



3D Environmental

Landscape & Vegetation Science

Groundwater Dependent Ecosystem (GDE) Management and Monitoring Plan

Isaac Downs Project

Prepared for **Stanmore IP South** by

3d Environmental

Final – April 2021 **(Revised following DAWE review).**

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Client: Stanmore IP South Pty Ltd

Purpose: Groundwater dependent ecosystem assessment for the Isaac Downs Project

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Final	14 April 2021	David Stanton	Finalisation of GDEMMP follow final review by DAWE

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List of Abbreviations

Abbreviation	Description
DAWE	Department of Agriculture Water and Environment (Commonwealth)
DES	Department of Environment and Science (Qld)
DoEE	Department of Environment and Energy (Commonwealth)
EA	Environmental Authority
EIS	Environmental Impact Statement
EPBC Act	Environment Protection and Biodiversity Conservation Act 1999 (Commonwealth)
EPBC Approval	Approval granted by the Commonwealth under the EPBC Act
EP Act (Water)	Environmental Protection Act (Qld) 1994
ESCP	Erosion and Sediment Control Plan
EWR	Environmental Water Requirement
GDE	Groundwater Dependent Ecosystem
GDEMMP	Groundwater Dependent Ecosystem Monitoring and Management Plan
GMMP	Groundwater Management and Monitoring Plan
IPM	Isaac Plains Mine
LAI	Leaf Area Index
LWP	Leaf Water Potential
ML	Mining Lease
MNES	Matters of National Environmental Significance, as defined under the EPBC Act.
NDVI	Normalised Difference Vegetation Index
REMP	Receiving Environment Monitoring Program
SMP	Soil Moisture Potential
SSMP	Significant Species Management Plan
WMP	Water Management Plan

Glossary

Alluvial aquifer	An aquifer comprising unconsolidated sediments deposited by flowing water usually occurring beneath or adjacent to the channel of a river.
Aquifer	A geological formation or structure that stores or transmits water to wells or springs. Aquifers typically supply economic volumes of groundwater.
Base flow	Streamflow derived from groundwater seepage into a stream.
Capillary fringe	The unsaturated zone above the water table containing water in direct contact with the water table though at pressures that are less than atmospheric. Water is usually held by soil pores against gravity by capillary tension.
Confined aquifer	A layer of soil or rock below the land surface that is saturated with water with impermeable material above and below providing confining layers with the water in the aquifer under pressure.
Perched groundwater system	A groundwater system or aquifer that sit above the regional aquifer due to a capture of infiltrating moisture on a discontinuous aquitard.
Phreatic zone	The zone of sub-surface saturation separated from the unsaturated zone in unconfined aquifers by the water table.

Phreatophyte	Plants whose roots extend downward to the water table to obtain groundwater or water within the capillary fringe.
Obligate phreatophyte	A plant that is completely dependent on access to groundwater for survival.
Evapotranspiration	The movement of water from the landscape to the atmosphere including the sum of evaporation from the land surface and transpiration from vegetation through stomata.
Facultative phreatophyte	A plant that occasionally or seasonally utilises groundwater to maintain high transpiration rates, usually when other water sources are not available.
Fractured rock aquifer	An aquifer in which water flows through and is stored in fractures in the rock caused by folding and faulting.
Fluvial	Relating to processes produced by or found in rivers.
Groundwater	Those areas in the sub-surface where all soil or rock interstitial porosity is saturated with water. Includes the saturated zone and the capillary fringe.
Water table	The upper surface of the saturated zone in the ground, where all the pore space is filled with water.
Groundwater dependent ecosystems (GDE)	Natural ecosystems which require access to groundwater on a permanent or intermittent basis to meet all or some of their water requirements so as to maintain their communities of plants and animals, ecological processes and ecosystem services (Richardson et al. 2011).
Infiltration	Passage of water into the soil by forces of gravity and capillarity, dependent on the properties of the soil and moisture content.
Leaf water potential (LWP)	The total potential for water in a leaf, consisting of the balance between osmotic potential (exerted from solutes), turgor pressure (hydrostatic pressure) and matric potential (the pressure exerted by the walls of capillaries and colloids in the cell wall).
Leaf area index (LAI)	The ratio of total one-sided area of leaves on a plant divided by the area of the canopy when projected vertically on to the ground.
Percolation	The downward movement of water through the soil due to gravity and hydraulic forces.
Permeability	A material's ability to allow a substance to pass through it, such as the ability of soil or rocks to conduct water under the influence of gravity and hydraulic forces.
Preferential flow	Movement of surface water rapidly from surface to aquifer along preferential flow paths, bypassing older moisture in the upper soil profile.
Unconfined aquifer	An aquifer whose upper surface is at atmospheric pressure, producing a water table, which can rise and fall in response to recharge by rainfall.
Soil water potential	A measure of the difference between the free energy state of soil water and that of pure water. Essentially a measure of the energy required to extract moisture from soil.
Stable isotope	An isotope that does not undergo radioactive decay.
Surface water	Movement of water above the earth's surface as runoff or in streams.
Transpiration	The process of water loss from leaves, through stomata, to the atmosphere.
Terrestrial GDE	Terrestrial vegetation supported by sub-surface expression of groundwater (i.e. tree has roots in the capillary fringe of groundwater table).
Vadose zone	The unsaturated zone, above the water table in unconfined aquifers.
Water Potential	The free energy potential of water as applied to soils, leaves plants and the atmosphere.

1.0 Introduction

1.1 Background

3d Environmental has been engaged by Stanmore IP South Pty Ltd (IP South) to prepare a Groundwater Dependent Ecosystem (GDE) Management and Monitoring Plan (GDEMMP) for the proposed Isaac Downs Project (ID Project), an open cut metallurgical coal project.

The Project is in the Bowen Basin coal field, Central Queensland, approximately 145 km south-west of Mackay and 10 km south-east of Moranbah. The proponent has applied for mining leases (MLs) and an environmental authority (EA) to enable the development of the Project, to mine approximately 35 million tonnes over 16 years, with a variable annual profile.

IP South is a subsidiary of Stanmore Coal Ltd (Stanmore). Stanmore IP Coal Pty Ltd (IP Coal, a separate subsidiary of Stanmore Coal Ltd (Stanmore), operates the Isaac Plains Mine (IPM) on granted mining lease (ML) 70342, ML 700016, ML 700017, ML 700018 and ML 700019, and subject to an existing environmental authority. Subject to agreement with IP Coal, IP South will utilise existing infrastructure at IPM for coal processing, rejects management, coal raiing, power supply and water management to minimise the infrastructure required for the Isaac Downs Project and reduce the Project's impacts, transitioning to Isaac Downs as production at IPM declines.

As a component of the approval process for the ID Project, a Groundwater Dependent Ecosystem (GDE) assessment was undertaken by 3d Environmental which identified the presence of GDEs associated with the Isaac River which forms the western boundary of the MLA and fringes the proposed mining pit. This GDEMMP has been developed in response to this finding.

1.2 Purpose of the Management Plan

This GDEMMP has been prepared to manage the environmental impacts of the Project on GDEs through the development of consistently applied monitoring actions, analysis and reporting of data trends. Corrective actions (mitigations) are described and should be implemented when statistically significant impacts on GDE function caused by mining activity are detected. The plan is to be used as a reference for management actions prior to construction, during construction and operation, extending though stages of project rehabilitation, decommission and post operation.

1.3 Objectives

Objectives of this GDEMMP are described as follows:

1. Characterise GDEs that are likely to be impacted by the ID Project in terms of ecological function, interaction with surface water and interaction with groundwater as presented in 3d Environmental (2020a).
2. Provide a synopsis of the potential risks to GDE integrity posed by mining activities associated with the ID Project.
3. Identify biophysical parameters that can be applied to the monitoring of GDE function that can be repeated objectively and consistently throughout the life of the ID Project to measure GDE health.
4. Describe the most appropriate actions to measure changes to biophysical function of GDEs that may indicate a decline in GDE health and provide a statistically robust framework that can demonstrate whether impacts to GDEs are associated with mining activities rather than natural variation.

5. Develop triggers that may be used to initiate the application of corrective actions, which can be refined over time as monitoring data is collected.
6. Develop a suite of corrective actions that may be applied to ameliorate impacts to GDEs and prevent or repair declining GDE health.
7. Develop disturbance thresholds and offset requirements should corrective actions not be successful.

1.4 Relevant Legislation

The ID Project is being assessed under the bilateral agreement between the Commonwealth and the State of Queensland using the EIS prepared under the *Environmental Protection Act 1994* (Qld) (EP Act), and it is intended that this GDEMMP satisfies both state and federal provisions. General principals under relevant state and federal regulatory mechanisms are described below.

1.4.1 Queensland Legislation

Environmental Protection Act 1994: Under regulatory provisions of the EP Act, IP South applied for a voluntary EIS on 6 March 2019, which was approved by the Department of Environment and Science (DES) on 5 April 2019. A site-specific EA was applied for on 28 June 2019 under Section 125 of the EP Act with the EIS process forming part of the EA application process. The EIS process will be completed on the issue of the EIS Assessment Report by DES in March 2021.

1.4.2 Federal Legislation

Environment Protection and Biodiversity Conservation Act 1999: The ID Project was referred on 6 March 2019 to the Commonwealth Department of the Environment and Energy (DoEE) (EPBC 2019/8413). On 14 May 2019, the Minister for the Environment determined the ID Project to be a controlled action under the EPBC Act. The controlling provisions are sections 18 and 18A (listed threatened species and communities) and sections 24D and 24E (a water resource, in relation to coal seam gas development and large coal mining development).

The *Environmental Protection and Biodiversity Conservation Act 1999* (EPBC Act) provides for the protection of environmental values, prescribed under the EPBC Act as Matters of National Environmental Significance (MNES). Any action that will or may cause a significant impact on MNES is subject to assessment approval process under the EPBC Act. In June 2013, the EPBC Act was amended to capture water resources as MNES. Under the amendment, water resources include groundwater and surface water, and organisms and ecosystems that depend on it to maintain ecological function and condition. These ecosystems are otherwise termed GDEs and are captured under the water trigger.

The regulatory guideline *Significant impact guidelines 1.3: Coal seam gas and large coal mining developments – impacts on water resources* (DoEE 2013a) identify a 'significant impact' as 'an impact which is important, notable, or of consequence, having regard to its context or intensity'. This GDEMMP addresses the uncertainties that are associated with the nature and significance of impacts to GDEs through provision of comprehensive monitoring protocols, including development of 'early warning' triggers which can be used to identify a decline in GDE health.



1.5 Relationship with other plans and management controls

This GDEMMP interacts with the following impact assessments and plans which directly aim to monitor, avoid and / or minimise impact to water and ecology:

1. **Groundwater monitoring and management:** Description of groundwater monitoring and management measures provided in the groundwater impact assessment report for Isaac Downs (AGE 2020).
2. **Isaac Downs Receiving Environment Management Plan (REMP) Document:** Monitors, identifies, and describes any impacts to aquatic ecology and surface water quality values from discharges associated with approved mining activities (FRC 2020a).
3. **Isaac Downs Erosion and Sediment Control Plan (ESCP):** Provides actions and processes to manage sediment dispersal, which may impact GDEs when associated with surface flows.
4. **Isaac Downs Water Management Plan (WMP):** Water management measures are contained in the Isaac Downs Project Surface Water Assessment (WRM 2020) which contains information on potential contaminants, water balance model, description of the site water management system, measures to manage / prevent saline and acid rock drainage, contingency procedures for emergencies and a monitoring and review program for the effectiveness of the WMP.
5. **Isaac Downs –Significant Species Management Plan (SSMP):** The Terrestrial Ecology Impact Assessment Report for the Isaac Downs Project (EcoSM 2020) Identifies Australian painted snipe (endangered), koala (vulnerable), greater glider (vulnerable), ornamental snake (vulnerable) and squatter pigeon (vulnerable) as potentially being impacted by the ID Project. The SSMP presents the management objectives and measures that are to be implemented within the ID Project footprint for species management and to minimise impacts to current biodiversity values of the site.
6. **Isaac Downs Project –Riparian Baseline Monitoring Program:** Includes measures to monitor the ecological condition of habitat for threatened species under relevant state and federal legislation. The program is described in the Terrestrial Ecology Impact Assessment Report for the Isaac Downs Project (EcoSM 2020).
7. Approvals documents for the Project, once granted (i.e. environmental authority and EPBC Act approval).

1.6 Structure of this Document

This GDEMMP intends to compile knowledge on the ecohydrological function of relevant GDEs, scope has been made to update monitoring requirements including methods, timing and interval as the knowledge base increases with each subsequent monitoring survey event. A summary of the key components of this GDEMMP is provided below:

- Section 2: A contextual description of the project in relation to mining layout and project timeframes.
- Section 3: A general description of the existing environment to contextualise hydrogeological and ecological setting with reference to detailed description provided in 3d Environmental (2020a).
- Section 4: Describes in detail the hydro-ecological function of GDEs in the Project area with reference to detailed information in 3d Environmental (2020a).
- Section 5: Provides a summary for what are considered the major risks to GDE health imposed by the ID Project, as presented in 3d Environmental (2020a).

- Section 6: A summary of how the biotic impacts to GDEs may manifest in the environment.
- Section 7: The general approach to the monitoring program.
- Section 8: An overview of monitoring techniques and their application.
- Section 9: A summary of reporting requirements for each monitoring event as well as preparation of a baseline synopsis.
- Section 10: Approach to determining trigger thresholds for which impacts to GDEs are investigated and corrective actions applied where appropriate.
- Section 11: A discussion identifying potential corrective actions that may be applied to ameliorate impacts to GDEs that have been created by mining activities.
- Appendix: Provides the basis for risk assessment, a summary of monitoring methods, monitoring timing, raw data from prior GDE surveys, and preliminary results from the November 2020 GDE monitoring assessment. The Appendix is structured to provide:
 - o Appendix A. Mining stages and development plans
 - o Appendix B. Summary of GDE sampling methods
 - o Appendix C. Sampling localities from the EIS assessment.
 - o Appendix D. Stable isotope results from the EIS assessment
 - o Appendix E. Summary data from November 2020 GDE monitoring assessment.
 - o Appendix F. GDE monitoring two-year schedule.

2.0 Project Description and Timing

2.1 Project Activities

The three mining lease applications (MLAs) associated with the Project being MLA 700046, MLA 700047 and MLA 700048, are shown on **Figure 2**, which also shows proposed mine infrastructure which will include a ROM coal haul road, linear infrastructure, access road, ROM coal pad, levee and mine infrastructure area. Specific infrastructure will include:

- A purpose built, dedicated haul road to the adjoining IPM to the north.
- A mining infrastructure area (MIA) which will comprise workshops and offices.
- A levee will be constructed during operations to protect the open cut mining operations from flood inundation up to the 1:1000-year flood event from the Isaac River.

Post mining, overburden dumps will be rehabilitated, and a residual void will remain outside of the floodplain of the Isaac River. The residual void area has been minimised through landform modifications and assessment of potential uses of the residual void area. A permanent levee will not be required post mining.

2.2 Project Stages and Timing

It is intended, subject to project approvals, that construction will commence in 2021 subject to obtaining all required approvals, with mining operations with mining commencing in 2022. The Project will extract approximately 3.2 Mtpa ROM coal over the first nine years, and then approximately 1 Mtpa over the next seven years as the strip ratio increases. Mining will be completed in 2037. Mine stage plans have been developed, representing the progression of mining activities at each stage, which will be used to inform the management of impacts throughout the life of the mine. The stage plans provided in **Appendix A** which relate to the following mine stages:

- **Year 1**, which is the initial stage of mining operations which includes infrastructure development and the initial box cut.
- **Year 3** box cut has been developed and out of pit dumping is in progress.
- **Year 5** with out of pit dumping substantially complete and in-pit dumping ongoing, with progressive rehabilitation occurring.
- **Year 10** at which point mining will be well advanced, with in-pit dumping ongoing and progressive rehabilitation occurring.
- **Year 16** being the final year of mining operations, with in-pit dumping complete and progressive rehabilitation occurring.
- **Final landform** – post mining rehabilitation and decommissioning completed.

3.0 Existing Environment

This section provides an overview of the local and regional setting, including climate, existing and surrounding landuse. For context, detailed information on the following features is described in Isaac Downs Project – Groundwater Dependent Ecosystem Assessment (3d Environmental 2020).

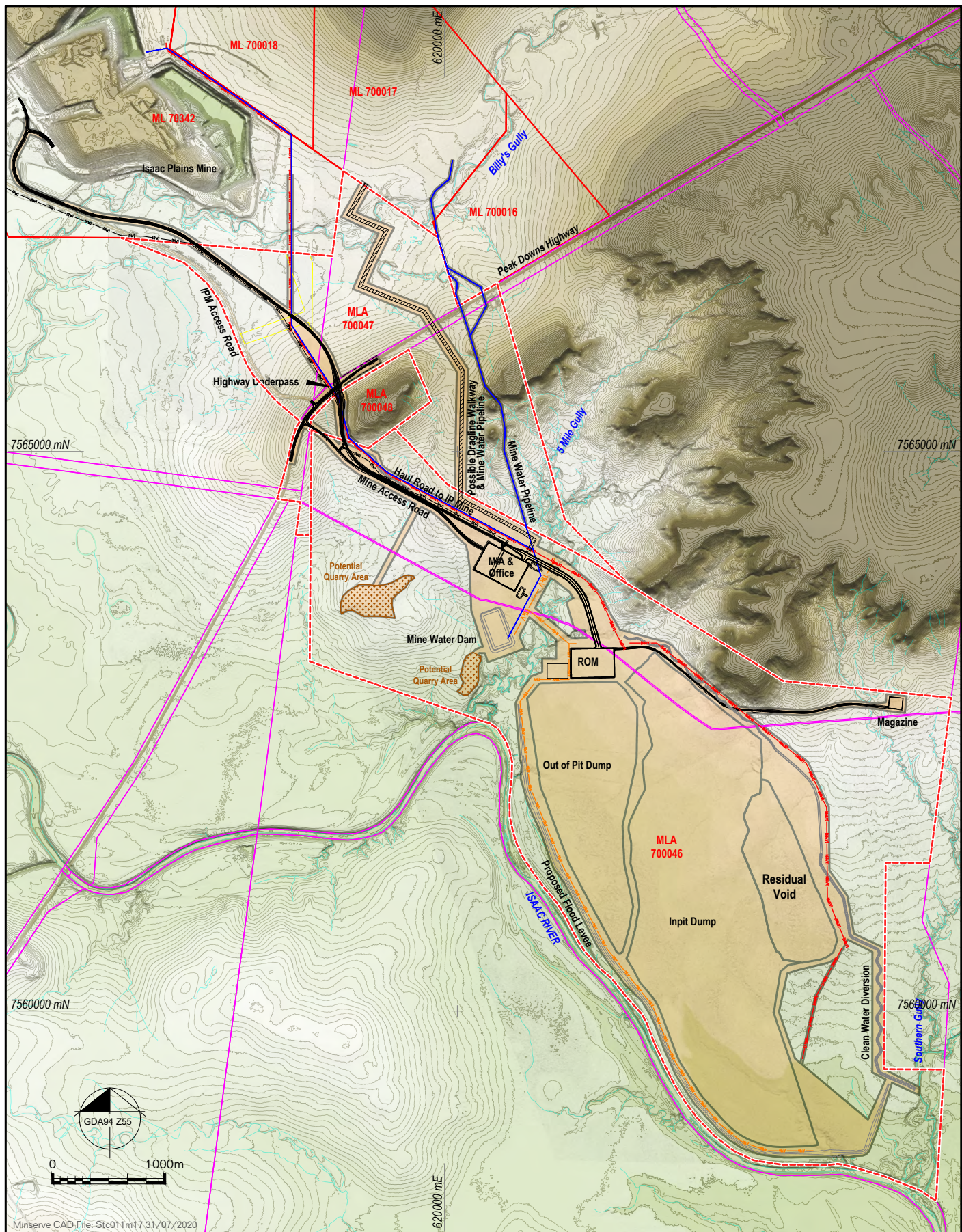
1. Ecological characteristics of the site including potentially groundwater dependent regional ecosystems (REs) and species (**Section 2.1** of 3d Environmental 2020).
2. Hydrogeological setting and the major groundwater bearing units (**Section 2.2** of 3d Environmental 2020).
3. Surface water flows including water quality and flood regimes (**Section 2.3** of 3d Environmental 2020).

3.1 Site Setting

The ID Project area is located within the Northern Bowen Basin subregion of the Brigalow Belt Bioregion in central Queensland. The Brigalow Belt North Bioregion is an ecologically complex area characterised by clay soils interspersed with Tertiary plateaus, sand plains, basalt plains and some more expansive ranges formed on sandstone and granite. Vegetation is typically dominated by forests and woodlands of *Acacia harpophylla* (Brigalow), *Acacia shirleyi* (lancewood) eucalyptus woodlands and grassland habitats.

The region surrounding the ID Project area has been extensively cleared of native vegetation to accommodate pastoral activities, except for topographically rugged areas and drainage lines where intact vegetation has generally been retained. Riparian vegetation associated with the larger watercourses is generally continuous, though largely restricted to channel margins with attenuations along minor tributaries and occasionally buffered by broader areas of floodplain woodland. Coal mining has been a more recent activity in the region, emerging in the 1970's as a major industrial activity. Several coal mines and projects are approved in the region including:

- the Grosvenor Mine adjacent to the IPM
- the Moranbah North Mine located northwest
- the Burton, Broadlea and Ironbark No. 1 Mines located north
- Carborough Downs Mine located north east
- Millennium and Poitrel Mines located several kilometres to the east, and
- the Moranbah South Project and Caval Ridge Mine located to the west.



LEGEND

- | | | | |
|---|--------------------------|--|------------------------|
| | ML | — | Drainage |
| | Isaac Downs Project MLAs | — | Roads - Major |
| | Project Footprint | — | Cadastral Boundary |
| | | — | Topography 1m Contours |

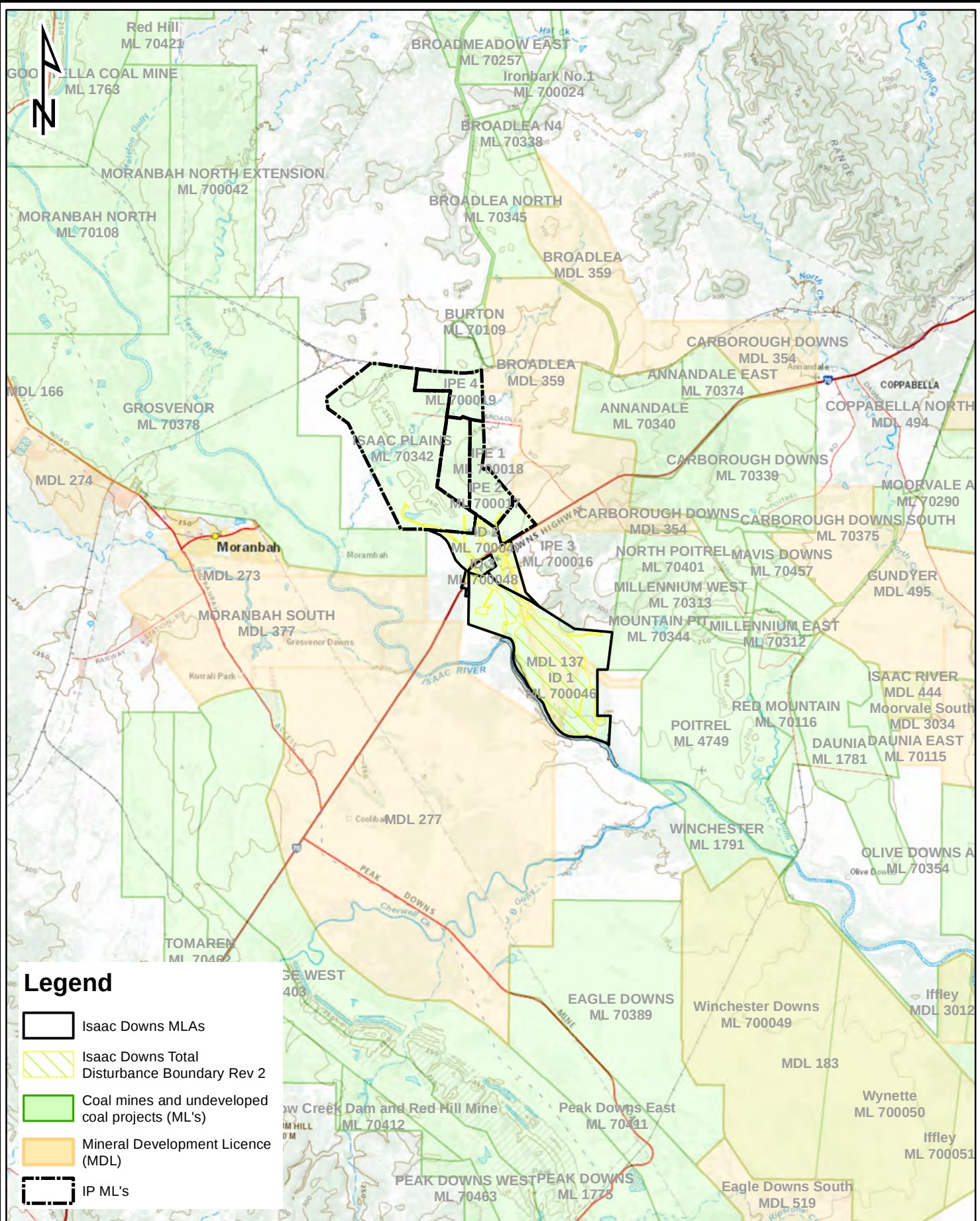
ISAAC DOWNS PROJECT
stanmore
 IP South

Proposed Project Layout
 Figure 2

Other non-approved projects (at the time of the voluntary EIS decision) that are in the process of being developed include:

- the Winchester South Project, located approximately 10 km south on the western side of the Isaac River, to be developed by Whitehaven Coal
- Olive Downs Project, located approximately 25 km south, to be developed by Pembroke Resources, which also fringes the Isaac River
- Eagle Downs Project located approximately 10 km south, to be developed by South32.

The location of coal mining operations that fringe the ID MLs is shown in **Figure 3**.



Legend

- Isaac Downs MLAs
- Isaac Downs Total Disturbance Boundary Rev 2
- Coal mines and undeveloped coal projects (ML's)
- Mineral Development Licence (MDL)
- IP ML's

Figure 3. Adjacent mining projects

Client

Stanmore IP South Pty Ltd



Scale 1:200,000

Drawn By DG

Checked DS

File Path

Date
29/10/2020

A4



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Mobile: 0447 822 119
www.3denvironmental.com.au

3.2 Climatic Considerations

The region is sub-tropical with average temperatures recorded in Moranbah of between 21.1°C and 34.8°C in the summer months, and 8.9°C and 25.2 °C in the winter months. The long-term average rainfall (30 years of data between January 1990 and December 2019) from the Moranbah Water Treatment Plant is 590.4mm (SILO 2020) with a pronounced wet season. Approximately 75% of the annual rainfall is recorded between November and March, inclusive (BoM 2020). Plant growth in the region is strongly limited by moisture rather than temperature (Hutchinson et al. 1992) which is reflected in the evapotranspiration rates at the Moranbah Airport for the 2019 – 2020 period being considerably higher than rainfall for all months (except for the wettest months). Between January 2015 and December 2019, the largest offset between rainfall and evapotranspiration occurred between October to December during the build-up to summer storms (**Figure 4**) (data from SILO 2020).

The region has experienced several significant drought events, many of which have resulted in tree dieback. The early to mid-1990's drought, the worst on record for north Queensland, and the millennium drought from 2000 through to 2007 both resulted in substantial dieback of native woodland habitats, typically affecting ironbark woodlands and most severely on basaltic substrates (Fensham et al 2009a). **Figure 5** demonstrates the major climatic cycles in terms of Cumulative Rainfall Departure (CRD) (Weber and Stewart 2004), representing a cumulative departure of monthly rainfall from the long term mean monthly rainfall (1990 to 2020) at the Moranbah Water Treatment Plant (SILO 2020). Strongly decreasing rainfall trends between 1990 to 1996; and 2000 to 2007 representing major drought periods are strongly evident, interspersed with periods of above average rainfall between January 1998 and January 2001, January 2010 and July 2012, and January 2016 to March 2017, which were considerably wetter than average conditions.

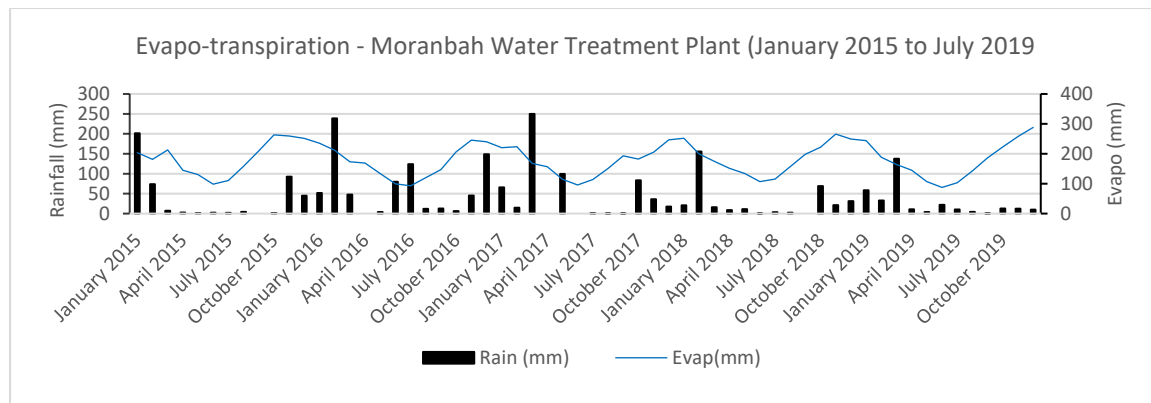


Figure 4. Evapotranspiration trends on a seasonal basis for Moranbah Water Treatment Plant.

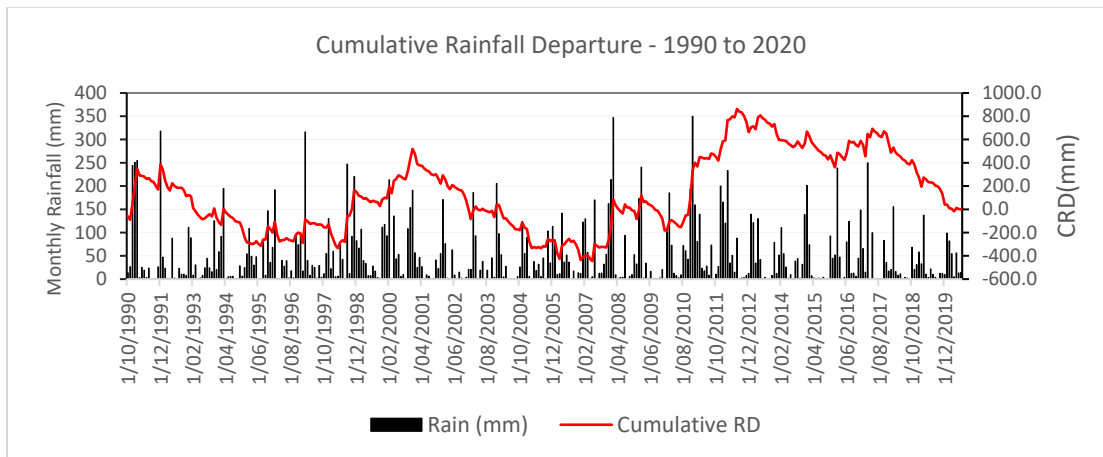


Figure 5. Cumulative rainfall departure calculated for the Moranbah Water Treatment Plant.

3.3 Topography and Drainage

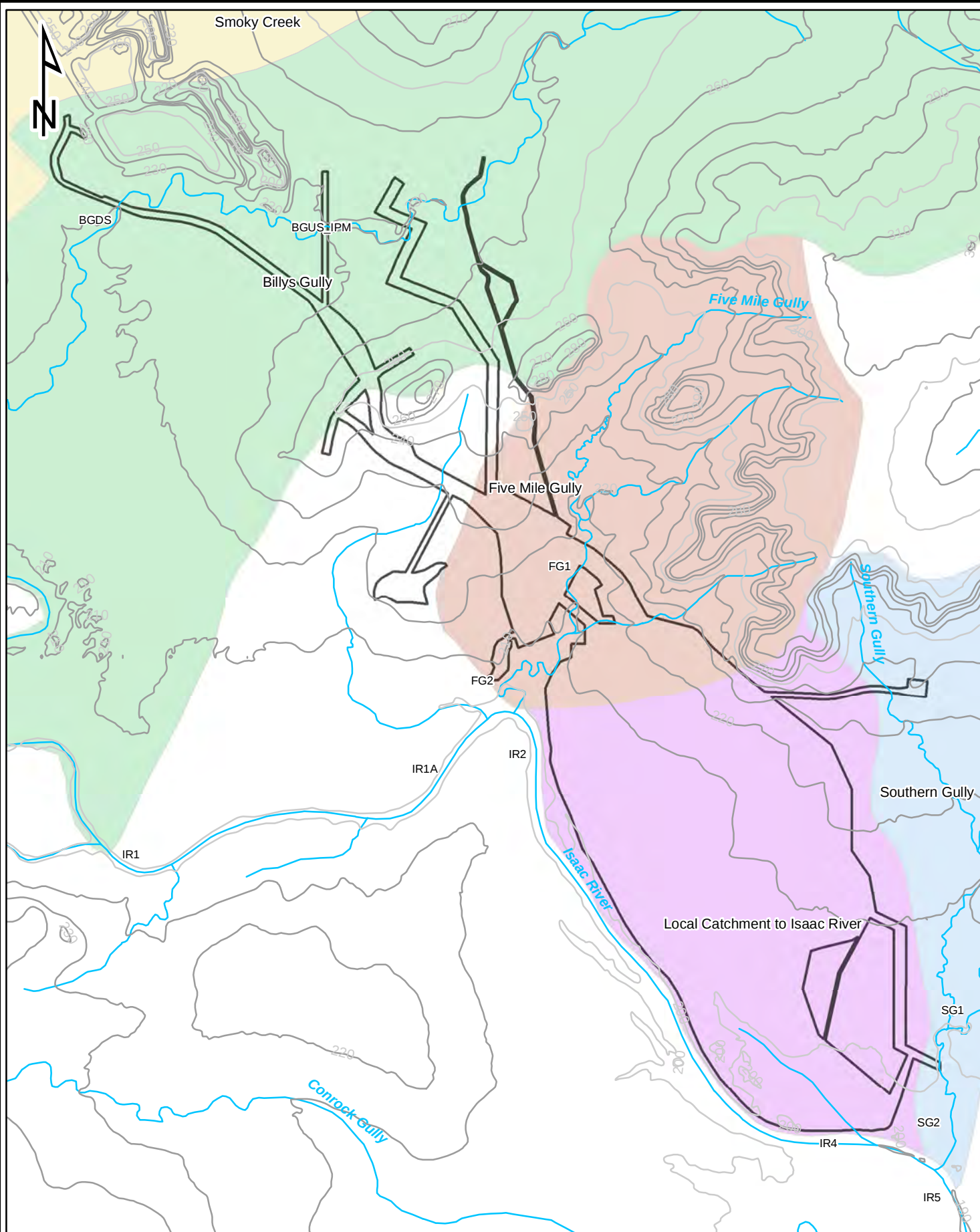
The ID Project is situated on gentle topography with the Isaac River forming a western boundary to the mining footprint, with a broad flood plain extending up to 2km east and west from the main river channel. To the east, the flood plain rises gently with slopes $<2^\circ$ to a broad jump-up which forms the most topographically elevated portion of the local landscape approximately 2km east of its nearest point to the Isaac River. Several drainage features traverse the Project area including the Isaac River, defined by a broad sandy flood channel incised into its flood plain, broadly defining the western limit of the mining footprint. Smaller tributaries include Five Mile Gully and 'Southern Gully' join the Isaac River to the immediate north of, and south of, the ID mining footprint respectively. A haul road crossing of Billy's Gully, an ephemeral watercourse which joins the Isaac River to the north of the Peak Down's Highway and immediately south of the IPM will be established (**Figure 6**).

3.4 Surface Geology

Isaac Downs is in the northern part of the Bowen Basin, comprising sediments that are mostly Permian to Triassic age representing principally fluvial and some marine sediments. Economic coal seams are contained in the Rangal Coal Measures, which are late Permian age and approximately 100 m thick. The Rangal's are underlain by the Fort Cooper Coal Measures and overlain by the Early Triassic Rewan Group. Coal deposits in the Project area are bound to the north and east by the Isaac Thrust Fault which is a major structural feature with over 50m vertical displacement. The main geological units in the Project area, from youngest to oldest include:

- Quaternary alluvium associated with Isaac River
- Thin Cainozoic surficial sediments
- Triassic/Permian sediments comprising
 - Surficial weathered zone at outcrop
 - Triassic Rewan Group sediments; and
 - Permian sediments that are divided into the Rangal Coal Measures, Fort Cooper Coal Measures and Moranbah coal measures.

In addition, there is a regional Tertiary basalt flow aligned along a paleochannel system situated to the north-west to west of the Project. (**Figure 7**).



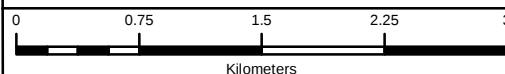
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- Drainage
- Isaac Downs Total Disturbance Boundary Rev 2

Figure 6. Topography and drainage

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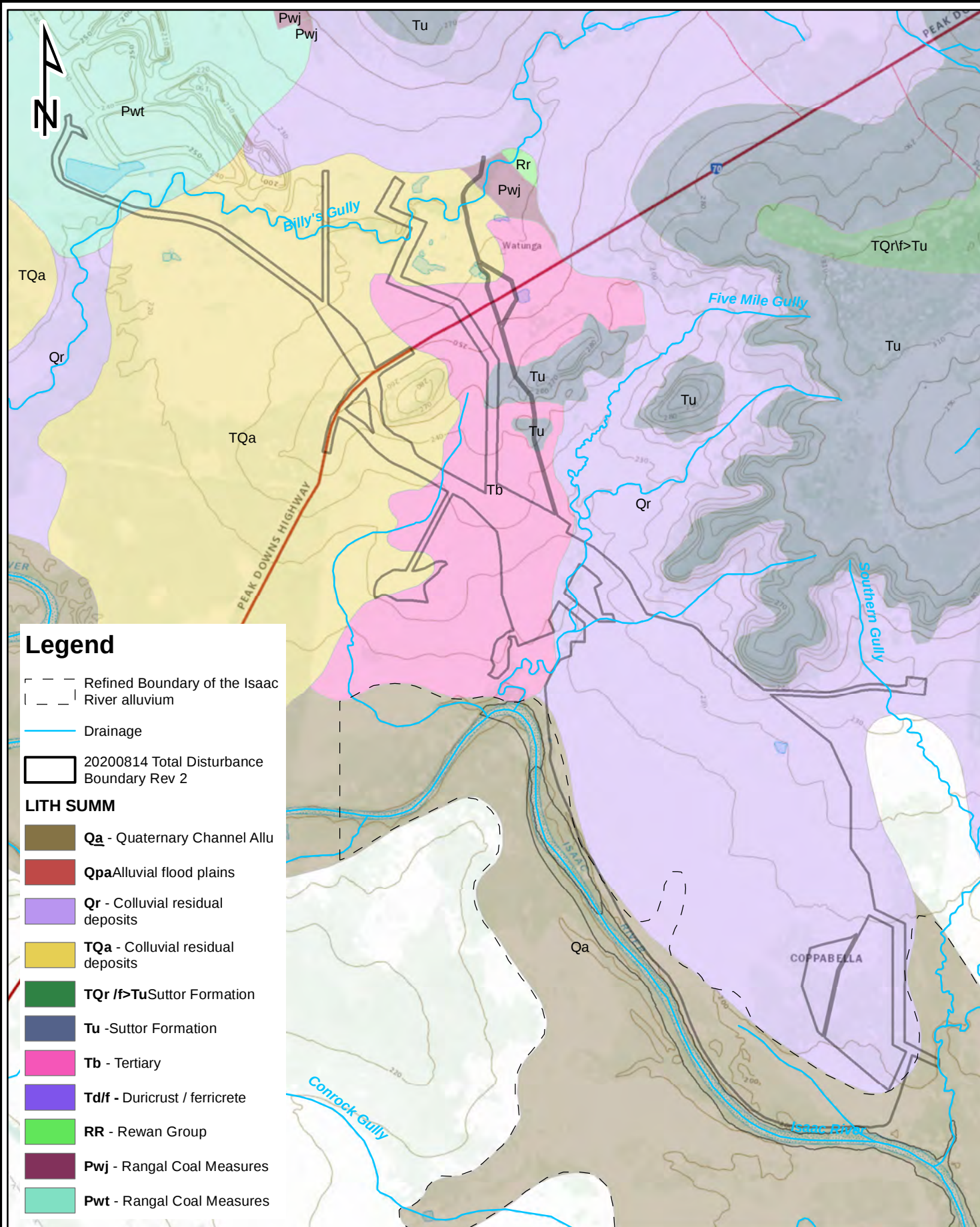
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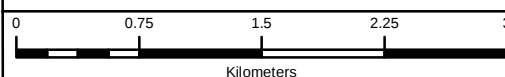


Source: DNRM 2018

Figure 7. Surface geology in the Isaac Downs project area

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4.0 The Distribution and Hydro-ecological Function of GDEs at Isaac Downs.

Detailed descriptions of the function of GDEs at Isaac Downs, including block model conceptualisations and cross sections have been developed and described in the **Section 5.0** of the Isaac Downs Project Groundwater Dependent Ecosystem Assessment Report (3d Environmental 2020) and should be referred to for more detailed conceptual information. In summary, two GDE areas are identified as being associated with the Isaac River within the Project area being GDE Area 1 and GDE Area 2 (see **Figure 8**). The characteristics of these GDE Areas are described below.

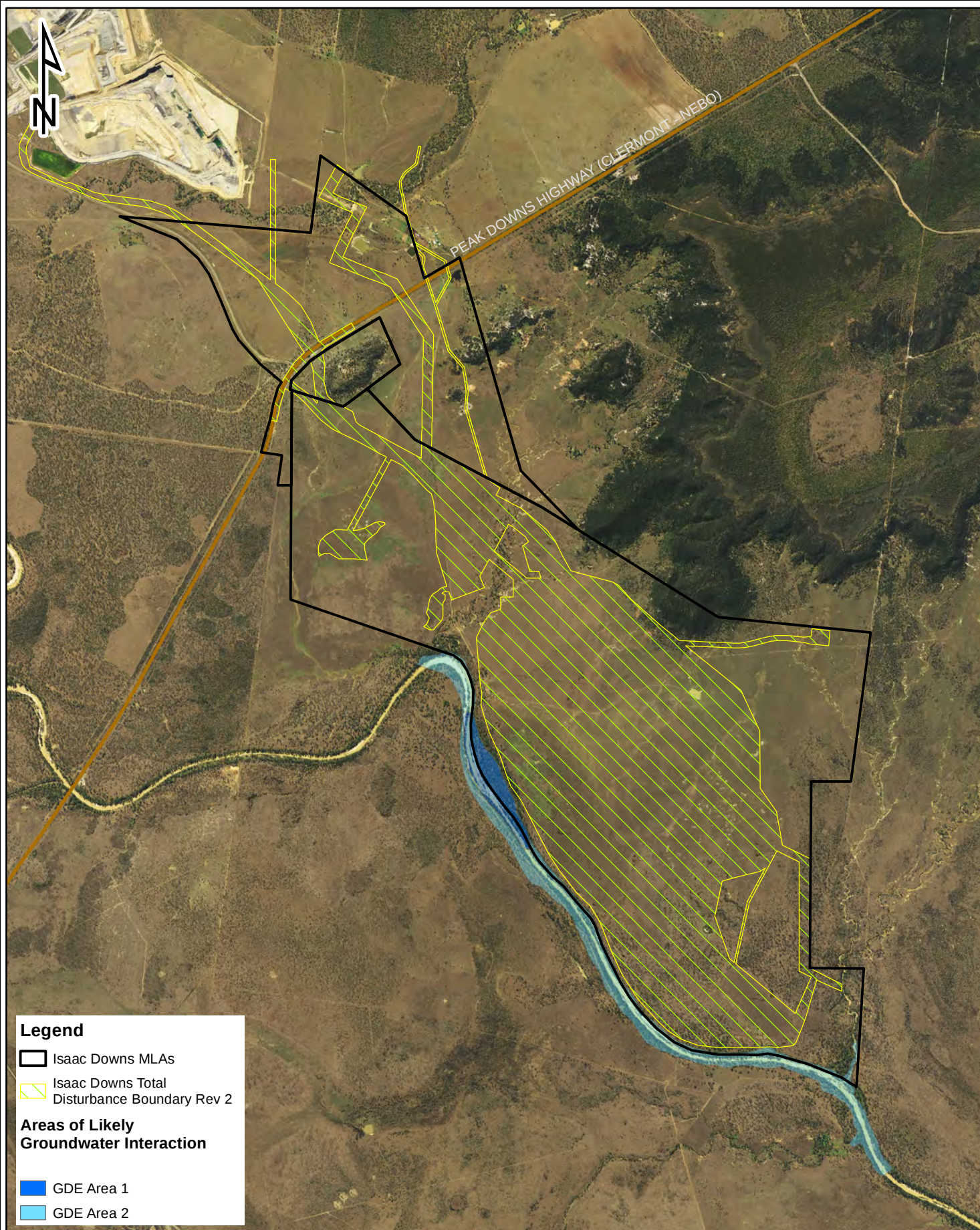
1. **GDE Area 1:** Most trees in this area are inferred to be permanently interacting with shallow groundwater in the alluvial aquifer. This is due to the geomorphic characteristics of the river channel in this location, with a broad inner bench and flood overflow facilitating rapid recharge of the shallow aquifer. There is also the likelihood, that basement rock subcrop is elevated in this area relative to other locations on the river and supports a perched aquifer that is disconnected from the broader aquifer associated with the Isaac River alluvium.
2. **GDE Area 2:** Vegetation on the riparian fringe is variably interacting with groundwater and surface water, and dependence varies in response to position on the riverbank and other geomorphic controls. Trees on the lower riverbank generally demonstrate a greater degree of groundwater interaction than those higher up the bank and on the upper terrace. There is also likely to be a significant proportion of trees in GDE Area 2 that demonstrate no, or limited dependence on groundwater.

From this assessment, it was concluded that vegetation on the older, more elevated alluvial terraces of the Isaac River consistently demonstrated water stress indicative of trees reliant on moisture held in the shallow soil moisture profile rather than groundwater.

5.0 Major Risks to GDE Function

A detailed assessment of the potential risks to GDEs at Isaac Downs is developed in **Section 6.0** of the Isaac Downs Groundwater Dependent Ecosystem Assessment Report (3d Environmental 2020) and this document should be consulted if additional detail or specific information is required. Drawdown of the groundwater in the coal seams, propagated into the Isaac River alluvium where coal seams sub-crop, provides the most likely potential impact pathway potentially leading to a decline in GDE function. Groundwater modelling by AGE (2020) indicates project related drawdown of the water table with declines of up to 10m in localised areas beneath the Isaac River where coal seams sub-crop into the alluvium (see **Figure 9**). However, the impacts of this drawdown to GDE function may be ameliorated by:

1. Flooding events and other environmental flows which are the major source of recharge for the groundwater resource being utilised by GDEs on the Isaac River (see **Section 6.0** of 3d Environmental 2020). Flow regimes (i.e. intensity, duration, frequency) will not be impacted by the Project, with negligible to minor changes in the extent and rate of change in flood behaviour (see **Section 2.3** of 3d Environmental 2020).
2. The capacity of river red gum (including forest red gum) to adapt to changing water availability and utilise moisture from several non-saturated water sources (see **Section 6.2.1** of 3d Environmental 2020).



Legend

- Isaac Downs MLAs
- Isaac Downs Total Disturbance Boundary Rev 2

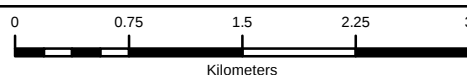
Areas of Likely Groundwater Interaction

- GDE Area 1
- GDE Area 2

Figure 8. Location of GDE Areas.

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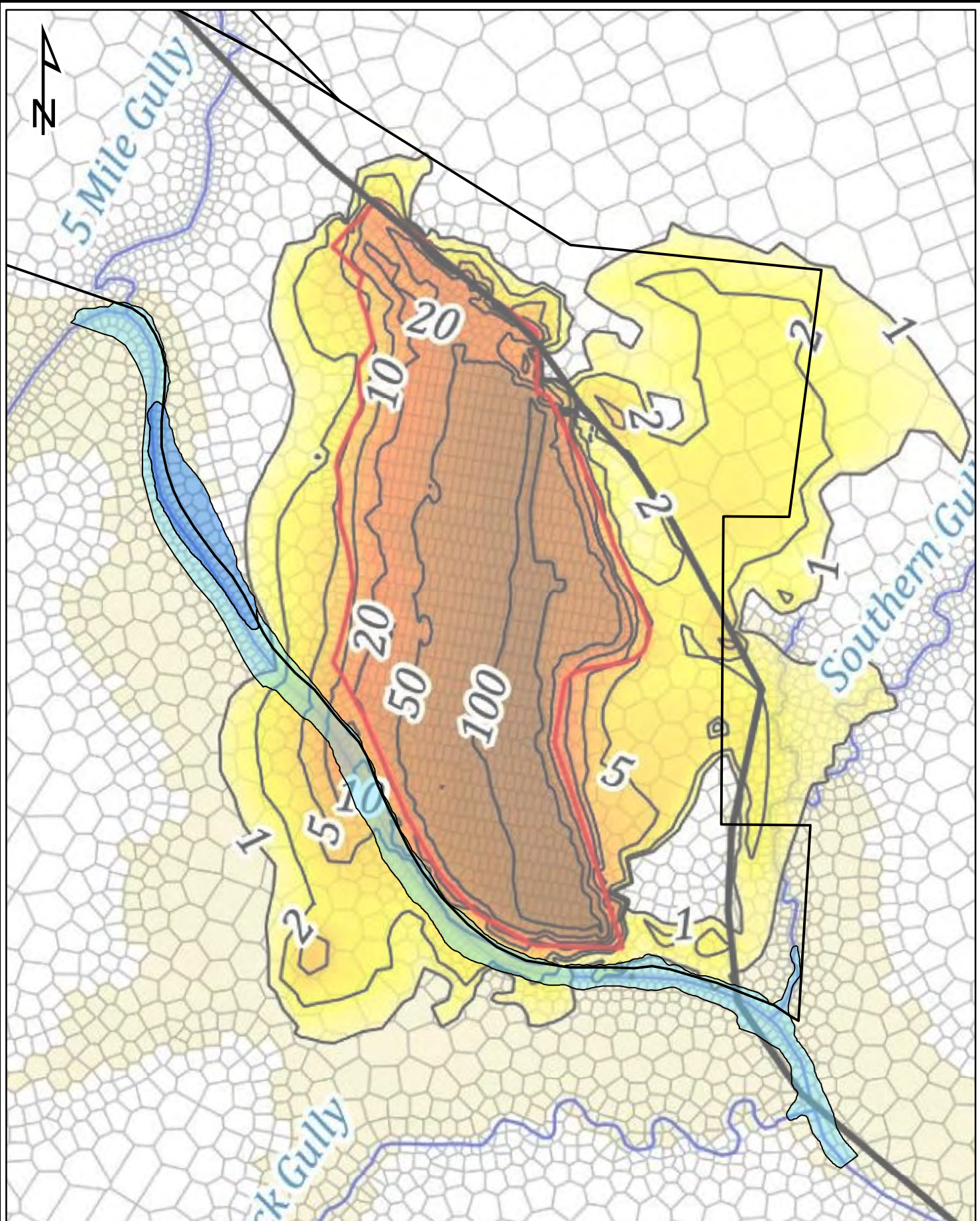
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Legend

Isaac Downs MLAs

Areas of Likely Groundwater Interaction

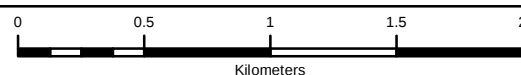
GDE Area 1

GDE Area 2

Figure 9. Location of mapped GDEs relative to maximum drawdown during mining.

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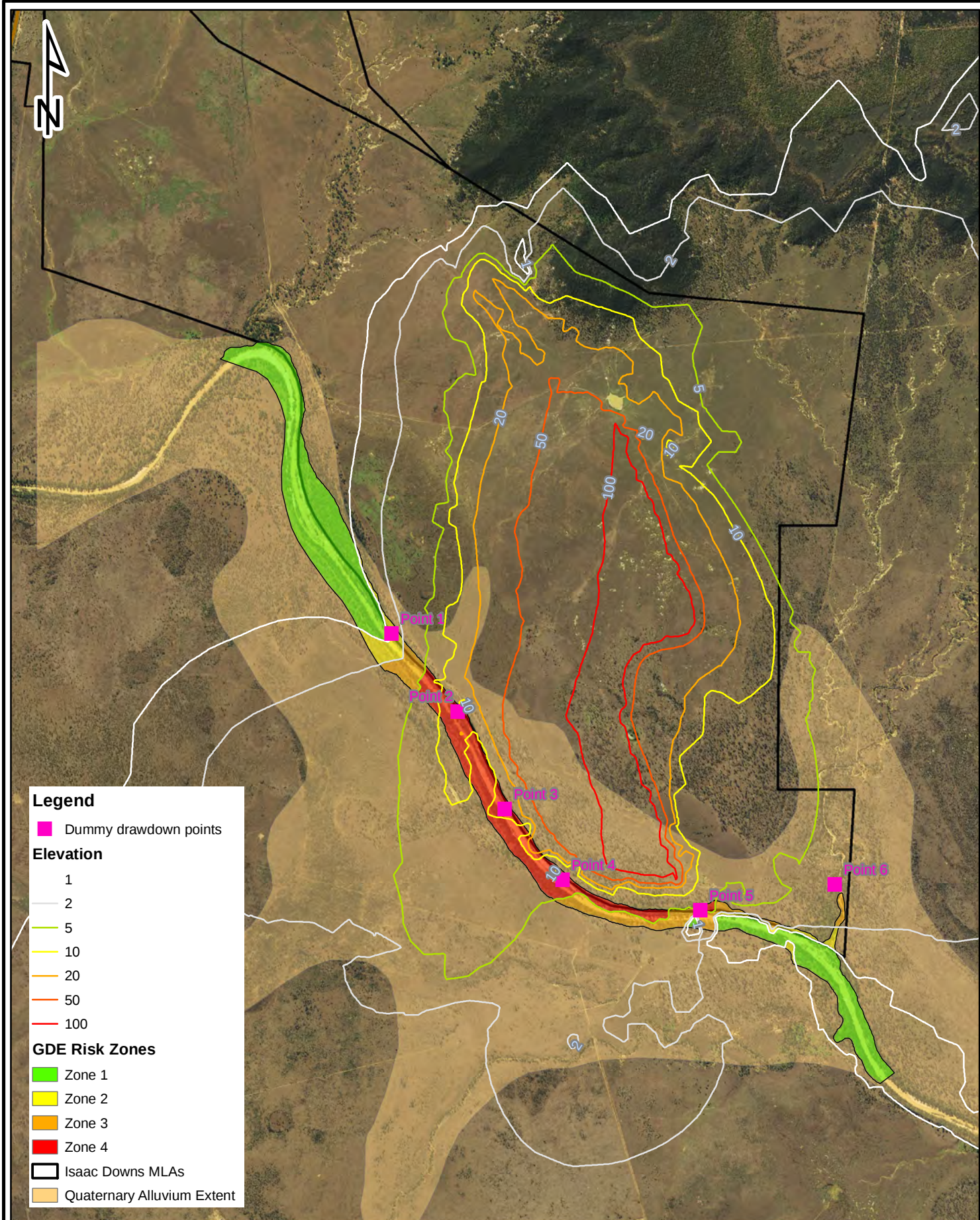
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Based on maximum predicted drawdown of the water table from the Project and rate of groundwater drawdown at specific point localities (dummy points) (AGE 2020), mapping of GDE zones was completed to characterise the likelihood of impacts to mapped GDE Areas. A summary of GDE 'Zones' for the purpose of risk assessment is provided in **Table 1** with a mapping of Zones (from 3d Environmental 2020) provided in **Figure 10**.

Table 1. Descriptors and ranking for the likelihood of impact to GDE health occurring attributed to specific GDE Risk Categories.

Rank	GDE Zone	Likelihood of Impact	Description
1	Zone 1	Highly unlikely	The GDE is outside area of predicted drawdown.
2	Zone2	Unlikely	< 2m drawdown over the 17 yr life of the mining operation or a maximum drawdown rate <0.1m / yr (Point 1, Point 5 and Point 6),
3	Zone3	Possible	> 2m drawdown to <5m drawdown over the life of the mining operation and a maximum drawdown rate <0.5m / yr (Point 3 and Point 4).
4	Zone4	Likely	>5m drawdown with a maximum drawdown rate >0.5m /yr (Point 2).



Legend

■ Dummy drawdown points

Elevation

1
2
5
10
20
50
100

GDE Risk Zones

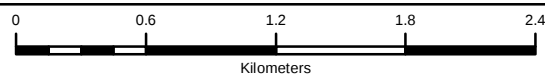
Zone 1
Zone 2
Zone 3
Zone 4

Isaac Downs MLAs
Quaternary Alluvium Extent

Figure 10.GDE zones of potential impact associated with maximum project water table drawdown

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6.0 Biophysical Response to Reduced Water Availability / Quality

Eamus et al (2009) provides a conceptual assessment of the major stressors that contribute to declining GDE health. Reduced water availability is the major determinate of GDE health and the flow-on effects of this are outlined in **Figure 11**. Based on conceptualisations provided in **Section 6.1** and risk assessment completed in **Section 6.5** of 3d Environmental (2020a), an unmitigated 'moderate' risk of impact to GDE function is associated with:

1. Zone 3 and Zone 4 of the GDE Zone mapping (**Figure 10**).
2. A period when maximum groundwater drawdown is associated with a period of drought¹ that diminishes the opportunity for groundwater recharge facilitated by river flows and flooding.

In a 'worst case' scenario when maximum drawdown coincides with a period of drought, the predicted impact would be of 'moderate' magnitude, which in the context of the risk assessment detailed in **Section 6.4** of 3d Environmental (2020) would result in a:

'Threshold breach of Leaf Area Index (LAI) that indicates plant stress linked to mining activities that does not result in > 25% dieback of mature canopy trees (defined as a canopy tree with DBH >60cm). The Impact is reversible with mitigation'.

The decrease in groundwater availability associated with drawdown of the water table, and seasonal dryness extending into the summer months when transpiration is highest will be likely to trigger stomatal closure and reduction in LAI. Over an extended period with sustained conditions of drought, increasing levels of plant mortality may occur and in a general context, these adverse physiological responses may ultimately result in the conversion of a diverse, functioning habitat to a simplified system with reduced ecological value (Doody et al 2009). As detailed in **Figure 11**, the time taken for the first measurable impacts on vegetation due to groundwater drawdown to manifest may take months with habitat conversion due to dieback of the original canopy taking many years to decades with the rate of dieback dependent on climatic controls. However, detectable changes in vegetation health would be apparent within months to a few years, if this were to occur. Many of the physical responses of vegetation to reduced water availability can also occur because of natural seasonal variation and hence any monitoring program must have capacity to distinguish what is natural variation from impacts that result from anthropogenic disturbance to the hydrogeological regime.

¹ Defined as a standardised 3-year cumulative index of <-1, meaning that based on average rainfall values, <2 years of rainfall is received over a period of 3 years (Fensham et al 2009b).

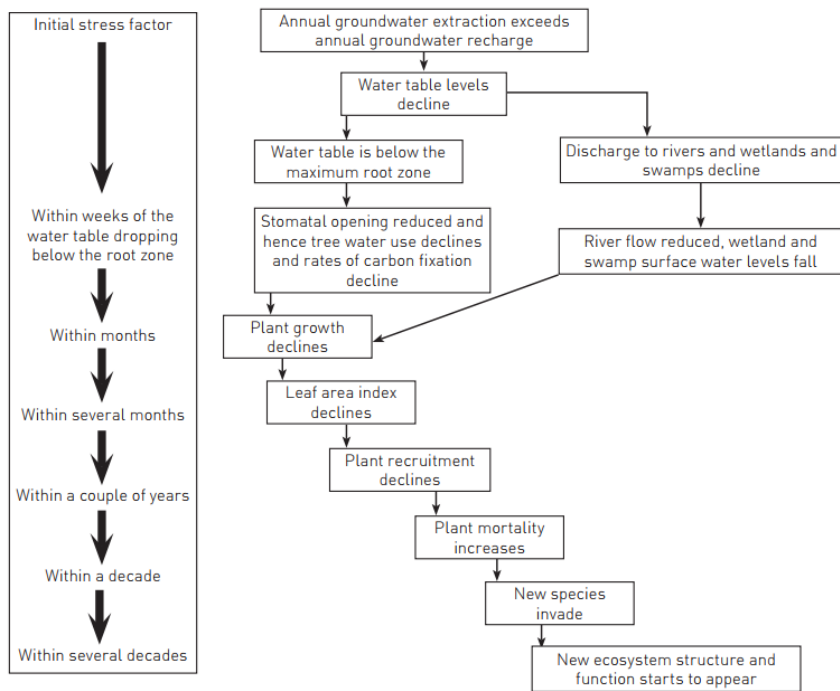


Figure 11. Schematic outline of the response of plants and communities of plants to reduced availability of groundwater from Eamus (2009).

7.0 Approach to Monitoring and Management Program

7.1 Overview

This document provides a framework for the management and monitoring of GDEs associated with the Isaac River including areas both within the area of predicted groundwater drawdown and more broadly throughout the Isaac River frontage upstream and downstream from the ID Project area. The monitoring program also considers the major tributaries of Southern Gully and Conrock Gully which occur in the south of the Project area, and while not being considered GDEs (BOM 2020), are captured within the monitoring program due to riparian linkages with the Isaac River GDE system. A sequential approach to monitoring and management has been applied which allows for adaptive implementation of monitoring and management protocols reliant on results of prior assessment activities. The major components of the GDEMMP include provision to:

- Apply monitoring and assessment techniques that support development of an environmental baseline for GDE function commencing prior to operations, including an upstream and downstream control site for GDE monitoring.
- Produce a statistically robust multi-parameter dataset that can be used to validate perturbations in GDE function that fall beyond thresholds of natural seasonal variation.
- Allow a flexible approach to monitoring which is subject to ongoing review and allows methods to be adapted based on results of lead-up monitoring and data analysis.
- Utilise biophysical and ecological parameters to establish:
 - an appropriate ecological trigger threshold, applied to indicate requirement for further investigation or corrective action; and
 - an appropriate disturbance level threshold applied to indicate requirement for offsets should corrective actions not be successful.
- Develop a comprehensive suite of management actions and corrective measures which will be applied if a breach of trigger threshold is identified, noting that the suite of management actions implemented will depend on impacts identified, and all may not be required for any given breach of a trigger threshold.
- Assess the effectiveness of management actions and corrective measures, determine if significant residual impacts to MNES have occurred, and where significant residual impacts have occurred, provide offsets.

The approach is consistent with the GDE Toolbox approach (Richardson 2011a and 2011b) which recommends a sequential assessment, as outlined below:

- Stage 1 – GDE location, classification and basic conceptualisation. The focus of Stage 1 is to gain a baseline understanding of where potential GDEs exist including classification of GDE type and ecohydrological function.
- Stage 2 – Characterisation of groundwater reliance. Stage 2 assessment builds on conceptual information provided in Stage 1 to characterise the degree of reliance of the GDE on groundwater.
- Stage 3 – Characterisation of ecological response to change: During Stage 3 assessment, knowledge of baseline ecohydrological function is utilised to describe and quantify likely changes to biophysical function and health of GDEs if impacts to groundwater regimes manifest.

The GDE characterisation undertaken by 3d Environmental (2020) as a component of the Project EIS process meets the requirements of Stage 1, the outcomes of which are described in accordance with conceptual models provided in **Section 5.0** of the EIS report (3d Environmental 2020). Ongoing adjustment of the ecohydrological models may be required as the monitoring program develops, and ecological data is collected and analysed.

Stage 2 and Stage 3 of the monitoring program will rely on collection of temporal data to support characterisation of baseline ecohydrological function. Seasonal monitoring events will allow for baseline data to be acquired to predict trends in GDE function and identify impacts that extend beyond the range of natural variation.

7.2 Approach

The monitoring and management program has been separated into two stages:

- Two years of intensive data collection during which investigative thresholds will be defined (see **Section 10**).
- The period after 2 years, comprising the remainder of operations and the post mining period, which will utilise data collected in the initial two years to re-assess the thresholds.

The process for establishing thresholds is described in **Section 10**, involving collection of data from the impact site (i.e. drawdown area) and two control sites, upstream and downstream from the area of potential impact. The thresholds for impact are linked to vegetation health and provide a comparison between the control and impact sites. Should the established thresholds be exceeded, this will trigger an investigation that will make use of other monitoring data (See **Section 10.2**) on the bio-physical function of vegetation, groundwater and surface water to determine the cause of a threshold exceedance. If activities associated with the ID Project is found to be the cause of the threshold exceedance, then mitigation measures (see **Section 11**) will be implemented, and the effect of mitigation measures monitored. If mitigation measures are not effective, an assessment will be made as to whether disturbance thresholds have been breached and, if so, the habitat quality data from the riparian 'habitat quality' monitoring program will be used to determine offset requirements, consistent with the approach outlined in Section 11. The riparian monitoring program is described in **Section 8.3** of the Terrestrial Ecology Impact Assessment Report (ECoSM 2020) for the amended Isaac Downs EIS.

The initial two years of intensive data collection aims to refine thresholds for monitoring and impact assessment, including provision of a dataset to support investigative action. For the subsequent period after 2 years, the process remains the same; however, the thresholds may be amended to reflect alternative parameters for monitoring and / or the threshold values attached to those parameters. Although the data collected in the initial GDE characterisation (3d Environmental 2020) included data that is critical to the characterisation of GDEs on the site, it lacked some of the vegetation indices that will form the basis of the ongoing monitoring program. It is therefore proposed that the initial two- year period of intensive data collection commence in the late dry season of 2020 (November) with a total of four monitoring events finalised in March 2022. While this may overlap with the early construction and operational phase of the mine, this will have little impact on the validity of the data for the purpose of ongoing monitoring as both control (outside the area of predicted drawdown) and impact (within the area of predicted drawdown) sites will be measured. This will facilitate collection of high resolution ecological, bio-physical and remote sensing

data, coincident with the early stages of mine development, to allow a robust comparison of control and impact sites to be made.

8.0 Monitoring and Analysis Techniques

The GDE Toolbox – Part 2 (Richardson 2011b) provides a suite of technically robust tools to identify GDEs and determine their ecological water requirements. These tools are based on established methods repeated in studies within Australia and abroad, many of which are published in peer-reviewed scientific journals. Many of these tools were applied in the EIS GDE characterisation (3d Environmental 2020) and for the purpose of baseline characterisation, are recommended for inclusion as a component of ongoing monitoring. **Table 2** provides a list of tools used in the GDE characterisation and describes their purpose and ongoing relevance to monitoring. Several additional methods adapted from the GDE Toolbox have also been included, being recommended components of an ongoing monitoring program. Technical details of recommended assessment methods are provided in **Appendix B**.

Table 2. Assessment methods that will be applied during GDE monitoring.

Assessment Method	Utilised in ID GDE Characterisation	GDE Toolbox Method No.	Method Description	Primary Utility
Conceptual modelling	Yes	Tool 2	Aims to conceptualise the interactions between biotic factors (e.g., trees) and abiotic (e.g., soil, surface water and groundwater). Conceptualisation formalises the understanding of the major components of a GDE system and allows impact pathways to be contextualised.	Conceptualisation and informing monitoring program design and implementation.
Leaf water potential	Yes	Tool 3	LWP provides the primary biophysical measure of tree water availability and defines a continuum between the relationship of soil, water and plant. Trees associated with high water availability will have a high (least negative) LWP. LWP provides an indication of which trees have access to a saturated or near saturated water source, although does not identify the nature of the source (i.e., groundwater, saturated pockets in the soil, surface water from stream pools).	Site based assessment with some application for seasonal monitoring to identify plant water deficits. Used in conjunction with Leaf Area Index (LAI).
Stable Isotopes of water in plants	Yes	Tool 4	The stable isotopic signature ($2H$ and $18O$) of the dominant water source for a tree will be imparted on its hydraulic architecture, typically measured in twigs. The stable isotope signature in twigs may be directly analogous to a single water source if that source provides a predominant contribution to a trees water requirement. It may also be a combination of a number or sources, requiring a mixing model to be employed to calculate relative contributions of each water source.	Identifies plant water sources. Monitoring application in the initial two-year baseline investigation to: 1. Determine the proportions of various water sources used by tree in response climate controls. 2. Determine how these contributions change over a seasonal cycle to fully evaluate the GDE risk profile.
Leaf Area Index	No	Tool 1, Tool 2	Leaf Area Index (LAI) is a ratio of the total leaf area within a canopy to the ground area covered by the canopy. It is a measure of canopy vigour and the	A fundamental application used in monitoring, in conjunction with remote sensing, to measure

Assessment Method	Utilised in ID GDE Characterisation	GDE Toolbox Method No.	Method Description	Primary Utility
			rationale applied is that plants with access to permanent sources of water (i.e., groundwater) will have greater vigour and LAI than vegetation that has only periodic access to groundwater resources (e.g., Zolfagher 2014). LAI is likely to vary on a seasonal basis if the sustaining source of moisture is variable, or the groundwater is only seasonally utilised.	seasonal variation in vegetation health.
Remote sensing	No	Tool No 1	Assessment utilises the Normalised Difference Vegetation Index (NDVI) as a measure of canopy health and vigour, that can be directly correlated to LAI. It is a widely accepted method and with advances in satellite technology, has the capacity to assess the health of individual trees rather than landscapes.	Application for long-term monitoring once baseline conditions have been established.
Site based groundwater monitoring	Yes – for data from regional groundwater units including the Permian coal measures, Triassic weathered sediments and the Isaac River alluvium.	Tool No 10, 13	Local installation of groundwater monitoring bores targeted to monitor the groundwater source which the GDE is utilising. Additional monitoring bores are proposed to specifically target groundwater / GDE interaction. Groundwater monitoring will include collection of EC and other water quality data.	Long term monitoring applications as a basis to draw correlations with biotic assessment parameters (e.g. LAI). Used to determine mechanisms of groundwater recharge into and discharge from the Isaac River.
Surface Water Monitoring	Ongoing monitoring under the developed REMP.	Tool No 10	Ongoing monitoring of surface water flows and quality from dedicated monitoring points (see Section 3.4.5).	Long term monitoring applications to draw correlations between surface flows and recharge of the Isaac River alluvium.
Riparian Monitoring Program	Yes – baseline data from terrestrial ecology surveys to characterise regional ecosystems composition, structure and biocondition.	n/a	Permanent riparian habitat quality monitoring sites have been established as a component of the terrestrial ecology impact assessment studies (EcoSM 2020). The quality and condition of habitat associated with GDEs associated with the Isaac River frontage potentially impacted by groundwater drawdown, as well as locations outside the area of proposed impact, will be monitored. Species specific habitat indices will also be	Site based assessment with some application for seasonal monitoring to assess changes in habitat quality in the riparian zone. Monitoring undertaken to inform: changes in GDE health have resulted in changes in habitat

Assessment Method	Utilised in ID GDE Characterisation	GDE Toolbox Method No.	Method Description	Primary Utility
			assessed in line with Queensland Government's Guide to Determining Terrestrial Habitat Quality – a toolkit for assessing land-based offsets under the Queensland Environmental Offsets Policy, Version 1.3. Additional sites may be required in GDE assessment localities chosen as control sites (see Section 8.1).	quality for the above listed species • remediation measures, if required, have benefited habitat quality • changes in habitat quality are in exceedance of the disturbance thresholds and require offsets.

8.1 Site Selection and Application

Table 3 provides the recommended data collection requirements for each of the chosen monitoring parameters. Parameters to be applied include LAI, LWP, NDVI image capture, stable isotope assessment of twig xylem, soil, surface water and groundwater. Data collection will occur within GDE Area 1 and GDE Area 2 including a control site located upstream at (-22.04613 / 148.14992) and downstream (-22.08047 / 148.20736). The upstream control site is approximately 4.5 km upstream from the northern limits of the predicted drawdown area in the Isaac River alluvium (2.8 km direct to the north-east). The downstream monitoring site is located 600m downstream from the confluence of Isaac River and Southern Gully, within an area where drawdown of the water table is not predicted. The location of the downstream monitoring site is constrained by the influence of the Poitrel Mine void which is a further 5km downstream. Specific detail on proposed monitoring methods is provided for statistical analysis (**Section 8.3**), stable isotopes (**Section 8.4**), NDVI analysis (**Section 8.5**) and groundwater monitoring (**Section 8.6**) with general information on monitoring procedures provided in the **Appendix B** as listed below:

1. LWP and SMP provided in **Appendix B1**
2. Stable Isotope analysis in **Appendix B2**
3. Measurement of field-based LAI in **Appendix B3**
4. NDVI assessment in **Appendix B4**
5. Groundwater monitoring bores in **Appendix B5**.

The location of areas proposed for specific monitoring activity is provided in **Figure 12** with summary of assessment sites provided in **Table 3**, and details of the sampling program in **Table 4**. The monitoring includes GDE sampling within predicted drawdown and non-drawdown areas (including control sites), and the related / nearby groundwater monitoring bores, habitat quality sites from EcoSM (2020) and surface water monitoring locations. The proposed GDE assessment sites in relation to predicted drawdown zones are shown in **Figure 13**. Where possible, sample points, including trees, should include those that were sampled during the EIS assessment (3d Environmental 2020) to facilitate dataset continuity, with sampling locations from the EIS shown in **Appendix C**.

Table 3. Sampling localities and associated monitoring programs and linkages.

Location	Drawdown Zone	Sites from EIS Study*	Relevant Groundwater Monitoring Bores*	Relevant Habitat Quality Sites
Drawdown Site 1 (DD1)	Zone 4	NA	MBID11, MBID21	HQ15, HQ16
Drawdown Site 2 (DD2)	Zone 4	Site 6	MBID03, MBID23	HQ13, HQ14
Drawdown Site 3 (DD3)	Zone 4 / Zone 3	NA	MBID07, MBID22, MBID28, RN162817	HQ11, HQ12
Drawdown Site 4 (Southern Gully) (DD4)	Zone 2	NA	MBID25, MBID26	HQ4
Non-drawdown Site 1 and Site 2 (ND1_2, ND3)	Zone 1	Site 1, Site 2	MBID01, MBID19	HQ17, HQ18, HQ21
Non-drawdown Site 3	Zone 1	Site 3	MBID01, MBID17	HQ22, HQ23
Upstream Control (IDUC)	Zone 1	NA	MBID17	To be established
Downstream Control (IDDC)	Zone 1	NA	MBID25	HQ5

*Includes groundwater monitoring bores installed into alluvium and weathered Triassic sediments.

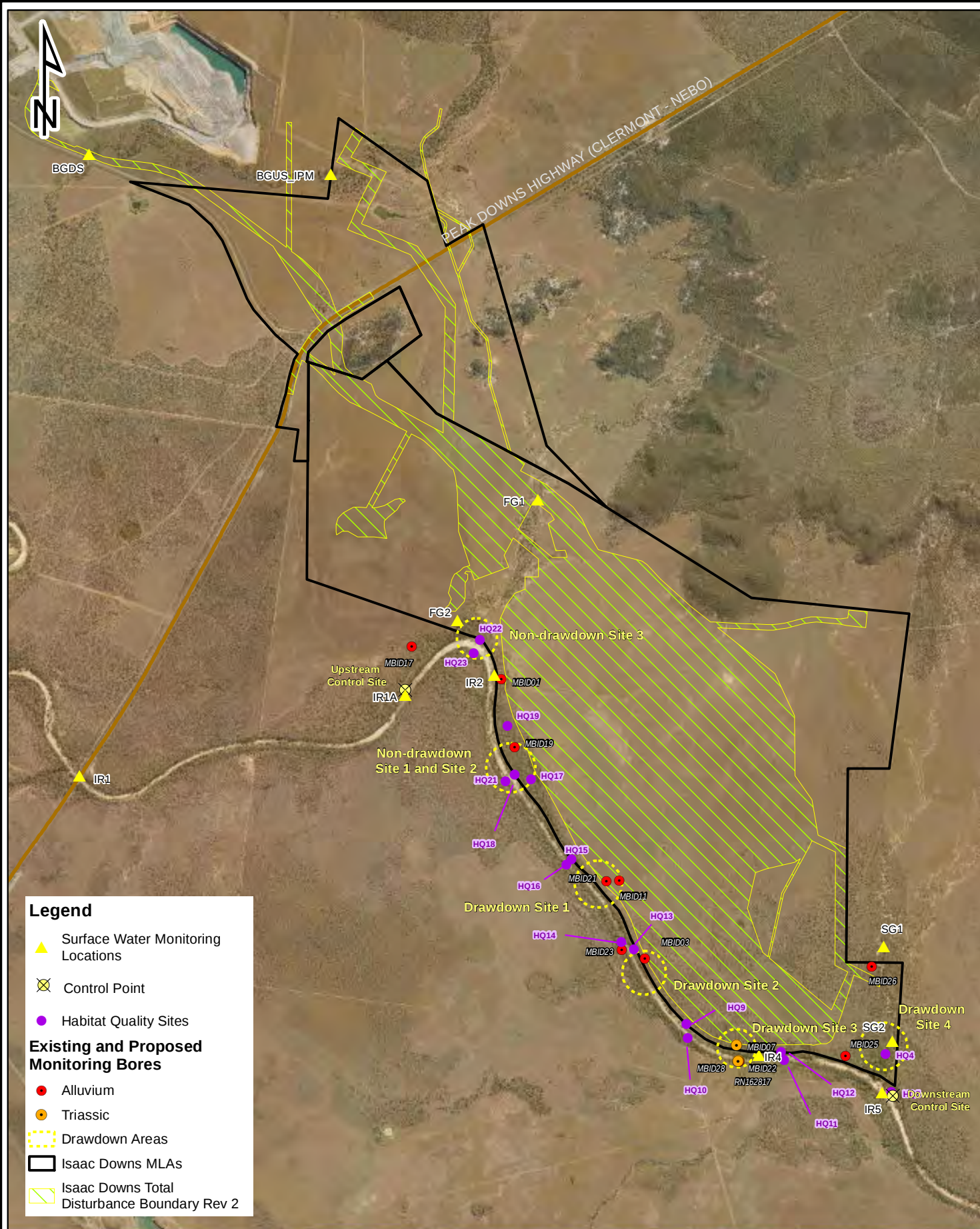
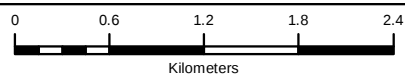


Figure 12. Location of proposed GDE assessment sites for ongoing monitoring.

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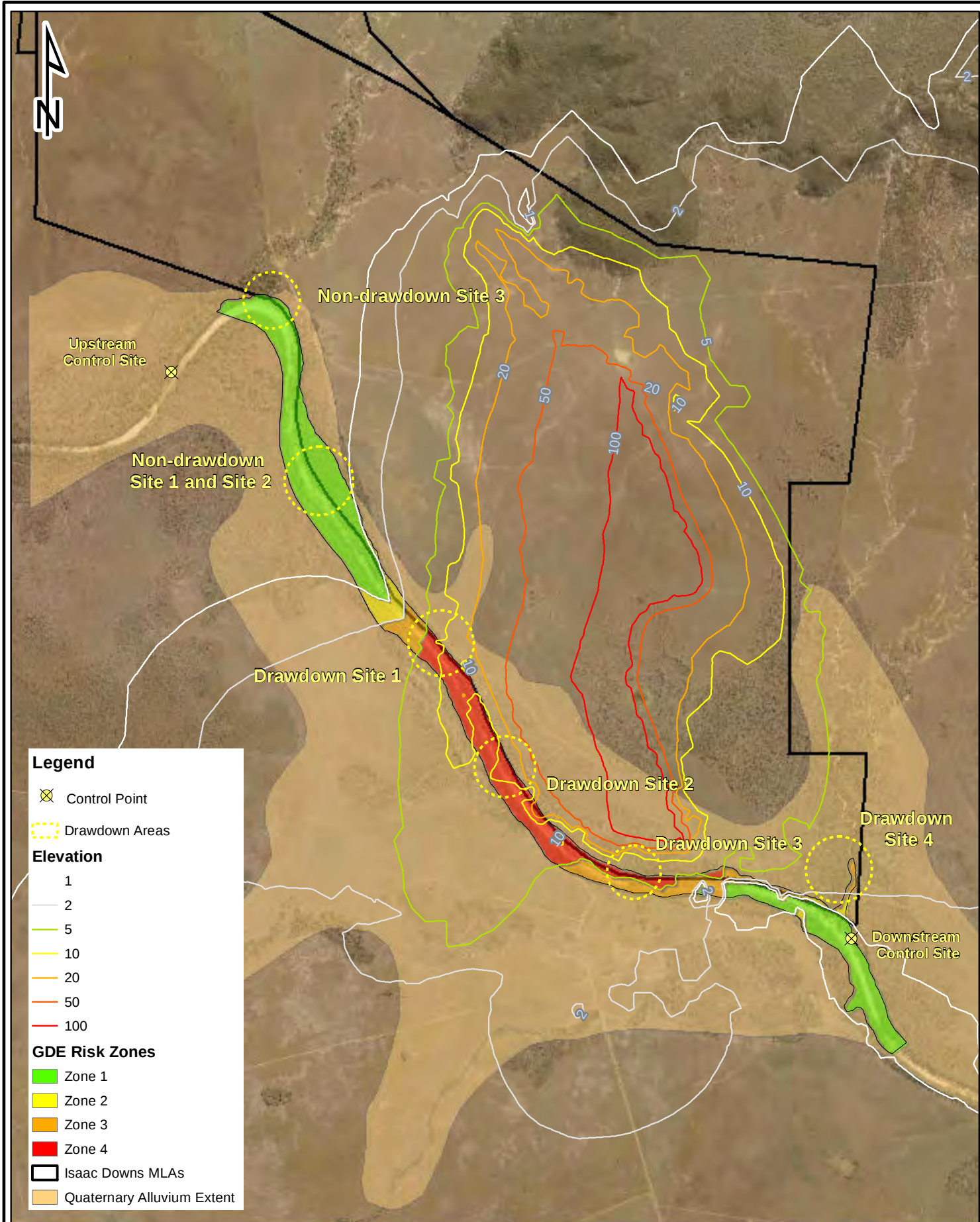
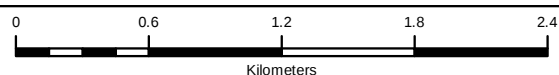


Figure 13.. Location of GDE assessment sites in relation to GDE risk zones.

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Table 4. Proposed GDE sampling program

Sampling Method	Sampling Locality	Sampling Intensity
LAI	Isaac River alluvium predicted drawdown area	A minimum of 15 permanently located capture points in the predicted drawdown area including: a) Five capture points in the vicinity of groundwater monitoring bore MBID11 and MBID21, coinciding with habitat quality sites* HQ15 and HQ16 (DD1). b) Five capture points in the vicinity of groundwater monitoring bore MBID03 and MBID23 which coincides with Site 6 from the EIS GDE assessment#. This locality coincides with habitat quality site HQ13 and HQ14 (DD2). c) Five capture points in the vicinity of groundwater monitoring bore MBID07, MDID22 and MBID28 which coincides with habitat quality sites HQ11 and HQ12 (DD3). d) Five capture points in the vicinity of monitoring bore MBID25 and MBID26 which coincides with habitat quality site HQ4 (DD4).
	Isaac River ID MLA outside the drawdown area.	A minimum of 10 permanently located capture points including: a) Five capture points in GDE Area 1 covering Site 1 and Site 2 from the EIS GDE assessment#. Capture points will coincide with groundwater monitoring bore MBID01 and MBID19 and habitat quality sites HQ17, HQ18 and HQ21 (ND1_2). b) Five capture points at Site 3 from the EIS GDE assessment#. Capture points are to coincide with habitat quality sites HQ22 and HQ23 with the nearest groundwater monitoring bore being MBID01 and the reference bore MBID17 (ND3).
	Isaac River Control Sites	A minimum of 10 permanently located capture points including: a) Five capture points at the upstream control site. b) Five capture points at the downstream control site at Southern Gully.
LWP ³	Isaac River alluvium predicted drawdown area	A minimum of 15 capture (tree) points in the predicted drawdown area including: a) Five trees in the vicinity of groundwater monitoring bore MBID11 and MBID21, coinciding with habitat quality sites* HQ15 and HQ16 (DD1). b) Five trees in the vicinity of groundwater monitoring bore MBID03 and MBID23 which coincides with Site 6 from the EIS GDE assessment#. This locality coincides with habitat quality site HQ13 and HQ14 (DD2). c) Five trees in the vicinity of groundwater monitoring bore MBID07, MDID22 and MBID28 which coincide with habitat quality site HQ11 and HQ12 (DD3). d) Five capture points in the vicinity of monitoring bore MBID25 and MBID26 which coincides with habitat quality site HQ4 (DD4).
	Isaac River ID MLs outside the drawdown area.	A minimum of 10 capture (tree) points including: c) Five trees in GDE Area 1 covering Site 1 and Site 2 from the EIS GDE assessment#. These trees coincide with groundwater monitoring bore MBID01 and MBID19 and habitat quality sites HQ17, HQ18 and HQ21 (ND1_2). d) Five trees at Site 3 from the EIS GDE assessment#. These trees coincide with habitat quality sites HQ22 and HQ23 with the nearest groundwater monitoring bore being MBID01 and the reference MBID17 (ND3).

Sampling Method	Sampling Locality	Sampling Intensity
	Isaac River Control Sites	A minimum of 10 capture (tree) points including: c) Five trees at the upstream control site. d) Five trees at the downstream control site at Southern Gully.
Stable Isotopes ²	All localities	The aim of the stable isotope program will be to determine the relative proportion of each moisture source being utilised by groundwater dependent vegetation and is to be completed as a component of the 2-year intensive data collection period. Further details of the purpose of the stable isotope sampling program are provided in Section 7.4 which details the methods to be applied. Sampling for stable isotopes will be completed for a minimum: a) 12 trees within the drawdown area including: a. three trees in the vicinity of groundwater monitoring bore MBID11 and MBID21, coinciding with habitat quality sites* HQ15 and HQ16 (DD1). b. three trees in the vicinity of groundwater monitoring bore MBID03 and MBID23 which coincides with Site 6 from the EIS GDE assessment[#] (DD2) and habitat quality site HQ13 and HQ14. c. Three trees in the vicinity of groundwater monitoring bore MBID07, MDID22 and MBID28 which coincides with habitat quality site HQ11 and HQ12 (DD3). d. Three trees in the vicinity of monitoring bore MBID25 and MBID26 which coincides with habitat quality site HQ4 (DD4). b) A minimum of six trees from GDE Area 1 including Site 1 and Site 2 from the EIS GDE assessment[#] c) A minimum of six trees from control sites, including three trees from the upstream control site and three trees from the downstream control site at Southern Gully. Stable isotope sampling will cover: d) Twigs from representative trees (12 from the area of predicted drawdown (DD1 to DD4), six from outside drawdown area (ND1_2, ND3) and six from control) e) Surface water from flows, if available at time of survey. f) Groundwater stored in riverbed (bank) sand aquifer in the river channel. g) Groundwater from alluvial monitoring bores collected during routine sampling events. h) Soil samples from auger holes, including 7 auger holes (three in the drawdown area; Two outside drawdown area; Two at control sites).
NDVI Capture	Approximately 100km ² capture to cover the relevant parts of Isaac Downs MLs ensuring the full extent of the GDE monitoring area to be covered	High resolution imagery from the WorldView 3 and WorldView 4 satellites (0.3m resolution, 4 -16 band multispectral) is recommended and will allow detailed monitoring of canopy vigour at extremely fine scale. The application of NDVI Imagery for the purpose of monitoring GDE / Vegetation health is discussed in Section 7.5. Localities will be established for permanent monitoring of NDVI to coincide with areas proposed for GDE monitoring and the location of habitat quality

² Collection of LWP and the analysis of stable isotopes was completed in the EIS assessment (3d Environmental 2020) and hence can be augmented with the intensive data collection period.

Sampling Method	Sampling Locality	Sampling Intensity
	(including control sites).	transects. Established transects will be 100m length with measurement of NDVI completed at 1m centres along transect.
Groundwater Monitoring Bores	GDE monitoring bores as part of the dedicated groundwater monitoring program.	Monitoring bores which are applicable to monitoring of impacts to GDEs include existing and proposed bores installed in the Isaac River alluvium and Triassic weathered sediments being MBID01, MBID03, MBID11, MBID17, MBID19, MBID21, MBID22, MBID23, MBID25, MBID26, MBID27, MBID28, RN162817. Monitoring of groundwater quality will be undertaken monthly or quarterly in accordance with the Isaac Downs groundwater monitoring program and will include parameters detailed in Section 10.2.4. The location and timing of groundwater monitoring bores (and the associated groundwater monitoring program) coincides with sites proposed for measurement of LAI, NDVI and riparian habitat quality to allow results for all parameters to be directly comparable.

* From the Terrestrial Ecology Impact Assessment Report prepared for ID by EcoSM (2020).

#From the Groundwater Dependent Ecosystem Assessment Report prepared for ID by 3d Environmental (2020a).

8.2 Interactions with Established Monitoring Programs and Parameters

The following interactions with monitoring programs that are either existing, or will be developed as a component of the ID project approval process:

1. **Surface water:** Surface water quality and environmental flows will be a component of the ID mine site REMP that has been developed (FRC 2020a), allowing for early detection of any impacts and employment of appropriate corrective actions. Surface flow and water quality datasets will be used, in conjunction with other parameters, to inform the baseline characterisation of the Isaac River GDE system and assess project impacts.
2. **Riparian habitat quality:** A riparian habitat quality monitoring program will be applied, utilising the habitat quality sites assessed by EcoSM (2020) to complement 'early warning' vegetation parameters measured as a component of the GDE monitoring program. The riparian monitoring program will assist measurement of the significance of any impacts to GDEs resultant from activities associated with the ID Project.
3. **Groundwater:** The groundwater monitoring program is described in AGE (2020). The program covers operation of the monitoring bore network established as part of the EIS groundwater investigations and will be continued throughout the life of the Project. Records of groundwater levels and water quality from monitoring bores will continue to provide baseline information for groundwater fluctuations in response to rainfall and Isaac River flow. These measurements will be used to distinguish groundwater drawdown resulting from proposed mining activities from natural fluctuation and provide a basis for investigation that can be related to the health and function of GDEs. Further information on the groundwater monitoring network including existing and proposed bores and water quality parameters is provided in **Section 8.6**.

8.3 Detection of Trends and Statistical Analysis

The BACI (Before After / Control Impact) provides a statistically robust survey design to test for environmental change in response to disturbance. The method takes single impact site and a single control site (outside the impact area) before and after the management or impact has occurred to detect environmental change. In this regard, the proposed monitoring program includes:

1. Four monitoring sites (comprising multiple trees and LAI capture points) within the area of proposed groundwater drawdown (see **Table 4**).
2. Two sites outside the area of predicted groundwater drawdown, though adjacent the Project mining leases.
3. Two control sites located upstream and downstream from the area of groundwater drawdown in the Isaac River alluvium.

Statistical analysis will need to consider interactions between multiple datasets to establish baseline conditions and allow identification of statistically significant deviations from these conditions that may be associated with ID Project mining activities. The most critical interactions will be between biotic health (typically measured in LAI, LWP and NDVI) and abiotic factors such as groundwater levels and salinity. Statistical tests applied to analysis of data will depend on whether datasets are normally distributed and may include bivariate analysis of two datasets (e.g., NDVI and LAI) applying a Pearson or Spearman Correlation. 'T-tests' will be applied to identify significant differences in mean values between sampling localities. More complex statistical analysis may be applied if investigative actions are required including multivariate analysis of variance (PERMANOVA) to interacting datasets.

The overriding purpose of the data collection and subsequent statistical analysis is to provide representation of natural variation in the system applied to both biotic factors and abiotic controls and allow appropriate trigger thresholds to be proposed, which are further discussed in **Section 9.0**.

8.4 Application of Stable Isotopes to Determine Relative Contribution of Various Moisture Sources Utilised by Groundwater Dependent Vegetation.

The two-year intensive data collected period will be used to refine existing information on the sources of water utilised by groundwater dependent vegetation, including relative contribution each moisture source makes to a tree's total water budget. While it may not be possible to precisely determine these proportions, it will be possible to determine the dominant sources of moisture utilised by trees at any sampling event. The process will involve:

1. Collection of xylem stable isotope samples from all trees proposed as permanent monitoring points (see **Table 4**) to determine isotopic signatures. To maximise the capacity to identify variations in moisture sources, trees proposed for sampling should be located at various geomorphic positions on the stream bank including trees at the foot of the bank, and trees on the upper terrace.
2. Collection of soil samples for stable isotope analysis from seven dedicated auger holes, four within the area of groundwater drawdown, one within GDE Area 1 (outside of drawdown area) and two augers placed at a control site. Augers should be:

- a. A maximum depth of 5m, or down to intersection with basement rock or groundwater strike.
 - b. Sampled at 0.5m intervals down the soil profile.
3. Collection of groundwater held in riverbed (bank) aquifer associated with the Isaac River channel for stable isotope analysis.
4. Opportunistic collection of rainfall for stable isotope analysis.
5. Opportunistic collection of water from Isaac River surface flows for stable isotope analysis.
6. Collection of groundwater from groundwater monitoring bores installed into the Isaac River alluvium for stable isotope analysis.

At a minimum sampling will need to be undertaken on a biannual basis, with collection of rainfall and surface water to be undertaken opportunistically throughout the baseline assessment period.

While comparison of stable isotope signatures in biplots, as completed during the EIS assessment (3d Environmental 2020), provides a rapid means to identify the predominant sources of moisture utilised by vegetation, analysis of time series (seasonal) datasets may provide a measure of the water source partitioning of trees (i.e., the proportions used of each potential moisture source) during the various seasons. The Line Conditioned Excess method (Petit and Froend 2018) provides the simplest analysis technique, which relies on establishment of a local meteoric water line (LMWL) applying the method of Crosbie (2012), which can be used to identify stable isotope datasets that have undergone significant evaporative fractionation. To test for evaporative isotopic enrichment, the line-conditioned excess (or precipitation offset as per Evaristo et al., 2015) of soil moisture, xylem water, groundwater and other collected water sources will need to be calculated ($lc\ excess = [\delta^2H - a\ \delta^{18}O - b]/S$ where a and b are the slope and intercept of the LMWL, and S is the standard deviation of both δ^2H and $\delta^{18}O$ values). Where $lc\ excess$ values are close to zero, it indicates values similar to rainfall isotope values that have not been affected by high rates of evaporation (as per Petit and Froend 2018). By comparing the $lc\ excess$ for soil moisture, surface flows, stored groundwater in the channel, groundwater, and xylem water, it will be possible to identify which moisture sources are significantly different from each other. This provides a fingerprinting tool for the comparison of the $lc\ excess$ for xylem moisture to groundwater and other potential moisture sources will enable the 'degree of similarity' to be calculated, and identification of the dominant source of moisture utilised during typical seasonal variation. More importantly, it will make it possible to identify the variety of water sources utilised by trees that occur at various distances from the river channel and positions on the stream bank, allowing impacts to vegetation that result from groundwater vegetation to be more accurately predicted. The basis and process for stable isotope sampling and analysis is provided in **Appendix B2** with raw data from stable isotope sampling undertaken during the EIS assessment provided in **Appendix D**.

8.5 Application of NDVI Analysis

The NDVI datasets will provide a permanent record of vegetation health captured biannually during the intensive data collection period, with annual capture in the following period thereafter. To provide analysis of vegetation health that can be repeated precisely between capture events, permanently placed 100m transects will be co-located with habitat quality sites (from EcoSM 2020) at each of the eight proposed GDE monitoring sites detailed in Table 3. Two additional sites will be established on Southern Gully and Conrock Gully upstream from the confluence of the Isaac River, to

monitor health of riparian vegetation associated with these tributaries. Using permanent transect start and end points (from either relevant habitat quality sites or other established locations), the NDVI value will be sampled at 1m intervals along each transect (101 points in total from start to end point). This will extract data that can be presented in a line graph, to represent seasonal variation between survey events (see **Appendix B4**). A minimum of eleven transects in total are to be selected within:

1. Each of the four drawdown sites (Drawdown Site 1 to Site 4)
2. Each of the three non-drawdown sites (Non-drawdown sites Site 1 to 3).
3. The upstream and downstream control sites.
4. A selected transect within RE11.3.25 in Southern Gully.
5. A selected transect within a riparian RE in Conrock Gully.

Additional locations for permanent transects may be chosen through the monitoring period should information gaps be identified which require additional NDVI data collection to address.

8.6 Groundwater Monitoring

The objective of the groundwater monitoring network design was to provide information to conceptualise the site hydrogeology and provide a monitoring network to establish baseline conditions. Of relevance to GDE function, the groundwater monitoring network will continue to provide baseline information concerning fluctuations in the groundwater table as a response to rainfall and Isaac River flow and assist identification of depressurisation of the alluvial aquifer and Triassic weathered sediments that is associated with mining activities. Groundwater quality and salinity will form part of the ongoing suite of chemical parameters that will be measured.

Groundwater monitoring bores will be manually dipped on at least a three-monthly frequency for all monitoring bores. Continuous groundwater level loggers have been installed in all monitoring network bores (excluding one landholder bore), and will be installed in proposed bores, to provide detailed information of water level changes from rainfall or Isaac River recharge, extended dry conditions, landholder bore activity and information on changes to groundwater levels when the Project commences.

Groundwater quality samples have been collected from nine sampling events between November 2018 to July 2020, with further monthly sampling after July 2020 until present. The sampling was undertaken from a subset of the monitoring bores within the monitoring network.

Existing and proposed groundwater monitoring bores, their purpose and function for ongoing monitoring (including monitoring of water levels and quality alluvium and Triassic weathered sediments) are described in groundwater impact assessment for the EIS (AGE, 2020).

Groundwater Quality Parameters: In the context of GDE health, salinity and standing water level are the most critical chemical and physical monitoring parameters. There are currently no water quality guidelines for GDEs that rely on subsurface expression of groundwater that characterise the Project area. The suite of water quality parameters that are important for vegetation health should be considered as part of the groundwater monitoring program (Australian Government 2013) and would include:

1. Salinity
2. Dissolved oxygen

3. pH
4. nitrogen
5. phosphorus
6. organic carbon

8.7 Summary results of dry season (November 2020) GDE monitoring assessment.

A late dry season field based GDE monitoring assessment has been completed between 20th and 24th November 2020 applying the proposed GDE sampling program detailed in **Table 4 (Section 8.1)**. The assessment coincided with an extremely dry preceding period with only 69.5mm of precipitation falling in the preceding 6 months (June to November) which is significantly below long-term average for those months of 233.8mm (SILO 2020), meaning vegetation would have been subject to maximum seasonal water stress. A dedicated monitoring report is being prepared, pending receipt and analysis of all assessment parameters. The following provides an interim summary of assessment results:

1. **Suitability of control and impact monitoring sites:** T-tests have been completed comparing LAI values from upstream / downstream control sites³ with LAI values from areas where drawdown is predicted and areas where drawdown is not predicted (ND1_2, ND3 as per **Table 3** and **Figure 12**). The T-tests indicate that some statistically significant differences occur between mean LAI values for these monitoring localities, although utilisation of both an upstream and downstream control site provides representation of structural endpoints enabling a meaningful comparison between monitoring localities for ongoing monitoring purposes. A summary of T-test results, mean LAI values per GDE monitoring area and raw data from the LAI field measurements is provided in **Appendix E1, Appendix E2** and **Appendix E3** respectively.
2. **Percentile values for LAI with potential application as impact thresholds:** The following LAI percentile values have been calculated for the four predicted drawdown sites (DD1, DD2, DD3, DD4), two sites outside the area of predicted drawdown (ND1_2, ND3) and the two control sites (IDUC, IDDC). These values may have application for setting disturbance thresholds at the completion of the baseline monitoring assessment:
 - a. Drawdown sites (DD1, DD2, DD3, DD4)
 - i. LAI average value = 0.5428
 - ii. 10 percentile LAI value = 0.3400
 - iii. 20 percentile LAI value = 0.4081
 - b. Non-drawdown sites (ND1_2, ND3)
 - i. LAI average value = 0.7417
 - ii. 10 percentile LAI value = 0.5455
 - iii. 20 percentile LAI value = 0.5701
 - c. Control sites
 - i. LAI average value = 0.5252
 - ii. 10 percentile LAI value = 0.3803
 - iii. 20 percentile LAI value = 0.4292

³ The location of upstream and downstream control sites has been adjusted following completion of dry season monitoring assessment and results from updated control site localities will be incorporated into all subsequent monitoring reports.

3. **LWP assessment:** Pre-dawn LWP measurements from 41 individual trees spread across the eight GDE monitoring areas have been captured. The monitoring assessment included trees measured during the EIS assessment where practical. **Appendix E4** provides a summary of mean LWP measurements per GDE monitoring area with **Appendix E5** providing raw field data including LWP measurements of trees undertaken during the EIS assessment. The LWP measurements support the conclusion of the EIS assessment, that groundwater reliance is patchy and discontinuous along the river frontage, with many trees demonstrating extremely low LWP values that are not consistent with groundwater utilisation.
4. **NDVI analysis:** High resolution imagery sourced from the WorldView 4 satellite (0.3m resolution, 4 -16 band multispectral) has been acquired (capture date 30 November 2020) to complement the field measured parameters. A total of 15 x 100m monitoring transects were placed at GDE monitoring locations coincident with groundwater monitoring bores and habitat quality monitoring sites with NDVI values have been captured at 1m intervals along each transect. The permanent placement of these transects will enable repeat measurement of canopy vigour with comparisons made on a seasonal basis. Raw plots from the NDVI transects at control and impact sites are provided in **Appendix E6** with a comparison of mean NDVI values for each monitoring area provided in **Appendix E7**. Raw NDVI and natural colour imagery captured during the assessment, shown in relation to GDE monitoring areas, LAI and LWP capture points is provided in **Appendix E8** and **Appendix E9**.
5. **Correlation analysis:** Pearson correlation (r) analysis identified the following relationships between monitoring parameters following the initial phase of GDE monitoring:
 - a. A strong and statistically significant positive correlation ($r = 0.927$; $p=0.008$) is calculated between average NDVI value (taken from representative NDVI transects) and average LAI for six of the assessment sites (IDUC, DD1, DD2, DD3, DD4, ND 1_2). For IDDC and ND3, this correlation breaks down and further collection of temporal data will be required to understand the anomalous nature of values at these localities. Graphical representation of average NDVI and LAI values per monitoring locality is provided in **Figure 14**.
 - b. A strong and statistically significant positive correlation ($r = 0.7316$; $p=0.039$) is calculated between average NDVI value (taken from representative NDVI transects) and average LWP for all assessment sites (**Figure 15**). This indicates that canopy vigour (in terms of chlorophyll abundance) is strongly controlled by moisture availability.
 - c. At the completion of the initial monitoring assessment, no statistically significant correlation could be identified between LWP and LAI calculated for individual trees ($r=0.1734$, $p=0.2783$). While additional temporal monitoring will be required to confirm the relationship between these parameters, this initial result suggests that foliage density can be maintained at relatively low levels of water availability for trees that are naturally adapted to conditions of water deficit (i.e., tolerant of low LWPs under natural conditions) (see **Figure 16**), and a low LWP does not necessarily constitute a tree with poor canopy health.

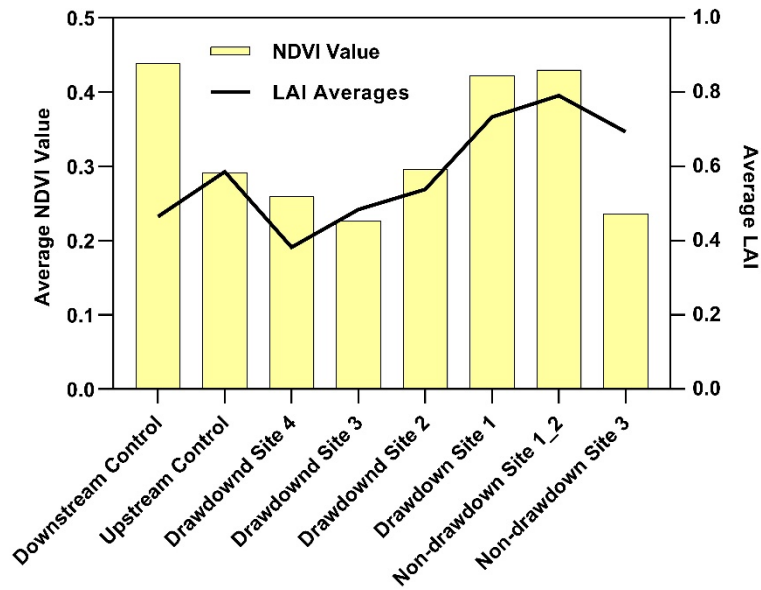


Figure 14. Correlation between average NDVI and average LAI for GDE monitoring sites, with a breakdown in correlation evident for the Downstream Control and Non-drawdown Site 3.

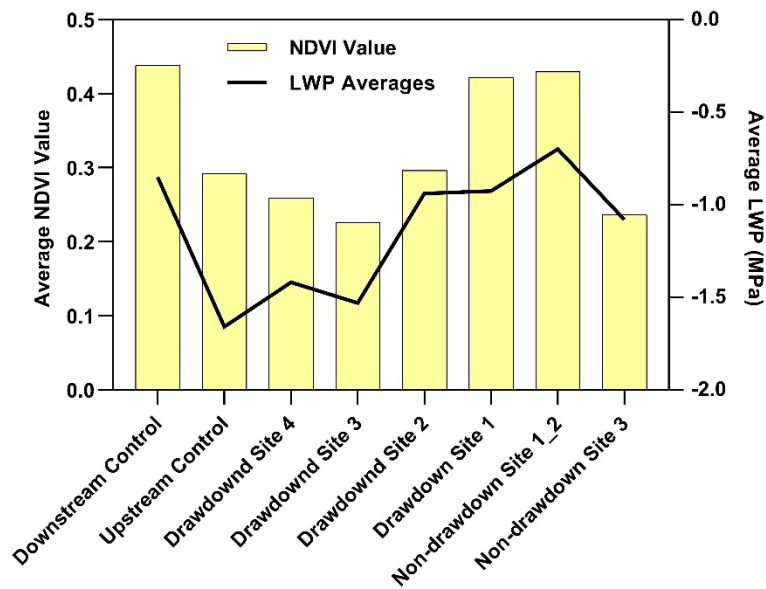


Figure 15. Correlation between average NDVI value and LWP averages for each GDE monitoring site.

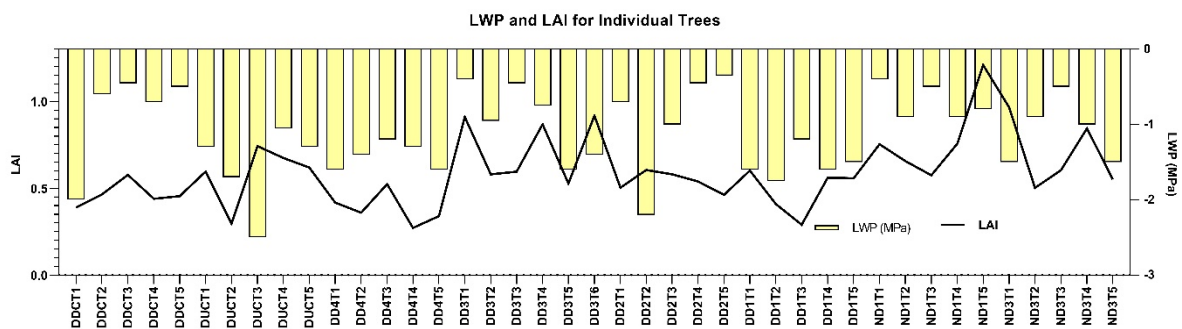


Figure 16. Comparison of LAI and LWP for individual trees at each GDE monitoring assessment locality.

9.0 Reporting, Periodic Review, Timing and Objectives

General program: This GDEMMP proposes methods that will result in collection of baseline ecological and biophysical data that will facilitate increased understanding of the ecohydrological function of the Isaac River GDE system. During compilation and analysis of monitoring data, information gaps or data trends may be identified that indicate a need to update the GDEMMP approach and methods. To accommodate this requirement:

1. Reporting will be prepared at the completion of each monitoring event which describes:
 - a. Methods employed.
 - b. Factors that may have influenced data and monitoring results.
 - c. Data trends for each of the parameters measured.
 - d. Information gaps which may influence the assessment.
 - e. Correlations between datasets which characterise ecological function.
 - f. Trends which appear abnormal or indicative of unexplained / un-natural decrease in ecological function, warranting further investigation or corrective action.
2. Bi-annual monitoring (four events covering two wet seasons and two dry seasons) should be undertaken for a two-year period.
3. At the completion of four monitoring events (excluding the original GDE assessment associated with the EIS), a consolidated report will be prepared which provides a synopsis of the data collected, including correlations between parameters and statistical analysis (where possible) of seasonal ecological function.

The aim of the four-event intensive data collection period is to determine the range of natural seasonal variation in the measured parameters, particularly LWP and LAI which are fundamental indicators of plant stress. These parameters can be correlated to the NDVI signature, which will allow future monitoring to be undertaken remotely at an 'on demand' basis, supplemented with field assessment. Additional field sampling assessments may be required if a significant departure from baseline condition is detected. Reporting and review requirements have been incorporated into a proposed two-year monitoring schedule as per **Appendix F**.

Ongoing monitoring following baseline: Following completion of the two-year (four-event) intensive data collection program in March 22, NDVI will be captured on an annual basis during the height of dry season (nominally October / November) to support ongoing monitoring of GDE health. NDVI threshold values will be calculated from correlations to LAI established during the baseline assessment, and annually checked for statistically significant threshold exceedance events that affect the impact site, in the absence of similar affects at the control site. The NDVI capture will be supplemented with field assessment measuring LAI and LWP at dedicated monitoring localities including control and impact sites on a two-yearly basis, at the peak of the dry season (typically October to November). Ongoing monitoring will also include monitoring of groundwater bores and riparian habitat monitoring, as per details provided in **Table 3** and **Table 4**.

Monitoring completion: A monitoring event that includes field assessment of monitoring parameters will be undertaken to coincide with completion of mining at the Project. This event will include:

1. A comparison to the baseline GDE dataset to identify any significant departure from pre-impact conditions.
2. Provision of a summary memorandum detailing ecological condition of the groundwater dependent vegetation at all dedicated monitoring sites including control and impact and future monitoring requirements.

Providing there has been no significant decline in ecological condition that can be attributed to mining operations, follow up field survey periods will be:

1. Two years from completion of mining operations, timed to coincide with the driest portion of the year (typically September to November).
2. Four years following completion of mining operations, timed to coincide with the driest portion of the year.
3. A final survey event at six years following completion of the mining operation, or when rehabilitation of the mine site has been successfully completed.

Capture of NDVI datasets should continue to be completed on an annual basis for the approximate six-year period. Considering the impact of groundwater drawdown on vegetation health can take several years to manifest, a period of six years, or until rehabilitation is successfully completed, should be a sufficient to capture any trend for declining vegetative health that is a result of ID mining activity.

10.0 Triggers for Investigative Action and Supporting Parameters

While groundwater associated with the Isaac River flood plain is an abiotic control on the ecohydrological function of riparian vegetation fringing the Isaac River, it is the actual health of the vegetation that defines GDE habitat values. Vegetation indices will be used to provide a baseline for ecological health and define trigger thresholds to direct when investigative actions are required. The indices used to define trigger thresholds, including potential parameters applied during investigative action are described in following sections. The management framework is intended to be adaptive, with future capacity for update dependent on the ongoing results of the baseline assessment, and any information gaps identified. Data derived from the groundwater monitoring program, specifically water level and water quality data, will provide supporting information to be used in the case that vegetation threshold values are breached, and investigative actions are necessary.

10.1 Vegetative Indices

Section 6.0 (Figure 11) identifies a decrease in LAI as an initial indicator of vegetative stress. LAI is a precursor to more intensive impacts to habitat values including canopy dieback and conversion to an alternative ecological state that may manifest over a longer time frame. LAI varies on a seasonal basis dependent on water availability, generally within the space of weeks to months, with the highest values lagging slightly behind moisture recharge events. Doody et al (2015) document typical annual LAI variation in the range of 14% to 35%, with LAI = 0.5 (i.e., 50% foliage to canopy ratio)

identified as a potential threshold, indicative of critical water stress beyond which vegetation health rapidly declines. This value is taken from river red gum forest on the Murray River and its applicability to the Isaac River GDE system needs to be tested. However, the LAI threshold can be adapted based on the results of pre-impact monitoring assessments. The process for thresholds based on LAI applies the following principles:

1. Collection of time series data of LAI from control and impact sites for a period of two years to establish and test thresholds applied to vegetation indices.
2. Identifying appropriate thresholds which will be applied as a trigger for investigation and provide a mechanism to review the appropriateness of the derived trigger.
3. Statistical analysis of time series data to characterise seasonal differences in assessment parameters at control and impact sites to identify if a threshold breach occurs.

The application of a threshold value for LAI / NDVI intends to provide an 'early warning' which will trigger a requirement for investigation to identify causal factors. This will allow mitigations to be applied to restore vegetation health if a threshold breach is linked to mining activities. Where a threshold breach occurs, appropriate baseline data from a range of biotic and abiotic parameters will be available to provide a sound basis for investigation. **Figure 17** details the process and decision framework from initial data collection through to corrective actions in the case that a threshold breach can be linked to mining activity. The initial two years of the assessment covers wet and dry season surveys, to provide a baseline against which future vegetation condition trends can be assessed. The two-year baseline assessment and decision-making process are as follows:

1. Establish the proposed monitoring sites to capture LAI and supporting biophysical data (LWP and NDVI) at the proposed monitoring localities in an initial dry season assessment event (November 2020). The proposed location of the impact and control sites has been previously identified in **Section 8.1** and **Table 3**.
2. Establish an appropriate trigger threshold value based on the percentile method detailed in DSITI (2017). The proposed process for establishment of the investigative trigger thresholds is:
 - a. Collect LAI data from the proposed impact and control sites (as per **Table 4**) at permanently located monitoring points in the initial dry season GDE assessment.
 - b. Undertake statistical analysis (t-test) to compare dataset means and ensure the appropriateness of the control site for comparative purposes.
 - c. If a significant difference is detected between the mean values of control and impact datasets in the initial assessment, the location of the control site will be re-evaluated.
 - d. Assuming suitability of the control site, set the lower of the 10th percentile (or LAI of 0.5 as per Doody et al 2015, whatever value is lowest) as a trigger value for investigative action.
3. Collect seasonal data (post wet season in March to April 2021) to provide a baseline which incorporates seasonal variation.
4. Complete a follow up dry season assessment (October to November 2021). Assess appropriateness of applied thresholds and assess data for significant differences in means (t-test) to identify if a threshold breach occurs.

5. Undertake a final wet season assessment (post wet season in March to April 2022) to complete the intensive data collection phase.

At each stage, decision pathways are provided when threshold breaches are identified, including requirements for investigative action and corrective measures where causal factors can be linked to mining activity. Corrective actions, including potential requirement for biodiversity offsets in a worst-case scenario, are discussed in **Section 11**.

Following the two-year baseline assessment, statistical correlation between various assessment parameters will be drawn, particularly the relationship between LAI and NDVI to allow ongoing monitoring to be completed remotely on an annual basis, and trigger thresholds to be adapted. The full suite of parameters collected during the baseline assessment period, with their relevance, intended application in both the baseline assessment and longer-term monitoring program is provided in **Table 5**. Supporting parameters are further discussed in **Section 10.2**. The process that occurs after the two-year intensive data collection period will follow the same process as shown in the flowchart in **Figure 17**. Instead of using LAI as a threshold parameter however, NDVI is proposed for use on an annual basis, with a field assessment of LAI and LWP completed every two years as a control measure. Both NDVI and follow up field assessment will be completed in the dry season at impact and control sites to determine if the threshold is exceeded and, if exceeded, trigger the flow chart process for investigation, mitigation (corrective action) and offsets.

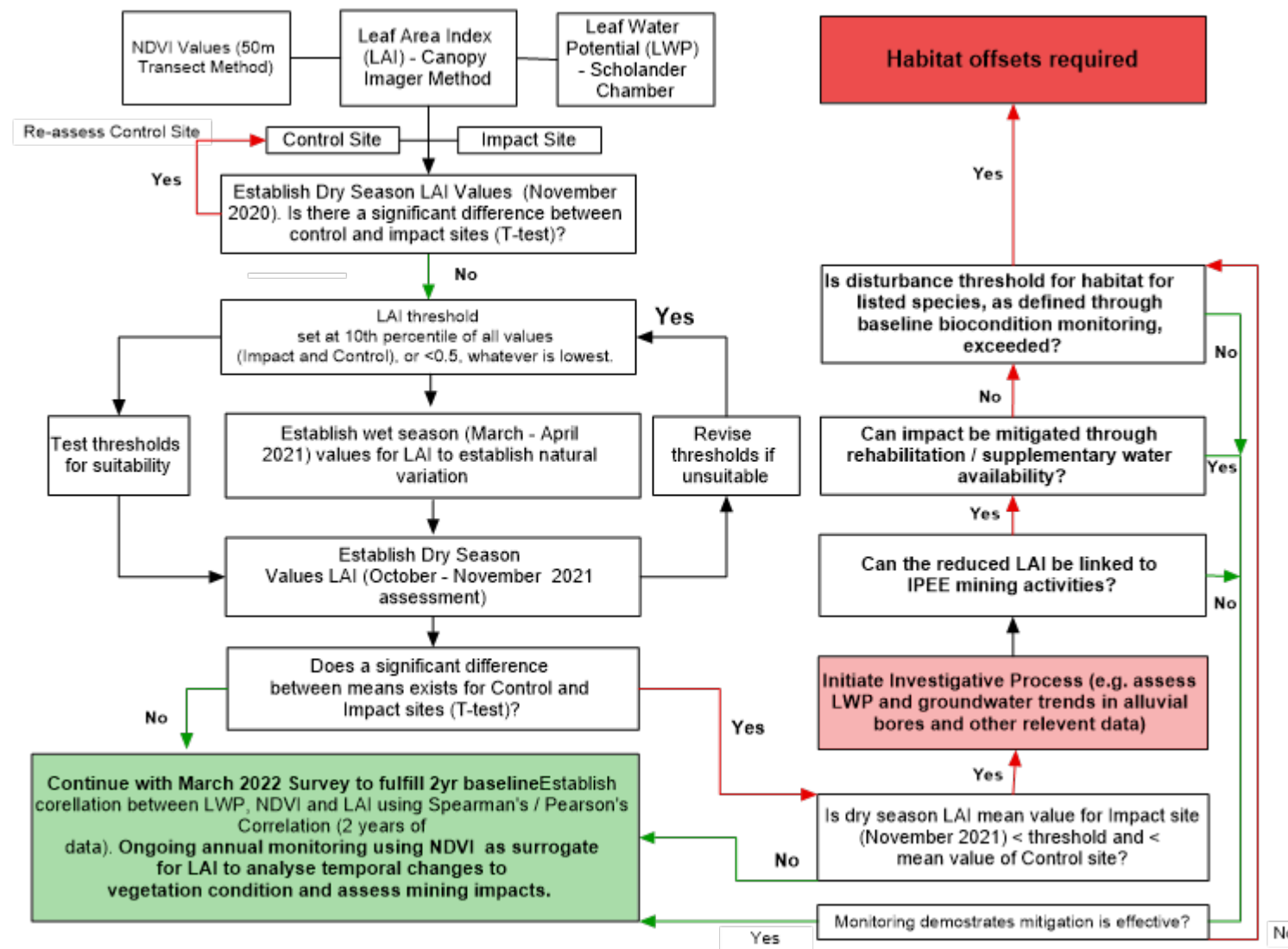


Figure 17. Decision process for application of investigative and corrective actions when trigger thresholds are exceeded for the initial 2-year baseline assessment.

10.2 Supporting Parameters

Supporting parameters are those that will be measured to provide a component of the baseline dataset and will be drawn on to support both the longer-term monitoring program and provide input into investigative action if required. Specifically, these supporting parameters will include LWP, stable isotopes, NDVI and groundwater monitoring in the Isaac River alluvial aquifer and Triassic weathered sediments.

10.2.1 Leaf water potential

LWP provides the primary biophysical measure of tree water availability and defines a continuum between the relationship of soil, water, and plant. While the relationship between LWP and LAI requires further monitoring to be more fully understood, circumstance where LWP remains high and LAI decreases dramatically where this relationship breaks down, indicates factors other than water availability may be influencing the relationship (e.g., insect defoliation). LWP measurements established during the two-year intensive data collection period will be a fundamental consideration for any future investigative action.

10.2.2 Normalised Difference Vegetation Index

NDVI is a measure of vegetation vigour, including a combination of greenness and biomass, which has a direct positive correlation to LAI. A correlation between field-based measurements of LAI and NDVI will be established over the 2-year intensive data collection period, to allow GDE monitoring to be undertaken remotely at a landscape scale on an annual basis. Upon completion of the two-year baseline, trigger threshold values for investigative action will be calculated based on the correlation between LAI and NDVI, and it is proposed that ongoing annual monitoring will utilise high resolution NDVI as a surrogate for field-based LAI / LWP measurements, supported by field sampling every two years. Further information on the NDVI process is provided in **Appendix B4**.

10.2.3 Stable isotopes

The primary role of stable isotope investigations is to inform how sources of moisture utilised by trees vary on a seasonal basis. The process for identifying dominant water sources using stable isotopes is discussed in **Section 7.4** with the dataset used to identify endpoints where vegetation is utilising groundwater alone, shifting in status to primary utilisation of soil moisture in the unsaturated zone, rainfall or surface water from Isaac River flows. While stable isotope analysis provides insight into site ecological function, allowing risks to GDE function to be characterised, its relevance to ongoing monitoring diminishes once a seasonal dataset is established as it is not an indicator of plant health. Stable isotope analyses may be applied beyond baseline dataset collection to support investigative actions when a specific requirement or application is identified, allowing status shifts in seasonal water utilisation to be identified.

10.2.4 Groundwater levels and quality

Groundwater monitoring data which will be useful to characterise GDE function, has been ongoing since the installation of 18 groundwater monitoring bores in late 2018 (November to December 2018 for MBID01 to MBID18), providing two-years' worth of water level and water quality data for

baseline characterisation, with additional monitoring bores installed in June-July 2020. The data will be used to:

1. Monitor linkages between recharge of the alluvial aquifer, surface flows and rainfall.
2. Establish water quality values, particularly for EC and how these may be influenced by recharge from the various sources.
3. Identify the degree to which the alluvial aquifer is utilised by vegetation (typically through analysis of stable isotopes) on a seasonal basis.
4. Identify ecological response to aquifer recharge including correlations between alluvial aquifer recharge, LAI, LWP, NDVI and climate data.
5. Monitor and quantify the impacts of mine pit development on drawdown in aquifers that support GDEs, particularly the aquifer associated with the Isaac River alluvium.

Water levels and water quality can be directly correlated to LAI to determine the relationship between groundwater and vegetation health. While Eamus (2006) defines 1500 $\mu\text{S}/\text{cm}$ as a measure where salinity becomes toxic to red gum, any impact to the seasonality and water quality of the alluvial aquifer will be directly imparted on LAI and supporting vegetative parameters. The ecological response of vegetation to falling groundwater levels cannot be accurately linked or quantified to specific thresholds as it will be influenced by several factors including:

1. The rate of drawdown which directly influences the capacity of trees to adapt to a declining water table and reduced water availability.
2. Water quality, as the response will be influenced by changes to salinity rather than by water levels alone.
3. Surface water flows including timing and duration of flooding.
4. Site specific adaptations to water stress inherent in the local groundwater dependent vegetation including exposure to drought conditions.

Hence thresholds for investigative action that relate to groundwater levels and quality are not proposed in this GDEMMP, which otherwise relies on vegetation indices which define GDE health and function. The chosen vegetation parameter (LAI) will provide a rapid response to detrimental impacts of groundwater drawdown (within weeks), with data from the groundwater monitoring program providing the basis for investigative action as required.

Groundwater Quality Parameters: In the context of GDE health, salinity and standing water level are the most critical chemical and physical monitoring parameters. There are currently no water quality guidelines for GDEs that rely on subsurface expression of groundwater that characterise the Project area. The suite of water quality parameters that are important for vegetation health which will be monitored at bores will include:

1. Salinity
2. Dissolved oxygen
3. pH
4. nitrogen
5. phosphorus
6. organic carbon

In addition, water quality will be sampled quarterly in accordance with the Isaac Downs groundwater monitoring program with continuous monitoring of standing water levels in each monitoring bore measured with pressure transducers.

Table 5. Assessment parameters, application, and analysis.

Data collection method	Purpose	Analysis methods / metrics
Primary Parameter		
LAI	Primary parameter used to measure plant stress and vegetation response to decreasing groundwater.	Threshold to be set at the lower of the 10th percentile for all LAI data from the initial dry season survey (or 0.5 from Doody et al 2015). A threshold response for investigative action will be triggered when: 1. The LAI at the impact site falls below the threshold value. 2. T-test indicates significant differences between means of control and impact sites, and. 3. Impact site has a lower mean LAI value. The initial establishment of the trigger threshold will be undertaken in the dry season 2020 and relies on initial means between impact and control sites to be comparable.
Supporting Parameters		
LWP	A measurement of water availability to trees, which will provide an important correlate with LAI and a baseline dataset to support a future requirement for investigative action. Supporting data which can be used to determine if any future LAI threshold trigger events are related to plant water availability.	1. Pearson / Spearman's correlation to establish if there is a statistical relationship between LAI and LWP as a basis for inclusion in investigative action, if required. 2. Application of a T-test to identify if significant differences between means of control and impact sites exist during the initial dry season assessment.
NDVI	A remotely sensed measurement of vegetation productivity that describes the greenness and the relative density / health of forest biomass.	Confirming the relationship between NDVI, LAI and LWP through application of Pearson's / Spearman's correlation. Longer term application to remotely monitor GDE health at completion of the 2yr intensive data collection period supplemented with field survey.
Stable Isotopes of twig xylem, soil, groundwater and surface water.	Application as a tracer to identify the predominant sources of water utilised by trees. Useful to determine how tree / water interaction varies on a seasonal basis as groundwater levels fluctuate. Most applicable in the baseline characterisation phase though may be useful supporting information if investigative actions are initiated.	Biplot comparisons of stable isotope values ($\delta^{18}O$ and δ^2H) of tree xylem, groundwater and soil moisture to identify phase shifts. Calculation of Ic-excess as per Section 8.4 to identify how the water sources of trees varies along the Isaac River frontage.
Groundwater monitoring data	The groundwater monitoring program, focused on the monitoring of the Isaac River alluvium and	1. Water quality measurement (as per Section 10.2.4) associated with routine water sampling schedules.

Data collection method	Purpose	Analysis methods / metrics
	Triassic weathered sediments for the purpose of GDE health will: 1. Monitor linkages between recharge of the alluvial aquifer, surface flows and rainfall. 2. Establish baseline water quality values, and the influence of aquifer recharge events from various sources. 3. Assist identification of the degree to which the alluvial aquifer is utilised by vegetation on a seasonal basis. 4. Identify ecological response to aquifer recharge including correlations between alluvial aquifer recharge, LAI, LWP, NDVI and climate data. 5. Monitor and quantify the impacts of mine pit development on drawdown in aquifers that support GDEs, particularly the aquifer associated with the Isaac River alluvium.	2. Analysis of water levels and water quality in the Isaac River alluvium and Triassic weathered sediments against vegetative indices including LAI and LWP through correlation testing (Pearson / Spearman's). 3. Pressure inducers (data loggers) installed into selected monitoring bores to record water level changes every 4 hrs.

11.0 Potential Corrective Actions and Adaptive Management

Corrective actions that halt or reverse impacts to GDEs are not well developed in literature and the suggested measures will require testing monitoring to determine / confirm their effectiveness if they are applied. Where impacts to GDEs are identified that can be related to mining activities, corrective actions will be taken to ameliorate the source of impact. Corrective actions will include treatment of affected vegetation through restoration of moisture supply, or infill planting to restore canopy gaps that have been created because of vegetation dieback.

11.1 Restoration of Tree Water Supply

Direct water injection: While there have been few case studies that have applied direct injection into the root zone, Berens et al (2009) investigated direct injection of fresh water into a saline aquifer on the Murray and found that while the trial resulted in temporary freshening of the capillary fringe, it had limited influence on tree condition as the radial extent of freshening (approximately 10 m) did not intersect with the root zone of salinity stressed trees. Therefore, application of this technique is likely to be practical for localised areas where impacts are detected in scattered trees or scattered groups of trees rather than application in broader scale impact mitigation.

Infiltration of surface water: Where impacts to the health of groundwater dependent vegetation is detected through LAI measurement that can be attributed to mining activities, it may be possible to restore water supply in critical portions of the tree root zone through enhancing natural infiltration. This would include:

1. Construction of a shallow trench (1m) depth within the drip zone (margins of canopy reach) of affected vegetation.
2. Flooding the trench with fresh water, where it meets water quality objectives (e.g. supply of water from sediment ponds to where it meets low flow WQO of < 720 $\mu\text{S}/\text{cm}$).

Trench construction involves disturbance of the upper soil profile and may result in damage to tree root architecture if inappropriately placed. Ecological advice should be sought prior to trench construction to ensure adverse impacts are minimised.

11.2 Infill Planting

River red gum (*Eucalyptus camaldulensis*) and forest red gum (*Eucalyptus tereticornis*) are the dominant groundwater dependent species occupying the banks of the Isaac River and are also the species that is most likely to demonstrate groundwater reliance. The species is ecologically adaptable, occurring on dry hillslopes as well as floodplains and is a significant plantation species. Malik and Sharma (2004) found that the species has a strong capacity to extract moisture from the shallow soil profile (0 – 150cm) in the 426mm rainfall belt and Kallarackel and Somen (1997) identified that growth rates are not limited by water deficit. Trials using locally sourced forest red gum seedlings should be undertaken to determine:

1. If infill planting of forest red gum in canopy gaps has capacity to ameliorate impacts caused by potential tree dieback.

2. Whether trees that have been planted in dry soil regimes have greater capacity to withstand environmental stressors than older established trees that have adapted over long periods to specific ecological water requirements (EWRs).

Small scale trials will commence upon approval of the GDEMMP, through planting of forest red gum and river red gum seedlings into existing canopy gaps. This will require some maintenance through drier periods until seedlings have established. Trials do not need to be extensive and will focus on the capacity of the species to survive, through planting of scattered trees into existing canopy gaps.

11.3 Monitoring of Corrective Actions

Where injection of fresh water into the tree root zone is applied as a management measure, the following approach to confirming the effectiveness of the measures should be considered:

1. Measurement of pre-impact LWP and LAI of trees where treatment is applied. Pre-impact canopy health can also be measured using NDVI imagery captured prior to treatment.
2. Repeat measurements for LAI and LWP to be taken at 1 month, three months and six months following treatment to measure vegetative response.
3. Ongoing annual monitoring of crown health of individual trees using high resolution NDVI in accordance with annual monitoring program post baseline assessment, supplemented with field measurements of LWP and LAI every two years.

Plantings will be checked for disease and loss of vigour:

1. At least weekly for the first month including any watering requirements to aid establishment.
2. Monthly for the next 5 months, and;
3. Annually following the initial six months, in conjunction with the annual GDE monitoring program.
4. Records must be kept of the above works.

11.4 Triggers for Ecological Offset

In the absence of positive results from mitigation measures and / or infill planting, and degradation of GDE habitat on the Isaac River frontage that can be directly attributed to mining activity, the requirement for biodiversity offsets will be assessed based on impacts to habitat. Disturbance thresholds that indicate a requirement for offsetting of GDEs and listed species (including habitat for koala and greater glider) will be developed in the first two years after the project approval in consultation with the Department of Agriculture, Water and the Environment, and the approach approved by the Minister in a revised GDEMMP, to be issued following completion of the two-year baseline monitoring assessment (see **Appendix F**). Triggers and requirements for offsets will be guided by the baseline biocondition information gathered in the Riparian Monitoring Program using the QLD habitat quality assessment methodology (Queensland Government's Guide to Determining Terrestrial Habitat Quality – a toolkit for assessing land-based offsets under the Queensland Environmental Offsets Policy, Version 1.3).

To adequately assess whether any detected reduction in habitat quality constitutes a threshold exceedance requiring an offset, it may be necessary to continue monitoring over an extended period (nominally 2 years). This will ensure that the original exceedance event represents a trend toward longer term decline in habitat condition or is a short-term perturbation that can be corrected with application of appropriate mitigation, or a return to normal climatic regimes.

Relevant EPBC Act listed species are identified in the *Isaac Downs – Terrestrial Ecology Impact Assessment Report – Isaac Downs Project (EcoSM 2020)* and assessment of the significance of impact should be guided by the proposed habitat quality assessment.

The decision-making process which determines the level of action required has been provided in **Figure 17**, which indicates ecological offset as a final measure applied to compensate habitat loss. The management framework is intended to be adaptive, with future capacity for update dependent on the ongoing results of the baseline assessment, and any information gaps identified.

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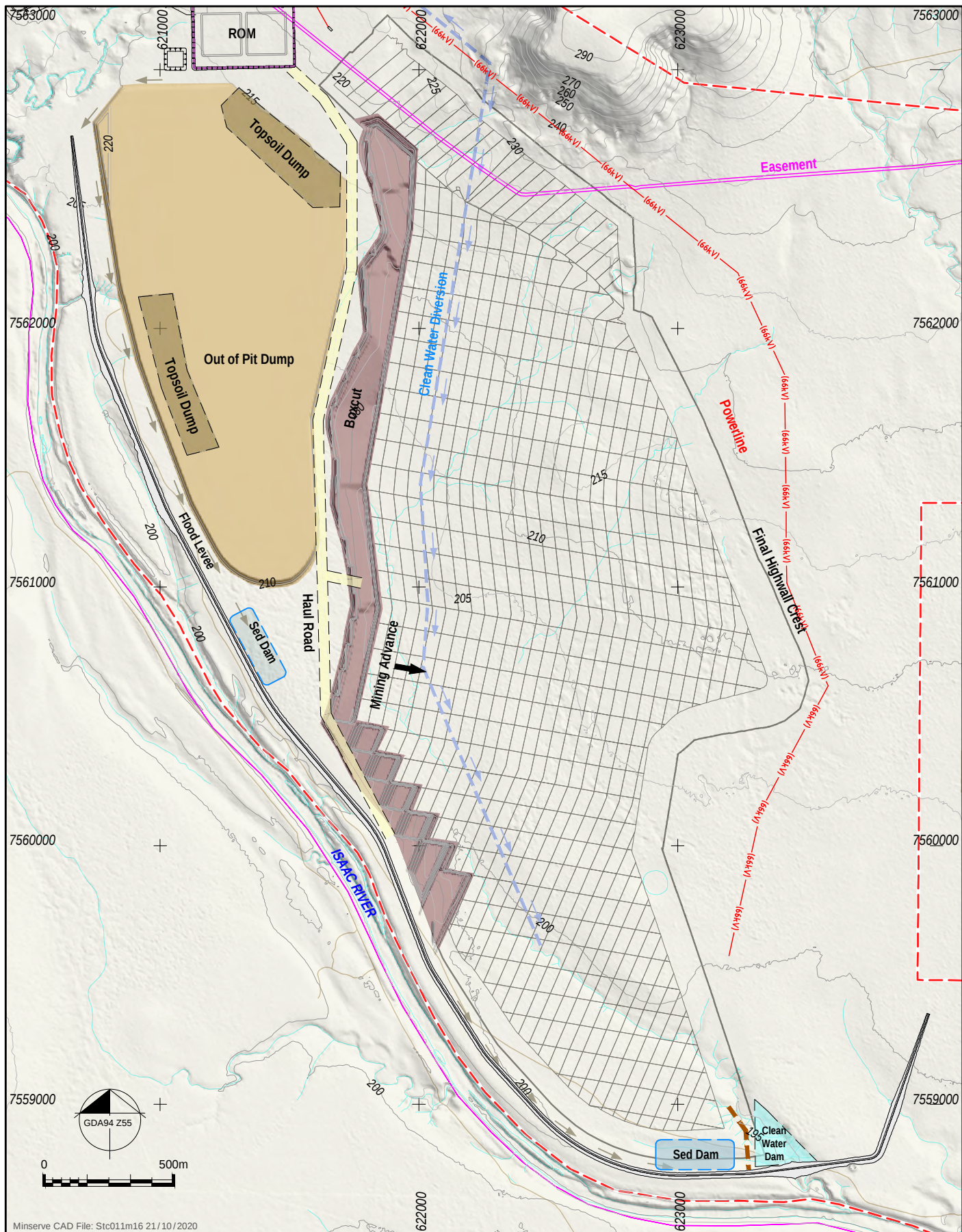
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13.0 Appendices

Appendix A. Isaac Downs Mining Stage Plans



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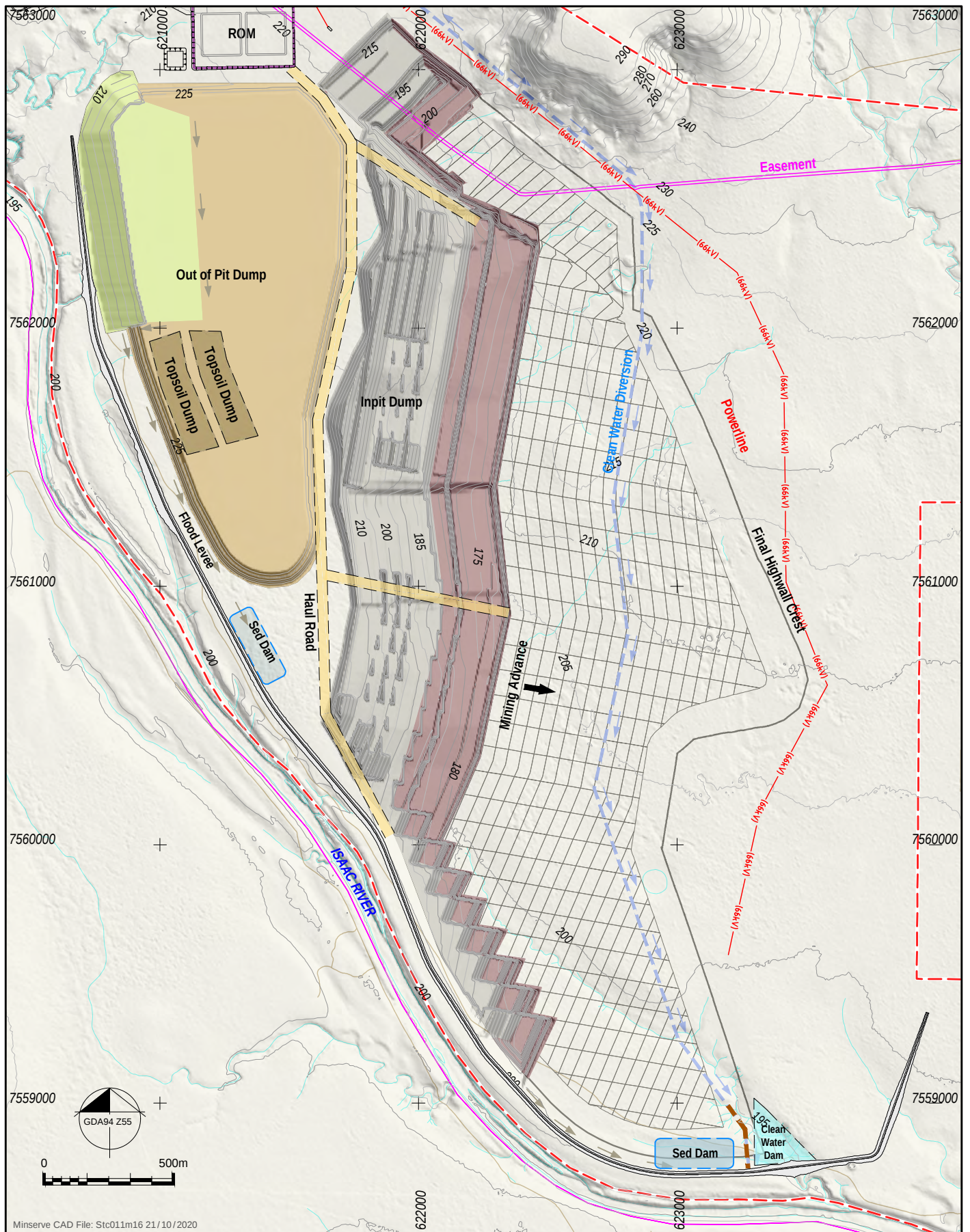
- Isaac Downs Project MLAs
- Drainage
- Cadastral Boundary

Mining Activity

- Inpit Dump
- Out of Pit Dump
- Mining Advance
- Established Rehabilitation
- Available for Rehabilitation

ISAAC DOWNS PROJECT
stanmore
 IP South

Mine Stage Plan - Year 01
 Figure 4-19

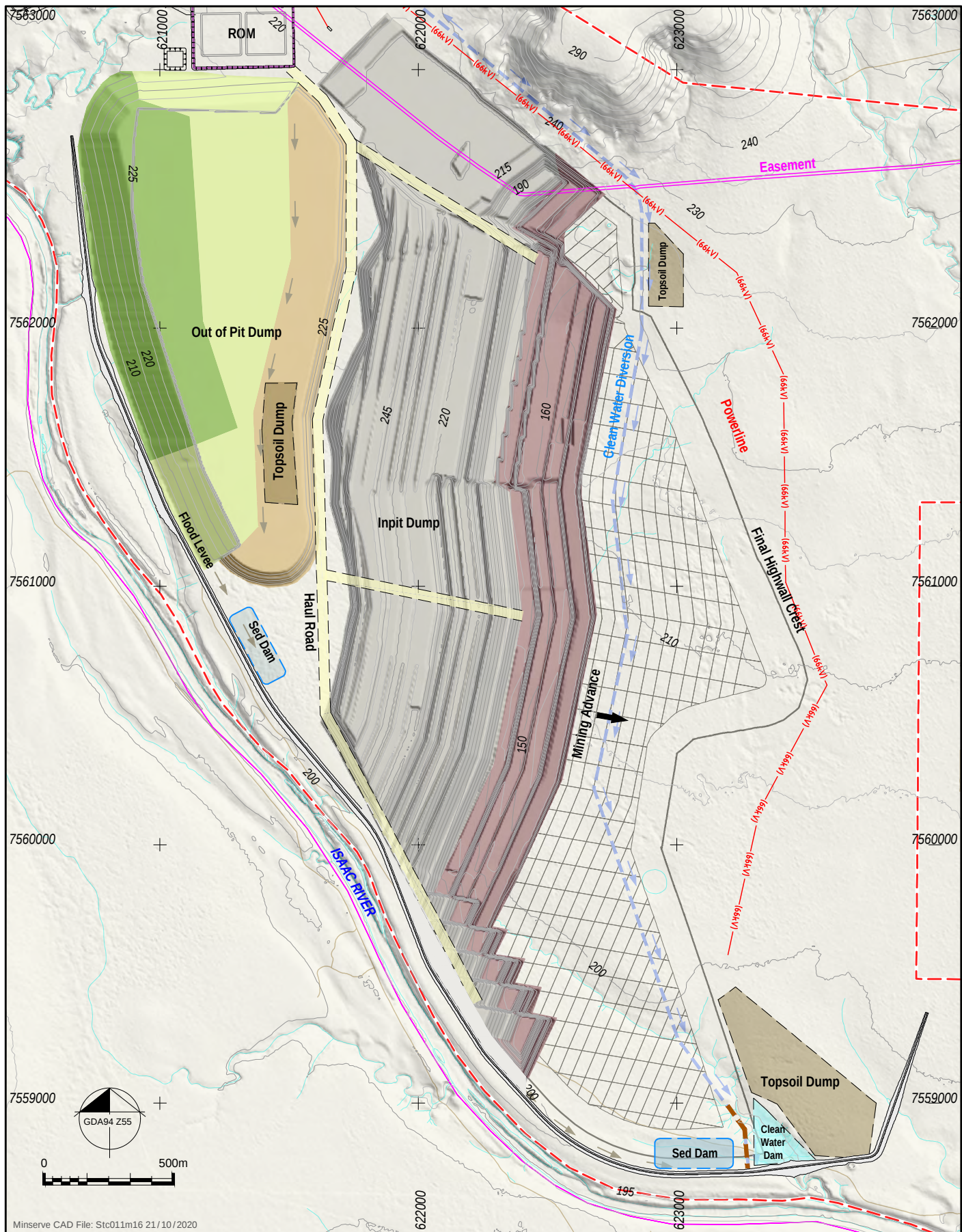


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- LEGEND**
- Isaac Downs Project MLAs
 - Drainage
 - Cadastral Boundary

- Mining Activity**
- Inpit Dump
 - Out of Pit Dump
 - Mining Advance
 - Established Rehabilitation
 - Available for Rehabilitation

ISAAC DOWNS PROJECT
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Mine Stage Plan - Year 03
 Figure 4-20



LEGEND

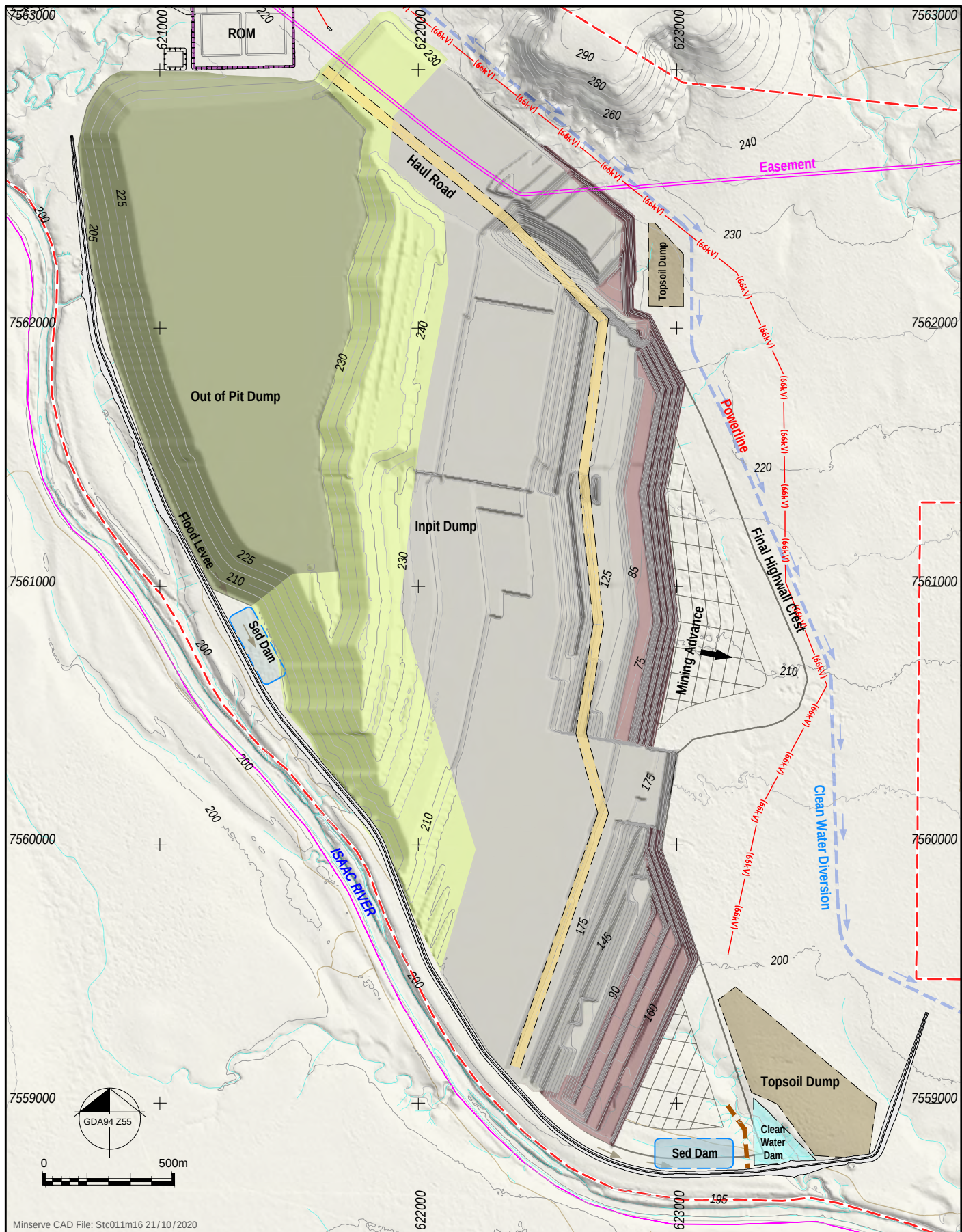
- Isaac Downs Project MLAs
- Drainage
- Cadastral Boundary

Mining Activity

- Inpit Dump
- Out of Pit Dump
- Mining Advance
- Established Rehabilitation
- Available for Rehabilitation

ISAAC DOWNS PROJECT
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 IP South

Mine Stage Plan - Year 05
 Figure 4-21



Minserve CAD File: Stc011m16 21/10/2020

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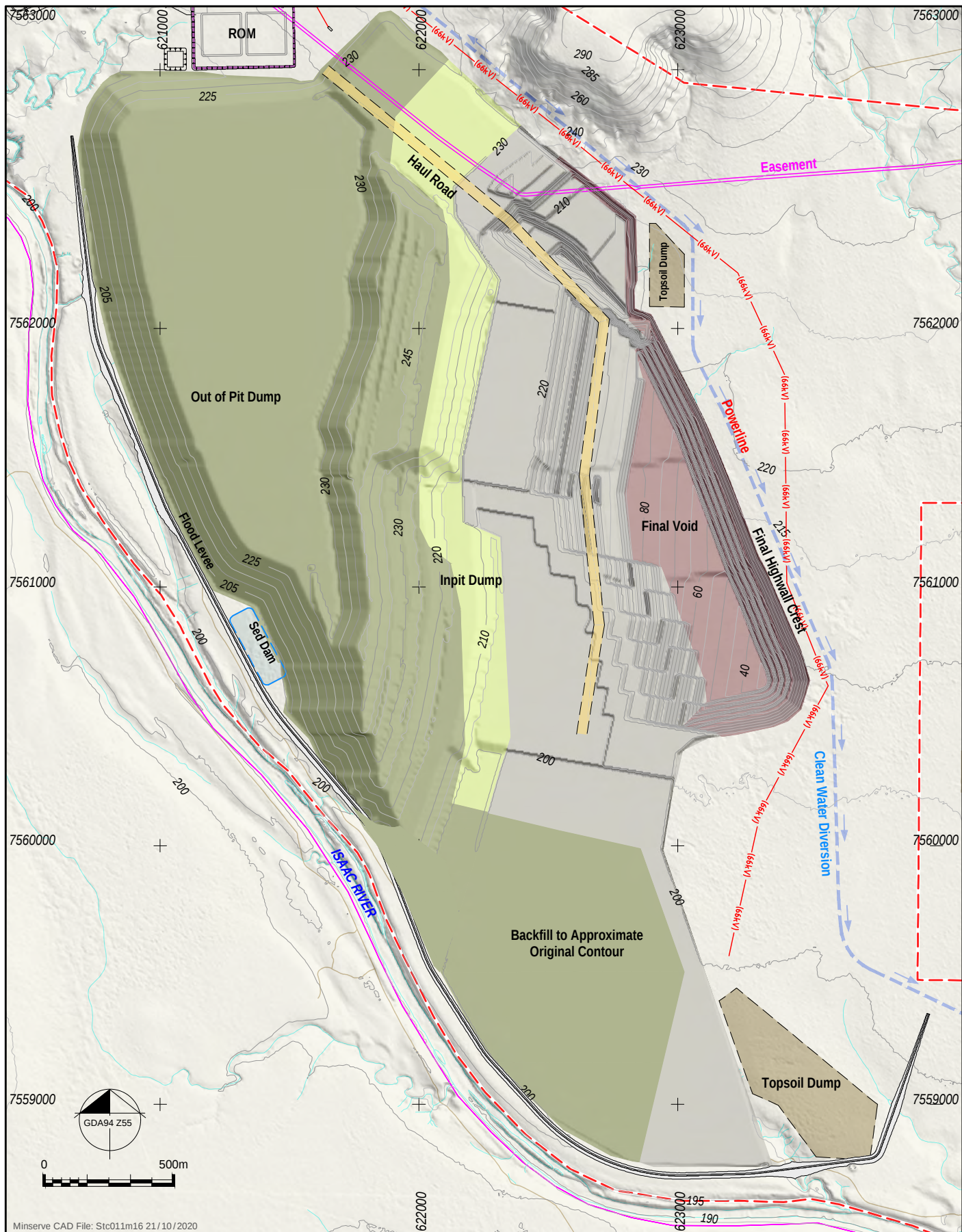
- Isaac Downs Project MLAs
- Drainage
- Cadastral Boundary

Mining Activity

- Inpit Dump
- Out of Pit Dump
- Mining Advance
- Established Rehabilitation
- Available for Rehabilitation

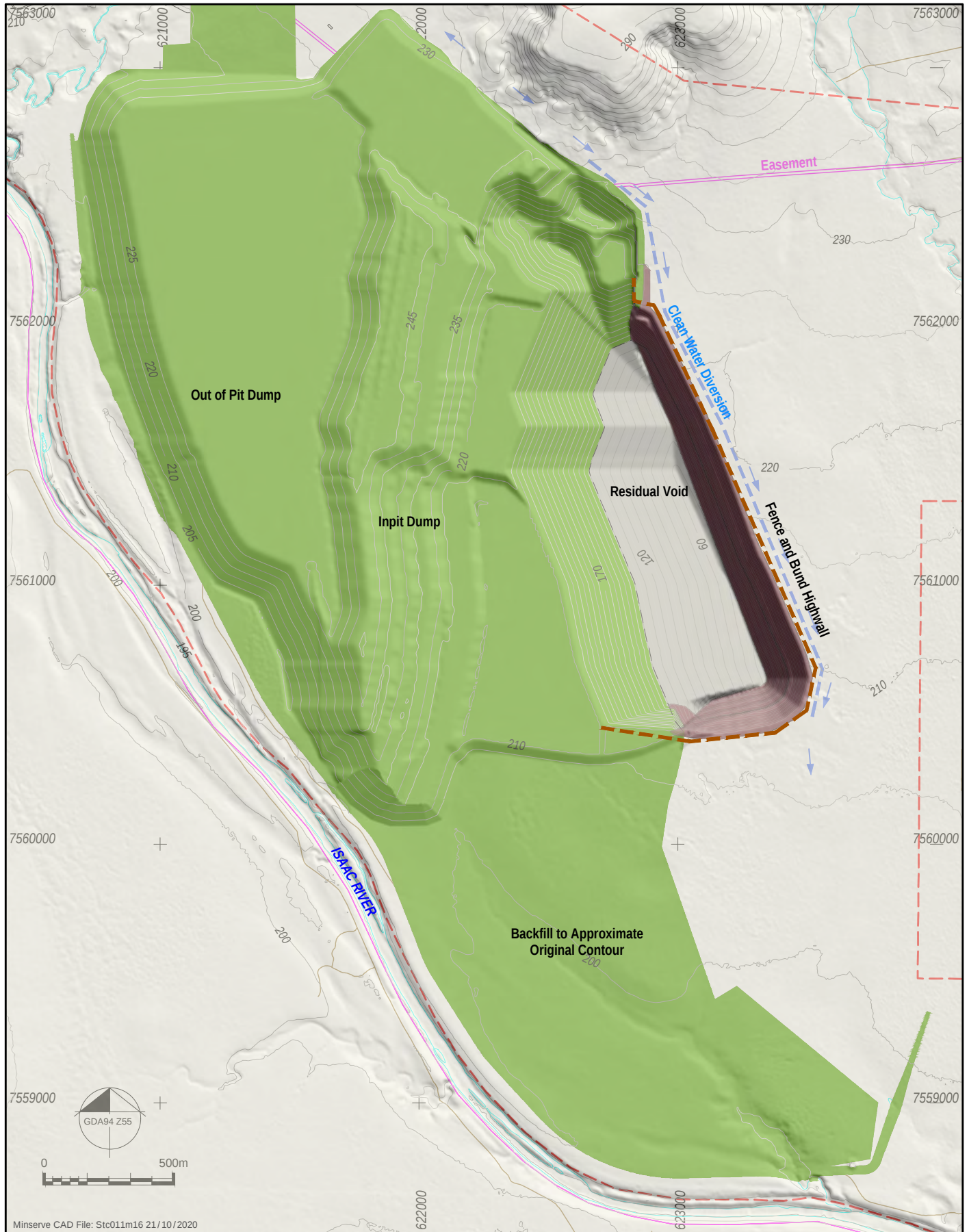
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Mine Stage Plan - Year 10
 Figure 4-22



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Mine Stage Plan - Year 16
 Figure 4-23



LEGEND

---	Isaac Downs Project MLAs		Residual Highwall
---	Drainage		Inpit Dump/Residual Void
---	Cadastral Boundary		Established Rehabilitation

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Proposed Final Landform
 Figure 4-36

Appendix B. Sampling Methods

B1. Leaf / Soil Moisture Potential

The measurement of leaf moisture potential will be targeted to specifically assess the interactions between tree roots and soil moisture / groundwater. These measurements will only be undertaken at the chosen localities on selected trees (as per **Section 8.1**) placed specifically to assess for these interactions.

Rationale

Leaf water potential is the total potential for water in a leaf consisting of the balance between osmotic potential, turgor pressure and matric potential. It is defined as the amount of work that must be done per unit quantity of water to transport that water from the moisture held in soil to leaf stomata. It is a function of soil water availability, evaporative demand and soil conductivity.

Measurement of leaf water potential is undertaken by collecting leaf samples at pre-dawn and using a Scholander pressure chamber (pressure bomb) to measure the pressure required to force water from the stem of the leaf. The results of the leaf water potential measurement are then compared to either the soil moisture potential at the same site collected at regular vertical intervals by drilling down to the water table and using a dewpoint potential meter.

It is assumed that trees will be using water from a source that requires the least energy (lowest water potential) to lift water from the soil, through plant xylem to the leaf for transpiration. This will be dependent to a large part on recent rainfall as well as the specific physical attributes of the soil that holds the rooting material. Heavy clays for example, may have a relatively high water content, although this water is hard to extract due to the cohesive forces of the fine particles which hold water very tightly. Clays will thus have a lower water potential than sand which has large pore spaces between the grains and much lower cohesive forces.

It must also be recognised that trees at the chosen monitoring sites may not be accessing water from one specific source exclusively. Moisture from several horizons within the soil profile may be contributing to tree water requirements, and the predominant source of water may vary on a seasonal basis. To maximise the likelihood of identifying trees that are predominantly using groundwater, it is important that assessments be undertaken in the seasonally driest part of the year.

Methodology

Leaf water potential needs to be measured pre-dawn (prior to sunrise). The basis of this requirement is that pre-dawn measurement provides an estimate of the water potential of the wettest part of the soil profile that contains a significant amount of root matter (Eamus et al 2006). It is assumed that pre-dawn leaf water potential will equilibrate overnight to the portion of the soil profile that has the highest water potential. Hence contemporaneous measurement of both pre-dawn leaf water potential from a canopy tree at a chosen monitoring locality and soil water potential from selected depth intervals down a co-located borehole will provide an indication of the predominant source of water (soil moisture or groundwater) being utilised by trees at the time of survey.

Measurement of Leaf Water Potential

Leaf water potential is measured pre-dawn (prior to 5.30 am in summer) using a Plant Water Potential Gauge (originally referred to as the Scholander pressure chamber or 'Pressure Bomb'). Measurement of leaf water potential requires:

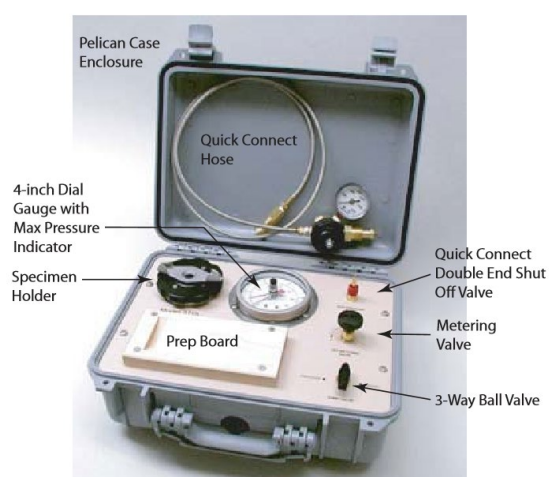
1. Collection of leaves from an accessible part of the tree crown.
2. Preparing of leaf material for insertion into the pressure bomb.
3. Measurement of Leaf Water Potential using the pressure bomb.

Collection of Leaf Material: Leaf material is to be collected from the highest accessible portion of the tree crown using an extension pole and attached lopper head (see **Section 8.5.2.2**). Leaf material should be selected that is disease free (as far as practical) and vigorous, preferably with indications of new leaf growth at the growing tips.

Preparation of Leaf Material: A representative sample of healthy leaf is removed from the collected material with sufficient leaf stem (petiole) to allow it to protrude outside the water potential meter (typically 1 to 2 cm). The stem is cut square with a sharp blade and immediately inserted into the water potential metre with the grommet sealed.

Use of the Plant Water Potential Gauge: The preferred Plant Water Potential gauge is the Model 3115 Plant Water Status Console due to its compactness and portability. The device is manufactured in USA (Soil Moisture Equipment Corp.) and distributed in Australia by ICT International (Armidale). The device fits into a 16 x 13 x 7inch Pelican Case and weighs approximately 11kgs which includes the compressed gas cylinder.

Additional Safety and Operational Measures: The Model 3115 console is accompanied with a detailed unit operation manual which describes in detail the required operational procedures. The unit operates on a compressed gas cylinder which should be professionally refilled with compressed N₂. As pressure is applied to the chamber, there is potential for the leaf petiole to be forcefully ejected from the chamber. Hence safety glasses will be required during unit operation.



B1. Model 3115 Plant Water Status Console with parts description.

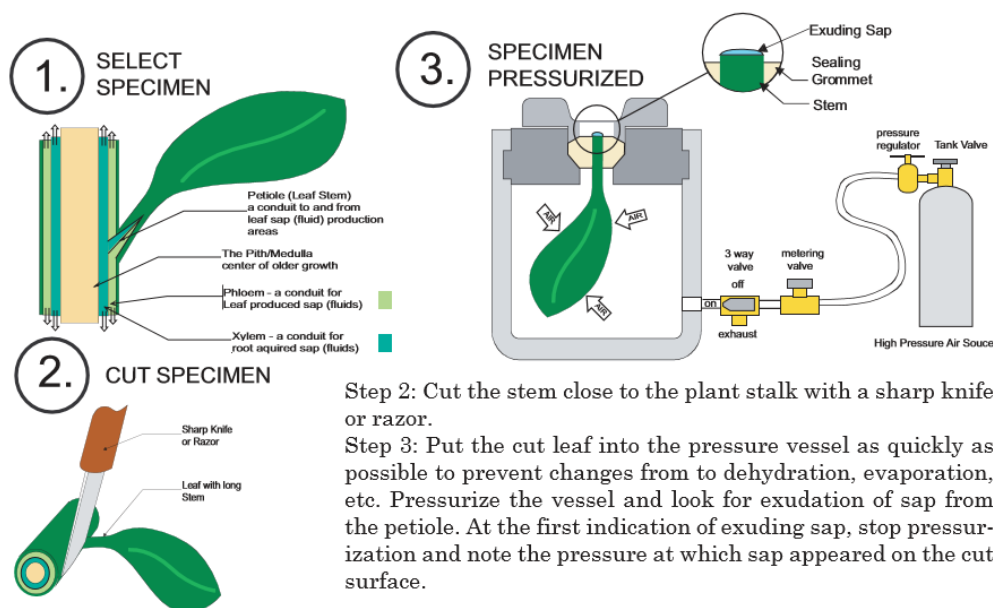
The Water Potential gauge measures leaf or stem water status by the following method:

1. A leaf or stem is collected from the tree that is targeted for assessment.

2. The petiole (leaf stem) is cut and placed in the pressure chamber with the cut stem protruding from the chamber at atmospheric pressure.
3. The vessel is sealed around the petiole and pressure applied via an external gas cylinder.
4. The protruding stem is observed and pressure readings recorded at the first point that water is noted to be exuding from the leaf.
5. The positive pressure applied to the leaf that forced water from the leaf stem is measured. This is the leaf water potential.

The process as supplied by Soil Moisture Equipment Corp (2006) is provided in **Figure 19** below.

Step 1: Select a representative sample specimen of the plant with sufficient length to fit into the pressure vessel.



Step 2: Cut the stem close to the plant stalk with a sharp knife or razor.

Step 3: Put the cut leaf into the pressure vessel as quickly as possible to prevent changes from dehydration, evaporation, etc. Pressurize the vessel and look for exudation of sap from the petiole. At the first indication of exuding sap, stop pressurization and note the pressure at which sap appeared on the cut surface.

B2. Diagrammatic illustration of the use of the Pressure Bomb as per Soil Moisture Equipment Corp. (2006).

Measurement of Soil Water Potential

Soil moisture potential should be measured, utilising a soil auger, in specific cases where results of LWP analysis require additional explanation. This would occur primarily as result of unexpectedly high, or unexpectedly low LWP measurements that cannot be contextualised based on seasonal conditions. The same sampling protocols applied to soil sampling for stable isotopes should be applied to assessment of soil moisture potential. This includes:

1. An initial soil sample taken within the top 10cm of the soil profile.
2. Subsequent sampling at 0.5m intervals down borehole to the top of the Permian basements.
3. Additional measurements taken whenever there is a noted change in soil texture within the soil core (i.e change from clay to sandy clay / loam).

Sampling should be undertaken with a portable hand auger with a maximum expected depth of 5m (BGMB3 is 4.5m depth).

The most convenient method of measuring soil moisture potential is with a portable Dew Point PotentiaMeter which enables measurement to be taken directly on site. Portable devices such as the WP4C uses the chilled mirror dew point technique to measure water potential with the sample being equilibrated with the headspace of a sealed chamber that contains a mirror and a means of detecting condensation on the mirror.

B3. The WP4C Dew Point PotentiaMeter available for hire from ICT International Pty Ltd.



The following protocols are to be followed:

1. A 7ml soil sample is inserted into the sample draw of the potentiaMeter in a 15ml stainless steel sample cup.
2. A soil sample takes between 10 -15mins to analyse.
3. Faster settings (fast mode) should be used for samples with limited water holding capacity such as sand.

The WPC4 unit will require 12V power inverter that plugs into the 12V port of a vehicle if measurements are to be taken in the field. Alternatively, samples can be collected in a sealed sample bag (with air removed) and measurements taken in an office or other areas where there is a reliable power source. The inverter should have a continuous output of at least 140 Watts.

Outputs

The water potential assessments of both leaf (target tree at site) and soil (from soil core) will provided the following data outputs:

1. Pre-dawn leaf water potential measurements of canopy / sub-canopy leaf samples taken with the Pressure Bomb (3115 unit). The output unit will be provided in MPA.
2. Soil moisture potential taken with the portable WPC4 Potentiometer at standard intervals along the drillhole core. The unit output will be measured in MPA consistent with leaf moisture potential. The intervals for measurement will be:
 - a. Top 10cm of the soil profile.
 - b. At 0.5m intervals from the soil surface to the top of the phreatic zones.
 - c. Where noticeable changes in soil texture or moisture content are noted during examination of the core.

The interval for measurement is purposefully coincident with the interval applied to soil sampling for stable isotopes. This will allow for more ready comparison of the results between differing sampling methods and applications.

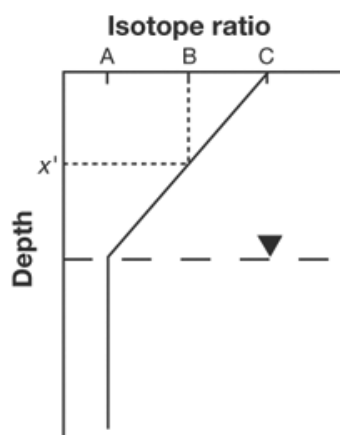
B2. Stable Isotope Analysis

The overarching aim of stable isotope analysis is to determine the degree to which trees utilise groundwater on either a permanent or seasonal basis. It will be applied during the initial phase of the baseline assessment to determine seasonal sources of moisture usage by selected trees, to be phased out once baseline water utilisation patterns are established (minimum of 2 years).

Rationale

Trees may utilise water from a range of sources including the phreatic zone, the vadose zone and surface water and the stable isotopes of water, oxygen 18 (^{18}O) and deuterium (^2H) may be a useful tool to help define the predominant source of water used by terrestrial vegetation. The method relies on a comparison between the stable isotope ratios of water contained in plant xylem (from a twig or xylem core) with concentrations in the various sources of water including potential artesian water sources, and shallow soil moisture. The heavier isotopes of ^{18}O and ^2H fractionate differently to the lighter isotopes equivalents (^{16}O and ^1H). Rainfall has a typically large $\delta^{18}\text{O}$ and $\delta^2\text{H}$ as it is formed through the process of condensation which concentrates heavier isotopes. Surface water may have an extremely high $\delta^{18}\text{O}$ if it is subject to a period of strong evaporation, whilst isotopic composition of groundwater will vary dependent on the input source, although tends to be relatively stable as it is not exposed to processes of fractionation.

The isotopic signature of water measured in a trees xylem may result from a combination of sources with varying signatures. As per Eamus et al (2006) below (Figure B4), if an isotopic signature of 'A' is recorded, then water is being sourced from the phreatic zone, and for 'C' at the surface. If an isotopic signature of 'B' is recorded, this may represent water sourced from the middle of the vadose zone (at depth x), or may be a combination of water from a deeper phreatic source (A) or a shallow source (B). Hence there is potential for considerable uncertainty when mixed isotopic signatures occur and it may be necessary to apply a linear mixing model to aid the interpretation (as per Thorburn et al, 1993).



B4. Schematic representation of isotope ratios within soil and groundwater and application in identifying plant water sources (from Eamus et al. 2006).

For a robust application of stable isotopes signatures obtained from plant xylem and soil pore spaces, the following general protocols should be observed:

1. Sampling of plant and soil material will need to be completed during a single sampling event to ensure the results are directly comparable.
2. Sampling of plant xylem material would be completed most efficiently from twigs, collected whilst undertaking leaf water potential measurements. Leaves have tendency to concentrate isotopic concentrations during the process of transpiration and evaporation and hence should not be used.
3. The sampling program is best completed following a period of extended drought / dry conditions to maximise the potential that plants are utilising groundwater sources.
4. Sampling of soil pore water should be undertaken at consistent intervals throughout the vadose zone (the unsaturated zone above the groundwater table) down to the groundwater table. Soil samples are to be collected to the depth of the saturated zone or consolidated bedrock (whichever comes first). Sampling needs to extend beyond the saturated zone to consolidated bedrock in the case that a perched aquifer is identified.

Methodology

Sampling of Soil Pore Water for Stable Isotopes

Method: Soil sampling is to be undertaken at regular intervals along a retrieved soil core to capture signatures for possible isotopic end points (ground water and surface water) and a range of potential plant moisture sources within from the upper soil surface to the top of the phreatic zone. Mensforth et al (1994) completed soil sampling at 0.1m increments to 0.4m depth; 0.2m increments to 2m depth and 0.5m increments to the groundwater surface while others such as O'Grady et al (2006) applied sampling interval of 0.5m down the entire profile. The proposed sampling interval for this assessment is:

1. Initial soil sample taken within the top 10cm of the soil profile.
2. Subsequent soil sampled taken at 0.5m intervals down borehole to the top of the phreatic zone.
3. Additional soil samples take whenever there is a noted change in soil texture within the soil core (i.e change from clay to sandy clay / loam).

Soil sampling should be continued until either the unconfined groundwater table is intersected or the top of the Pleistocene surface halts auger penetration.

Soil sampling protocols: The following protocols for soil sampling are to be applied based on advice from ANU Stable Isotope Laboratory:

1. A minimum 50ml equivalent of soil is to be collected for each sample to be analysed.
2. Samples are to be immediately sealed to prevent evaporation in an airtight container (double bagging recommended).
3. Samples are to be labelled with the drill hole number and sampling depth / interval in a consistent format to aid data entry and recognition
4. Samples are to be kept on ice and transported to a freezer for temporary storage prior to dispatch to the laboratory (at the completion of each hole).

5. Frozen samples are to be dispatched in an a sealed (as airtight as possible) esky via overnight courier.

Equipment: The following equipment will be required by the site geologist / ecologist.

1. Stainless steel spatula for sample collection (paint scraper or putty knife sufficient).
2. Tape measure (15m extendable steel builders measure).
3. Sealable polypropylene containers (30 to 70ml adequate)
4. Permanent marking pens.
5. Esky for sample storage and dispatch.
6. A chest freezer will need to be accessed off site for storage.

Sampling of Xylem Water for Stable Isotopes

This will require twigs to be collected from the outer branches of mature Red Gum (or Poplar Box) trees that are the subject of the assessment. It is anticipated that up to 4 twig samples will be collected from individual trees directly adjacent to the assessment locality. At each site, the following sampling protocols should be observed: Method: Sampling of leaf twigs will be undertaken in conjunction with sampling of leaves for water

1. Outer branches of up to four trees, including the central tree at the assessment locality plus three adjacent trees are to be harvested for twig material.
2. Trees subject to assessment are to be marked with a GPS.
3. Outer branches from each tree will be harvested using an extendable aluminium pole and lopping head. The longest commercially available extension pole is 7.5m giving a maximum reach of approximately 10m.
4. Stem material that is the equivalent to one joint length of the small finger should be sourced (based on advice from ANU). Hence collected branches should contain some stem diameters of at least 10mm.
5. Selected stems are to be cut into maximum 5cm lengths and the bark stripped. One to two stems of 10mm diameter stems will be sufficient although more material will be required for smaller diameter stems.
6. Stems are to be sealed in wide mouth sample containers with leakproof polypropylene closure.
7. Samples should be immediately labelled with the tree number and placed in an iced storage vessel before being transported to a freezer for temporary storage prior to dispatch to the laboratory (at the completion of each hole).
8. Frozen samples are to be dispatched in an a sealed (as airtight as possible) esky via overnight courier.

Equipment: The following equipment will be required by the site geologist / ecologist.

1. An extendable 7.5m aluminium pruning pole with an attached lopper head.
2. High quality secateurs for cutting stem material.
3. 125m wide mouth sample containers with a polypropylene seal cap (up to 16 required).
4. Permanent marking pens.
5. Esky for sample storage and dispatch. May be included with the frozen soil samples.

6. A chest freezer will need to be accessed off site for storage.

Groundwater sampling for stable isotopes

Method: Groundwater samples are to be collected from each groundwater monitoring bore using the low flow method. Groundwater sampling will follow methods described in the Geosciences Australia *Groundwater Sampling and Analysis – A Field Guide* (Sundaram, et al., 2009). Care should be taken not to oxygenate or agitate the sample during pumping or sample collection.

Samples for analysis of stable isotopes should be collected in laboratory prepared 28ml glass McCartney bottles or 15ml Vacutainers and kept cool during storage and transport.

Sample Despatch and personnel

Personnel: Samples are to be collected, bagged and stored by the supervising geologist / ecologist who will also be responsible for the sample dispatch to the receiving laboratory

Dispatch: Samples are to be dispatched directly to the ANU Stable Isotope Laboratory (address provided below).

Hilary Stuart-Williams
Stable Isotope Laboratory
Research School of Biology
R.N. Robertson Building (46)
The Australian National University Canberra ACT 0200 Australia

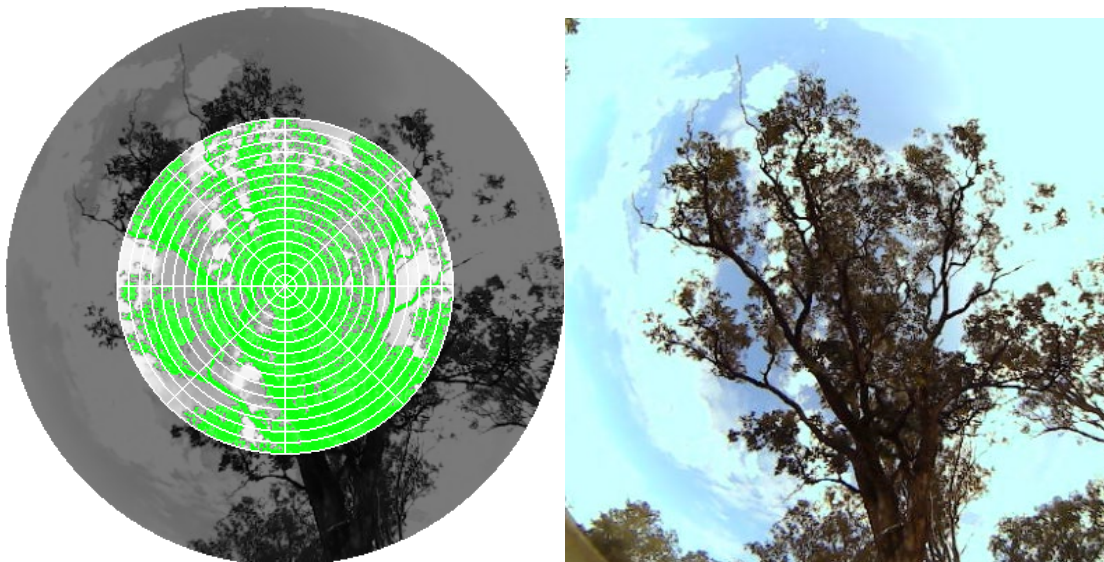
B3. Field Based Assessment of Leaf Area Index

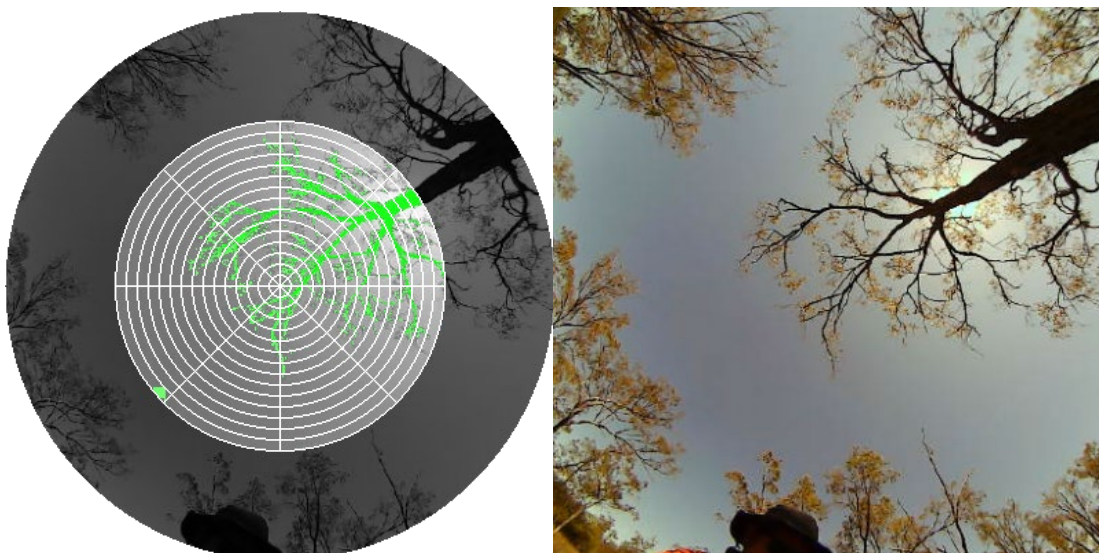
Leaf Area Index (LAI) is a ratio of the total leaf area within a canopy to the ground area covered by the canopy. It is a measure of canopy vigour and the rationale applied is that plants with access to permanent sources of water (i.e. groundwater) will have greater vigour and hence LAI than vegetation that has only periodic access to groundwater resources (e.g. Zolfagher 2014). If a previous permanent groundwater resource is withdrawn (as might occur in a CSG operation), then leaf fall will occur, and LAI will decrease.

Measurement of LAI is typically completed with a hemispherical lens, is labour intensive and utilises specialised software to analyse foliage cover. The CI-110 Plant Canopy Analyzer provides a self-leveling, wide-angled lens to capture hemispherical photographs for the analysis of leaf area index (LAI) and gap fraction analysis and photosynthetically active radiation (PAR). This instrument is integrated with the corresponding software program, and a GPS, allowing for fast and simple analysis, with immediate data available on site including:

- Leaf area index (LAI)
- Leaf angle distribution
- Extinction coefficients
- PAR LAI

The unit provides considerably greater accuracy in LAI measurement than standard hemispherical cameras and is time saving due to the immediate access of data. Raw data outputs are provided below demonstrating a *Eucalyptus populnea* with a canopy density of 83% and a Gap Fraction LAI of 0.8 compared to a stressed *Eucalyptus populnea* with a canopy density of 52% and a Gap Fraction LAI of 0.3 (second row). Zenith angle is set at 45° to filter out adjacent canopy trees and other interference.



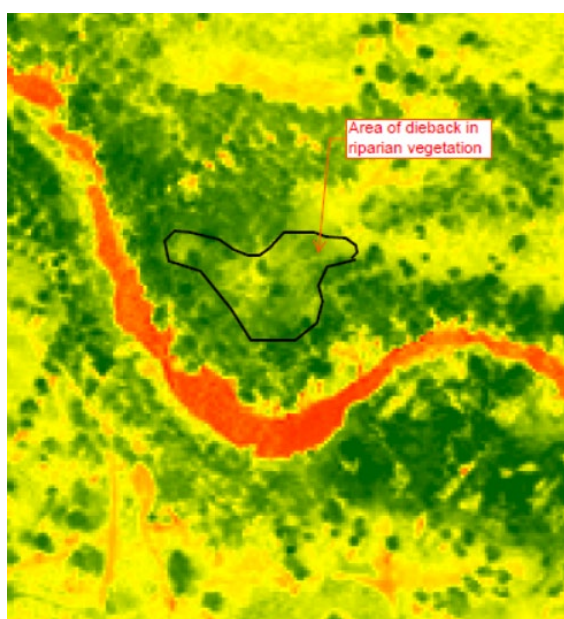


B5. Raw data outputs are provided below demonstrating a *Eucalyptus populnea* with a canopy density of 83% and a Gap Fraction LAI of 0.8 compared to a stressed *Eucalyptus populnea* with a canopy density of 52% and a Gap Fraction LAI of 0.3 (second row).

B4. Remote Sensing Methods

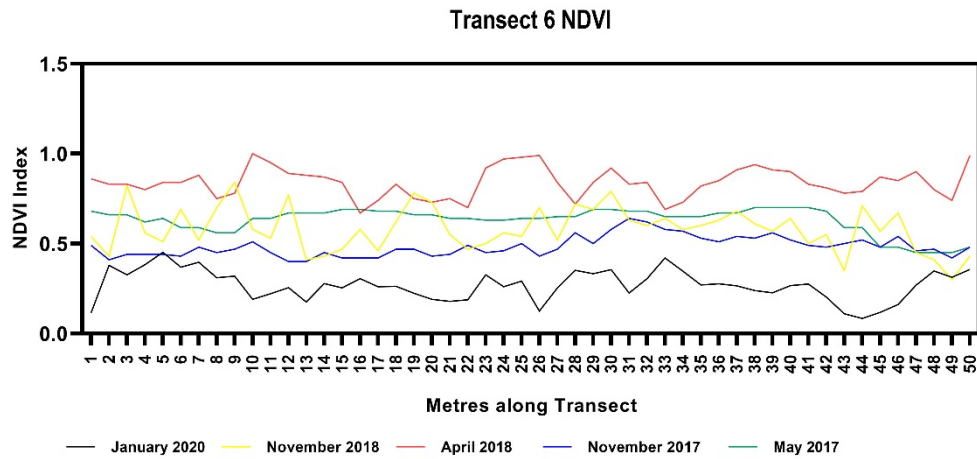
There are remote sensing based assessments used to calculate LAI (TERRA and AQUA satellites), although the spatial resolution of at 250 m x 250 m is not going to be useful for the application, due to the fragmented nature of the landscape with large areas of clearing interspersed amongst native woodland.

Recent availability of high-resolution satellite imagery (WorldView-3/WorldView-2 and GeoEye-1; 0.5m Resolution 4-band Pan) to map canopy and foliage dieback in habitats potentially affected by gas seeps. Assessment utilises the Normalised Difference Vegetation Index (NDVI) as a measure of canopy health and vigor. It is a widely accepted method and with advances in satellite technology, has the capacity to assess the health of individual trees rather than landscapes. The strength of the assessment is that it enables the health of riparian (and other GDE) vegetation to be monitored across the entire landscape, rather than just a limited number of individual sites. The landscape-scale capability also has an ability to overcome issues surrounding a lack of site access and provides a long-term monitoring record of vegetation health that can be utilised as reference when a need arises. Capture can be undertaken reactively and can be tasked with a days' notice, providing weather, particularly cloud cover is amenable. An example of high resolution NDVI Imagery showing dieback in riparian vegetation is provided in **A7** (capture date May 2017).



A7. Healthy vegetation in bright green grading to bare ground and water in red. Area of recent canopy dieback is indicated.

Measurements of NDVI values at set intervals along permanently established transects also provides a quantifiable and easily rectifiable measure of vegetation productivity that can be undertaken on a seasonal basis. This would form a component of the baseline dataset against which trends in vegetation productivity and fluctuations in groundwater regime can be correlated. Figure A8 provides an example of a vegetation transect that has been monitored for vegetation production for period of years, showing the strong decrease in vegetative productivity between May 2017 and January 2020.

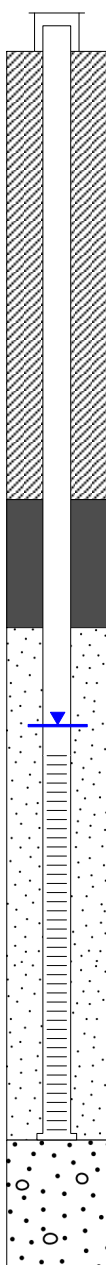


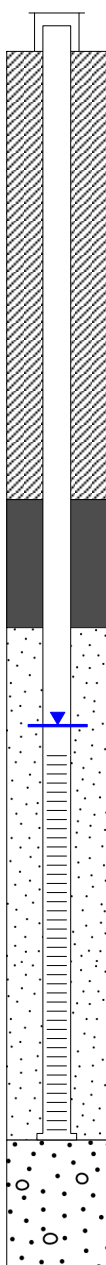
A8. Seasonal variations in vegetation productivity, measured using NDVI, showing a decrease in vegetation health over a 2.5yr sampling period for a permanent monitoring transect in the Surat Basin.

B5. Applicable Groundwater Monitoring Bore Logs

 Australasian Groundwater & Environmental Consultants Pty Ltd Level 2, 15 Mallon Street, Bowen Hills, Queensland 4006		BOREHOLE LOG page:1 of 1 MBID01 (MB04)			
PROJECT No: G1803B PROJECT NAME: Isaac Downs DATE DRILLED: 11/13/2018 LOGGED BY: K.Hume (AGE)		DRILLING COMPANY: Wizard Drilling DRILLER: Darren Faint DRILLING METHOD: Mud Rotary DRILL RIG: Bourne 500 THD		EASTING: 620535 mE NORTHING: 7561989 mN DATUM: Zone 55 RL: 202.653 mAHD TD: 18 mBGL	
COMMENTS:					
Soil or Rock Field Material Description		Graphic Log	Depth (mBGL) R.L. (mAHD)	Bore Construction	Bore Description
			204		
			203		Protective lockable steel collar: +1.3 m Stick up: +0.58 m
CLAY: low plasticity, well graded, light reddish brown, Drilled with mud.			0		
			202		
			1		
			201		124 mm PCD: 0 m to 18 m (Mud)
			2		
			200		50 mm uPVC Class 18 blank casing: 0 m to 11 m
CLAY: low plasticity, well graded, light reddish brown.			3		
			4		Bentonite grout (2.5%): 0 m to 6 m
			5		
			199		
			198		
			197		
			6		
GRAVEL: sub-rounded, quartz and lithic clasts, poorly graded, light reddish brown.			196		
			7		Bentonite seal: 6 m to 8.8 m
GRAVEL: sub-rounded, quartz and lithic clasts, poorly graded, light brown.			195		
			8		
SAND: rounded, well graded, light brown.			194		
			9		
GRAVEL: medium gravel, sub-rounded, quartz and lithic clasts, poorly graded, light brown.			193		
			10		
SAND: rounded, well graded, light brown.			192		SWL: 10.30 mbgl
			11		
GRAVEL: coarse sand, sub-rounded, quartz and lithic clasts, poorly graded, light brown, wet.			191		50 mm uPVC Class 18 machine slotted casing, slot aperture: 1mm, 11 m to 17 m
			12		
GRAVEL: sub-rounded, quartz and lithic clasts, poorly graded, light brown.			190		2 - 4 mm washed, rounded, quartz gravel pack: 8.5 m to 17 m
			13		
			189		
			14		Bore development: 32mins; EC: 5453mS μ S/cm; pH: 7.83
CLAYBOUND GRAVEL: medium gravel, angular, quartz and lithic clasts, gap graded, light brown.			188		Airlift flow rate: 0.18 L/s
			15		
			187		
			16		
CLAYBOUND GRAVEL: medium plasticity, coarse gravel, angular, quartz and lithic clasts, gap graded, light brown.			186		
			17		End cap
CLAY: high plasticity, sub-rounded, well graded, light grey.			185		Gravel backfill: 17 m to 18 m
			18		End of hole: 18 m BGL

AGE Australasian Groundwater & Environmental Consultants Pty Ltd Level 2, 15 Mallon Street, Bowen Hills, Queensland 4006		BOREHOLE LOG page:1 of 1			
PROJECT No: G1803B PROJECT NAME: Isaac Downs DATE DRILLED: 11/14/2018 LOGGED BY: K.Hume (AGE)		DRILLING COMPANY: Wizard Drilling DRILLER: Darren Faint DRILLING METHOD: Air Rotary DRILL RIG: Bourne 500 THD		EASTING: 621899 mE NORTHING: 7559331 mN DATUM: Zone 55 RL: 201.322 mAHD TD: 20 mBGL	
COMMENTS:					
Soil or Rock Field Material Description		Graphic Log	Depth (mBGL) R.L. (mAHD)	Bore Construction	Bore Description
			202		Protective lockable steel collar: +1.3 m Stick up: +0.73 m
			0		
			201		
CLAY: low plasticity, well graded, light brown, dry.			1		
			200		
			2		124 mm PCD: 0 m to 20 m (Air rotary)
			199		
			3		50 mm uPVC Class 18 blank casing: 0 m to 14 m
			198		
			4		Bentonite grout (2.5 %): 0 m to 10 m
SAND: low plasticity, very fine sand, sub-rounded, well graded, clay matrix, reddish brown, dry.			197		
			5		
			196		
			6		
			195		
			7		
			194		
			8		
			193		
			9		
			192		
			10		
GRAVEL: fine sand, sub-rounded, quartz and lithic clasts, poorly graded, brown / yellow, moist.			191	-10 m	
			11		Bentonite seal: 10 m to 12 m
			190		
			12	-12 m	
			189		
			13		
			188		
			14	-14 m	
GRAVEL: medium plasticity, medium sand, sub-rounded, quartz and lithic clasts, poorly graded, brown / yellow, dry.			187		SWL: 14.38 mbgl
			15		
SAND: medium sand, well graded, brown / yellow, dry.			186		
			16		2 - 4 mm washed, rounded, quartz gravel pack: 12 m to 20 m
GRAVEL: fine sand, sub-rounded, quartz and lithic clasts, poorly graded, brown / yellow, dry.			185		
			17		50 mm uPVC Class 18 machine slotted casing, slot aperture: 1 mm, 14 m to 20 m
SAND: medium sand, well graded, brown / yellow.			184		
			18		
GRAVEL (40 %): medium gravel, angular, quartz and lithic clasts, poorly graded, clay matrix, bluish grey.			183		
			19		End cap
GRAVEL (50 %): medium sand, angular, quartz and lithic clasts, poorly graded, clay matrix, bluish grey.			182		End of hole: 20 m BGL
			20		
			181	-20 m	
			21		

 Australasian Groundwater & Environmental Consultants Pty Ltd Level 2, 15 Mallon Street, Bowen Hills, Queensland 4006		BOREHOLE LOG page:1 of 1 MBID11 (MB16)			
PROJECT No: G1803B PROJECT NAME: Isaac Downs DATE DRILLED: 11/20/2018 LOGGED BY: K.Hume (AGE)		DRILLING COMPANY: Wizard Drilling DRILLER: Darren Faint DRILLING METHOD: Mud Rotary DRILL RIG: Bourne 500 THD		EASTING: 621655 mE NORTHING: 7560072 mN DATUM: Zone 55 RL: 201.391 mAHD TD: 17 mBGL	
COMMENTS:					
Soil or Rock Field Material Description	Graphic Log	Depth (mBGL) R.L. (mAHD)	Bore Construction	Bore Description	
		202 -0		Protective lockable steel collar: +1.3 m Stick up: +0.8 m	
CLAY: low plasticity, sub-rounded, well graded, reddish brown, dry.		201 -1			
CLAY: low plasticity, sub-rounded, well graded, brown, dry.		200 -2		124 mm PCD: 0 m to 19 m (Mud)	
		199 -3		Bentonite grout (2.5 %): 0 m to 7 m	
CLAYBOUND SAND: very fine sand, sub-rounded, well graded, reddish brown, dry.		198 -4		50 mm uPVC Class 18 blank casing: 0 m to 13 m	
		197 -5			
SAND: fine sand, sub-rounded, quartz and lithic clasts, poorly graded, light yellowish brown, moist.		196 -6			
		195 -7			
		194 -8		Bentonite seal: 7 m to 9 m	
		193 -9			
		192 -10			
		191 -11		SWL: 10.53 mbgl	
SAND: medium sand, sub-rounded, quartz and lithic clasts, poorly graded, light yellowish brown, moist.		190 -12		2 - 4 mm washed, rounded, quartz gravel pack: 11 m to 17 m	
		189 -13			
		188 -14			
		187 -15		50 mm uPVC Class 18 machine slotted casing, slot aperture: 1 mm, 13 m to 19 m	
		186 -16			
		185 -17		End cap	
SANDSTONE: medium sand, sub-rounded, quartz and feldspar, well graded, greyish black, distinctly weathered wet.		184 -18		Gravel backfill: 17 m to 19 m	
		183 -19		End of hole: 19 m BGL	

 Australasian Groundwater & Environmental Consultants Pty Ltd Level 2, 15 Mallon Street, Bowen Hills, Queensland 4006		BOREHOLE LOG page:1 of 1		
		MBID11 (MB16)		
PROJECT No: G1803B PROJECT NAME: Isaac Downs DATE DRILLED: 11/20/2018 LOGGED BY: K.Hume (AGE)		DRILLING COMPANY: Wizard Drilling DRILLER: Darren Faint DRILLING METHOD: Mud Rotary DRILL RIG: Bourne 500 THD		
COMMENTS:		EASTING: 621655 mE NORTHING: 7560072 mN DATUM: Zone 55 RL: 201.391 mAHD TD: 17 mBGL		
Soil or Rock Field Material Description	Graphic Log	Depth (mBGL) R.L. (mAHD)	Bore Construction	Bore Description
		202 -0		Protective lockable steel collar: +1.3 m Stick up: +0.8 m
CLAY: low plasticity, sub-rounded, well graded, reddish brown, dry.		201 -1		
CLAY: low plasticity, sub-rounded, well graded, brown, dry.		200 -2		124 mm PCD: 0 m to 19 m (Mud)
		199 -3		Bentonite grout (2.5 %): 0 m to 7 m
CLAYBOUND SAND: very fine sand, sub-rounded, well graded, reddish brown, dry.		198 -4		50 mm uPVC Class 18 blank casing: 0 m to 13 m
		197 -5		
SAND: fine sand, sub-rounded, quartz and lithic clasts, poorly graded, light yellowish brown, moist.		196 -6		
		195 -7		
		194 -8		Bentonite seal: 7 m to 9 m
		193 -9		
		192 -10		
		191 -11		SWL: 10.53 mbgl
SAND: medium sand, sub-rounded, quartz and lithic clasts, poorly graded, light yellowish brown, moist.		190 -12		2 - 4 mm washed, rounded, quartz gravel pack: 11 m to 17 m
		189 -13		
		188 -14		
		187 -15		50 mm uPVC Class 18 machine slotted casing, slot aperture: 1 mm, 13 m to 19 m
		186 -16		
		185 -17		End cap
SANDSTONE: medium sand, sub-rounded, quartz and feldspar, well graded, greyish black, distinctly weathered wet.		184 -18		Gravel backfill: 17 m to 19 m
		183 -19		End of hole: 19 m BGL

 Australasian Groundwater & Environmental Consultants Pty Ltd Level 2, 15 Mallon Street, Bowen Hills, Queensland 4006		BOREHOLE LOG page:1 of 1		
		MBID17 (MB03)		
PROJECT No: G1803B PROJECT NAME: Isaac Downs DATE DRILLED: 12/9/2018 LOGGED BY: I.Crow (AGE)		DRILLING COMPANY: Wizard Drilling DRILLER: Darren Faint DRILLING METHOD: Mud Rotary DRILL RIG: Bourne 500 THD		
COMMENTS:		EASTING: 619680 mE NORTHING: 7562295 mN DATUM: Zone 55 RL: 200.76 mAHD TD: 17 mBGL		
Soil or Rock Field Material Description	Graphic Log	Depth (mBGL) R.L. (mAHD)	Bore Construction	Bore Description
		202		
		201		Protective lockable steel collar: +1.3 m Stick up: +0.78 m
SOIL: low plasticity, poorly graded, clay matrix, dark brownish grey, dry.		0		
		1		
		2		124 mm PCD: 0 m to 17 m (Mud)
		3		Bentonite grout (2.5 %): 0 m to 6 m
SOIL: low plasticity, poorly graded, clay matrix, dark brown, dry.		4		50 mm uPVC Class 18 blank casing: 0 m to 9 m
		5		
		6		
		7		
SAND (90 %): coarse sand, sub-angular, quartz and lithic clasts, light brown, loose, dry.		8		Bentonite seal: 6 m to 8 m
		9		
SANDY CLAY (90 %): medium plasticity, coarse sand, sub-angular, quartz and lithic clasts, poorly graded, clay matrix, light brown, soft, moist.		10		SWL: 8.78 mbgl
		11		
SANDY CLAY (90 %): medium plasticity, coarse sand, sub-angular, quartz and lithic clasts, poorly graded, clay matrix, light brown, soft, moist, Water strike @ 11mbgl.		12		
CLAYBOUND GRAVEL (70 %): medium plasticity, coarse sand, sub-angular, Lithic clasts, poorly graded, clay matrix, light brown, wet.		13		2 - 4 mm washed, rounded, quartz gravel pack: 8 m to 15 m
CLAYBOUND GRAVEL: Lithic clasts, hard, loose, wet, Drillers noted this section of gravel was very hard (13m); base of alluvium at 14m.		14		50 mm uPVC Class 18 machine slotted casing, slot aperture: 1 mm, 9 m to 15 m
		15		
SILTSTONE (80 %): high plasticity, fine gravel, sub-angular, Lithic clasts, poorly graded, clay matrix, light grey, distinctly weathered wet.		16		
		17		End cap End of hole: 17 m BGL
		18		



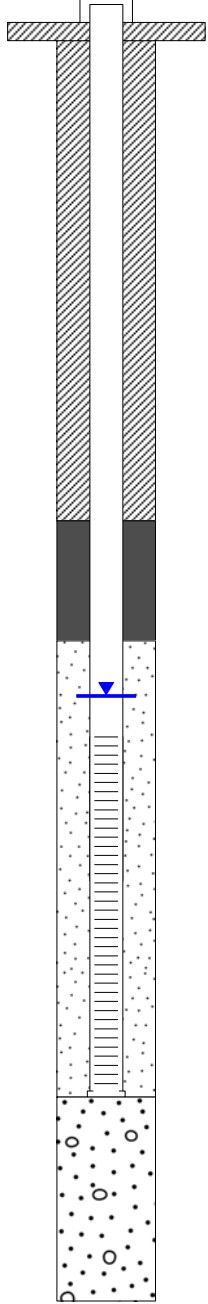
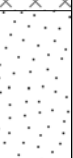
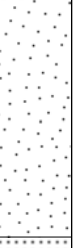
MBID19

PROJECT No: **G1803M**
PROJECT NAME: **Issac Downs remote bore installation**
DATE DRILLED: **14/11/2020**
LOGGED BY: **Richard Haselwood**

DRILLING COMPANY: **Wizard Drilling**
DRILLER: **Geoff Rogers**
DRILLING METHOD: **Mud rotary**
DRILL RIG: **McCulloch DR800 Mk2**

TD: **21 mBGL**
GL ELEVATION: **201.7 mAHD**
EASTING: **620764 mE**
NORTHING: **7561516 mN**
DATUM: **GDA 94 z55 UTM**

COMMENTS:

Soil or Rock Field Material Description	Graphic Log	Depth (mBGL) R.L. (mAHD)	Bore Construction	Bore Description
		202 0		Protective lockable steel collar: +0.9 m Stick up: +0.73 m Cement pad: 0.5 m x 0.5 m x 0.2m
SOIL: dark reddish-brown, residual soil, very loose.				
SILT: dark red, very loose.		200 2		
SILT: dark reddish-brown, very loose.		198 4		Bentonite grout (2 - 5 %): 0 m to 8 m
SAND: brown, very loose.		196 6		
		194 8		50 mm uPVC Class 18 blank casing: - 0.73 m to 11.6 m
GRAVEL, extremely coarse: grey, loose.		192 10		Bentonite seal: 8 m to 10 m 125 mm Blade: 0 m to 21 m (mud rotary) Water level: 10.92 m bgl on 23/11/2020
		190 12		
SAND, coarse: orangey-grey, loose.		188 14		3 mm washed, rounded, quartz gravel pack: 10 m to 17.6 m
		186 16		50 mm uPVC Class 18 machine slotted casing, slot aperture: 1 mm, 11.6 m to 17.6 m
SANDSTONE, fine to medium: light grey, extremely weathered, extremely low strength rock.		184 18		Water quality measurements on 23/11/2020: electrical conductivity: 2,609 µS/cm; pH: 6.09
				End cap
SANDSTONE, fine: grey, extremely weathered, extremely low strength rock.		182 20		Backfill: 17.6 m to 21 m
SANDSTONE, fine to medium: light grey, distinctly weathered, extremely low strength rock.				End of hole: 21 m BGL

BORE REPORT

Client: Stanmore Coal IP Pty Ltd

Project: Isaac Downs Coal Mine - EIS

Location: Peaks Downs Highway, via Moranbah

Project No: 018-168C

BORE MBID 21

Page No: 1 of 2

Date: 22 June 2020

Ground Surface Level: RL200.0m*

DRAFT

Depth (m)	Description	RL (m)	Lithology	Sample Type	Sample Depth (m)	Test Results	Groundwater Monitoring Bore
0	SILTY SAND (SM) - brown, fine to medium grained (topsoil) - very dense, pale brown	200.0					
0.5				S	0.5	Casing 19,24,28	
0.95		199.0			0.95	N=52 Grout	
1.5				S	1.5	15,18,13	
1.95		198.0			1.95	N=31	
3.0		197.0		U	3.0	pp>600	
3.15					3.15		
4.5		196.0			4.5	Backfill	
4.94		195.0		S	4.94	12,17,30/140mm	
6.0		194.0		S	6.0	7,11,12	
6.45					6.45	N=23	
7.5		193.0		U	7.5	pp=300	
7.9		192.0			7.9	Bentonite	
9.0		191.0		S	9.0	6,10,11	
9.45					9.45	N=21	

D Disturbed Sample

B Bulk Sample

U Undisturbed Tube (50mm diameter)

pp Pocket Penetrometer Test (kPa)

E Environmental Sample

S Standard Penetrometer Test (SPT)

HB SPT Hammer Bouncing

() No Sample Recovery

C NMLC Coring

Is(50) Point Load Test Result (MPa)

(d) Diametral Point Load Strength Test

(a) Axial Point Load Strength Test

Rig: Hydrapower Scout

Drilling Method: Auger to 3.0m, then washbore

Groundwater: No free groundwater encountered during drilling

Remarks: *Approximate ground surface level interpolated from Robert Bird Group Drawing 20103-RBG-ZZ-XX-SK-CV-018 (Rev A) Dated April 2020

Handheld GPS Coordinates

E: 621529

Logged by: ML

N: 7560060

BORE REPORT

Client: Stanmore Coal IP Pty Ltd
Project: Isaac Downs Coal Mine - EIS
Location: Peaks Downs Highway, via Moranbah
Project No: 018-168C

BORE MBID 21

Page No: 2 of 2

Date: 22 June 2020

Ground Surface Level: RL200.0m*

DRAFT

Depth (m)	Description	RL (m)	Lithology	Sample Type	Sample Depth (m)	Test Results	Groundwater Monitoring Bore
10	SANDY CLAY (CI) - very stiff, orange-brown mottled grey, fine to medium grained	190.0				Screen	
11	SILTY SAND (SM) - medium dense, pale grey mottled orange, fine to coarse grained	189.0		S	10.5 10.95	9,14,14 N=28	
12	SANDY GRAVEL (GP) - medium dense, orange-brown, fine to medium subrounded, medium to coarse grained sand	188.0		S	12.0 12.45	7,8,11 N=19	
13		187.0				Sand	
14	SILTY SAND (SM) - medium dense, orange-brown, medium to coarse grained	186.0		S	13.5 13.95	6,11, N=19	
15	SILTY CLAY (CH) - very stiff, orange-brown mottled pale grey	185.0		S	15.0 15.45	12,12,15 N=28	
16		184.0					
17	End of Bore at 16.95 m	183.0		S	16.5 16.95	9,10,2 N=22	
18		182.0					
19		181.0					

D Disturbed Sample
B Bulk Sample
U Undisturbed Tube (50mm diameter)
pp Pocket Penetrometer Test (kPa)

E Environmental Sample
S Standard Penetrometer Test (SPT)
HB SPT Hammer Bouncing
() No Sample Recovery

C NMLC Coring
Is(50) Point Load Test Result (MPa)
(d) Diametral Point Load Strength Test
(a) Axial Point Load Strength Test

Rig: Hydrapower Scout

Drilling Method: Auger to 3.0m, then washbore

Groundwater: No free groundwater encountered during drilling

Remarks: *Approximate ground surface level interpolated from Robert Bird Group Drawing 20103-RBG-ZZ-XX-SK-CV-018 (Rev A) Dated April 2020

Handheld GPS Coordinates

E: 621529

Logged by: ML

N: 7560060

BORE REPORT

Client: Stanmore Coal IP Pty Ltd
Project: Isaac Downs Coal Mine - EIS
Location: Peaks Downs Highway, via Moranbah
Project No: 018-168C

BORE MBID 22

Page No: 1 of 4
Date: 26 June 2020
Ground Surface Level: RL198.0m*

DRAFT

Depth (m)	Description	RL (m)	Lithology	Sample Type	Sample Depth (m)	Test Results	Groundwater Monitoring Bore
0	SILTY SAND (SM) - dark brown, fine to medium grained (topsoil)	198.0					
1	CLAYEY SAND (SC) - medium dense, brown mottled orange, fine to coarse grained	197.0		S	0.5 0.95	5,9,10 N=19	
2	SILTY CLAY (CH) - hard, brown mottled orange, with fine grained sand	196.0		U	1.5 1.9	pp>600	
3	CLAYEY SAND (SC) - medium dense, brown, fine to medium grained	195.0		S	3.0 3.45	Grout 5,8,8 N=16	
4	SILTY SAND (SM) - medium dense, orange-brown, fine to coarse grained	194.0		S	4.5 4.95	4,5,7 N=12 Casing	
5	SAND (SP) - medium dense, orange-brown, fine to coarse grained, with silt fines	193.0		S	6.0 6.45	Backfill 5,6,11 N=17	
6	CLAYEY SAND (SC) - dense, orange-brown, fine to coarse grained, with fine to medium subrounded gravel	192.0		S	7.5 7.95	12,21,27 N=48	
7	SANDY CLAY (CI) - hard, orange mottled pale grey, fine to coarse grained sand	191.0		S	9.0 9.45	8,25,30/145mm	
8		190.0					
9		189.0					

D Disturbed Sample

B Bulk Sample

U Undisturbed Tube (50mm diameter)

pp Pocket Penetrometer Test (kPa)

E Environmental Sample

S Standard Penetrometer Test (SPT)

HB SPT Hammer Bouncing

() No Sample Recovery

C NMLC Coring

Is(50) Point Load Test Result (MPa)

(d) Diametral Point Load Strength Test

(a) Axial Point Load Strength Test

Rig: Hydrapower Scout

Drilling Method: Auger to 3.0m, then washbore

Groundwater: No free groundwater encountered during drilling

Remarks: *Approximate ground surface level interpolated from Robert Bird Group Drawing 20103-RBG-ZZ-XX-SK-CV-018 (Rev A) Dated April 2020

Handheld GPS Coordinates

E: 622796

Logged by: ML

N: 7558353

BORE REPORT

Client: Stanmore Coal IP Pty Ltd

Project: Isaac Downs Coal Mine - EIS

Location: Peaks Downs Highway, via Moranbah

Project No: 018-168C

BORE MBID 22

Page No: 2 of 4

Date: 26 June 2020

Ground Surface Level: RL198.0m*

DRAFT

Depth (m)	Description	RL (m)	Lithology	Sample Type	Sample Depth (m)	Test Results	Groundwater Monitoring Bore
10	SANDY CLAY (CI) - hard, orange mottled pale grey, fine to coarse grained sand	188.0					
11	CLAYEY SAND (SC) - dense, orange mottled pale grey, fine to coarse grained	187.0		S	10.5 10.95	8,13,18 N=31	
12	- medium dense	186.0		S	12.0 12.45	5,8,11 N=19	
13		185.0					
14	SILTY CLAY (CH) - hard, pale grey mottled orange	184.0		S	13.5 13.75	18,30/100mm	
15	- red-brown	183.0		S	15.0 15.26	12,30/105mm	
16		182.0					
17		181.0		S	16.5 16.64	30/140mm	
18		180.0		S	18.0 18.25	22,30/95mm	
19		179.0					

D Disturbed Sample

B Bulk Sample

U Undisturbed Tube (50mm diameter)

pp Pocket Penetrometer Test (kPa)

E Environmental Sample

S Standard Penetrometer Test (SPT)

HB SPT Hammer Bouncing

() No Sample Recovery

C NMLC Coring

Is(50) Point Load Test Result (MPa)

(d) Diametral Point Load Strength Test

(a) Axial Point Load Strength Test

Rig: Hydrapower Scout

Drilling Method: Auger to 3.0m, then washbore

Groundwater: No free groundwater encountered during drilling

Remarks: *Approximate ground surface level interpolated from Robert Bird Group Drawing 20103-RBG-ZZ-XX-SK-CV-018 (Rev A) Dated April 2020

Handheld GPS Coordinates

E: 622796

Logged by: ML

N: 7558353

BORE REPORT

Client: Stanmore Coal IP Pty Ltd

Project: Isaac Downs Coal Mine - EIS

Location: Peaks Downs Highway, via Moranbah

Project No: 018-168C

BORE MBID 22

Page No: 3 of 4

Date: 26 June 2020

Ground Surface Level: RL198.0m*

DRAFT

Depth (m)	Description	RL (m)	Lithology	Sample Type	Sample Depth (m)	Test Results	Groundwater Monitoring Bore
20	SILTY CLAY (CH) - hard, red-brown	178.0		S	19.5 19.95	18,18,28 N=46	
21		177.0		S	21.0 21.12	30/120mm	Screen →
22		176.0					
23	MUDSTONE (XW) - extremely low strength, grey	175.0		S	22.5 22.58	30/80mm	Bentonite →
24		174.0		S	24.0 24.08	30/80mm	
25		173.0					
26	- very low to low strength	172.0		S	25.5 25.55	30/50mm	
27	- extremely low strength	171.0		S	27.0 27.09	30/90mm	
28		170.0					

D Disturbed Sample

B Bulk Sample

U Undisturbed Tube (50mm diameter)

pp Pocket Penetrometer Test (kPa)

E Environmental Sample

S Standard Penetrometer Test (SPT)

HB SPT Hammer Bouncing

() No Sample Recovery

C NMLC Coring

Is(50) Point Load Test Result (MPa)

(d) Diametral Point Load Strength Test

(a) Axial Point Load Strength Test

Rig: Hydrapower Scout

Drilling Method: Auger to 3.0m, then washbore

Groundwater: No free groundwater encountered during drilling

Remarks: *Approximate ground surface level interpolated from Robert Bird Group Drawing 20103-RBG-ZZ-XX-SK-CV-018 (Rev A) Dated April 2020

Handheld GPS Coordinates

E: 622796

Logged by: ML

N: 7558353

BORE REPORT

Client: Stanmore Coal IP Pty Ltd
Project: Isaac Downs Coal Mine - EIS
Location: Peaks Downs Highway, via Moranbah
Project No: 018-168C

BORE MBID 22

Page No: 4 of 4
Date: 26 June 2020
Ground Surface Level: RL198.0m*

DRAFT

Depth (m)	Description	RL (m)	Lithology	Sample Type	Sample Depth (m)	Test Results	Groundwater Monitoring Bore
29	MUDSTONE (XW) - extremely low strength, red-brown mottled pale grey	169.0		S	28.5 28.59	30/90mm	
30		168.0		S	30.0 30.07	30/70mm	
31		167.0				Sand	
32		166.0		S	31.5 31.59	30/85mm	
33	- low strength, grey	165.0		S	33.0 33.04	30/40mm	
34		164.0					
35		163.0		S	34.5 34.54	30/40mm	
36	End of Bore at 36.06 m	162.0		S	36.0 36.05	30/50mm	
37		161.0					
38		160.0					

D Disturbed Sample
B Bulk Sample
U Undisturbed Tube (50mm diameter)
pp Pocket Penetrometer Test (kPa)

E Environmental Sample
S Standard Penetrometer Test (SPT)
HB SPT Hammer Bouncing
() No Sample Recovery

C NMLC Coring
Is(50) Point Load Test Result (MPa)
(d) Diametral Point Load Strength Test
(a) Axial Point Load Strength Test

Rig: Hydrapower Scout

Drilling Method: Auger to 3.0m, then washbore

Groundwater: No free groundwater encountered during drilling

Remarks: *Approximate ground surface level interpolated from Robert Bird Group Drawing 20103-RBG-ZZ-XX-SK-CV-018 (Rev A) Dated April 2020

Handheld GPS Coordinates

E: 622796

Logged by: ML

N: 7558353

BORE REPORT

Client: Stanmore Coal IP Pty Ltd

Project: Isaac Downs Coal Mine - EIS

Location: Peaks Downs Highway, via Moranbah

Project No: 018-168C

BORE MBID 23

Page No: 1 of 2

Date: 28 June 2020

Ground Surface Level: RL198.0m*

DRAFT

Depth (m)	Description	RL (m)	Lithology	Sample Type	Sample Depth (m)	Test Results	Groundwater Monitoring Bore
0	SILTY SAND (SM) - brown, fine to medium grained (topsoil) - medium dense	198.0					
0.5				S	0.5	8,10,11	
0.95		197.0			0.95	N=21	
1.5				S	1.5	9,9,11	Grout
1.95		196.0			1.95	N=20	
3.0		195.0		S	3.0	6,13,13	Backfill
3.45					3.45	N=26	
4.5		194.0		S	4.5	8,14,18	
4.95		193.0			4.95	N=32	Casing
6.0		192.0		S	6.0	10,14,16	
6.45					6.45	N=30	Bentonite
7.5		191.0		S	7.5	14,22,27	
7.95		190.0			7.95	N=49	
9.0		189.0		S	9.0	13,21,27	
9.45					9.45	N=48	

D Disturbed Sample

B Bulk Sample

U Undisturbed Tube (50mm diameter)

pp Pocket Penetrometer Test (kPa)

E Environmental Sample

S Standard Penetrometer Test (SPT)

HB SPT Hammer Bouncing

() No Sample Recovery

C NMLC Coring

Is(50) Point Load Test Result (MPa)

(d) Diametral Point Load Strength Test

(a) Axial Point Load Strength Test

Rig: Hydrapower Scout

Drilling Method: Auger to 3.0m, then washbore

Groundwater: No free groundwater encountered during drilling

Remarks: *Approximate ground surface level interpolated from Robert Bird Group Drawing 20103-RBG-ZZ-XX-SK-CV-018 (Rev A) Dated April 2020

Handheld GPS Coordinates

E: 621677

Logged by: ML

N: 7559407

BORE REPORT

Client: Stanmore Coal IP Pty Ltd
Project: Isaac Downs Coal Mine - EIS
Location: Peaks Downs Highway, via Moranbah
Project No: 018-168C

BORE MBID 23

Page No: 2 of 2

Date: 28 June 2020

Ground Surface Level: RL198.0m*

DRAFT

Depth (m)	Description	RL (m)	Lithology	Sample Type	Sample Depth (m)	Test Results	Groundwater Monitoring Bore
10	SILTY SAND (SM) - dense, orange-brown, fine to coarse grained, trace of fine subrounded gravel	188.0					
11		187.0		S	10.5 10.95	13,20,26 N=46	
12	- orange-pale grey, interbedded with sandy clay bands	186.0		S	12.0 12.45	10,14,24 N=38	Screen Sand
13		185.0					
14	SILTY CLAY (CH) - very stiff, grey mottled orange	184.0		S	13.5 13.95	8,12,17 N=29	
	End of Bore at 13.95 m						
15		183.0					
16		182.0					
17		181.0					
18		180.0					
19		179.0					

D Disturbed Sample

B Bulk Sample

U Undisturbed Tube (50mm diameter)

pp Pocket Penetrometer Test (kPa)

E Environmental Sample

S Standard Penetrometer Test (SPT)

HB SPT Hammer Bouncing

() No Sample Recovery

C NMLC Coring

Is(50) Point Load Test Result (MPa)

(d) Diametral Point Load Strength Test

(a) Axial Point Load Strength Test

Rig: Hydrapower Scout

Drilling Method: Auger to 3.0m, then washbore

Groundwater: No free groundwater encountered during drilling

Remarks: *Approximate ground surface level interpolated from Robert Bird Group Drawing 20103-RBG-ZZ-XX-SK-CV-018 (Rev A) Dated April 2020

Handheld GPS Coordinates

E: 621677

Logged by: ML

N: 7559407



**Australasian Groundwater & Environmental
Consultants Pty Ltd**

Level 2, 15 Mallon Street, Bowen Hills, Queensland 4006

BOREHOLE LOG

page:1 of 1

MBID25

PROJECT No: **G1803M**
PROJECT NAME: **Issac Downs remote bore installation**
DATE DRILLED: **15/11/2020**
LOGGED BY: **Richard Haselwood**

DRILLING COMPANY: **Wizard Drilling**
DRILLER: **Geoff Rogers**
DRILLING METHOD: **Mud rotary**
DRILL RIG: **McCulloch DR800 Mk2**

TD: **21 mBGL**
GL ELEVATION: **198.01 mAHD**
EASTING: **623927 mE**
NORTHING: **7558587 mN**
DATUM: **GDA 94 z55 UTM**

COMMENTS:

Soil or Rock Field Material Description	Graphic Log	Depth (mBGL) R.L. (mAHD)	Bore Construction	Bore Description
				Protective lockable steel collar: +0.9 m Stick up: +0.65 m Cement pad: 0.5 m × 0.5 m × 0.2m
SOIL: dark reddish-brown, residual soil, very loose.		198 0		
SAND, fine: orangey-brown, very loose.		196 2		
SAND, medium: orangey-buff, very loose.		194 4		Bentonite grout (2 - 5 %): 0 m to 8 m
SAND, fine to medium: orangey-brown, very loose.		192 6		
SAND, fine: reddish-brown, very loose.		190 8		50 mm uPVC Class 18 blank casing: - 0.65 m to 12 m
SILT: orangey-brown, very loose.		188 10		Bentonite seal: 8 m to 10 m
GRAVEL, extremely coarse: orangey-grey, sandy laminae (2-20mm), silty laminae (2-20mm), loose.		186 12		125 mm Blade: 0 m to 21 m (mud rotary)
MUDSTONE: light grey, extremely weathered, extremely low strength rock.		184 14		3 mm washed, rounded, quartz gravel pack: 10 m to 18 m
SILTSTONE: dark reddish-brown, extremely weathered, firm.		182 16		50 mm uPVC Class 18 machine slotted casing, slot aperture: 1 mm, 12 m to 18 m
SILTSTONE: reddish-grey, extremely weathered, soft.		180 18		Water level: 16.19 m bgl on 23/11/2020 Water quality measurements on 23/11/2020: electrical conductivity: 2,793 µS/cm; pH: 7.20
MUDSTONE: grey, extremely weathered, extremely low strength rock.		178 20		End cap
				Backfill: 18 m to 21 m
				End of hole: 21 m BGL



**Australasian Groundwater & Environmental
Consultants Pty Ltd**

Level 2, 15 Mallon Street, Bowen Hills, Queensland 4006

BOREHOLE LOG

page:1 of 1

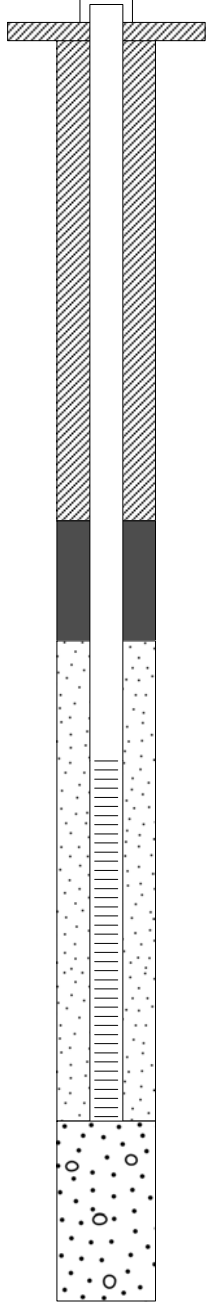
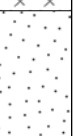
MBID26

PROJECT No: **G1803M**
PROJECT NAME: **Issac Downs remote bore installation**
DATE DRILLED: **15/11/2020**
LOGGED BY: **Richard Haselwood**

DRILLING COMPANY: **Wizard Drilling**
DRILLER: **Geoff Rogers**
DRILLING METHOD: **Air rotary**
DRILL RIG: **McCulloch DR800 Mk2**

TD: **21 mBGL**
GL ELEVATION: **202.13 mAHD**
EASTING: **624171 mE**
NORTHING: **7559434 mN**
DATUM: **GDA 94 z55 UTM**

COMMENTS:

Soil or Rock Field Material Description	Graphic Log	Depth (mBGL) R.L. (mAHD)	Bore Construction	Bore Description
		202 0		Protective lockable steel collar: +0.9 m Stick up: +0.66 m Cement pad: 0.5 m x 0.5 m x 0.2m
SOIL: orangey-brown, sandy in part, residual soil, loose.		200 2		
SILT: orangey-grey, loose.		198 4		Bentonite grout (2 - 5 %): 0 m to 8 m
SAND, fine: buff-orange, silty throughout, loose.		196 6		
SAND, fine: reddish-brown, silty throughout, loose.		194 8		50 mm uPVC Class 18 blank casing: - 0.66 m to 12 m
SAND, medium: orangey-buff, silty in part, loose.		192 10		Bentonite seal: 8 m to 10 m
SAND, medium: grey. loose.		190 12		125 mm Blade: 0 m to 21 m (air rotary)
SAND, medium: orangey-grey, loose.		188 14		3 mm washed, rounded, quartz gravel pack: 10 m to 18 m
MUDSTONE: grey, extremely weathered, extremely low strength rock.		186 16		50 mm uPVC Class 18 machine slotted casing, slot aperture: 1 mm, 12 m to 18 m
MUDSTONE: dark grey, distinctly weathered, very low strength rock.		184 18		Bore dry when dipped on 23/11/2020
		182 20		End cap
				Backfill: 18 m to 21 m
				End of hole: 21 m BGL



MBID27

PROJECT No: **G1803M**
PROJECT NAME: **Issac Downs remote bore installation**
DATE DRILLED: **12/11/2020**
LOGGED BY: **Richard Haselwood**

DRILLING COMPANY: **Wizard Drilling**
DRILLER: **Geoff Rogers**
DRILLING METHOD: **Air rotary**
DRILL RIG: **McCulloch DR800 Mk2**

TD: **21 mBGL**
GL ELEVATION: **198.79 mAHD**
EASTING: **622212 mE**
NORTHING: **7557636 mN**
DATUM: **GDA 94 z55 UTM**

COMMENTS:

Soil or Rock Field Material Description	Graphic Log	Depth (mBGL) R.L. (mAHD)	Bore Construction	Bore Description
		0		Protective lockable steel collar: +0.9 m Stick up: +0.72 m Cement pad: 0.5 m × 0.5 m × 0.2m
SOIL: dark reddish-brown, residual soil, very soft.		198		
		2		
CLAY: orangey-brown, soft.		196		
		4		Bentonite grout (2 - 5 %): 0 m to 8 m
SAND: buff-brown, residual soil, very soft.		194		
		6		
CLAY: buff, soft.		192		50 mm uPVC Class 18 blank casing: - 0.66 m to 12 m
		8		
		190		Bentonite seal: 8 m to 10 m
MUDSTONE: light grey, extremely weathered, soft.		10		125 mm Blade: 0 m to 21 m (air rotary)
		188		
COAL: brownish-grey, extremely weathered, extremely low strength rock.		12		Water level: 11.58 m bgl on 23/11/2020
		186		
MUDSTONE: light buff-grey, distinctly weathered, extremely low strength rock.		14		3 mm washed, rounded, quartz gravel pack: 10 m to 18 m
		184		50 mm uPVC Class 18 machine slotted casing, slot aperture: 1 mm, 12 m to 18 m
MUDSTONE: dark grey, slightly weathered, very low strength rock.		16		
		182		
MUDSTONE: dark grey, slightly weathered, low strength rock.		18		
		180		End cap
		20		Backfill: 18 m to 21 m
		178		End of hole: 21 m BGL

BORE REPORT

Client: Stanmore Coal IP Pty Ltd
Project: Isaac Downs Coal Mine - EIS
Location: Peaks Downs Highway, via Moranbah
Project No: 018-168C

BORE MBID 28

Page No: 1 of 2

Date: 29 June 2020

Ground Surface Level: RL198.0m*

DRAFT

Depth (m)	Description	RL (m)	Lithology	Sample Type	Sample Depth (m)	Test Results	Groundwater Monitoring Bore
0	SILTY SAND (SM) - dark brown, fine to medium grained (topsoil)	198.0					
1	CLAYEY SAND (SC) - medium dense, brown mottled orange, fine to medium grained	197.0					Grout
2	SILTY CLAY (CH) - hard, brown mottled orange, with fine grained sand	196.0					
3	CLAYEY SAND (SC) - medium dense, brown, fine to medium grained	195.0					
4		194.0					
5	SILTY SAND (SM) - medium dense, orange-brown, fine to medium grained	193.0					Casing
6	SAND (SP) - medium dense, orange-brown, fine to coarse grained, with silt fines	192.0					Backfill
7		191.0					
8	CLAYEY SAND (SC) - dense, orange-brown, fine to coarse grained, with fine to medium subrounded gravel	190.0					
9	SANDY CLAY (CI) - hard, orange mottled pale grey, fine to coarse grained sand	189.0					Bentonite

D Disturbed Sample

B Bulk Sample

U Undisturbed Tube (50mm diameter)

pp Pocket Penetrometer Test (kPa)

E Environmental Sample

S Standard Penetrometer Test (SPT)

HB SPT Hammer Bouncing

() No Sample Recovery

C NMLC Coring

Is(50) Point Load Test Result (MPa)

(d) Diametral Point Load Strength Test

(a) Axial Point Load Strength Test

Rig: Hydrapower Scout

Drilling Method: Auger to 3.0m, then washbore

Groundwater: No free groundwater encountered during drilling

Remarks: *Approximate ground surface level interpolated from Robert Bird Group Drawing 20103-RBG-ZZ-XX-SK-CV-018 (Rev A) Dated April 2020

Handheld GPS Coordinates

E: 622795

Logged by: ML

N: 7558353

BORE REPORT

Client: Stanmore Coal IP Pty Ltd
Project: Isaac Downs Coal Mine - EIS
Location: Peaks Downs Highway, via Moranbah
Project No: 018-168C

BORE MBID 28

Page No: 2 of 2

Date: 29 June 2020

Ground Surface Level: RL198.0m*

DRAFT

Depth (m)	Description	RL (m)	Lithology	Sample Type	Sample Depth (m)	Test Results	Groundwater Monitoring Bore
10	SANDY CLAY (CI) - hard, orange mottled pale grey, fine to coarse grained sand	188.0					
11	CLAYEY SAND (SC) - dense, orange mottled pale grey, fine to coarse grained	187.0				Sand	
12		186.0					
13		185.0				Screen	
14	SILTY CLAY (CH) - hard, pale grey mottled orange	184.0					
15	End of Bore at 15 m	183.0					
16		182.0					
17		181.0					
18		180.0					
19		179.0					

D Disturbed Sample

B Bulk Sample

U Undisturbed Tube (50mm diameter)

pp Pocket Penetrometer Test (kPa)

E Environmental Sample

S Standard Penetrometer Test (SPT)

HB SPT Hammer Bouncing

() No Sample Recovery

C NMLC Coring

Is(50) Point Load Test Result (MPa)

(d) Diametral Point Load Strength Test

(a) Axial Point Load Strength Test

Rig: Hydrapower Scout

Drilling Method: Auger to 3.0m, then washbore

Groundwater: No free groundwater encountered during drilling

Remarks: *Approximate ground surface level interpolated from Robert Bird Group Drawing 20103-RBG-ZZ-XX-SK-CV-018 (Rev A) Dated April 2020

Handheld GPS Coordinates

E: 622795

Logged by: ML

N: 7558353

BORE REPORT

REG NUMBER 162817

REGISTRATION DETAILS

OFFICE Mackay	BASIN 1304	LATITUDE 22-04-25	MAP-SCALE
DATE LOG RECD	SUB-AREA	LONGITUDE 148-11-28	MAP-SERIES
D/O FILE NO.	SHIRE 3980-ISAAC REGIONAL	EASTING 622899	MAP-NO
R/O FILE NO.	LOT 8	NORTHING 7558531	MAP NAME
H/O FILE NO.	PLAN SP277384	ZONE 55	PROG SECTION
	ORIGINAL DESCRIPTION	ACCURACY	PRES EQUIPMENT
		GPS ACC	
GIS LAT -22.07373883	PARISH NAME 6000-NO LONGER USED	ORIGINAL BORE NO 5 MILE BORE	
GIS LNG 148.19119613	COUNTY	BORE LINE -	
CHECKED Y			
		POLYGON	
		RN OF BORE REPLACED	
		DATA OWNER	
FACILITY TYPE Sub-Artesian Facility	DATE DRILLED 01/01/2002		
STATUS Existing	DRILLERS NAME		
ROLES	DRILL COMPANY		
	METHOD OF CONST.		

CASING DETAILS

PIPE	DATE	RECORD NUMBER	MATERIAL DESCRIPTION	MAT SIZE (mm)	SIZE DESC	OUTSIDE DIAM (mm)	TOP (m)	BOTTOM (m)
A	01/01/2002	1	Polyvinyl Chloride			140		

STRATA LOG DETAILS

RECORD NUMBER	STRATA TOP (m)	STRATA BOT (m)	STRATA DESCRIPTION
1	0.00	32.00	NO DETAILS. 7.5 LPS

STRATIGRAPHY DETAILS

**** NO RECORDS FOUND ****

AQUIFER DETAILS

**** NO RECORDS FOUND ****

PUMP TEST DETAILS PART 1

BORE REPORT

REG NUMBER 162818

REGISTRATION DETAILS

OFFICE Mackay	BASIN 1304	LATITUDE 22-04-26	MAP-SCALE
DATE LOG RECD	SUB-AREA	LONGITUDE 148-11-29	MAP-SERIES
D/O FILE NO.	SHIRE 3980-ISAAC REGIONAL	EASTING 622909	MAP-NO
R/O FILE NO.	LOT 8	NORTHING 7558529	MAP NAME
H/O FILE NO.	PLAN SP277384	ZONE 55	PROG SECTION
	ORIGINAL DESCRIPTION	ACCURACY	PRES EQUIPMENT
		GPS ACC	
GIS LAT -22.07375619	PARISH NAME 6000-NO LONGER USED		ORIGINAL BORE NO 5 MILE WINDMILL
GIS LNG 148.19129319	COUNTY		BORE LINE -
CHECKED Y			
			POLYGON
			RN OF BORE REPLACED
			DATA OWNER
FACILITY TYPE Sub-Artesian Facility	DATE DRILLED		
STATUS Existing	DRILLERS NAME		
ROLES	DRILL COMPANY		
	METHOD OF CONST.		

CASING DETAILS

PIPE	DATE	RECORD NUMBER	MATERIAL DESCRIPTION	MAT SIZE (mm)	SIZE DESC	OUTSIDE DIAM (mm)	TOP (m)	BOTTOM (m)
A	01/01/1900	1	Polyvinyl Chloride			140		

STRATA LOG DETAILS

RECORD NUMBER	STRATA TOP (m)	STRATA BOT (m)	STRATA DESCRIPTION
1	0.00	30.00	NO DETAILS. DEPTH APPROX.

STRATIGRAPHY DETAILS

**** NO RECORDS FOUND ****

AQUIFER DETAILS

**** NO RECORDS FOUND ****

PUMP TEST DETAILS PART 1

BORE REPORT

REG NUMBER 162818

**** NO RECORDS FOUND ****

PUMP TEST DETAILS PART 2

**** NO RECORDS FOUND ****

BORE CONDITION

**** NO RECORDS FOUND ****

ELEVATION DETAILS

PIPE	DATE	ELEVATION	PRECISION	DATUM	MEASUREMENT POINT	SURVEY SOURCE
A	08/02/2006	207.80	GPS	AHD	R	ISAAC PLAINS BORE CENSUS

WATER ANALYSIS PART1

**** NO RECORDS FOUND ****

WATER ANALYSIS PART 2

**** NO RECORDS FOUND ****

WATER LEVEL DETAILS

PIPE	DATE	MEASURE (m)	N/R	RMK	MEAS TYPE
A	08/02/2006	-13.41	R		ACT

PIPE	DATE	MEASURE (m)	N/R	RMK	MEAS TYPE
------	------	-------------	-----	-----	-----------

PIPE	DATE	MEASURE (m)	N/R	RMK	MEAS TYPE
------	------	-------------	-----	-----	-----------

WIRE LINE LOG DETAILS

**** NO RECORDS FOUND ****

FIELD MEASUREMENTS

**** NO RECORDS FOUND ****

SPECIAL WATER ANALYSIS

**** NO RECORDS FOUND ****

BORE REPORT

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**** End of Report. Produced: 14/08/2018 11:34:59 AM ****

BORE REPORT

REG NUMBER 162817

**** NO RECORDS FOUND ****

PUMP TEST DETAILS PART 2

**** NO RECORDS FOUND ****

BORE CONDITION

**** NO RECORDS FOUND ****

ELEVATION DETAILS

PIPE	DATE	ELEVATION	PRECISION	DATUM	MEASUREMENT POINT	SURVEY SOURCE
A	08/02/2006	206.10	GPS	AHD	R	ISAAC PLAINS BORE CENSUS

WATER ANALYSIS PART1

**** NO RECORDS FOUND ****

WATER ANALYSIS PART 2

**** NO RECORDS FOUND ****

WATER LEVEL DETAILS

PIPE	DATE	MEASURE (m)	N/R	RMK	MEAS TYPE
A	08/02/2006	-13.26	R		ACT

PIPE	DATE	MEASURE (m)	N/R	RMK	MEAS TYPE
------	------	-------------	-----	-----	-----------

PIPE	DATE	MEASURE (m)	N/R	RMK	MEAS TYPE
------	------	-------------	-----	-----	-----------

WIRE LINE LOG DETAILS

**** NO RECORDS FOUND ****

FIELD MEASUREMENTS

**** NO RECORDS FOUND ****

SPECIAL WATER ANALYSIS

**** NO RECORDS FOUND ****

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2 Ownership:

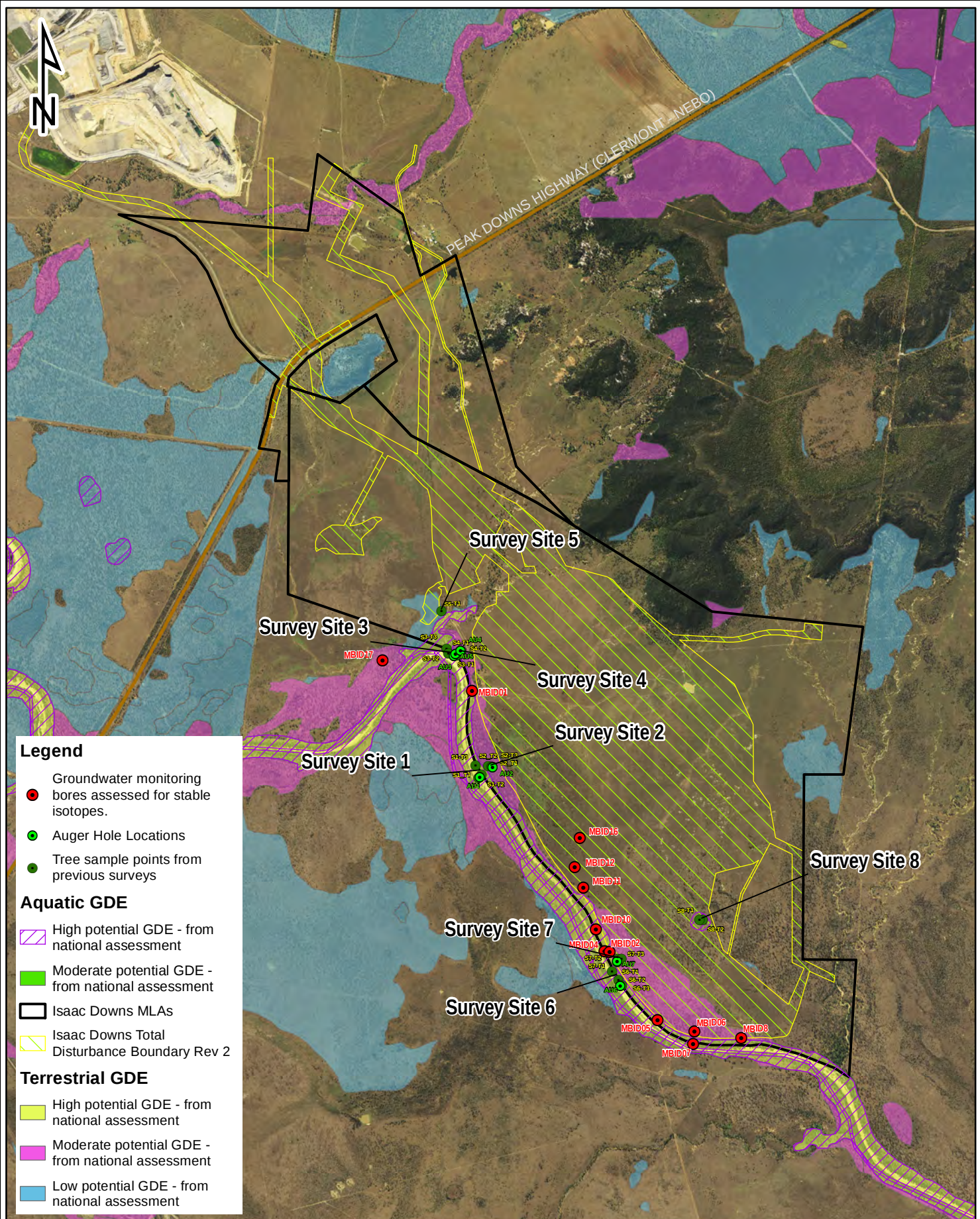
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**** End of Report. Produced: 14/08/2018 11:31:35 AM ****

Appendix C. Sampling Localities and Methods from EIS

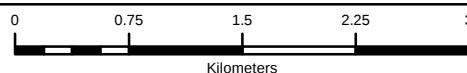


Source: BOM GDE Atlas (2020).

Appendix C. GDE sampling locations and methods

Client

Stanmore IP South Pty Ltd



Scale 1:50,000

Drawn By DG

Checked DS

File Path

Date 29/10/2020

A4



P. O. Box 959
Kenmore, Qld 4069
Mobile: 0447 822 119
www.3denvironmental.com.au

Appendix D. Raw Stable Isotope Data from Isaac Downs EIS Assessment

Stable Isotope Analysis

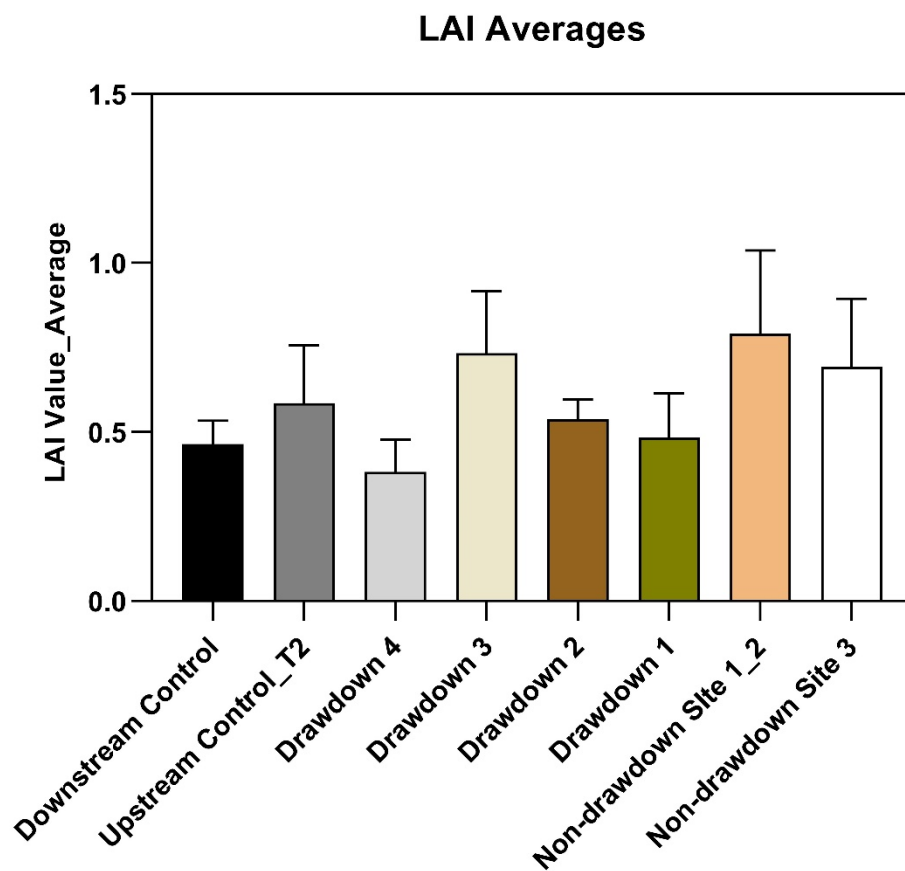
Sample	Accepted	d2H VSMOW		Accepted	d18O VSMOW
	H			O	
MB14-MBID16	standard	-32.21		standard	-4.30
MB14-MBID16		-32.75			-4.39
MB11-MBID06		-49.66			-7.20
MB11-MBID06		-49.68			-7.12
MB04-MBID01		-26.92			-3.60
MB04-MBID01		-24.10			-2.81
MBID12		-34.87			-4.95
MBID12		-35.13			-5.10
FROST	-75.93	-75.68		-13.77	-13.76
FROST	-75.93	-75.80		-13.77	-13.87
COW	-0.22	-0.35		-0.24	-0.16
COW	-0.22	0.22		-0.24	-0.19
MB07-MBID07		-36.51			-5.46
MB07-MBID07		-36.50			-5.56
MB12-MBID05		-38.17			-5.70
MB12-MBID05		-37.30			-5.78
MB06-MBID10		-35.16			-5.12
MB06-MBID10		-34.44			-5.10
MB03-MBID17		-28.75			-4.44
MB03-MBID17		-28.20			-4.52
MB10-MBID08		-39.39			-5.80
MB10-MBID08		-39.20			-5.81
MB05D-MBID04		-32.17			-4.77
MB05D-MBID04		-32.31			-4.77
MBID02		-29.05			-4.15
MBID02		-28.26			-3.89
COW	-0.22	-0.99		-0.24	-0.40
COW	-0.22	-1.18		-0.24	-0.43
FROST	-75.93	-75.47		-13.77	-13.80
FROST	-75.93	-75.86		-13.77	-13.77

Appendix E. Summary Data from November 2020 GDE Monitoring Assessment

Appendix E1. T-test for comparison of LAI mean values between control and impact sites.

Downstream control (Mean LAI = 0.4649)	Drawdown 4	Drawdown 3	Drawdown 2	Drawdown 1	Non- drawdown 1_2	Non- drawdown 3
T value	t=1.573	t=3.066	t=1.821	t=0.2825	t=2.843,	t=2.400
Degrees Freedom	df=8	df=9	df=8	df=8	df=8	df=8
Mean LAI Value	0.3824	0.7332	0.538	0.4836	0.7901	0.6993
P Value	p= 0.1544	p=0.013	p= 0.1061	p= 0.2413	p= 0.0217	p= 0.0432
Statistically Significant Differences	No	Yes	No	No	Yes	Yes
Upstream control (Mean LAI = 0.5856)	Drawdown 4	Drawdown 3	Drawdown 2	Drawdown 1	Non- drawdown 1_2	Non- drawdown 3
T value	t=2.317	t= 1.365	t= 0.5880	t=1.057	t=1.523	t=0.9107
Degrees Freedom	df=8	df=9	df=8	df = 9	df=8	df=8
Mean LAI Value	0.3824	0.7332	0.538	0.4836	0.7901	0.6993
P Value	p= 0.0492	p=0.9196	p=0.5728	p=0.3215	p=0.1162	0.3891
Statistically Significant Differences	Yes	No	No	No	No	No

Appendix E2. Mean LAI values for GDE monitoring localities.



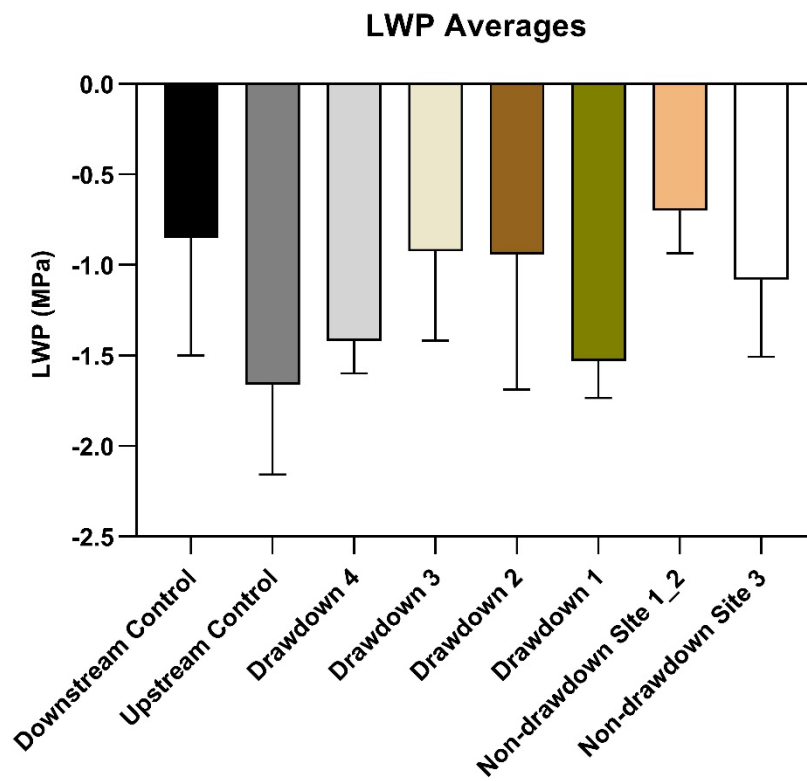
Appendix E3. Raw data from LAI field measurements.

Timestamp	Impact Area	Filename	Longitude	Latitude	Sunflecks	PAR Average	PAR LAI	GAP Fraction LAI
11/23/2020 4:55:21 AM	Drawdown	DD3T_1.ci110	148.1916	-22.073	100%	38	4.706746	0.9101824
11/23/2020 4:58:09 AM	Drawdown	DD3T_2.ci110	148.1918	-22.0729	100%	73	3.961445	0.5800227
11/23/2020 5:00:01 AM	Drawdown	DD3T_3.ci110	148.1921	-22.0729	100%	50	4.400747	0.5953562
11/23/2020 5:02:08 AM	Drawdown	DD3T_4.ci110	148.1921	-22.0727	100%	43	4.562379	0.8687891
11/23/2020 5:03:51 AM	Drawdown	DD3T_5.ci110	148.1918	-22.0729	100%	73	3.960117	0.5266511
11/23/2020 5:06:17 AM	Drawdown	DD3T_6.ci110	148.1918	-22.0729	100%	73	3.960117	0.9179622
11/23/2020 5:19:59 AM	Drawdown	DD2T_1.ci110	148.1816	-22.0642	100%	66	4.079489	0.5030637
11/23/2020 5:21:39 AM	Drawdown	DD2T_2.ci110	148.1815	-22.0642	100%	58	4.226751	0.6051204
11/23/2020 5:24:05 AM	Drawdown	DD2T_3.ci110	148.1818	-22.0648	100%	89	3.733447	0.5804862
11/23/2020 5:26:32 AM	Drawdown	DD2T_4.ci110	148.1817	-22.065	100%	76	3.910228	0.5389072
11/23/2020 5:28:58 AM	Drawdown	DD2T_5.ci110	148.1822	-22.0653	100%	78	3.885535	0.4622823
11/23/2020 5:41:15 AM	Drawdown	DD1T_1.ci110	148.1778	-22.0584	100%	88	3.744932	0.6018231
11/23/2020 5:42:45 AM	Drawdown	DD1T_2.ci110	148.1779	-22.0584	100%	90	3.708989	0.4085942
11/23/2020 5:45:09 AM	Drawdown	DD1T_3.ci110	148.1778	-22.0587	100%	95	3.647212	0.28968
11/23/2020 5:49:28 AM	Drawdown	DD1T_4.ci110	148.1782	-22.059	100%	78	3.876285	0.5601367
11/23/2020 5:51:53 AM	Drawdown	DD1T_5.ci110	148.1785	-22.0592	100%	216	2.698145	0.5575907
11/24/2020 4:25:22 PM	Drawdown	DD4T_1.ci110	148.2046	-22.0732	100%	76	3.913736	0.4171316

Timestamp	Impact Area	Filename	Longitude	Latitude	Sunflecks	PAR Average	PAR LAI	GAP Fraction LAI
11/24/2020 4:26:11 PM	Drawdown	DD4T_2.ci110	148.2047	-22.0734	100%	281	2.390441	0.3594701
11/24/2020 4:28:31 PM	Drawdown	DD4T_3.ci110	148.2054	-22.0733	100%	71	3.991507	0.5242256
11/24/2020 4:29:47 PM	Drawdown	DD4T_4.ci110	148.2053	-22.0736	100%	135	3.246069	0.2713915
11/24/2020 4:31:12 PM	Drawdown	DD4T_5.ci110	148.2051	-22.0741	100%	79	3.8591	0.340004
11/22/2020 6:17:13 AM	Control	IDCUT_1.ci110	148.1524	-22.0462	58%	282	2.386745	0.5965444
11/22/2020 7:56:36 AM	Control	IDCUT_2.ci110	148.153	-22.0464	100%	239	2.579937	0.2956193
11/22/2020 8:01:22 AM	Control	IDCUT_3.ci110	148.1531	-22.0463	100%	481	1.767445	0.7424625
11/22/2020 8:08:11 AM	Control	IDCUT_4.ci110	148.1537	-22.0464	100%	211	2.724903	0.674315
11/22/2020 8:12:32 AM	Control	IDCUT_5.ci110	148.1541	-22.0463	100%	373	2.061159	0.6189069
11/24/2020 4:43:00 PM	Control	IDDCT_1.ci110	148.2063	-22.0781	100%	54	4.29874	0.389731
11/24/2020 4:41:44 PM	Control	IDDCT_2.ci110	148.2063	-22.0779	100%	86	3.770674	0.4644249
11/24/2020 4:46:20 PM	Control	IDDCT_3.ci110	148.2065	-22.0787	100%	57	4.24614	0.5768941
11/24/2020 4:48:50 PM	Control	IDDCT_4.ci110	148.2068	-22.0795	100%	78	3.879753	0.4391071
11/24/2020 4:49:57 PM	Control	IDDCT_5.ci110	148.2069	-22.0799	100%	64	4.102923	0.454218
11/22/2020 5:09:57 AM	Non-drawdown	ND1T_1.ci110	148.1697	-22.0489	100%	103	3.556934	0.7529624
11/22/2020 5:12:07 AM	Non-drawdown	ND1T_2.ci110	148.17	-22.0487	100%	70	4.011478	0.6559746
11/22/2020 5:14:09 AM	Non-drawdown	ND1T_3.ci110	148.1697	-22.0484	100%	67	4.062382	0.5749801
11/22/2020 5:17:20 AM	Non-drawdown	ND1T_4.ci110	148.1697	-22.0472	100%	71	3.986329	0.7570087
11/22/2020 5:19:25 AM	Non-drawdown	ND1T_5.ci110	148.1694	-22.0469	100%	88	3.734815	1.20962

Timestamp	Impact Area	Filename	Longitude	Latitude	Sunflecks	PAR Average	PAR LAI	GAP Fraction LAI
11/22/2020 5:43:15 AM	Non-drawdown	ND3T_1.ci110	148.1675	-22.0379	100%	160	3.043094	0.9662218
11/22/2020 5:46:04 AM	Non-drawdown	ND3T_2.ci110	148.1668	-22.0375	100%	164	3.01485	0.501779
11/22/2020 5:47:40 AM	Non-drawdown	ND3T_3.ci110	148.1668	-22.0373	100%	127	3.312043	0.6040511
11/22/2020 5:49:57 AM	Non-drawdown	ND3T_4.ci110	148.1665	-22.0373	100%	109	3.49474	0.8442059
11/22/2020 5:52:46 AM	Non-drawdown	ND3T_5.ci110	148.1667	-22.0378	100%	488	1.749929	0.5504543

Appendix E4. LWP Mean Values for GDE monitoring localities.



Appendix E5. LWP Measurement Summary

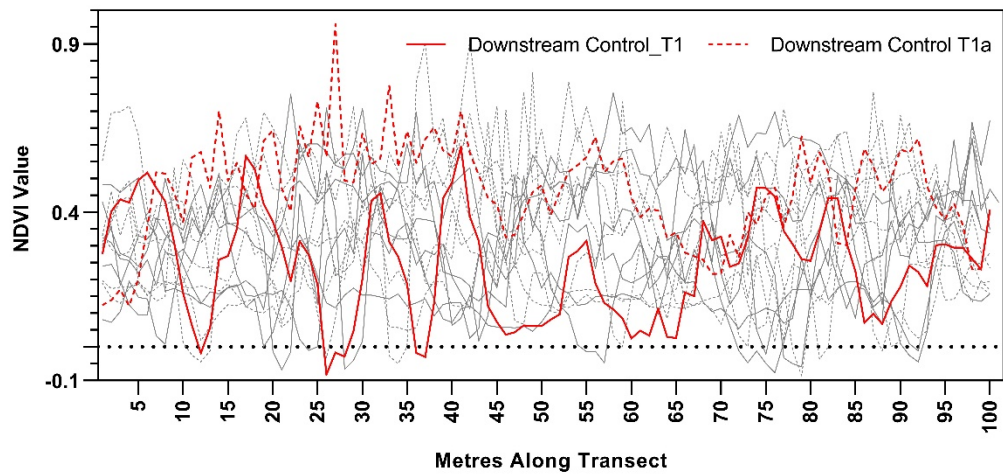
TREE	Tree from ID EIS	Species	Y	X	HGT (m)	DBH (cm)	LWP1 MPa	LWP ID EIS	Geomorphic Position	Isotope Analysis
IDUCT1		Eucalyptus camaldulensis	-22.046238	148.152411	23	70	-1.3		Near top of terrace	Y
IDUCT2		Eucalyptus camaldulensis	-22.046358	148.153015	90	27	-1.7		3m from top of bank near channel	
IDUCT3		Eucalyptus camaldulensis	-22.04628	148.153169	90	26	-2.5		15m from top of bank - mid terrace	Y
IDUCT4		Eucalyptus camaldulensis	-22.046427	148.153777	70	23	-1.5		3 m from top of bank near channel	Y
IDUCT5		Eucalyptus camaldulensis	-22.04633	148.15407	100	25	-1.3		Near top of terrace	
ND3T1	S3T1	Eucalyptus camaldulensis	-22.037994	148.167417	90	23	-1.5	-1.25	2m from bank -near channel	
ND3T2		Eucalyptus camaldulensis	-22.037581	148.166782	110	27	-0.9		On bank, directly above channel on inner levee - elevated 6-7m above channel floor	Y
ND3T3		Eucalyptus camaldulensis	-22.037365	148.16674	75	22	-0.5		8m above channel, adjacent to tributary gully	Y
ND3T4	S3T3	Eucalyptus camaldulensis	-22.037372	148.166498	100	26	-1	-1.89	5m above channel - mid terrace	Y
ND3T5	S3T2	Eucalyptus camaldulensis	-22.037884	148.166661	60	19	-1.5	-1.9	On sandy levee within main channel	
ND1T1		Eucalyptus camaldulensis	-22.048898	148.169737	70	18	-0.4	-0.1	Instream island in main channel.of Isaac River	Y
ND1T2		Eucalyptus camaldulensis	-22.048692	148.169926	75	22	-0.9	-0.49	Edge of inner bench above river channel	
ND1T3		Eucalyptus camaldulensis	-22.048413	148.169606	65	18	-0.5		Edge of inner bench above river channel	Y
ND1T4		Eucalyptus camaldulensis	-22.047177	148.169699	65	23	-0.9		60 metres from main channel	
ND1T5		Eucalyptus camaldulensis	-22.046918	148.169348	90	25	-0.8		40m from main channel on suppressed overflow	Y
DD2T1		Eucalyptus camaldulensis	-22.064183	148.181573	80	24	-0.7		15m from top of bank - mid terrace	Y
DD2T2		Eucalyptus camaldulensis	-22.0642	148.181442	65	22	-2.2		On bank, 3m directly above channel	
DD2T3		Eucalyptus camaldulensis	-22.06484	148.181837	80	21	-1		On inner terrace situated 3m above river channel. Moderately steep bank above.	
DD2T4		Eucalyptus camaldulensis	-22.065086	148.181862	60	21	-0.45		Mid way up bank 9m above sandy channel of Isaac River	Y

TREE	Tree from ID EIS	Species	Y	X	HGT (m)	DBH (cm)	LWP1 MPa	LWP ID EIS	Geomorphic Position	Isotope Analysis
DD2T5		Eucalyptus camaldulensis	-22.065295	148.182203	100	23	-0.35		On inner terrace situated 5m above river channel. Moderately steep bank above.	Y
DD3T1		Eucalyptus camaldulensis	-22.073013	148.191573	65	24	-0.4		Top of bank 8m above main channel - low mounded levee above overflow	Y
DD3T2		Eucalyptus camaldulensis	-22.072861	148.191784	80	25	-0.95		Margins of overflow, 25m from main channel and 10 above	
DD3T3		Eucalyptus camaldulensis	-22.073012	148.19199	65	23	-0.45		Top of bank 5m from edge of bank, 8m above main channel - low mounded levee above overflow	
DD3T4		Eucalyptus camaldulensis	-22.072816	148.192125	70	24	-0.75		Margins of overflow, 25m from main channel and 10 above	Y
DD3T5		Eucalyptus camaldulensis	-22.072719	148.191612	80	26	-1.6		10m from margins of overflow and 40m from main channel - greater than 10m above main channel.	
DD3T6		Eucalyptus camaldulensis	-22.072344	148.191495	120	26	-1.4		80m from main channel on upper terrace of river. >12m above main channel	Y
DD1T1		Eucalyptus camaldulensis	-22.058299	148.17785	85	23	-1.6		35m from main channel - 10 m above channel just below top of terrace	Y
DD1T2		Eucalyptus camaldulensis	-22.058462	148.177851	90	24	-1.75		25m from main channel - 7 - 8m above channel mid terrace	
DD1T3		Eucalyptus camaldulensis	-22.058702	148.17779	60	18	-1.2		3m from edge of bank, 3m above channel floor	Y
DD1T4		Eucalyptus camaldulensis	-22.058947	148.178218	65	19	-1.6		20m from edge of bank, mid terrace, 4 - 6m above channel floor	
DD1T5		Eucalyptus camaldulensis	-22.059239	148.17851	80	23	-1.5		20m from edge of bank, mid terrace, 4 - 6m above channel floor. On old overflow terrace?	Y
DD4T1		Eucalyptus camaldulensis	-22.073189	148.20456	70	23	-1.6		Flood plain location on alluvium 80m from Southern Gully. Elevated >5m above channel	Y
DD4T2		Eucalyptus camaldulensis	-22.06503	148.1817	70	23	-1.4		Flood plain location on alluvium 60m from Southern Gully. Elevated >5m above channel	

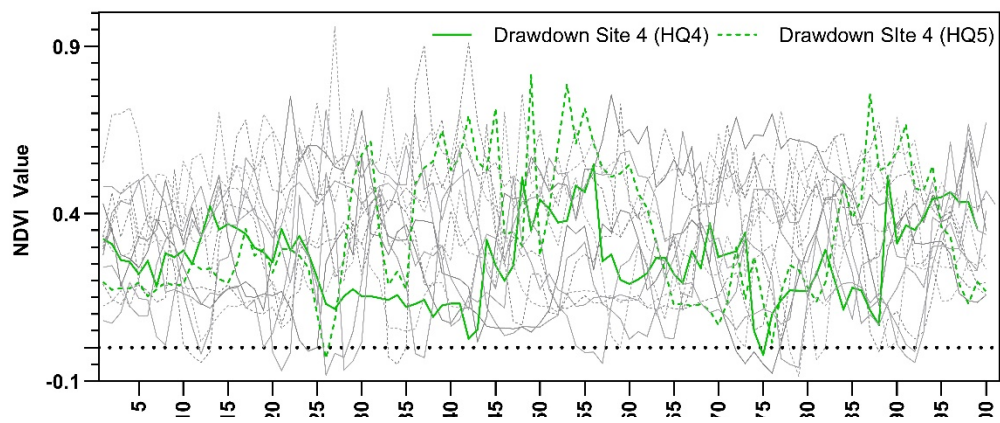
TREE	Tree from ID EIS	Species	Y	X	HGT (m)	DBH (cm)	LWP1 MPa	LWP ID EIS	Geomorphic Position	Isotope Analysis
DD4T3		Eucalyptus camaldulensis	-22.073314	148.205433	75	22	-1.2		Inner terrace of Southern gully, elevated 5m above channel.	Y
DD4T4		Eucalyptus camaldulensis	-22.073582	148.205427	70	18	-1.3		Inner terrace of Southern gully, elevated 5m above channel.	
DD4T5		Eucalyptus camaldulensis	-22.073988	148.2051	75	22	-1.6		Upper terrace, >5m directly above channel	
IDDCT1		Eucalyptus camaldulensis	-22.077864	148.206375	100	26	-2		40m from at base of inner terrace. 5m above flood channel	Y
IDDCT2		Eucalyptus camaldulensis	-22.078138	148.206202	70	18	-0.6		10m from channel on sandy terrace separating river channel from overflow. 3 - 5m above channel floor	
IDDCT3		Eucalyptus camaldulensis	-22.078765	148.206499	60	18	-0.45		5m from channel on sandy terrace separating river channel from overflow. 3 - 5m above channel floor	Y
IDDCT4		Eucalyptus camaldulensis	-22.079462	148.206846	75	23	-0.7		25m from channel at base of inner terrace adjacent to narrow overflow. > 5m above channel floor	Y
IDDCT5		Eucalyptus camaldulensis	-22.079914	148.206866	70	23	-0.5		10m from top of bank on low overflow. 3 to 5m above channel floor.	

Appendix E6. Raw NDVI data plots from permanent transects.

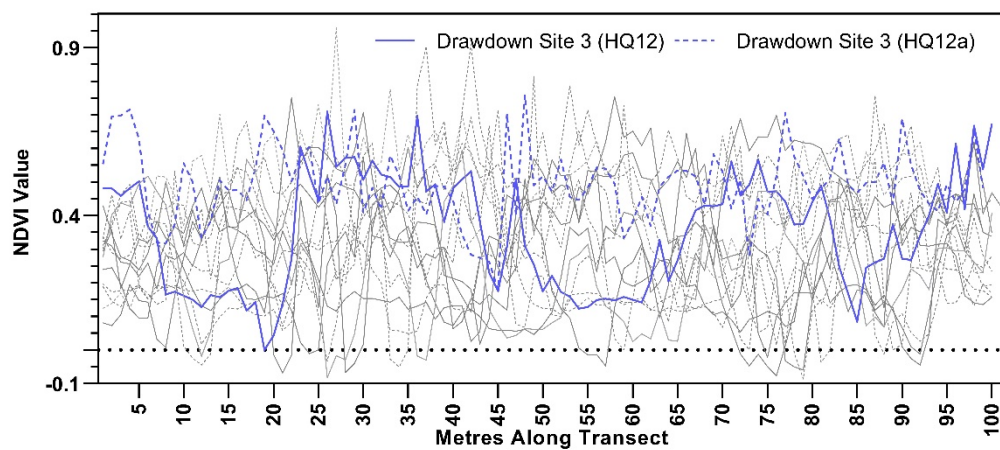
NDVI Transects _Downstream Control



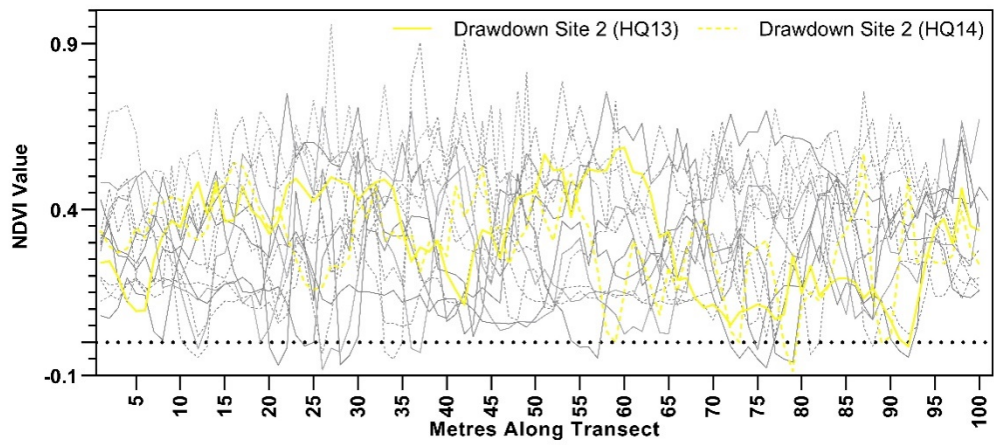
NDVI Transects _Drawdown Site 4



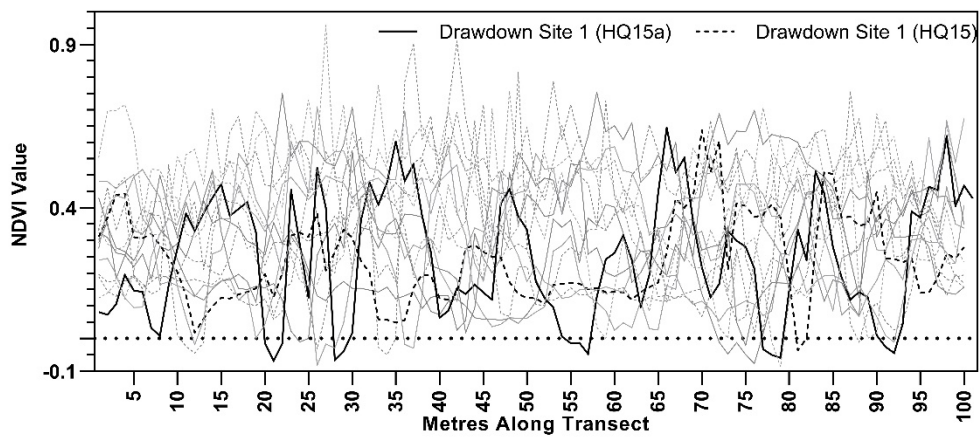
NDVI Transects _Drawdown Site 3



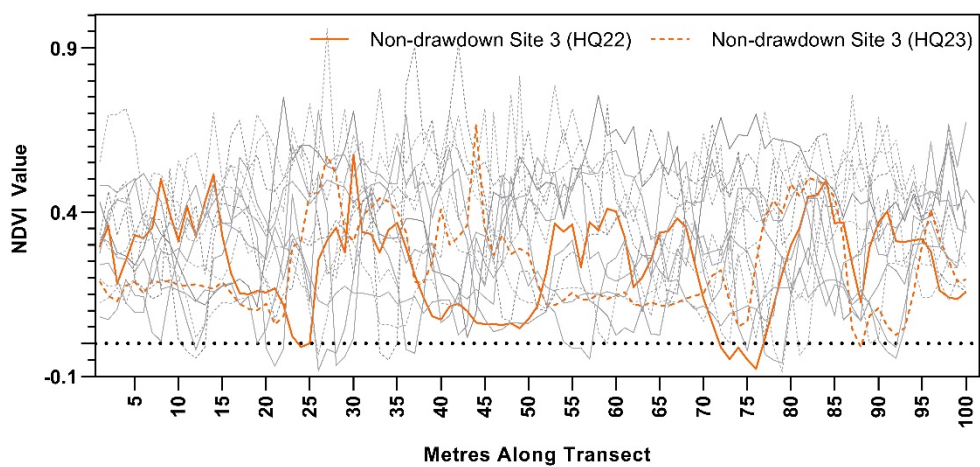
NDVI Transects _Drawdown Site 2



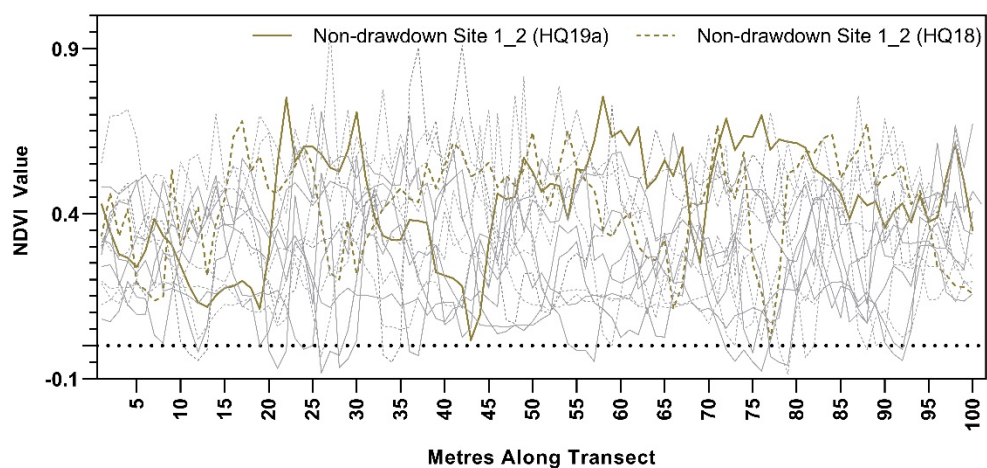
NDVI Transects _Drawdown Site 1



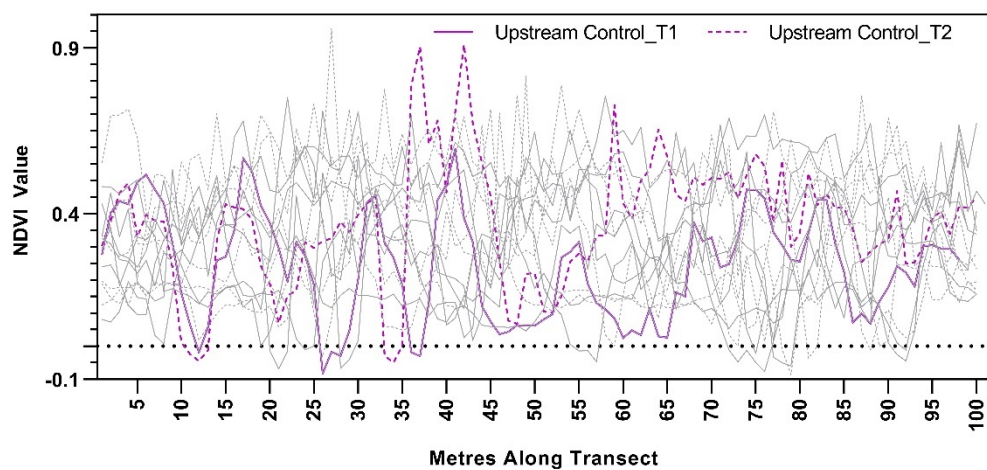
NDVI Transects _Non-drawdown Site 3



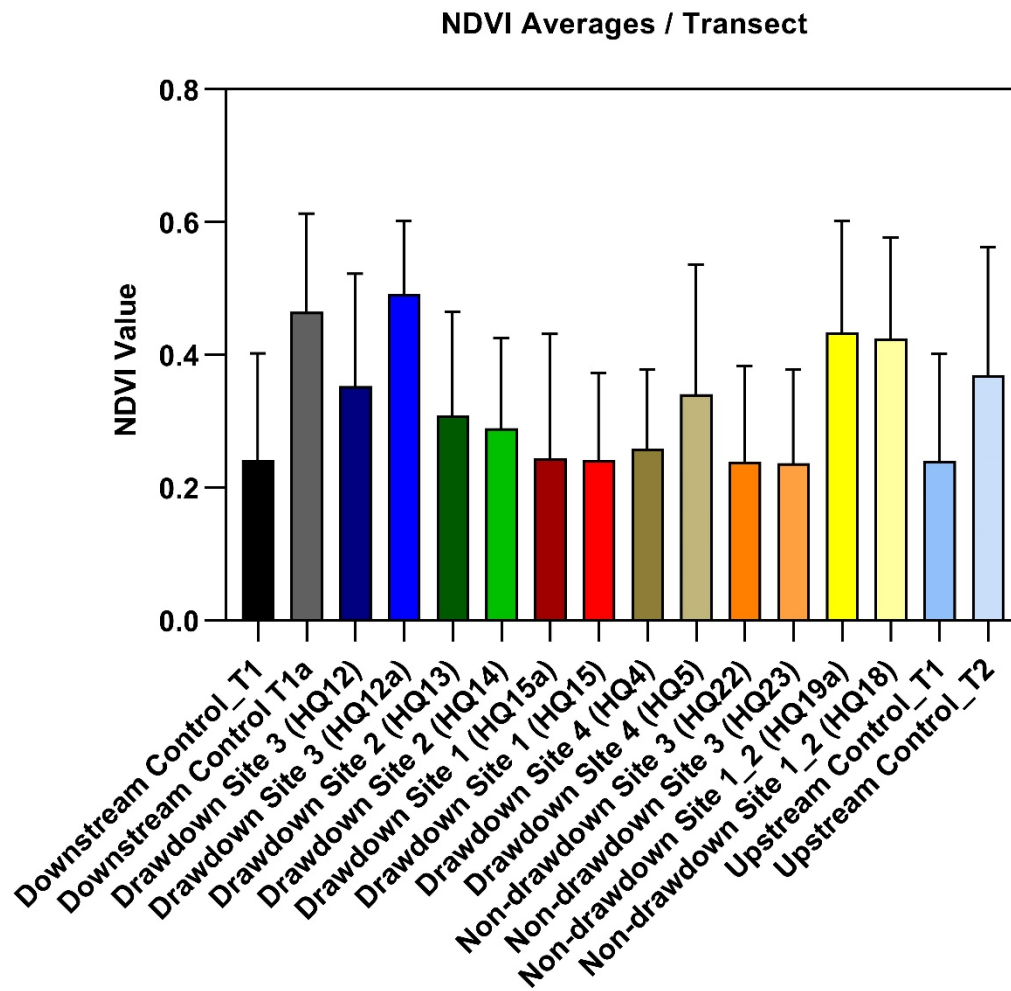
NDVI Transects _Non-drawdown Site 1_2



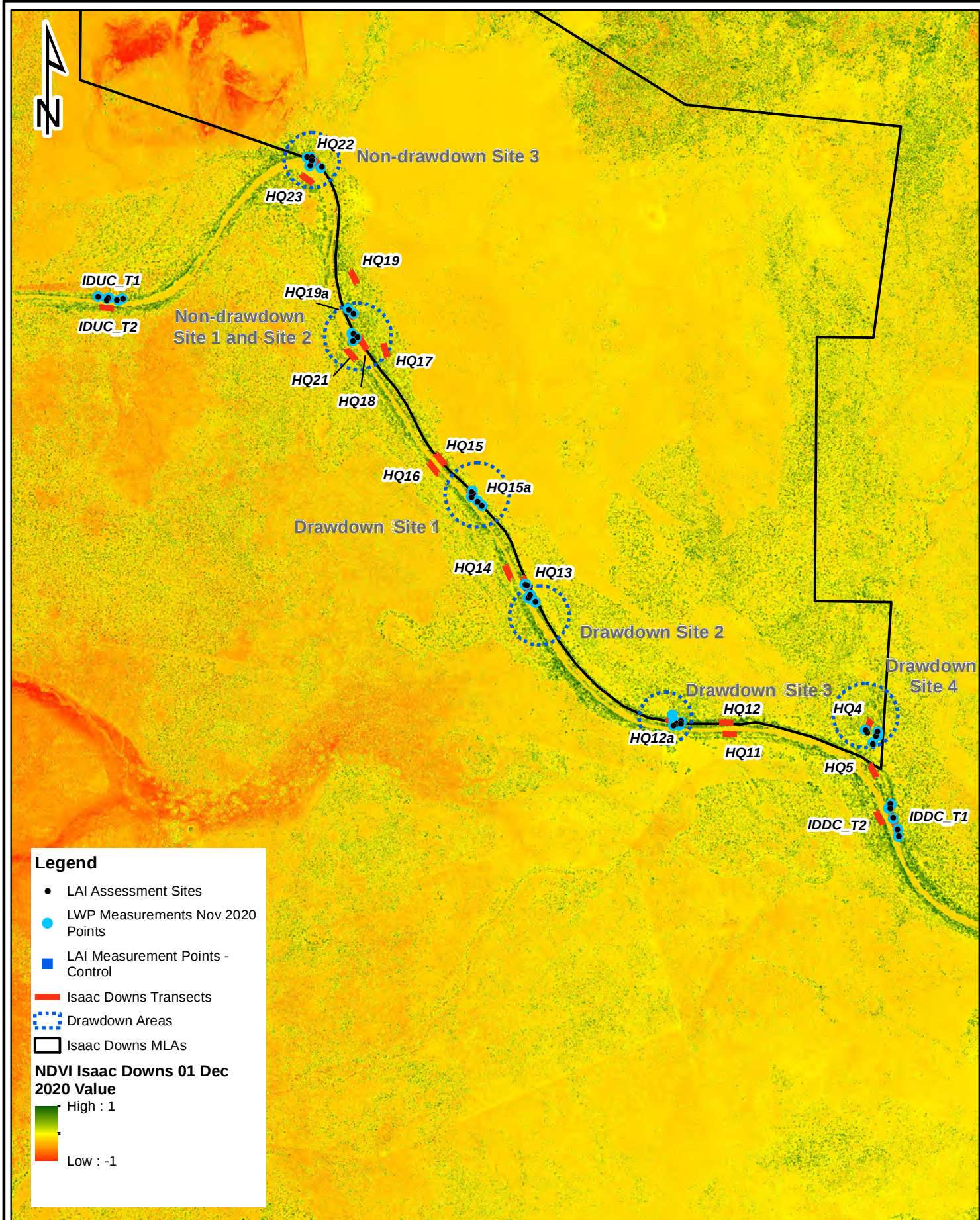
NDVI Transects _Upstream Control



Appendix E7. Comparison of mean NDVI values for transects placed in each monitoring area.



Appendix E8. Processed NDVI imagery shown in relation to LAI and LWP monitoring points, NDVI transects at each GDE monitoring area.



Legend

- LAI Assessment Sites
- LWP Measurements Nov 2020 Points
- LAI Measurement Points - Control
- Isaac Downs Transects
- ⋯ Drawdown Areas
- ▭ Isaac Downs MLAs

NDVI Isaac Downs 01 Dec 2020 Value

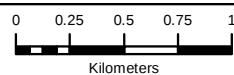
High : 1

Low : -1

Appendix E8. NDVI in relation to GDE monitoring areas and points

Client

Stanmore IP South Pty Ltd



Scale 1:35,000

Drawn By DG

Checked DS

File Path



P. O. Box 959
Kenmore, Qld 4069
Mobile: 0447 822 119
www.3denvironmental.com.au

Date
17/02/2021

A4

Appendix E9. Natural colour imagery shown in relation to LAI and LWP monitoring points, NDVI transects at each GDE monitoring area.



Legend

- LAI Assessment Sites
- LWP Measurements Nov 2020 Points
- LAI Measurement Points - Control
- Isaac Downs Transects
- ⋯ Drawdown Areas
- Isaac Downs MLAs

Appendix E9. Worldview natural colour imagery in relation to GDE monitoring areas and points

Client

Stanmore IP South Pty Ltd



Scale 1:35,000

Drawn By DG

Checked DS

File Path



3D Environmental
Landscape & Vegetation Science

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Date
17/02/2021

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Appendix F. GDE Monitoring Program for Initial Two Years

Event	Timing	Areas for Monitoring	Parameters Measured	Additional Datasets / Techniques Recommended	Other Interacting Datasets / Data Collection Requirements	Outputs
Monitoring Survey 1	Dry Season (October to December 2020)	- Isaac River GDE Area 2 - Drawdown Impact Area. - Isaac River – GDE Area 1 and GDE 2, outside of Drawdown Impact Area. - Isaac River – Northern and Southern Control Sites.	- LWP - Stable isotopes (trees, soils, surface water and water in channel sands) - Leaf Area Index	NDVI Imagery to coincide with the survey.	Groundwater monitoring data from identified monitoring bores (water quality and data from pressure transducers). Stable isotope composition of groundwater from selected monitoring bores. Stable isotope data from collected rainfall, if any. Stable isotope data from surface water flows. If any. Rainfall and climate data from automated weather station at IPM.	GDE Monitoring Report- Monitoring Event 1.
Monitoring Survey 2	Wet Season (February to April 2021)	- Isaac River GDE Area 2 - Drawdown Impact Area. - Isaac River – GDE Area 1 and GDE 2, outside of Drawdown Impact Area. - Isaac River – Northern and Southern Control Sites.	- LWP - Stable isotopes (trees, soils, surface water and water in channel sands) - Leaf Area Index	NDVI Imagery to coincide with the survey.	Groundwater monitoring data from identified monitoring bores (water quality and data from pressure transducers). Stable isotope composition of groundwater from selected monitoring bores. Stable isotope data from collected rainfall, if any. Stable isotope data from surface water flows, if any. Rainfall and climate data from automated weather station at IPM.	GDE Monitoring Report- Monitoring Event 2.
Monitoring Survey 3	Dry Season (October to	Isaac River GDE Area 2 -	- LWP - Stable isotopes	NDVI Imagery to coincide with the survey.	Groundwater monitoring data from identified	GDE Monitoring Report- Monitoring Event 3.

Event	Timing	Areas for Monitoring	Parameters Measured	Additional Datasets / Techniques Recommended	Other Interacting Datasets / Data Collection Requirements	Outputs
	December 2021)	Drawdown Impact Area. - Isaac River – GDE Area 1 and GDE 2, outside of Drawdown Impact Area. - Isaac River – Northern and Southern Control Sites.	(trees, soils, surface water and water in channel sands) Leaf Area Index		monitoring bores (water quality and data from pressure transducers). Stable isotope composition of groundwater from selected monitoring bores. Stable isotope data from collected rainfall, if any. Stable isotope data from surface water flows, if any. Rainfall and climate data from automated weather station.	
Monitoring Survey 4	Wet Season (February to April 2022)	- Isaac River GDE Area 2 - Drawdown Impact Area. - Isaac River – GDE Area 1 and GDE 2, outside of Drawdown Impact Area. - Isaac River – Northern and Southern Control Sites.	- LWP - Stable isotopes (trees, soils, surface water and water in channel sands) - Leaf Area Index	NDVI Imagery to coincide with the survey.	Groundwater monitoring data from identified monitoring bores (water quality and data from pressure transducers). Stable isotope composition of groundwater from selected monitoring bores. Stable isotope data from collected rainfall, if any. Stable isotope data from surface water flows, if any. Rainfall and climate data from automated weather station.	GDE Monitoring Report- Monitoring Event 4.
2 Year GDE Monitoring Review						
2 Year Review - Baseline GDE Monitoring Assessment	At completion of Monitoring Survey 4	NA	NA	NA	NA	– Compilation of data from all surveys – Analysis of baseline ecohydrological function of Isaac River GDE sites – Correlation between LAI and NDVI (plus other

Event	Timing	Areas for Monitoring	Parameters Measured	Additional Datasets / Techniques Recommended	Other Interacting Datasets / Data Collection Requirements	Outputs
						parameters) to provide a baseline for ongoing annual vegetation monitoring. – Identification of sources of water utilised by trees on a seasonal basis through analysis of stable isotope results for multiple parameters. – Review of risk assessment and identification of areas where risk profile is increased / diminished. – Revised GDEMMP issued based on results and outcomes of the 2-year baseline monitoring program.