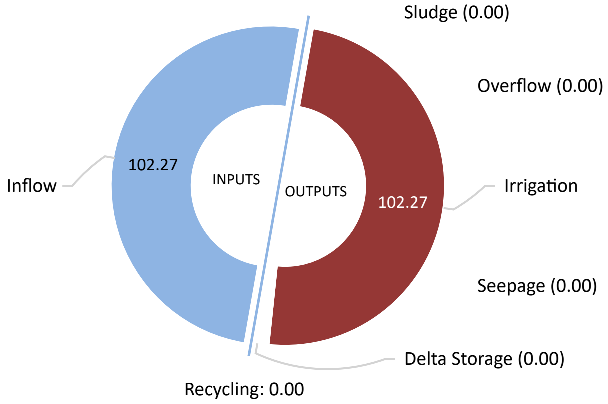
Pond System Nutrients and Salt Balance:

Nitrogen Balance (kg/year)



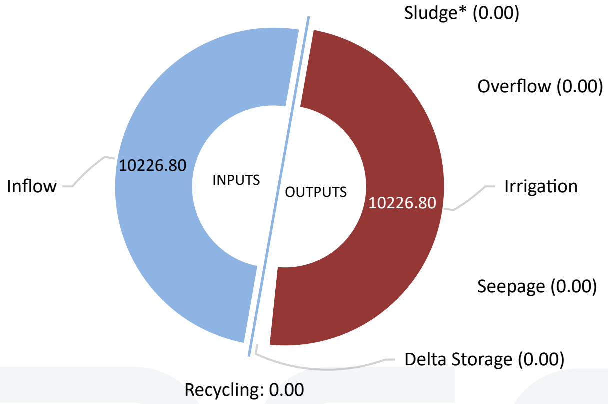
Name	Value
Inflow	306.80
Recycling	0.00
Volatilisation	0.00
Sludge	0.00
Overflow	0.00
Irrigation	306.80
Seepage	0.00
Delta Storage	0.00

Phosphorus Balance (kg/year)



Name	Value
Inflow	102.27
Recycling	0.00
Sludge	0.00
Overflow	0.00
Irrigation	102.27
Seepage	0.00
Delta Storage	0.00

Salt Balance (kg/year)



Name	Value
Inflow	10226.80
Recycling	0.00
Sludge*	0.00
Overflow	0.00
Irrigation	10226.80
Seepage	0.00
Delta Storage	0.00

* Salt removal in sludge is not calculated from the pond salt balance. However if salt could be assumed to be present in the sludge at the same concentration as in the pond supernatant (up to a maximum of salt added in inflow) - then salt accumulation in the sludge could be 0.00 kg/year

Pond System Sludge Accumulation: 0.00 kg dwt/year

Pond System Performance - Nutrient: 1 closed storage tank

Pond Nutrient Concentrations and Salinity:

Average across simulation period	Pond 1
Average nitrogen concentration of pond liquid (mg/L)	30.00
Average phosphorus concentration of pond liquid (mg/L)	10.00
Average salinity of pond liquid (dS/m)	1.56

Value on final day of simulation period	Pond 1
Final nitrogen concentration of pond liquid (mg/L)	30.00
Final phosphorus concentration of pond liquid (mg/L)	10.00
Final salinity of pond liquid (dS/m)	1.56

Irrigation Performance:

Water Use: (assumes 100% Irrigation Efficiency)

Pond water irrigated (m3/year)	10226.80
Average Shandy water irrigation (m3/year) (minimum - maximum)	0.00 (0.00 - 0.00)
Total water irrigated (m3/year)	10226.80
Proportion of irrigation events requiring shandying (fraction of events)	0.00
Proportion of years shandying water allocation of 0 m3/year is exceeded (fraction of years)	0.00
Average exceedance as a proportion of annual shandy water allocation (fraction of allocation) (minimum - maximum)	0.00 (0.00 - 0.00)

Irrigation Quality:

Average nitrogen concentration of irrigation water - before ammonia loss during irrigation (mg/L)	30.00
Average nitrogen concentration of irrigation water - after ammonia loss during irrigation (mg/L)	30.00
Average phosphorus concentration of irrigation water (mg/L)	10.00
Average salinity of irrigation water (dS/m)	1.56

Irrigation Diagnostics:

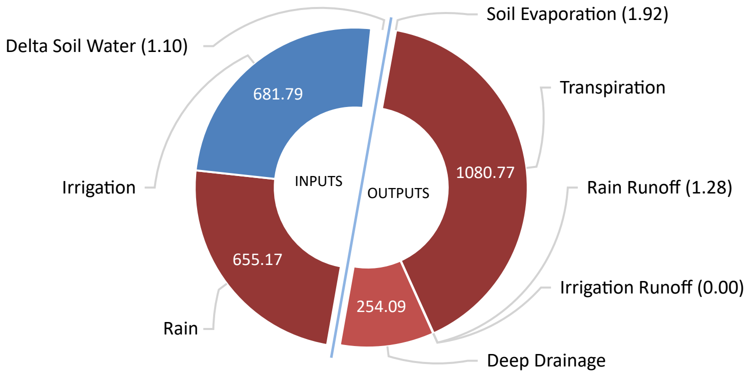
Proportion of Days irrigation occurs (fraction)	1.00

Land Performance - Soil Water

Paddock: Gemini Sand, 1.5 ha
Soil Type: Sand, 80.70 mm PAWC at maximum root depth

Land Water Balance (mm/year):

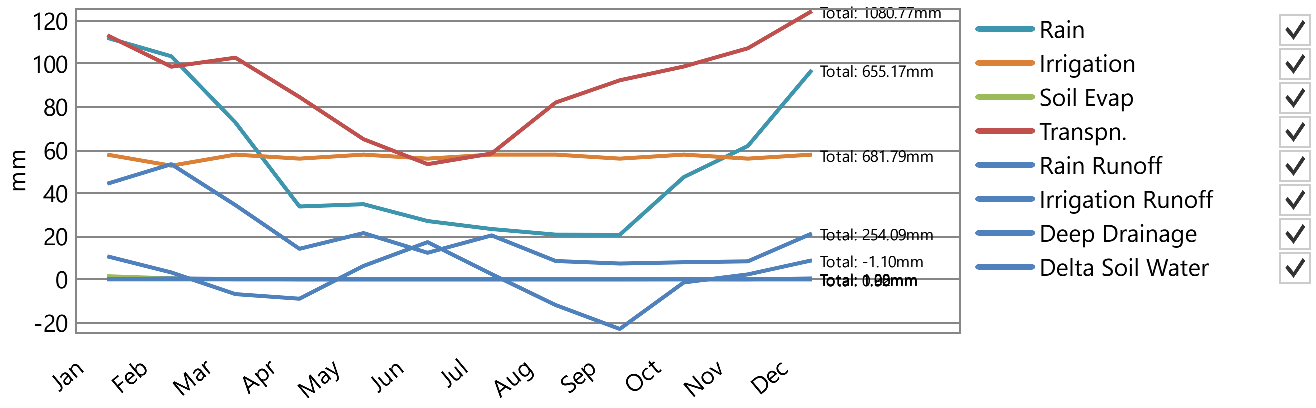
☒ mm/year ☐ % Total inputs



Name	Value
Rain	655.17
Irrigation	681.79
Soil Evaporation	1.92
Transpiration	1080.77
Rain Runoff	1.28
Irrigation Runoff	0.00
Deep Drainage	254.09
Delta Soil Water	-1.10

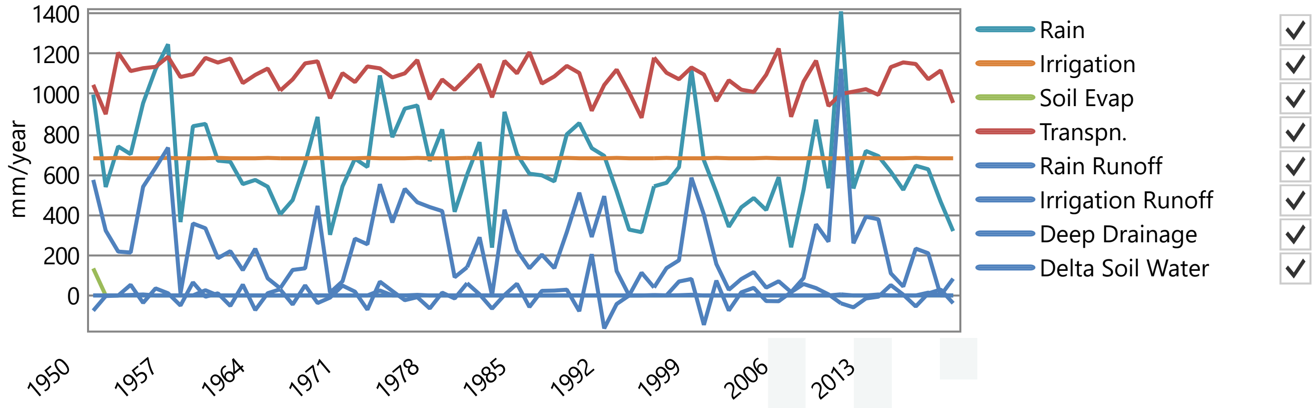
Average Monthly Totals (mm):

☒ Chart ☐ Table



Average Annual Totals (mm/year):

☒ Chart ☐ Table

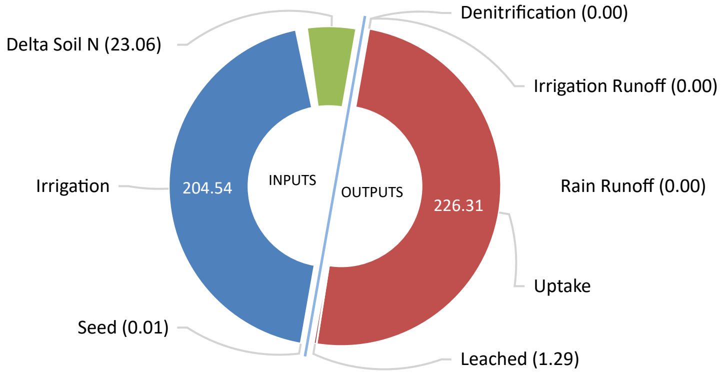


Land Performance - Soil Nutrient

Paddock: **Gemini Sand, 1.5 ha** **Soil Type**: **Sand**

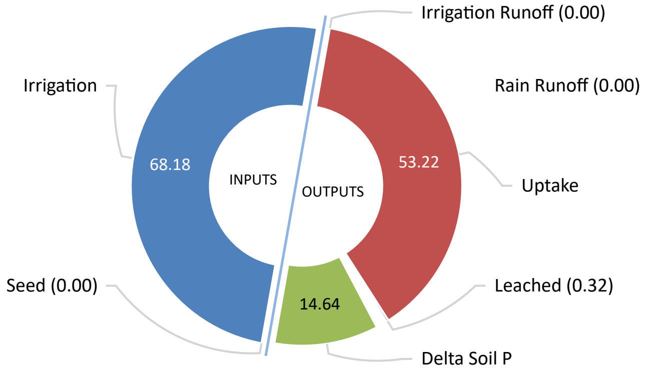
Irrigation ammonium volatilisation losses (kg/ha/year): 0.00
Proportion of total nitrogen in irrigated effluent as ammonium (fraction): 0.25

Land Nitrogen Balance (kg/ha/year)



Name	Value
Seed	0.01
Irrigation	204.54
Denitrification	3.27E-03
Irrigation Runoff	0.00
Rain Runoff	0.00
Uptake	226.31
Leached	1.29
Delta Soil N	-23.06

Land Phosphorus Balance (kg/ha/year)

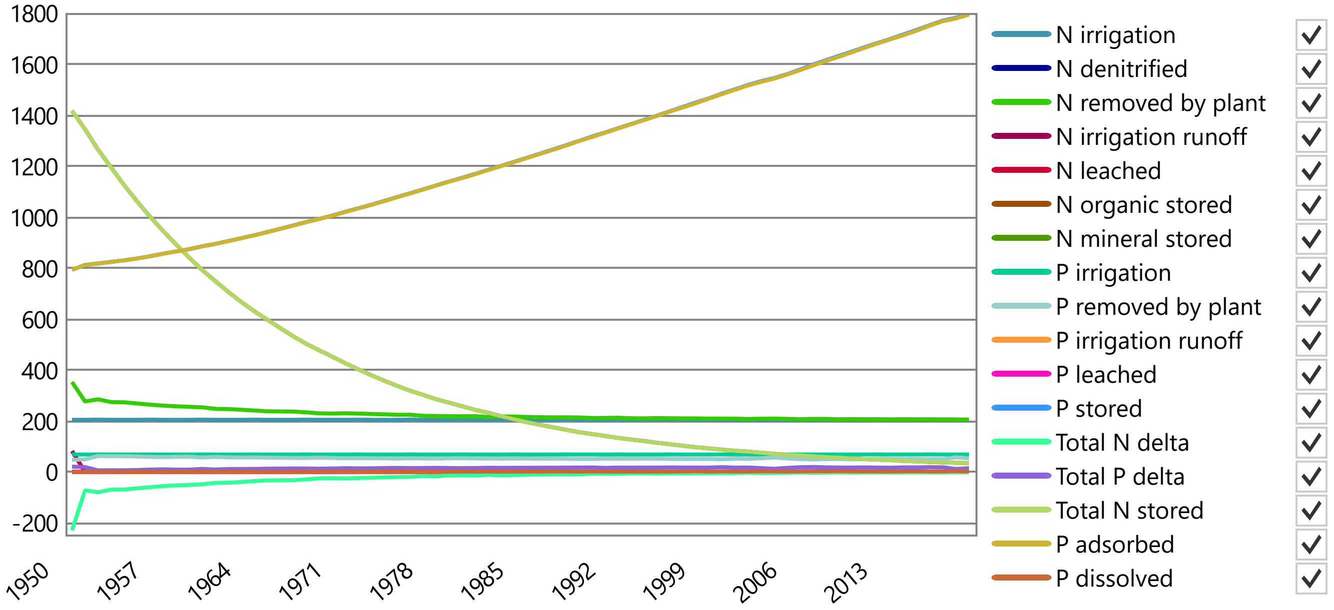


Name	Value
Seed	1.29E-03
Irrigation	68.18
Irrigation Runoff	0.00
Rain Runoff	0.00
Uptake	53.22
Leached	0.32
Delta Soil P	14.64

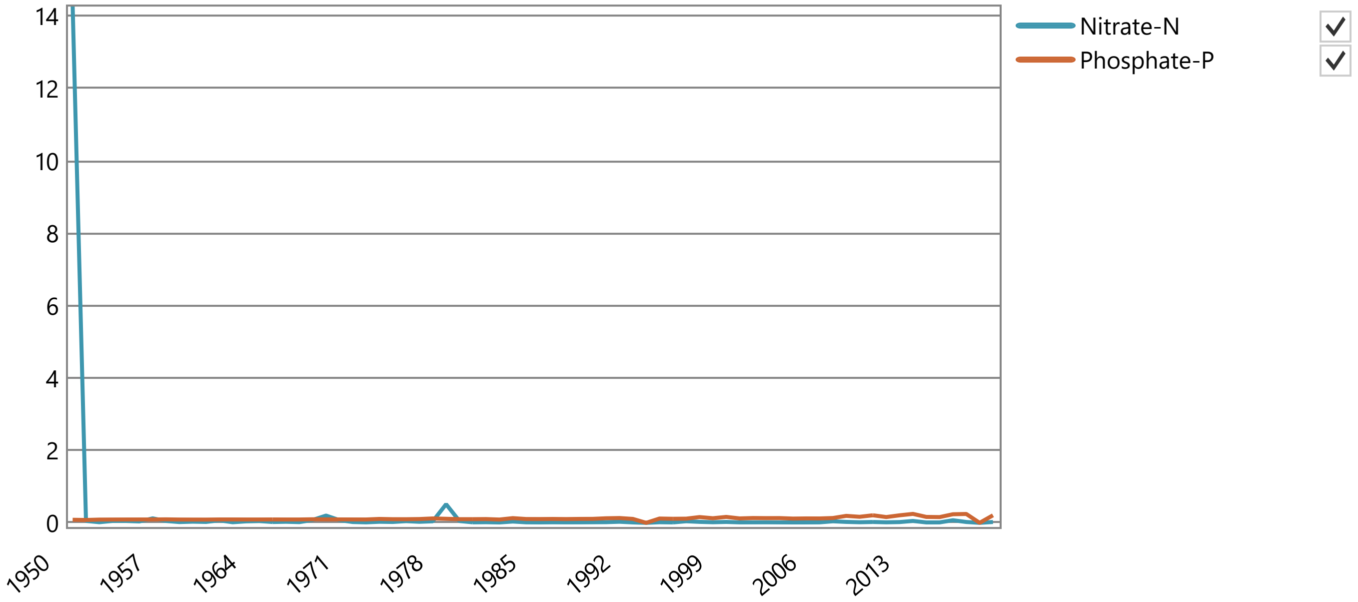
Land Performance - Soil Nutrient

Paddock: **Gemini Sand, 1.5 ha** **Soil Type**: **Sand**

Annual Nutrient Totals (kg/ha):



Annual Nutrient Leaching Concentration (mg/L):



Plant Performance and Nutrients

Paddock: Gemini Sand, 1.5 ha **Soil Type**: Sand

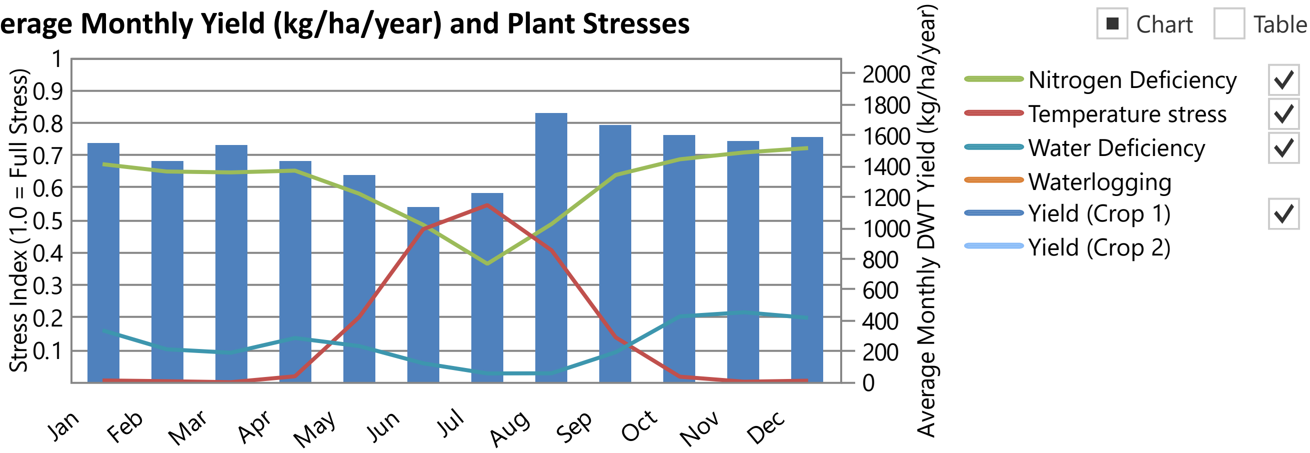
Plant: Continuous Rhodes Grass Pasture

Average annual shoot dry matter yield (kg/ha/year)	17859.55 (16257.55 - 23931.03)
Average monthly plant (green) cover (fraction) (minimum - maximum)	0.70 (0.66 - 0.76)
Average monthly root depth (mm) (minimum - maximum)	1198.88 (1189.54 - 1200.00)

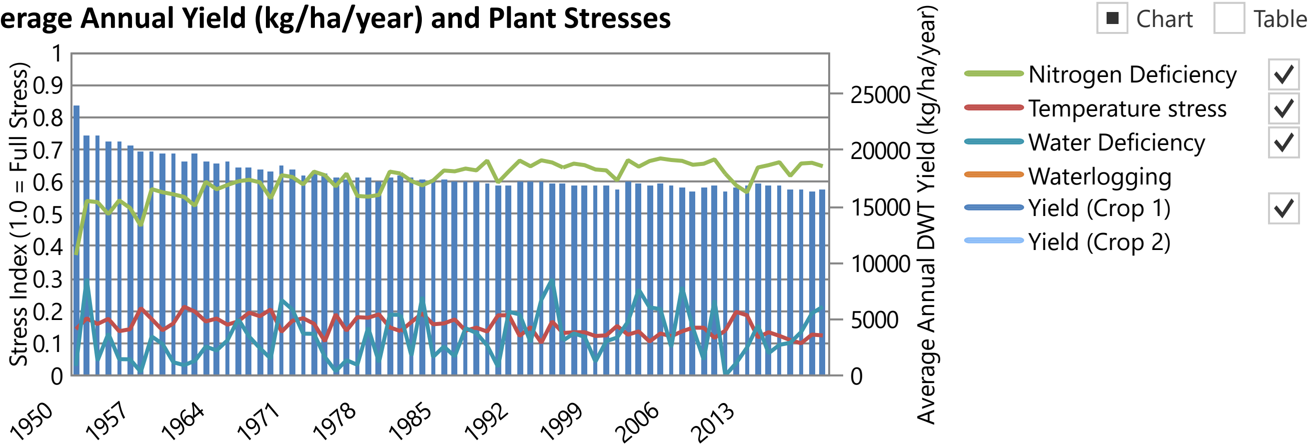
Nutrient Uptake (minimum - maximum):

Average annual net nitrogen removed by plant uptake (kg/ha/year)	226.31 (205.32 - 352.89)
Average annual net phosphorus removed by plant uptake (kg/ha/year)	53.22 (47.24 - 62.41)
Average annual shoot nitrogen concentration (fraction dwt)	0.01 (0.01 - 0.02)
Average annual shoot phosphorus concentration (fraction dwt)	0.003 (0.002 - 0.003)

Average Monthly Yield (kg/ha/year) and Plant Stresses



Average Annual Yield (kg/ha/year) and Plant Stresses



No. of harvests/year: 3.11 (normal)

No. days without crop/year (days/year): 0.00

Land Performance

Paddock: Gemini Sand, 1.5 ha **Soil Type: Sand**

Plant: Continuous Rhodes Grass Pasture

Salt tolerance	Tolerant
Salinity threshold EC sat. ext. (dS/m)	7.00
Proportion of yield decrease per dS/m increase (fraction/dS/m)	0.03
No. years assumed for leaching to reach steady-state (years)	10.00

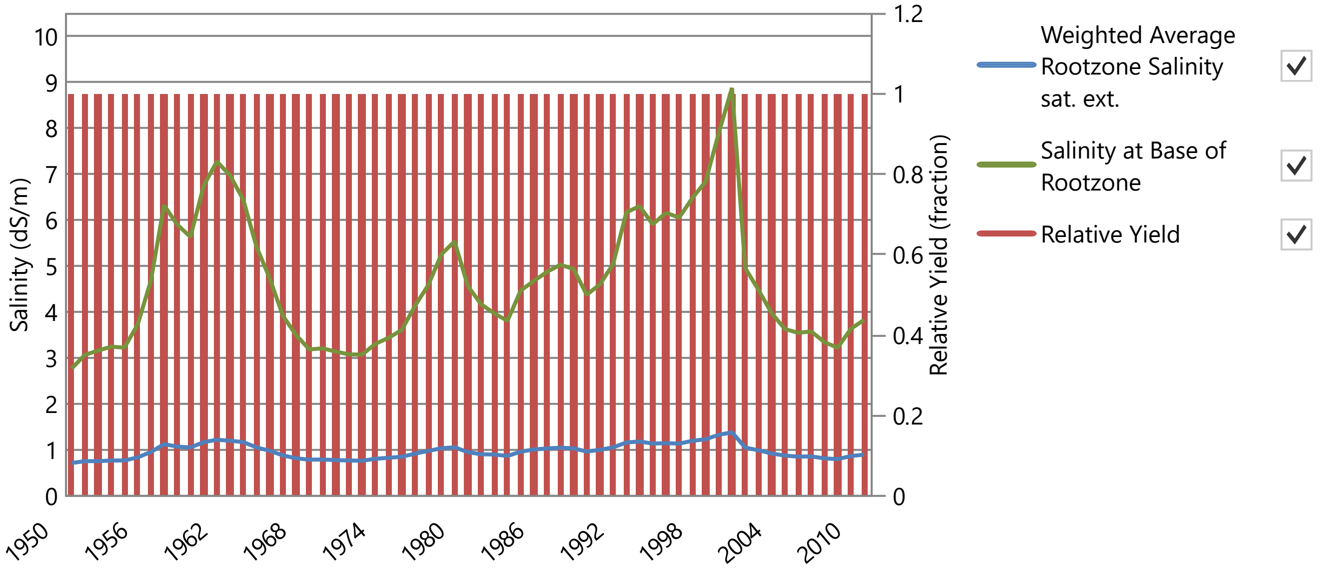
Soil Salinity:

Salinity of infiltrated water (Average salinity of rainwater = 0.03 dS/m) (dS/m)	0.82
Salt added by rainfall (kg/ha/year)	125.55
Average annual effluent salt added & leached at steady state (kg/ha/year)	6943.41
Average leaching fraction based on 10 year running averages (fraction)	0.39
Average water-uptake-weighted rootzone salinity sat. ext. (dS/m)	0.97
Salinity of the soil solution (at drained upper limit) at base of rootzone (dS/m)	4.68
Relative crop yield expected due to salinity (fraction)	1.00
Proportion of years that crop yields would be expected to fall below 90% of potential due to salinity (fraction)	0.00

Average Annual Rootzone Salinity and Relative Yield:

☒ Chart ☐ Table

All values based on 10 year running averages

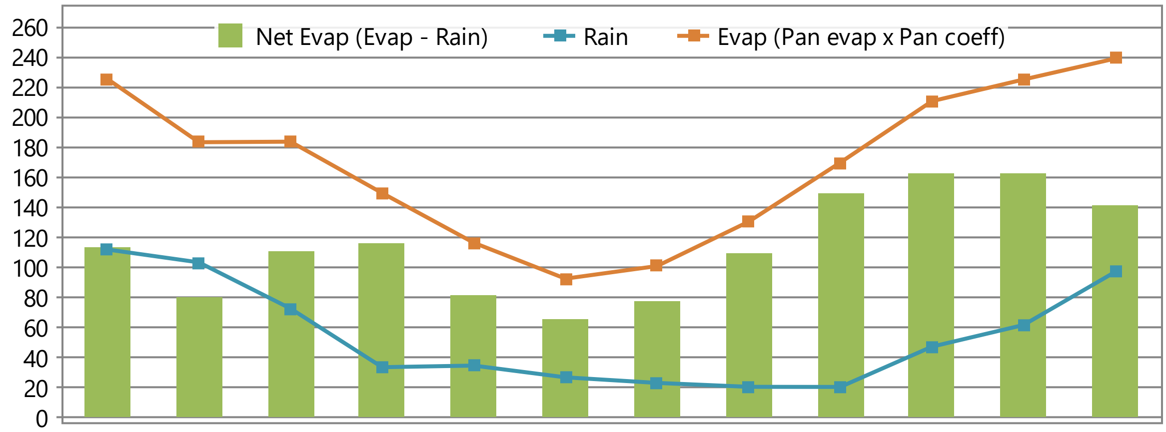


Sustainability Diagnostics: Gemini Operation - Extreme Permeable

Averaged Historical Climate Data Used in Simulation (mm)

Location: **Gemini -23.65_149.20, -23.65°, 149.2°**

Run Period: **01/01/1950 to 31/12/2019** 70 years, 0 days



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Rain	112.0	103.5	72.8	33.8	34.9	27.1	23.4	20.8	20.7	47.4	61.9	97.1	655.2
Evap	225.4	183.3	183.7	149.5	116.5	92.6	101.0	130.5	169.8	210.6	225.0	238.9	2026.9
Net Evap	113.4	79.8	110.9	115.7	81.6	65.6	77.7	109.8	149.1	163.2	163.1	141.8	1371.7
Net Evap/day	3.7	2.8	3.6	3.9	2.6	2.2	2.5	3.5	5.0	5.3	5.4	4.6	3.8

Sustainability Diagnostics: Gemini Operation - Extreme Permeable

Pond System: 1 closed storage tank

New Sewage Treatment Plant - 10226.80 m3/year or 28.00 m3/day generated on average

Effluent entering pond system after any pretreatment and recycling

Average (Minimum-Maximum) influent quality calculated for 365.24 non-zero flow days, after any pretreatment and recycling.

Constituent	Concentration (mg/L)	Load (kg/year)
Total Nitrogen	30.00 (30.00 - 30.00)	306.80 (306.60 - 307.44)
Total Phosphorus	10.00 (10.00 - 10.00)	102.27 (102.20 - 102.48)
Total Dissolved Salts	1000.00 (1000.00 - 1000.00)	10226.80 (10220.00 - 10248.00)
Volatile Solids	0.00 (0.00 - 0.00)	0.00 (0.00 - 0.00)
Total Solids	0.00 (0.00 - 0.00)	0.00 (0.00 - 0.00)

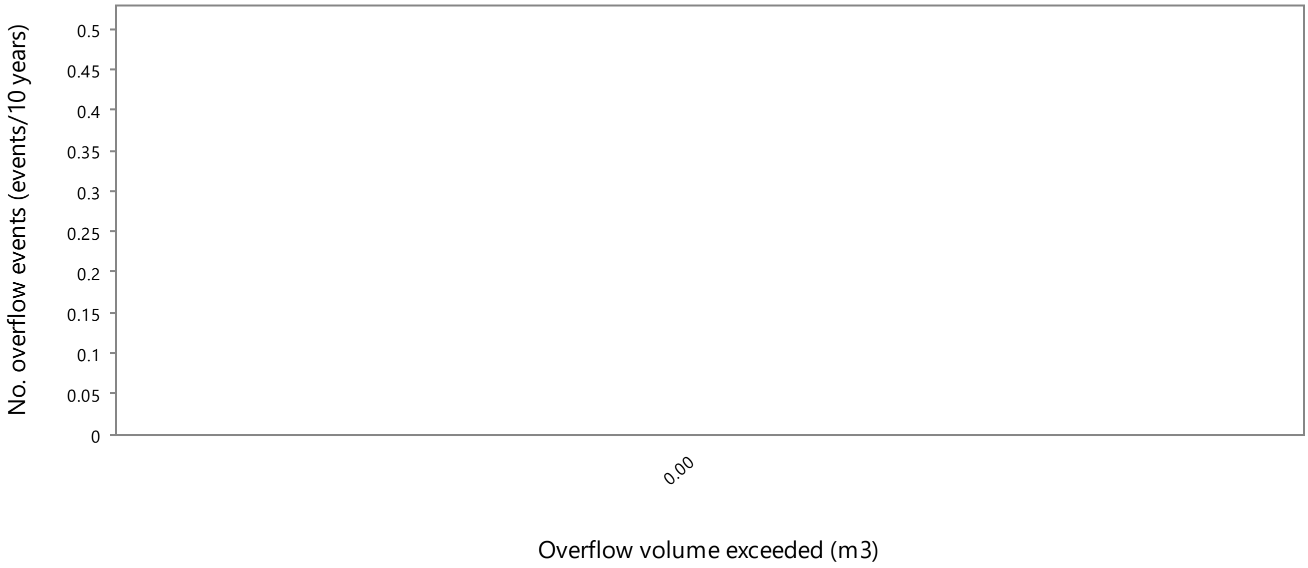
Last pond (Wet weather store): 84.00 m3

Theoretical hydraulic retention time (days)	3.00
Average volume of overflow (m3/year)	0.00
No. overflow events per year exceeding threshold* of 0.03 m3 (no./year)	0.00
Average duration of overflow (days)	0.00
Effluent Reuse (Proportion of Inflow + Net Rain Gain that is Irrigated) (fraction)	1.00
Probability of at least 90% effluent reuse (fraction)	1.00
Average salinity of last pond (dS/m)	1.56
Salinity of last pond on final day of simulation (dS/m)	1.56
Ammonia loss from pond system water area (kg/m2/year)	0.00

* The threshold is the volume equivalent to the top 1 mm depth of water of a full pond

Overflow exceedance:

■ Chart ☐ Table



Export plot

Sustainability Diagnostics: Gemini Operation - Extreme Permeable

Irrigation Information

Irrigation: 1.5 ha total area (assumed 100% irrigation efficiency)

	Quantity/year	Quantity/ha/year
Total irrigation applied (m3)	10226.80	6817.87
Total nitrogen applied (kg)	306.80	204.54
Total phosphorus applied (kg)	102.27	68.18
Total salts applied (kg)	10226.80	6817.87

Shandying

Annual allocation of fresh water for shandying (m3/year)	0.00
Average Shandy water irrigation (m3/year) (minimum - maximum)	0.00 (0.00 - 0.00)
Average exceedance as a proportion of annual shandy water allocation (% of allocation) (minimum - maximum)	0.00 (0.00 - 0.00)
Proportion of irrigation events requiring shandying (fraction of events)	0.00
Minimum shandy water is used	False

Irrigation Issues

Proportion of Days irrigation occurs (fraction)	1.00

Sustainability Diagnostics: Gemini Operation - Extreme Permeable

Paddock Land: Gemini Sand: 1.5 ha

Irrigation: New Irrigation Method with 0% ammonium loss during irrigation

Irrigation triggered every 1 days
Irrigate a fixed amount of 2.00 mm each day
Irrigation window from 1/1 to 31/12 including the days specified
A minimum of 0 days must be skipped between irrigation events

Soil Water Balance (mm): Sand, 80.70 mm PAWC at maximum root depth

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Rain	112.0	103.5	72.8	33.8	34.9	27.1	23.4	20.8	20.7	47.4	61.9	97.1	655.2
Irrigation	57.9	52.7	57.9	56.0	57.9	56.0	57.9	57.9	56.0	57.9	56.0	57.9	681.8
Soil Evap	1.5	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.9
Transpn.	113.2	98.6	102.8	84.6	65.0	53.4	58.4	82.0	92.3	98.7	107.2	124.4	1080.8
Rain Runoff	0.1	0.4	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	1.3
Irr. Runoff	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Drainage	44.4	53.4	34.5	14.2	21.5	12.3	20.4	8.5	7.3	7.9	8.4	21.3	254.1
Delta	10.7	3.2	-6.8	-9.0	6.2	17.3	2.4	-11.9	-23.0	-1.4	2.3	8.8	-1.1

Soil Nitrogen Balance

Average annual effluent nitrogen added (kg/ha/year)	204.54
Average annual soil nitrogen removed by plant uptake (kg/ha/year)	226.31
Average annual soil nitrogen removed by denitrification (kg/ha/year)	3.27E-03
Average annual soil nitrogen leached (kg/ha/year)	1.29
Average annual nitrate-N loading to groundwater (kg/ha/year)	1.29
Soil organic-N kg/ha (Initial - Final)	1494.50 - 34.57
	154.21 - 0.01
Average nitrate-N concentration of deep drainage (mg/L)	0.51
Max. annual nitrate-N concentration of deep drainage (mg/L)	14.29

Soil Phosphorus Balance

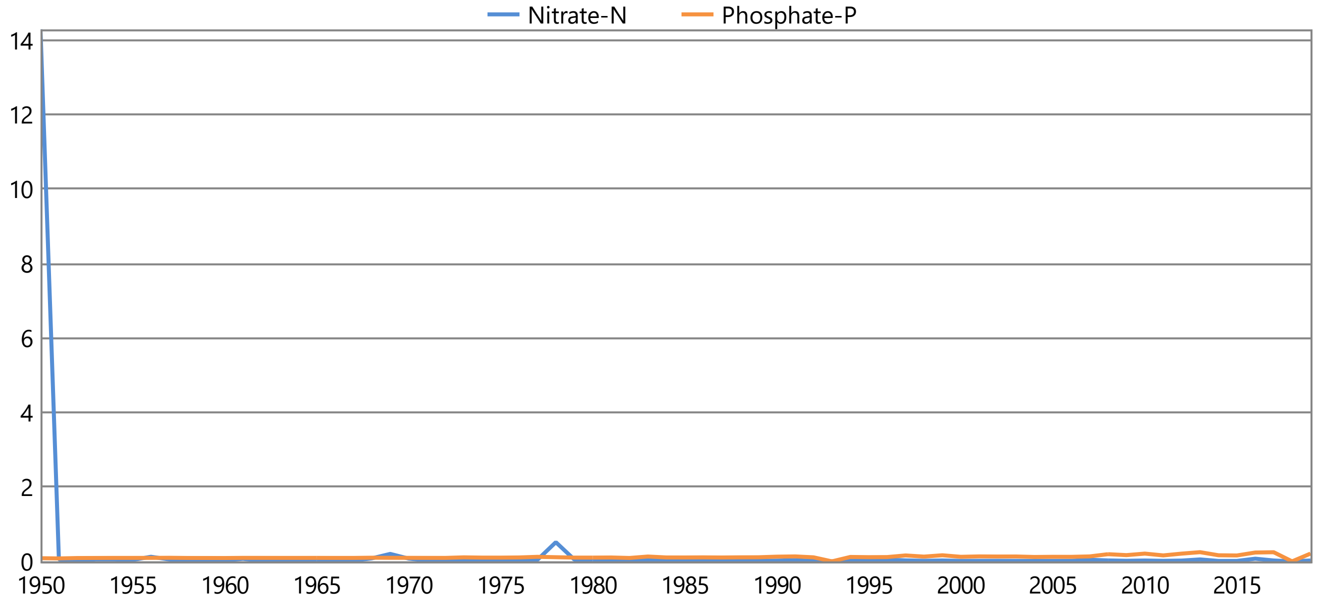
Average annual effluent phosphorus added (kg/ha/year)	68.18
Average annual soil phosphorus removed by plant uptake (kg/ha/year)	53.22
Average annual soil phosphorus leached (kg/ha/year)	0.32
Dissolved phosphorus (kg/ha) (Initial - Final)	0.19 - 2.02
Adsorbed phosphorus (kg/ha) (Initial - Final)	773.25 - 1796.48
Average phosphate-P concentration in rootzone (mg/L)	0.95
Average phosphate-P concentration of deep drainage (mg/L)	0.13
Max. annual phosphate-P concentration of deep drainage (mg/L)	0.25
Design soil profile storage life based on average infiltrated water phosphorus concn. of 5.10 mg/L (years)	30.18

Sustainability Diagnostics: Gemini Operation - Extreme Permeable

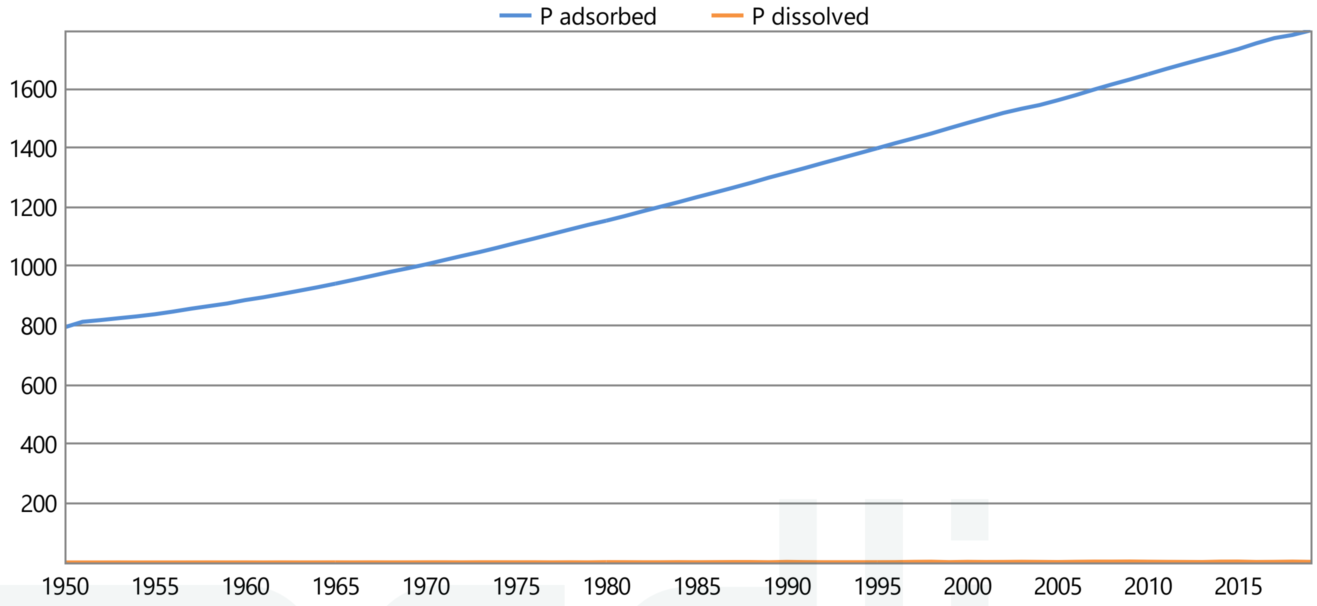
Paddock Land: Gemini Sand: 1.5 ha

Irrigation: New Irrigation Method with 0% ammonium loss during irrigation

Annual nutrient leachate concentration (mg/L)



Annual Phosphate-P in soil (kg/ha)



Sustainability Diagnostics: Gemini Operation - Extreme Permeable

Paddock Plant Performance: Gemini Sand: 1.5 ha

Average Plant Performance (Minimum - Maximum): Continuous Rhodes Grass Pasture

Average annual shoot dry matter yield (kg/ha/year)	17859.55 (16257.55 - 23931.03)
Average monthly plant (green) cover (fraction)	0.70 (0.66 - 0.76)
Average monthly crop factor (fraction)	0.63 (0.60 - 0.68)
Total plant cover (both green and dead) left after harvest (fraction)	1.00
Average monthly root depth (mm)	1198.88 (1189.54 - 1200.00)
Average number of normal harvests per year (no./year)	3.11 (2.00 - 4.00)
Average number of normal harvests for last five years only (no./year)	3.00
Average number of crop deaths per year (no./year)	0.00 (0.00 - 0.00)
Average number of crop deaths for last five years only (no./year)	0.00
Average annual nitrogen deficiency index (0 = no stress, 1 = full stress) (coefficient)	0.61 (0.37 - 0.67)
Average January temperature stress index (0 = no stress, 1 = full stress) (coefficient)	0.01 (0.00 - 0.05)
Average July temperature stress index (0 = no stress, 1 = full stress) (coefficient)	0.55 (0.25 - 0.83)
Average monthly water stress index (0 = no stress, 1 = full stress) (coefficient)	0.12 (0.03 - 0.22)
Average monthly waterlogging index (0 = no stress, 1 = full stress) (coefficient)	0.00 (0.00 - 0.00)
No. days without crop/year (days)	0.00

Soil Salinity - Plant salinity tolerance: Tolerant

Assumes 1.0 dS/m Electrical Conductivity = 640 mg/L Total Dissolved Salts

All values based on 10 year running averages

Salinity of infiltrated water (Average salinity of rainwater = 0.03 dS/m) (dS/m)	0.82
Salt added by rainfall (kg/ha/year)	125.55
Average annual effluent salt added & leached at steady state (kg/ha/year)	6943.41
Average leaching fraction based on 10 year running averages (fraction)	0.39
Average water-uptake-weighted rootzone salinity sat. ext. (dS/m)	0.97
Salinity of the soil solution (at drained upper limit) at base of rootzone (dS/m)	4.68
Relative crop yield expected due to salinity (fraction)	1.00
Proportion of years that crop yields would be expected to fall below 90% of potential due to salinity (fraction)	0.00

Run Messages

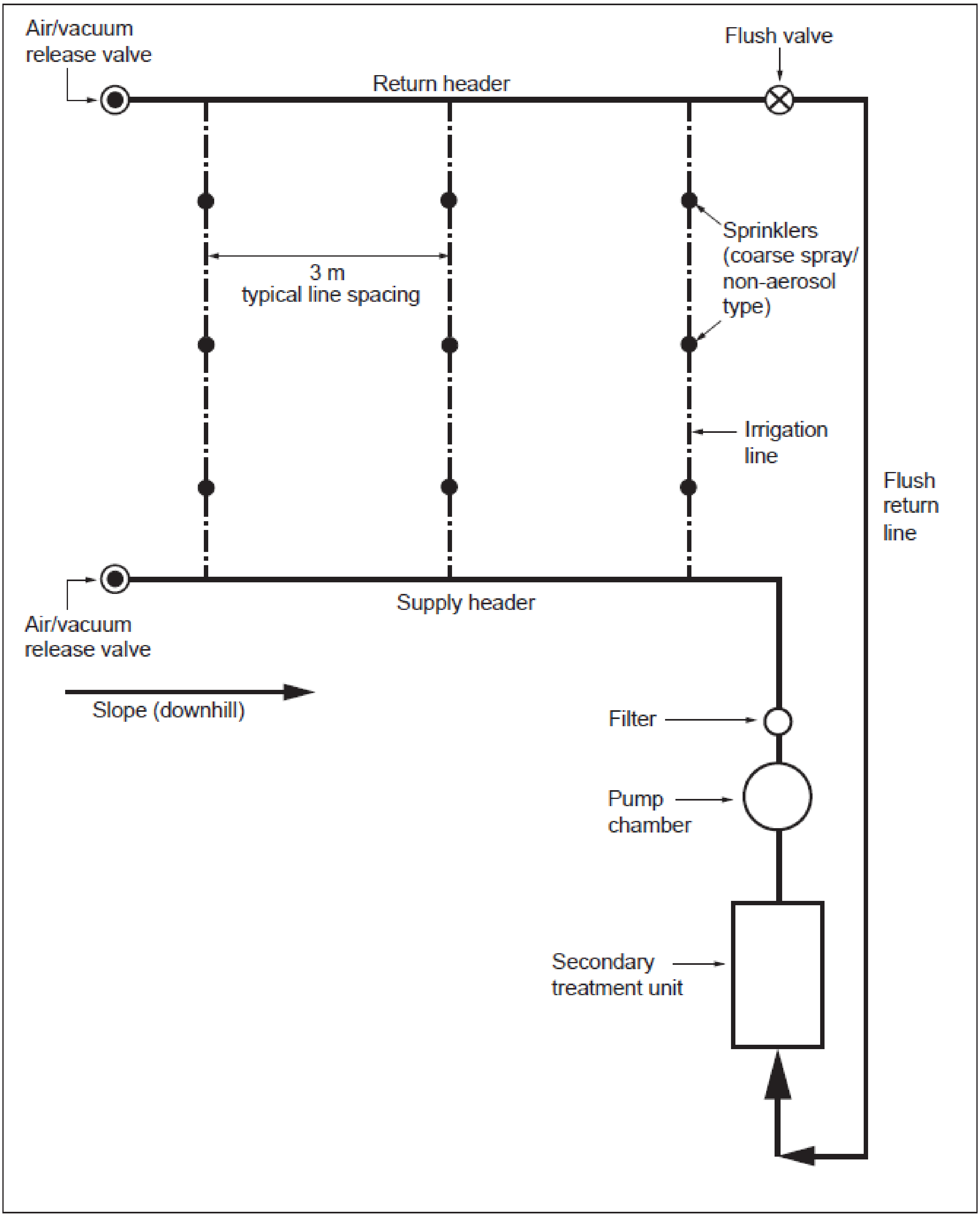
Messages generated when the scenario was run:

Full run chosen

APPENDIX

F

EXAMPLE OF IRRIGATION SETOUT



Example of a spray irrigation system utilising a large number of sprinklers with small spray radius (Source: AS/NZS 1547:2012)

APPENDIX

G

RESPONSE TO DES' RFI

Response to DES' Request for Further Information

Sewerage			
Section	**Comment**	**Requirement**	**Response**
Supporting information Section 3.5.3 Sewerage	In relation to the release of treated effluent to land, the application states that the design of the system will ensure no runoff from the disposal area occurs.	Further information is to be provided on the following: • Any predicted overflows to the environment from any storage needs to be justified in terms of environmental impact.	The MEDLI modelling exercise confirmed that by applying a scheduled 2mm/day over 3.8 ha in mine construction phase and 1.9 ha in mine operation phase, no overflow events would occur. Although the model indicated that effluent irrigation could occur every day, in day to day life there are times when irrigation should not occur. Such events would include during substantial rain events when the ground is showing signs of saturation (such as surface water pooling). In order to account for such events, 3 days of wet weather storage (in tanks) were accounted for in the model as is recommended in the *QLD Government Technical Guideline For Disposal of Effluent via Irrigation*. • In the construction period at least 168 m3 tank capacity will be required, • During operation period at least 84m3 tank capacity will be required.
		• Description of buffer zones from all sensitive receptors to the irrigation area and sewage treatment plant.	At this point in time the precise location of the irrigation area and sewage treatment plant cannot be 100% confirmed. This will be confirmed during detailed design. The assessment has identified a preferred area. This area is close to the primary source of domestic wastewater (accommodation facilities) and it is assumed domestic wastewater from the Mine Infrastructure Area can be practically pumped to this location. Additional details justifying why this area is suitable can be found in Section 3.1 of the report. An example of how the irrigation area can be set out is provided in Figure 12-1 of the report and demonstrates how it could practically achieve the setback distances recommended in *QLD Government Technical Guideline For Disposal of Effluent via Irrigation*
		• The assessments should be carried out for the proposed and future effluent disposal rates.	Assessments have been based on the understanding provided by the client that the construction phase will accommodate up to 280 persons and the operational phase up to 140 persons.
		• Description of management measures to be implemented to ensure the irrigation of effluent does not exceed water holding capacity of the soil or the uptake capacity of the crop (that may, as a consequence, result in water logging, surface runoff or excessive deep drainage).	In the absence of site-specific soil data, the assessment analysed the response to extreme conservative soils. One being an extremely permeable sand, and the other being an extremely impermeable clay. The design irrigation rate and area and chosen pasture were sufficient to prevent waterlogging, surface runoff or excessive deep drainage in either extreme soil type. This has been validated through the MEDLI model.
		• Description of the capacity of the vegetation and soils in the irrigation area(s) to assimilate these salts on a long-term sustainable basis.	Rhodes grass was assumed to be the pasture which will be irrigated on the site. This pasture is considered to be moderately salt tolerant. MEDLI modelling indicated long term irrigation would result in salinity levels too low to cause any reduction in the grass health.

		• Description of irrigation application method and scheduling (triggered).	The assessment was based on utilising a scheduled daily irrigation rate of 2mm/day. For further detail refer to Section 6.2 of the report.
		• Description of risks of human exposure from irrigation of effluent or aerosol drift.	Refer to Section 9.1 of the report
		• Description of risks aerosol drift to off-site locations and cause odour nuisance.	Refer to Section 9.2 of the report.
	It has been stated that the proponent will operate a sewage treatment plant (STP) located at the accommodation facility. This STP will have a maximum capacity of 140 equivalent persons (EP). The expected workforce at the site accommodation is about 140 persons in "normal" conditions, the accommodation facility will be constructed to accommodate up to 280 persons (see page 54 of the Supporting Information report).	Justify the proposed capacity of 140 EP given the accommodation capacity. Consideration to contingencies following a STP failure event and maintenance issues in line with risks noted in the above requirement should be provided.	The assessment has utilised two scenarios conservative scenarios, being 140 equivalent persons during operation and 280 equivalent persons during construction. Refer to Section 4.1 of the report for further detail
Additional information - Requirements for effluent release to land	As the proposed activity involves the release of treated effluent to land, the following should be submitted in relation to effluent sources and type: • Type of treatment applied – include description of treatment process, design details including size/volumes, peak design capacity of the sewage treatment system. • Quantity, description of average and maximum wastewater flows. Also include dry versus wet weather period over time. • Quality (key contaminants of concern), describe and quantify the concentrations of key contaminants including total nitrogen, total phosphorous, electrical conductivity/total dissolved salts and sodium/sodium absorption ratio. Include average and maximum concentrations of treated effluent generated at the site.	Address the effluent sources and type in relation to the releases of treated effluent releases.	The sources of effluent have been described in Section 1.1 of the report. Section 3.1 states at this stage it is assumed all domestic wastewater will be channelled to a single treatment plant and disposal area. The approximate area being investigated is outlined in Figure 3-1. Conservative estimates of wastewater flow are provided in Section 4. These estimates are simplistic and reflect adopting each worker as an equivalent person (EP) with each EP generating 200L/day in accordance with the *Environmental Protection Regulation 2019*. Adopting each worker as a full EP is likely overly conservative, but this can only be refined further during detailed design. Conservative assumptions on the treated wastewater quality have been provided in Section 4.2. The quality is reflective of a standard secondary treated effluent. Once detailed design progresses more specific treated effluent quality data can be estimated. The risks associated with contaminants such as pathogens, odour, toxicants have been discussed in Section 9. Many of the risk management measures are based upon exposure reduction measures (i.e. lessening aerosol production via spay method, irrigation timing and use of buffer zones). Buffer zones are discussed in more detail in Section 11.2 and an example of how the irrigation area could be set out while implementing buffer zones is provided in Figure 12-1.

	• Quality (other contaminants) – provide a risk assessment of other contaminants including Heavy metals, Pharmaceuticals, Toxins, Pathogens including E.coli and quantity of treated effluent generated at the site.		
	No standard conditions apply to STPs of more than 100 EP. As the proposed activity involves the release of treated effluent to land, identify the location of effluent discharge (irrigation scheme) and include a layout plan showing: • Property boundaries • Proposed irrigation area boundary, location of any wet weather storage infrastructure, sampling and discharge points including GPS Co-ordinates (Latitude, Longitude) and Elevation • Topography including drainage lines, water courses or any 'waters' • Any sensitive receiving environments such as sensitive / high ecological value areas in close vicinity of the irrigation scheme • Any buffer distances to any sensitive receivers. As the proposed activity involves the release of treated effluent to land, the following should be submitted in relation to historic climate data for area used for designing the scheme: • Provide a description of most locally relevant climate data, weather patterns which can be obtained from Silo DataDrill (web link) data • Provide a description of the frequency of inundation in the area and assess if this is a risk. The location of the sewage treatment plant and any other high-risk areas of the activity	Additional information such as disposal area and size, wet weather storage capacity is required along with an appropriate risk assessment of the potential impact of this activity to the relevant environmental values. The STP capacity, disposal area location and size as well as the wet weather storage capacity should be included in the proposed conditions. Address historic climate data to support the proposed irrigation scheme.	At this point in time the precise location of the irrigation area and sewage treatment plant cannot be 100% confirmed. This will be confirmed during detailed design. The assessment has identified a preferred area. This area is close to the primary source of domestic wastewater (accommodation facilities) and it is assumed domestic wastewater from the Mine Infrastructure Area can be practically pumped to this location. Additional details justifying why this area is suitable can be found in Section 3.1 of the report. Sensitive areas (waterways, ecosystems and residents etc) are described in Section 3. An example of how the irrigation area can be set out is provided in Figure 12-1 of the report. This example demonstrates how an irrigation area could practically achieve the setback distances from sensitive areas recommended in *QLD Government Technical Guideline For Disposal of Effluent via Irrigation* The MEDLI model utilised historical climate data from SILO based on the closest grid point available. A review of the Central Highlands Council Flood Overlay is provided in Section 3.1.1 and identifies the site is well away from the Q100 floodplain.

	should be located above the Q100 floodplain.		
	As the proposed activity involves the release of treated effluent to land, the following should be submitted in relation to the soil characteristics of the proposed effluent irrigation area and the site suitability. Based on site investigation and available data, provide the following: • Description of soil profile including erodibility, texture, structure, impermeable layers and any evidence of rising water table ○ Hydraulic properties: ○ Moisture content at field capacity, permanent wilting point and saturation ○ Saturated hydraulic conductivity • Chemical properties: ○ Nitrogen content, especially organic nitrogen ○ Phosphorus content ○ Phosphorus sorption capacity ○ Exchange sodium percentage ○ Background concentration of any contaminants. • Proposed vegetation for effluent irrigation area ○ Species of plant cover • Management of plant biomass. It is department's expectation the plant biomass be cut and removed from the irrigation/ disposal area.	Describe the soil characteristics of the proposed effluent irrigation area.	Due to access restrictions soil sampling was unable to occur at the site, thus field analysis and laboratory testing could not be undertaken. Section 5 of the report describes soil characteristics noted in AARC's 2019 *Gemini Project Soil and Land Suitability Assessment.* Rhodes grass has been selected as the proposed vegetation for the effluent irrigation area. Section 11.4 describes the ongoing management required of the plant biomass. This is expected to involve removal of clippings from the irrigation area.
	As the proposed activity involves the release of treated effluent to land, the following should be submitted in relation to groundwater: • Presence of groundwater or temporary perched water tables, levels over time and background water quality. • Any risk of effluent reaching groundwater.	Describe the impacts to groundwater of the proposed treated effluent release.	Section 3.3 of the report discusses findings of the desktop investigation relating to groundwater, with groundwater expected at ~46m below ground level. In the absence of site-specific soil data, the assessment analysed the response of MEDLI to extreme conservative soils. One being an extremely permeable sand, and the other being an extremely impermeable clay. The design irrigation rate and area and chosen pasture resulted in negligible concentrations of nutrient leaching in either extreme soil type.

	As the proposed activity involves the release of treated effluent to land, the following should be submitted in relation to the irrigation management area: • Irrigation regime proposed (how irrigation is triggered and applied) • Irrigation method and infrastructure required • Management of any potential aerosol drift generated from above ground irrigation	Describe the proposed irrigation management area.	The specific irrigation area and associated infrastructure will need to be confirmed at detailed design. At this point in time spray irrigation specification recommendations from AS/NZS 1547:2012 have been provided in Section 11. When combined with the setback distances as per the example in Section 12.3 the risk of aerosol exposure is negligible.
	As the proposed activity involves the release of treated effluent to land, the following should be submitted in relation to wet weather storage management: • Type and volume • How any overflows will be managed • Algae management if proposing open lagoon or pond • If open storage, design of the wet weather storage including lining to ensure any potential of effluent leaching to groundwater is prevented • Contingency plans	Describe wet weather storage management.	The MEDLI modelling exercise confirmed that by applying a scheduled 2mm/day over 3.8 ha in mine construction phase and 1.9 ha in mine operation phase, no overflow events would occur. Although the model indicated that effluent irrigation could occur every day, in day to day life there are times when irrigation should not occur. Such events would include during substantial rain events when the ground is showing signs of saturation (such as surface water pooling). In order to account for such events, 3 days of wet weather storage (in tanks) were accounted for in the model as is recommended in the *QLD Government Technical Guideline For Disposal of Effluent via Irrigation*. • In the construction period at least 168 m3 tank capacity will be required, • During operation period at least 84m3 tank capacity will be required. As closed tanks can be used instead of ponds, there are negligible risks with algae blooms or leaching into the groundwater. Once detailed design information is available, a site specific contingency plan can be developed to manage the wet weather storage tanks. Such contingency plans tend to focus on having a plan in place for sewage treatment plant shut downs, maintenance periods when >3 days storage may be required.
	As the proposed activity involves the release of treated effluent to land, address the predicted environmental impacts of the proposed effluent irrigation scheme. The preferred model is MEDLI. This model assesses the hydraulic load applied to the irrigation areas, the fate of nitrogen, phosphorus and salts, and required wet weather storage volume. The results of the MEDLI assessment is to be provided and include the following: • the proposed size of the irrigation area(s) • the proposed wet weather storage volumes • irrigation rates • frequency of overtopping • irrigation rates • soil water balance	The department requires a “water balance method” (typically “MEDLI”) to determine the suitable wet weather storage volume and size and locations of effluent irrigation areas based on the volume of wastewater generated at a facility, taking into account climatic conditions, vegetation being irrigated, effluent quality with regard to TN, TP, TDS, EC and soil properties to ensure no runoff from the effluent irrigation disposal area(s) and wet weather storage, with minimal “irrigation-induced deep drainage”. Where MEDLI is not used, a justification for the validity and calibration for the model is required.	Cardno holds copies of the four (4) MEDLI model scenario input and output files and can provide these to DES upon request.

	- soil nutrients balance - any risk of contamination to groundwater and measures to be implemented to protect groundwater - crop performances - predicted irrigation-induced annual deep drainage rate (mm/year) - predicted average deep drainage Nitrate and Phosphorus annual concentrations (mg/L) - interpretation of output details For assessments using MEDLI model Version 1.3, the following model input and output files are to be provided: - those files that end with "IPT.SUM" (Input Summary); and - those files that end with "SUMM.STA" (Summary Output) Each file name begins with a 4-digit reference number and neither file contents nor the format is to be altered or changed. For assessments using MEDLI model Version 2.0, the following model input and output files are to be provided: - *.medr (Output file) - *.med (Scenario file)		
Waste Management Supporting information Section 12.5 Waste management	Sewage will be treated in an STP. Treated effluent will be released for irrigation. More information is needed to determine the conditions required to manage risk.	Describe any waste treatment processes proposed and the anticipated end products of these processes including the quality of the irrigation water. Include details of any waste residues from the process including sludge.	Conservative estimates of the effluent quality are provided in Section 4.2. These assumptions are reflective of a standard secondary treated effluent. More specific quality data can be provided at detailed design. At this point in time it is assumed that sludge will be dewatered on site and the resulting dried sludge will be removed via a licensed regulated waste contractor. In the event sludge re-use options are considered, additional information has been provided in Section 10 of the report.