Appendix P - Groundwater Dependent Ecosystem Assessment

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Rustlers Roost and Quest 29 Open-Cut Mine Redevelopment

Supplementary Environmental Impact Statement (SEIS)

Appendix P – Groundwater Dependent Ecosystem Assessment

Prepared pursuant to the Environment Protection Act 2019

September 2022

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Section 1 Introduction

1.1 Background

CDM Smith Australia Pty Ltd (CDM Smith) has been engaged by Primary Gold Pty Ltd (PGO) to assess the potential impacts of the Rustler Roost and Quest 29 proposed mining project to Groundwater Dependent Ecosystem (GDEs). This report will provide the basis from which a detailed GDE Management Plan (GDEMP) can be developed.

The project proposes to mine below the watertable and therefore pit dewatering will be required. This in turn will result in the propagation of a cone of depression on the watertable, which can pose a range of risks to ecosystems via the lowering of the watertable of local and connected aquifers to GDEs (IESC 2014). These risks may include but are not limited to:

- Reduced (changed) flows to groundwater dependent ecosystems (GDEs) including:
  - Altered groundwater baseflow to streams, rivers, lakes or ponds, as well as delayed groundwater response to recharge and/or discharge.
  - Reduced water availability in sensitive wetlands or swamps by compromising underlying horizons upon which groundwater may be perched.
- Modification of the location and/or flow rate of hillside groundwater springs;

This report assess the impact of project dewatering on potential GDEs, which have been classified into three broad types (based on 2017; Richardson et al., 2011 and Eamus et al., 2006):

- Aquifer and cave ecosystems (subterranean GDEs);
- Ecosystems dependent on the surface expression of groundwater (aquatic GDEs), such as;
  - River baseflow systems, aquatic and riparian ecosystems that exist in or adjacent to streams (including the hyporheic zone) which are fed by groundwater.
  - Wetlands, aquatic communities and fringing vegetation dependent on groundwater-fed lakes and wetlands. These include palustrine and lacustrine wetlands that receive groundwater discharge and can include spring and swamp ecosystems.
- Ecosystems dependent on the subsurface presence of groundwater (terrestrial GDEs).

1.2 Objective and Scope

The objective of this assessment is to enable clear communication of the likely impact of the project on GDEs and provide an ongoing approach to actively manage the potential risks to GDEs from the project activities. Due to the potential impact on GDEs within the Project area relating to possible drawdown in groundwater levels, it is important to place the specific occurrences of GDEs and groundwater conditions within the context of a broader understanding of how GDEs exist and access water. This allows for future environmental triggers, responsive actions and mitigation measures to be clearly aligned with risk and informed by the integration of all data sources from monitoring activities, conceptualisation and numerical modelling.

The focus of this report is as follows:

- Respond to the regulatory comments received during the Draft EIS public consultation period finalised on 13 January 2022. Section 4 of the Supplement to the Draft EIS (SEIS) provides all comments received during the Draft EIS consultation period. There were a total of 5 submissions received related to GDEs, these are identified in Table 1-1 below;

- Summarise data and knowledge used to inform the conceptualisation of the key hydro-ecological process associated with identifying potential GDEs associated with the estimated area of impact of the project;
- Describe works undertaken to identify all GDE types within the project area and surrounds;
- Complete a risk assessment that allows for consideration of risks attached to GDEs; and
- Propose a future works program including GDE monitoring and the development of management framework for the GDEs to guide approaches moving forward.

This report is based upon current data and will continue to be reviewed and updated periodically as more information is collected in relation to hydrogeology and GDEs to improve management outcomes.

Table 1-1 Relevant Comments Received on GDEs

No.	EIS Section	Theme or Issue	Comment / Requested Additional Information
Northern Territory Environmental Protection Authority (NT EPA)			
5	Section 7.5.7	Terrestrial ecosystems	**Comment** The Draft EIS does not consider the impacts of increased flows on riparian vegetation, despite modelling indicating that discharges could double or potentially triple surface flow volumes in receiving waterways. **Additional Information Required** Demonstrate that riparian vegetation will not be significantly impacted by modelled discharge and flows from the mine site.
6	Appendix N	Terrestrial ecosystems	**Comment** Appendix N of the Draft EIS indicates that the predicted reduction in flow of Annie's Dam catchment exceeds a maximum 20%, which is required for river health. This is because nearly 50% of Annie's dam catchment is consumed by the proposed tailings storage facility (TSF). The potential for significant impacts from flow reduction to a groundwater dependent ecosystem (GDE) that appears to occur below Annie's Dam has not been considered. **Additional Information Required** 1. Assess the impacts to GDEs downstream from Annies Dam due to reductions in groundwater flows from the TSF post-closure. 2. Assess the impacts to GDEs downstream from Annies Dam due to contaminated seepage flows from the TSF post-closure.
7	Numerical groundwater model – Section 7.2, Appendix H and Appendix I	Hydrological processes	**Comment** Groundwater model classification It is noted that the results of the groundwater model are considered preliminary due to the lack of detailed input data (e.g. transient groundwater levels, aquifer hydraulic property data) that could be used for model refinement and model calibration. The constructed groundwater model has characteristics of a Class 1 model based on the criteria in the Australian Groundwater Modelling Guidelines (Barnett et al. 2012). The current model is a regional scale (Class 1) model. Guidelines recommend at least a Class 2 model for adequate impact assessment and water balance modelling for dewatering projects. The revised model must be capable of accurately predicting drawdown effects, inform dewatering requirements, and provide for adequate water balance calculations. **Additional Information Required** 1. Refine the constructed numerical model to at least a Class 2 model based on the criteria in the Australian Groundwater Modelling Guidelines (Barnett et al.

No.	EIS Section	Theme or Issue	Comment / Requested Additional Information
			2012) noting the existing groundwater monitoring is inadequate for the calibration of the numerical model to a Class 2 standard. 2. Improve the groundwater model's performance and capability for predicting potential impacts to the surrounding environment including GDEs with a high degree of confidence. The model must be capable of accurately predicting drawdown effects, inform dewatering requirements, and provide for adequate water balance calculations. 3. Model and describe how the proposal has been designed to consider, or allow for, impacts of a changing climate e.g. capacity and efficiency of water facilities to allow for potential increase in evaporation and/or large rainfall events, and changes in the frequency or intensity of extreme weather events.
12	Groundwater drawdown - Section 7.3, and Appendix H	Hydrological processes	**Comment** Drawdown from pit dewatering The current (regional scale) groundwater modelling has shown that the calculated 1 m drawdown from the pit dewatering extends 5 km to the north and 3 km to the south of the Rustlers Roost pits, and 2 km to the south-west of the Quest 29 pits. The baseflow contribution to creeks and streams would normally sustain hyporheic zones, any permanent and semipermanent pools/waterholes, and support associated flora and fauna (e.g. riparian vegetation including potential GDEs) following the wet season. These processes are likely to be interrupted as a result of drawdown and alteration of the natural flow characteristics. **Additional Information Required** The information is required to clarify and demonstrate riparian vegetation and GDEs will not be significantly impacted by groundwater drawdown, seepage, and discharges from the mine site. 1. Assess (quantify) the pre-mining groundwater contribution (baseflow) to creeks and stream flows where drawdown effects are expected to occur, and 2. Identify and assess the likely impacts to environmental flows (quality and quantity), and riparian vegetation including potential GDEs. 3. Assess the interaction of groundwater behaviour in the primary aquifer with groundwater in alluvial aquifers as well as surface water. 4. Review the water management strategy and update the Water Management Plan to ensure impacts to environmental flows (quality and quantity), and riparian vegetation including potential GDEs are avoided or minimised to be as low as practicable. Note: The above information should be provided in consideration of the NT EPA’s hierarchies for environmental decision-making and waste management (avoid, mitigate, re-use, recycle etc.) Refer to Part 2 of the EP Act.
Department of Environment, Parks and Water Security (DEPWS)			
Flora and Fauna Division			
29	7.5.7	Aquatic Ecosystem	Section 7.5.7 states: "Section 7.3 states that the Project is unlikely to significantly affect surface water flows and therefore the aquatic ecosystem assessment has assumed that there is unlikely to be any significant impact to aquatic ecosystems from runoff quantity/flow changes". This statement appears inconsistent with the results of the modelled discharge scenarios in the EIS which suggests that the volume of surface water will double and potentially triple to 13.3GL/year. As the modelling suggests that there will be a change in the volume of surface water due to the proposal, it is unclear why the draft EIS has not considered the change as a risk to aquatic ecosystems and riparian vegetation. It is recommended that further information is requested by the NT EPA including an assessment of how increased surface flows may impact on riparian vegetation and aquatic ecosystems.

No.	EIS Section	Theme or Issue	Comment / Requested Additional Information
30	S.3.13.1 7.3.2.S	Aquatic Ecosystem Terrestrial Ecosystems	The ToR for the proposal requested that the EIS provide the following: "As a minimum, the assessment should consider: • the extent to which Terrestrial groundwater drawdown and seepage or discharge of mine affected water Ecosystems could impact riparian vegetation over time". This requirement does not appear to have been addressed with the applicant providing the following response: Section 7.3.2.6 states: "There are no recorded GDE's within the Quest 29 Project area. The GOE atlas (BOM 2021) maps a low-moderate potential for terrestrial GDEs at two locations on ephemeral watercourses that drain north of the lease (ML 29783) between 2 km to 3 km downstream from the Project area (Appendix H). Groundwater modelling in Appendix H suggest that drawdown contours (1m) extend towards the location of the potential terrestrial GDEs and states that the proposal has the "potential of affecting terrestrial and aquatic GDEs". The EIS describes and maps potential GDE's (Types 1-3) adjacent to the proposal area but provides no quantification or assessment of the risk to those habitats. It is recommended that further information is sought to quantify the extent and value of GDEs at risk of being impacted by drawdown and changes in groundwater quality.
Water Resources Division			
33	General Groundwater Assessment		The BoM Groundwater Dependent Ecosystems (GDEs) Atlas (comprised of mostly coarse national-scale datasets in this area) should not be relied on solely to survey potential GDEs in the project area and the receiving environment. More thorough site-specific surveys (combination of field-based and publicly available remote sensing) should be undertaken.
Department of Industry, Tourism and Trade (DITT)			
Mining Operations Division			
50	Appendix B-Risk Assessment Register	Seepage risk and controls for the TSF	The proposed expansion of the TSF will encompass Annie's Dam/ various drainage lines/ the heap leach pad and heap leach ponds. Annie's Dam in particular is a potential groundwater source for the identified downstream groundwater fed riparian vegetation site (see RP6-US site in Appendix M)/ which may make this a likely vector for seepage from the expanded TSF footprint. Primary Gold has not demonstrated an adequate analysis of environmental risks/ or developed the necessary mitigating management actions associated with construction of the expanded TSF/ making potential impacts difficult to ascertain.
Environment Centre NT (ECNT)			
56		Impact on groundwater dependent ecosystems	Risk mitigation strategies are limited solely to the observation that “No documented drawdown impacts from previous operations” exist and that “Groundwater monitoring” will occur. ECNT believes this to be insufficient as there is no credible contingency planning outlined for this risk. A reliance on the fact of no previous drawdown impacts being documented is inadequate due to the significant expansion and changes involved with the updated Project. Furthermore, monitoring of groundwater is only effective insofar as it is attached to concrete risk mitigation strategies that can be implemented if the monitoring reveals that adverse impacts are occurring. ECNT submits that the Proponent should be required to describe what action they commit to take if monitoring shows drawdown impact, and to outline concrete levels or thresholds that groundwater monitoring would use as a rubric to identify this impact.

Section 2 Area of Interest

The area of interest in terms of this GDE assessment relates to the predicted drawdown impacts from the mine. Initial estimates of groundwater drawdown were made using a steady state numerical groundwater model (Appendix H of the Draft EIS). This was a conservative assessment and is likely to have overpredicted drawdown. Further groundwater modelling work has been undertaken to refine the drawdown estimate (Appendix O of the SEIS) however this data was not available in time to be included in this report.

Using the steady state groundwater modelling results is a conservative approach to estimating the effects on GDEs as this is likely to overestimate groundwater drawdown extent and magnitude. This assessment provides a broader assessment of risks and should be refined based on the updated modelling, if an unacceptable risk is identified.

The area of interest (i.e. the drawdown extent predicted by the steady state groundwater numerical model) is shown in Figure 2-1.

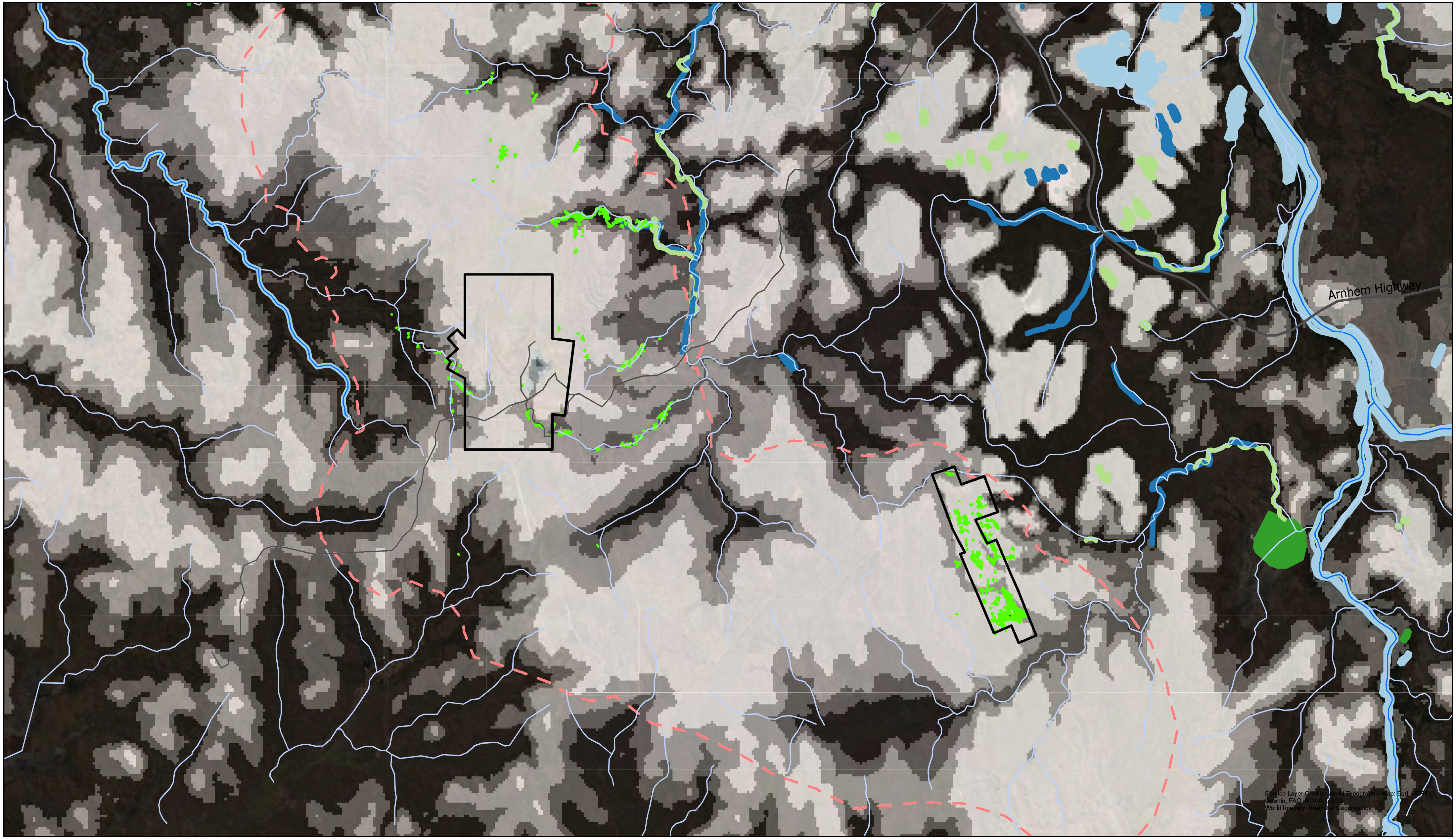

Figure 2-1: Depth to Groundwater

Legend

- ▬ Principal Road
- ▬ Minor Road
- ▬ Major Watercourse
- ▬ Minor Watercourse
- ▭ Project Area
- 🟦 Known GDE - from regional studies
- 🟦 High potential GDE - from national assessment
- 🟩 Moderate potential GDE - from national assessment
- 🟩 Low potential GDE - from national assessment
- 🟩 NDVI Cutoff (0.55)

Depth to Groundwater

- ■ 0 - 2 metres
- ■ 2.001 - 5 metres
- ■ 5.001 - 10 metres
- >10 metres
- ▬ Drawdown 1m (Quantile 0.95)

N

0 1 2
Kilometres

Date: 14/07/2022
Author: JPH

GCS GDA 1994

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Section 3 Environmental Setting

3.1 Hydrogeology

A summary of the hydrogeological conceptual model for the Rustlers Roost Mine site and the Quest 29 Mine Site is provided below based on Appendix O of the SEIS – Updated Groundwater Modelling Report.

- **Climate**

  The site is located in a tropical monsoonal area, with two distinct seasons: a summer wet season and winter dry season, with two subsidiary transitional periods between them. The average annual rainfall at Middle Point Rangers station (BoM 014090) is 1,420 mm, with the highest monthly rainfall occurring in January (mean monthly rainfall of 350 mm). SILO monthly evapotranspiration is between 140 mm (February) and 230 mm (October). Climate change has been incorporated into this assessment using the projected rainfall model developed for the hydrologic and hydraulic modelling, which uses the RCP scenario 4.5.

- **Geology**

  The geology of the project area is within the northern flank of the Pine Creek Orogeny, consisting of transgressive marine sequence dominated by folded shallow marine sediments of the Early Proterozoic South Alligator Group. The group includes the Koolpin Formation, Geowrie Tuff and Mount Bonnie Formation and the intrusive Zamu Dolerite at the Quest 29 site.

  The Rustlers Roost Gold Mine is predominantly underlain by folded greywacke and mudstone units. The greywacke units vary between 20 and 50 metres thick within individual beds and have upward fining sequences ranging from 0.5 to 10 metres. Individual beds are usually massive, weakly jointed, relatively soft and erode preferentially to form drainage features parallel to the bedding.

  The Koolpin Formation and Zamu Dolerite occupy the majority of the Quest 29 portion of the Project area (Primary Gold, October 2020). Regionally, the Koolpin formation averages 100 m in thickness but ranges up to 200 m in fold hinges. The Koolpin formation is intruded in areas by the Zamu dolerite (massive quartz dolerite).

- **Aquifers**

  The regional groundwater system comprises of intermediate-scale aquifers associated with unconsolidated sediments and local-scale aquifers associated with fractured and weathered rocks (Tickell, 2019). Aquifers, where they occur, are typically associated with increased structural deformation of the metasediments. Regional scale mapping indicates expected bore yields of 1-3 L/s in the metasediments and <0.75 L/s in the Mt Bundey Granite (Tickell, 2019). Higher permeabilities are likely associated with structural deformation within the metasediments/dolerite (Sirocco, 1999) and at local scale. At Rustlers Roost, aquifers are typically associated with increased structural deformation within the metasediments.

- **Groundwater flow**

  The degree to which groundwater can flow through the rock (hydraulic conductivity of the aquifers) will be dependant on the frequency and connectivity of fractures. Where weathering or structural processes result in highly connected fractures a higher local hydraulic conductivity could be expected, compared to the overall bulk hydraulic conductivity of the rock. The shallower portions of the aquifers are expected to have the highest hydraulic conductivity, with deeper portions likely to have much lower permeability associated with a lower density of interconnected fractures.

  Groundwater flow in the unconfined aquifers will generally follow topography, from high elevations to lower elevations. At Rustlers Roost there is a topographical divide that is likely to be reflected in the groundwater, with local flow towards the north and south, generally away from the main pit which is located within the expected groundwater divide. At Quest 29 there is also a groundwater divide north-south based on topography.

- **Recharge and discharge**

  The local aquifer system recharges by direct infiltration of rainfall and run-off through areas of aquifer outcrop or shallow subcrop and overlying cover materials (Primary Gold, 2019). During high rainfall and runoff events localised recharge from creek beds may also occur when groundwater levels are below the base of the creek. Groundwater recharge from small dams located within the lease area may also occur to a much lesser extent. These dams would give localised groundwater “highs” which are superimposed on the regional flow pattern (Environmental and Earth Sciences Pty Ltd, January 1993).

  Local groundwater discharge is mainly through seepage within the existing open pits and more regionally through discharge into creeks and surface water drainages/bodies.

- **Groundwater quality**

  Groundwater at Rustlers Roost showed low dissolved element levels indicating that there is minimal elemental dissolution from the rock and that a high level of meteoric rainfall infiltration into the folded and fractured turbidite sediments is occurring. The groundwater quality monitoring has shown groundwater is typically fresh, acidic to near neutral and has exceedances of aquatic ecosystems guideline values (GVs) for some metals and nutrients at some sampling occasions and locations. The elevated phosphorus and metal concentrations may be associated with underlying mineralogical deposits entailing weathered zones.

  The groundwater at Quest 29 is acidic to neural and fresh. Exceedances of the adopted aquatic freshwater trigger values were observed for several analytes in all monitoring wells. All monitoring bores, except for Q29MB01 and Q2MB02, showed similar water chemistry with small variations indicating limited impacts from previous mining activities.

- **Beneficial uses and environmental values**

  Based on the Beneficial Use Declarations for the area, beneficial uses for the receiving environment include agricultural and stock water supply, environmental and riparian and cultural.

3.2 Regional Eco-hydrology

An understanding of the regional climate as well as the geological, hydrological and hydrogeological character of the study area is the foundation for considering the Project setting relative to GDEs. Groundwater systems will be impacted by drawdown related to project activities, but in order for the risk of groundwater drawdown on GDEs to be assessed, the presence of GDEs, the nature of their occurrence, their type and their distribution must be evaluated.

This section presents the ecological setting in relation GDEs that have been defined by a series of studies in the Project area and surrounds.

3.2.1 Terrestrial Ecology and Riparian Vegetation

Overall, the existing riparian vegetation within the Project area has been affected by previous mining activities and current land use at different levels of disturbance with some sections still providing crucial services to aquatic ecosystems like shading, structured habitat and food source.

An established relationship of tree physiology and the ability to access deeper water sources is the height and girth (diameter at breast) of existing the trees. In general, the taller the tree and the bigger the girth, the more extensive the root network development that can access shallow and deeper water sources, including potentially the capillary fringe above the watertable. An additional field work program was established to support existing site inspections (i.e. EcOz 2020) to capture specific details of the dominate large trees across the study area (Appendix C of the SEIS – Ecological Assessment Report). This included collecting data on the height, diameter of the tree, CIW and breast height at accessible reference locations.

Mount Bundey Creek

During the EcOz sampling in October 2020 (EcOz, 2020), most of the riparian vegetation in the Mount Bundey Catchment appeared to be disturbed due to land clearing and mining activities (EcOz, 2020). Furthermore, weeds were common along the banks (*Hyptis suaveolens* and Sida sp.). Previous surveys of the Mount Bundey catchment suggest that clearing of land beyond the riparian zone is greater in the downstream section than in the upstream area near the Project.

Table 3-1 shows the large trees identified in the Rustlers Roost Mount Bundey Creek catchment during the recent field investigations, with tree larger tree heights ranging from 10 to 18 metres (reference locations are shown in Figure 3-1).

Table 3-1 Large trees in the Mount Bundey catchment (Rustlers Roost) (Connect Environmental, 2022)

Ref	Species	Height (m)	Diameter at breast height (cm)	CIW (m)	Breast height (m)
5	*Melaleuca viridiflora*	8	20	5	0.5
6	*Melaleuca viridiflora*	7	14	5	0.5
7	*Lophostemon lactifluus*	6	10	0	0
15	*Lophostemon grandiflorus*	14	80	5	1.5
16	*Eucalyptus bigalerita*	18	60	5	1.5
17	*Lophostemon grandiflorus*	10	45	5	1.5
18	*Erythrophleum chlorostachys*	15	35	5	1.5
19	*Barringtonia acutangula*	0	0	0	0
23	*Lophostemon grandiflorus*	9	30	5	1.5

Marrakai Creek

Marrakai Creek, a higher order stream, displays similar landform and surface geology features as the Mount Bundey Creek catchment and terminates into Adelaide River in the west. There has been some disturbance in the catchment from pastoral activities, however most of the riparian vegetation is in relatively good condition. Furthermore, some areas in the upper reaches of Marrakai Creek are also listed in the directory of important wetlands in Australia, which at the closest point is approximately 8 km downstream from the Rustlers Roost Project area. During the EcOz sampling, the riparian vegetation associate with Marrakai Creek was more intact and the survey sites were free of weeds (EcOz 2020).

Table 3-2 shows the large trees identified in the Rustlers Roost Marrakai Creek catchment, of the sites visited no large trees (>10 metres) were identified (reference locations are shown in Figure 3-1).

Table 3-2 Large trees in the Marrakai Creek catchment (Rustlers Roost)

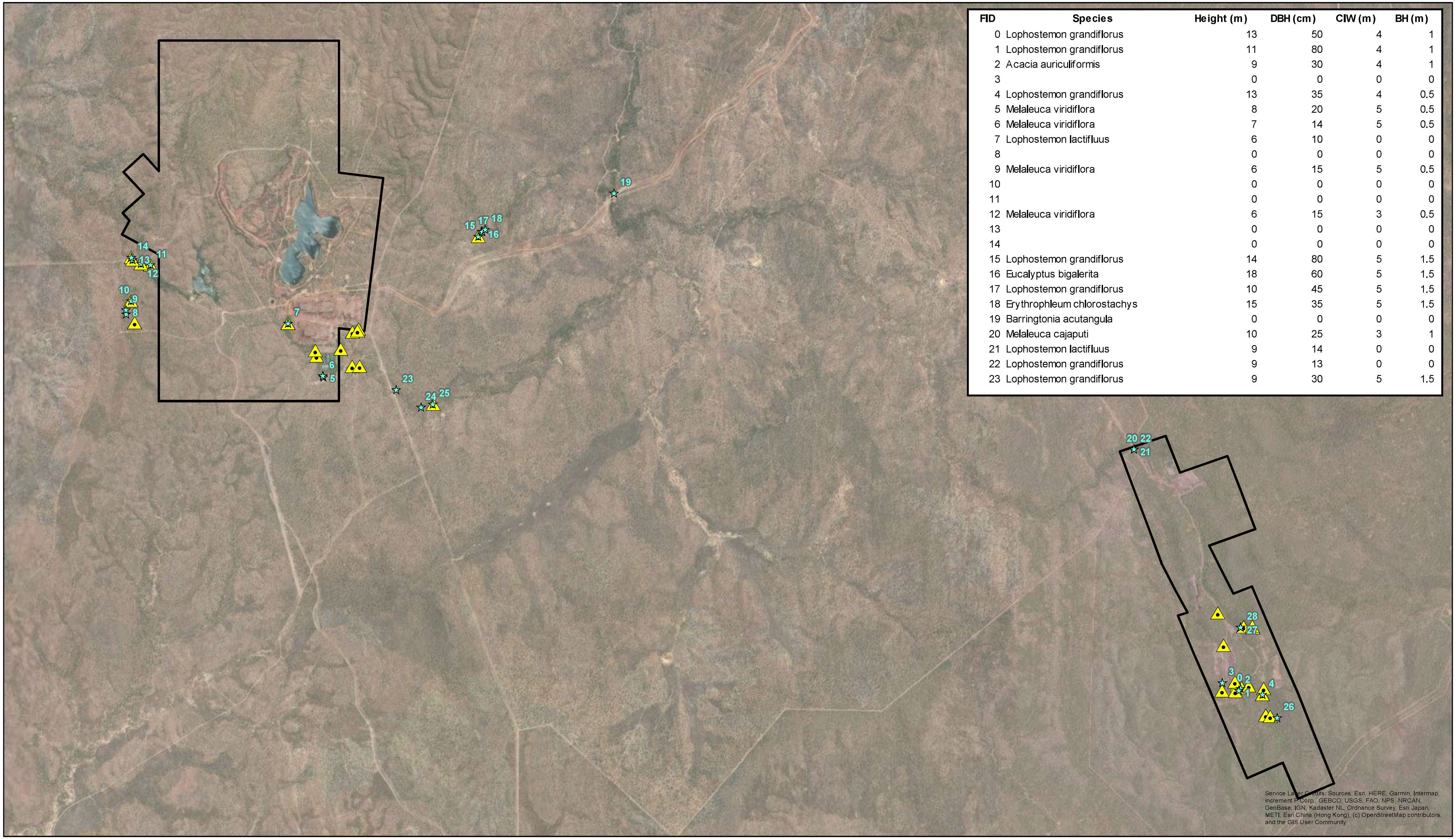
Ref	Species	Height (m)	Diameter at breast height (cm)	CIW (m)	Breast height (m)
9	*Melaleuca viridiflora*	6	15	5	0.5
12	*Melaleuca viridiflora*	6	15	3	0.5

Quest 29

At the Quest 29 site the riparian vegetation had been disturbed, with original native vegetation already cleared and large stockpiles of fill material present adjacent to the riparian zones. Table 3-3 shows the large trees identified in the Quest 29 portion of the project area during the recent field survey (reference locations are shown in Figure 3-1).

Table 3-3 Large trees in the Quest 29 project area

Ref	Species	Height (m)	Diameter at breast height (cm)	CIW (m)	Breast height (m)
0	*Lophostemon grandiflorus*	13	50	4	1
1	*Lophostemon grandiflorus*	11	80	4	1
2	*Acacia auriculiformis*	9	30	4	1
4	*Lophostemon grandiflorus*	13	35	4	0.5
20	*Melaleuca cajaputi*	10	25	3	1
21	*Lophostemon lactifluus*	9	14	0	0
22	*Lophostemon grandiflorus*	9	13	0	0



FID	Species	Height (m)	DBH (cm)	CIW (m)	BH (m)
0	Lophostemon grandiflorus	13	50	4	1
1	Lophostemon grandiflorus	11	80	4	1
2	Acacia auriculiformis	9	30	4	1
3		0	0	0	0
4	Lophostemon grandiflorus	13	35	4	0.5
5	Melaleuca viridiflora	8	20	5	0.5
6	Melaleuca viridiflora	7	14	5	0.5
7	Lophostemon lactifluus	6	10	0	0
8		0	0	0	0
9	Melaleuca viridiflora	6	15	5	0.5
10		0	0	0	0
11		0	0	0	0
12	Melaleuca viridiflora	6	15	3	0.5
13		0	0	0	0
14		0	0	0	0
15	Lophostemon grandiflorus	14	80	5	1.5
16	Eucalyptus bigalerita	18	60	5	1.5
17	Lophostemon grandiflorus	10	45	5	1.5
18	Erythrophleum chlorostachys	15	35	5	1.5
19	Barringtonia acutangula	0	0	0	0
20	Melaleuca cajaputi	10	25	3	1
21	Lophostemon lactifluus	9	14	0	0
22	Lophostemon grandiflorus	9	13	0	0
23	Lophostemon grandiflorus	9	30	5	1.5

Service Layer Credits: Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), (c) OpenStreetMap contributors, and the GIS User Community

Figure 3-1: Ecological Field Survey Areas for Potential Terrestrial GDEs

Legend

☆ GDE observations

▲ NDVI 0.55 cutoff notes

▭ Project Area

N

0 0.5 1

Kilometres

Date: 14/07/2022
Author: JPH
Coordinate System: GCS GDA 1994
Datum: GDA 1994
Units: Degree

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3.2.2 Hydrology

The Rustlers Roost Mine site is located on the catchment divide and in the headwaters of Marrakai Creek and Mount Bundey Creeks. Marrakai Creek flows to the west of the site and is a sub catchment of the Adelaide River. Mount Bundey Creek flows to the east and is a sub catchment of the Mary River. The Quest 29 Mine site is predominantly located in the Charles Creek sub-catchment of the McKinley River, which also flows into the Mary River system. A minor northern portion of the Quest 29 is in the upper Mount Bundey Creek sub-catchment of the Mary River system.

The mine sites are located in the headwaters of the creeks and these local catchments are comprised of ridges and dissected hills that are drained by small steep rivulets. The streamflows in these upper areas are ephemeral, with flows only occurring for a few weeks-months each year throughout the wet season, in response to rainfall events (Surface Water & Erosion Solutions, 2021).

The main creeks are ephemeral and flow only in the wet season, with the annual receding hydrographs continuing into the dry season. There are no stream flow or level gauges in the project area and therefore the flow characteristics described below are based on the hydrological modelling undertaken by Surface Water & Erosion Solutions 2022 (future stream flow from 2031 to 2120 assuming RCP 4.5 climate change model).

- Mount Bundey Creek has no flow for on average 134 days a year, with a maximum predicted 198 dry days and a minimum predicted 60 dry days. The most common no flow months are May, June, July, August and September;
- Charles Creek has no flow for on average 151 days a year, with a maximum predicted 205 dry days and a minimum predicted 101 dry days. The most common no flow months are March, April, May, June and July;
- The McKinley River has no flow for on average 119 days a year, with a maximum predicted 189 dry days and a minimum predicted 36 dry days. The most common no flow months are March, April, May, June and July; and
- The Mary River has no flow for on average 98 days a year, with a maximum predicted 173 dry days and a minimum predicted 5 dry days. The most common no flow months are June, July, August and September.

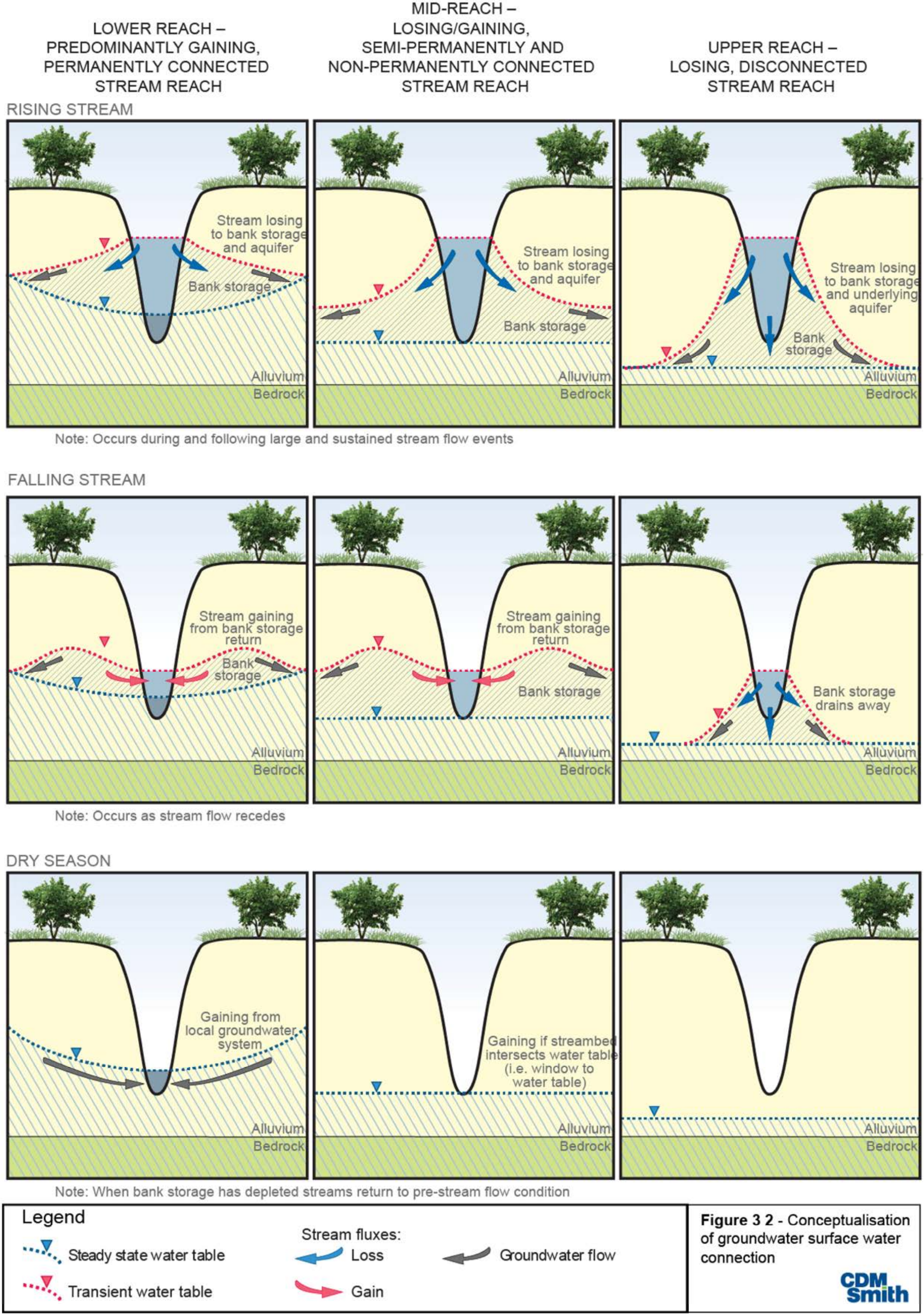
Aquatic habitat values for aquatic plants in the Project area are limited by the ephemeral nature of flows in the higher order watercourses that drain the sites, and the lack of natural permanent water bodies. No submerged aquatic plants were identified during the surveys, underpinning the highly ephemeral nature of the creeks and drainage lines (AES, 2019).

3.2.3 Groundwater-surface Water Interaction

Conceptually, across the broader landscape there are three general conceptual models of groundwater and stream interaction (Figure 3-2).

It is likely that the ephemeral stream reaches within the area of impact (predicted drawdown) are losing disconnected streams, where water levels are above the adjacent water table, a hydraulic gradient is generated away from the watercourse, resulting in stream losses to groundwater (i.e. the stream is losing). As well as recharging the water table aquifer, these stream losses potentially replenish storage in the stream banks (bank storage).

In disconnected stream reaches, bank storage will drain away to the water table or back to the stream as flood heights decline. Given there is no streamflow gauging in the catchment, the frequency and magnitude of flows are not known but it is inferred that losing conditions will sometimes occur during and following high intensity rainfall and runoff events from tributary catchments.



Note: Occurs during and following large and sustained stream flow events

Note: Occurs as stream flow recedes

Note: When bank storage has depleted streams return to pre-stream flow condition

Figure 3 2 - Conceptualisation of groundwater surface water connection

Section 4 Groundwater Dependent Ecosystems

4.1 Introduction

The BOM GDE Atlas provided the initial assessment of the presence of Type 3 GDEs across the study area based primarily on;

- Broad scale remote sensing (areas where evapotranspiration was greater than rainfall);
- The dominance of a particular vegetation type; and
- The landscape position.

The spatial outcome was a series of polygons that contain information pertaining to the rules used to classify the vegetation as a potential GDE.

The BOM GDE Atlas classified the vegetation in the Project area as having High to Low potential of being a GDE, with a GDE defined as a "Natural ecosystems that require access to groundwater to meet all or some of their water requirements on a permanent or intermittent basis, so as to maintain their communities of plants and animals, ecosystem processes and ecosystem services" (Richardson et al., 2011). It is important to note that neither this definition nor the GDE Atlas map products, provides any guidance as to the sensitivity of GDEs (i.e. how the condition of the ecosystems may be impacted by changes in groundwater levels), as this was not the primary objective of the mapping. In addition, the GDE Atlas classification of GDEs in the study area is based upon regional studies, with no validation via local studies or field data. It has therefore been necessary to conduct additional studies (field based and remote sensing) with the objective of refining the location of GDEs and to increase the understanding of how these trees may be impacted by changes in groundwater levels (i.e. their sensitivity to change).

In summary, the GDE Atlas mapping has provided a useful starting point to assess the potential areas of vegetation that may be accessing groundwater. However, addition studies have being requested to update the mapping of potential GDEs to ensure the validity of the existing assessment of GDEs within the project area.

4.2 Aquifer and Cave Ecosystems (Subterranean GDEs)

At this stage no field data has been collated to assess the range of stygofauna species that may be present within the impacted aquifers. Given the regional nature of the groundwater system, species present are likely to be ubiquitous across the Project area, with no particular species occurring within isolation to other species with geographic boundaries.

4.3 Ecosystems Dependent on the Surface Expression of Groundwater (Aquatic GDEs)

Based upon available and the current understanding of groundwater surface water interactions within the area of predicted drawdown, the presence of aquatic GDEs is considered unlikely. And are not considered further within this report. The main data for this conclusion are;

- Stream flow is ephemeral, such that almost 50% of the time the streams are dry and do not receive baseflow from groundwater; and
- There exist no mesic or semi mesic species within the stream beds that may indicate permanent saturation of the stream bed caused by shallow water tables.

4.4 Ecosystems Dependent on the Subsurface Presence of Groundwater (Terrestrial GDEs)

4.4.1 Groundwater Use by Riparian Vegetation

A significant library of literature exists regarding tree water use by riparian vegetation within relatively arid regions, that focuses largely on larger Eucalypts, such as *Eucalyptus tereticornis*, *Eucalyptus camaldulensis*, *Eucalyptus populnea* and *Eucalyptus coolabah (*Bren et al., 1986, Mensforth et al 1994; Lamontagne et al 2005, Doody et al. (2015), Kath et al., 2014, Costello, 2016).

Investigations into tree water use in the wet-dry tropics across the Daly River catchment (O'Grady et al., 2006) showed that a range of riparian species are likely to be utilising groundwater, including *Lophostemon grandifloras* found within the study area; however, the dominate source for water for transpiration is soil water sourced from stream and rainfall recharge.

Comprehensive studies across the Ti Tree basin (Cook and Eamus, 2018) limited any significant groundwater use by larger tress to 12 metres. In reviewing groundwater discharge by vegetation studies across Australia, O'Grady (2010), established that overall studies indicate that groundwater use by vegetation is restricted to less than 10 metres (Figure 4-1).

A key physiological attribute of high groundwater using vegetation is to have deep sinker roots, hypothesised to grow down towards zones of higher water supply (Bren et al., 1986) but also to provide structural support. Larger tree species, such as *Eucalyptus tereticornis*, *Eucalyptus camaldulensis* that develop dimorphic root systems have recorded groundwater use down to 10-12 metres below the ground surface.

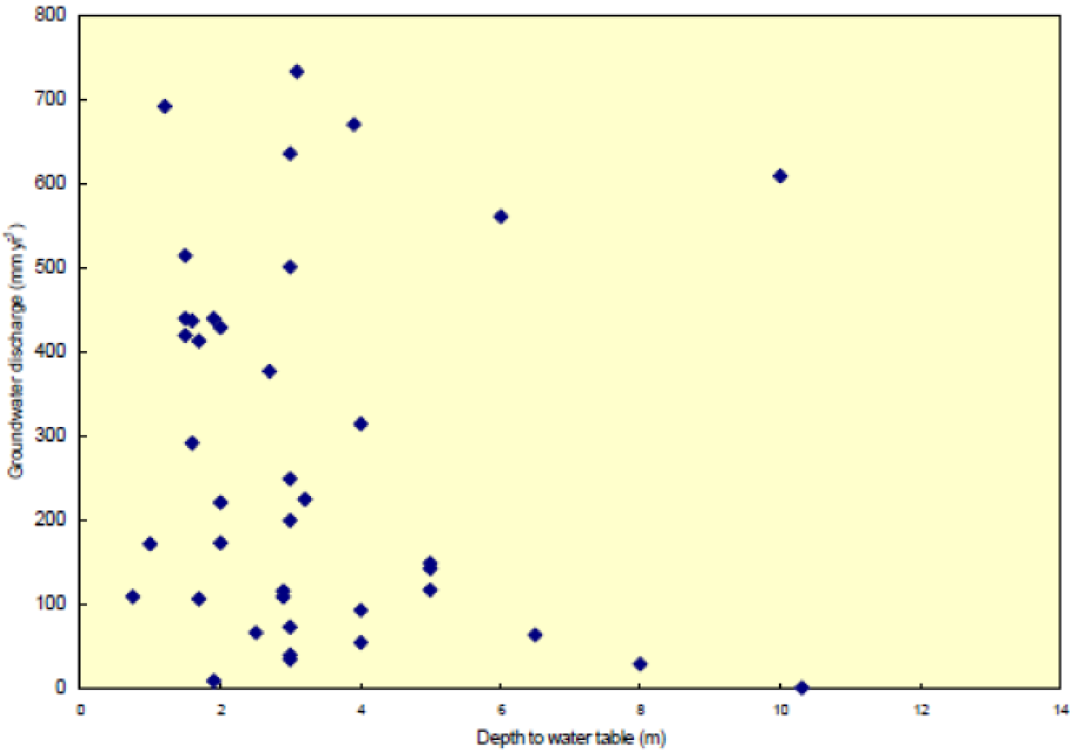


Figure 4-1 Groundwater discharge by vegetation depths, after O'Grady 2010

Of the two dominate tall trees identified in the Project area, *Eucalyptus bigalerita*, and *Lophostemon grandifloras*, less information is available. These species are generally not referred to within literature as groundwater using and are not known as large riparian GDE species. However, it is likely that they are able to access deeper water sources, but unlikely that the depths would be greater than 10 metres.

4.4.2 Terrestrial GDE Conceptualisation

The landscape in which terrestrial vegetation communities are found is a water limiting environment (i.e. potential evaporation is greater than rainfall) and there is a concentration of water towards drainage lines. Land clearance has generally left vegetation close to creek lines intact and there are commonly small to average size trees in the riparian zone.

The overall water balance of shallow alluvial systems (common along these watercourses) is driven by the hydrology of the creeks and groundwater discharge processes. Recharge to the alluvial aquifer is likely dominated by event-based creek infiltration with lower rates of diffuse rainfall-recharge across the rest of the alluvium. Groundwater leaves the alluvial aquifer via throughflow. There is no evidence of groundwater discharge to the creeks within the Project area.

A conceptual model of how semi-arid flood plain ecosystems respond to wetting and drying phases in terms of biomass production is provided in (Figure 4-2). Although this figure describes a somewhat different landscape, principals are likely to be similar. The concept proposed by Colloff and Baldwin (2010) is that the resilience of the system is a function of how the transition between wet and dry phases occurs, which may have a cycle frequency of many years.

Conceptually, the transition from dry to wet phase involves the replenishment of soil water, and depending on the extent and severity of the dry period, biotic collapse could eventually occur if the return to wet phase is not sufficient. The vegetation communities inhabiting the riparian zones are likely to exist according to similar drying and wetting phases. For the majority of time, streams within the impacted area of drawdown will be existing within a drying phase before being disturbed by an episodic wet phase. Through this cycle they have developed a resilience to these associated changes in water availability over longer time periods (as demonstrated by their existence).

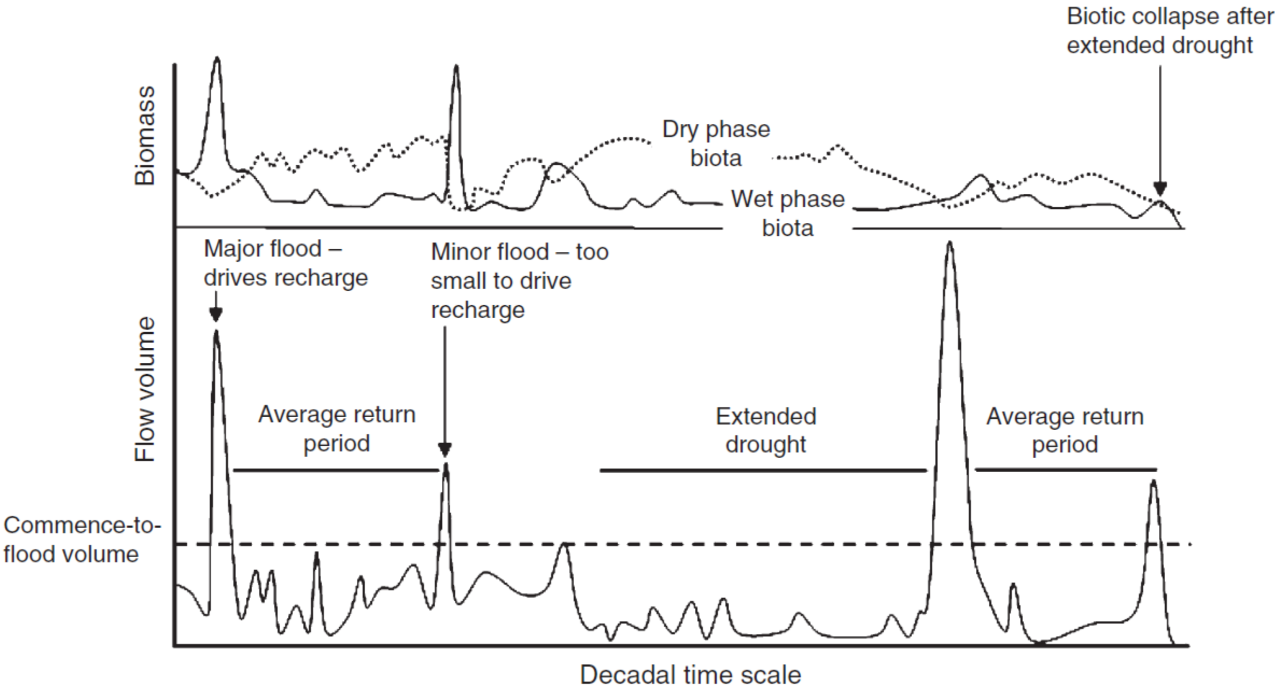


Figure 4-2 Conceptual model of wet and dry phase biomass production (Colloff and Baldwin, 2010)

Available soil moisture for transpiration will be greatest following the wet periods that generate both diffuse vertical recharge and flood recharge events (even relatively small ones). At this starting point, the previously relatively dry alluvium is effectively re-wetted to field capacity (i.e. for diffuse recharge to occur, a wetting front must pass vertically through unsaturated soils and leave behind remnant soil moisture prior to reaching the watertable). Following these wet periods, sources of soil moisture will be from direct rainfall infiltration, bank infiltration during smaller stream flow events and soil moisture derived from the top of the watertable as it slowly declines. As the succeeding dry phase becomes longer, soil moisture stores generally diminish except for seasonal replenishment during minor wet events. Soil moisture is used opportunistically by vegetation, however during this drying phase the net soil moisture stores become successively depleted over time.

Vegetation communities in the study area are thought to be well-adapted to long dry periods interspersed with seasonal rainfall, creek flow and minor flooding events. Flood events provide a hydraulic disturbance to the semi-arid vegetation communities (Brock et al., 2005) and as such, they have developed survival and response mechanisms to the wet and dry phases. As discussed, a key strategy adopted by semi-arid riparian vegetation is the ability to access soil water from different depths. This can range from shallow soil moisture accessed by shallow lateral roots too deep within the profile via tap roots (Dawson and Pate, 1996). Vegetation is able to change sources of water depending on changing soil moisture conditions (i.e. soil zones of low osmotic potential are accessed prior to zones of high osmotic potential).

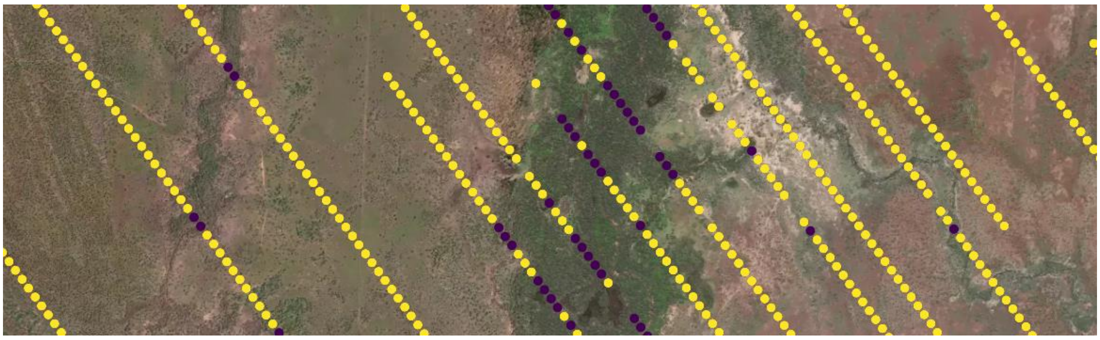
It is largely unknown at this stage if the larger trees, present across the study area have the root structure to access deeper soil moisture from the capillary fringe above the watertable.

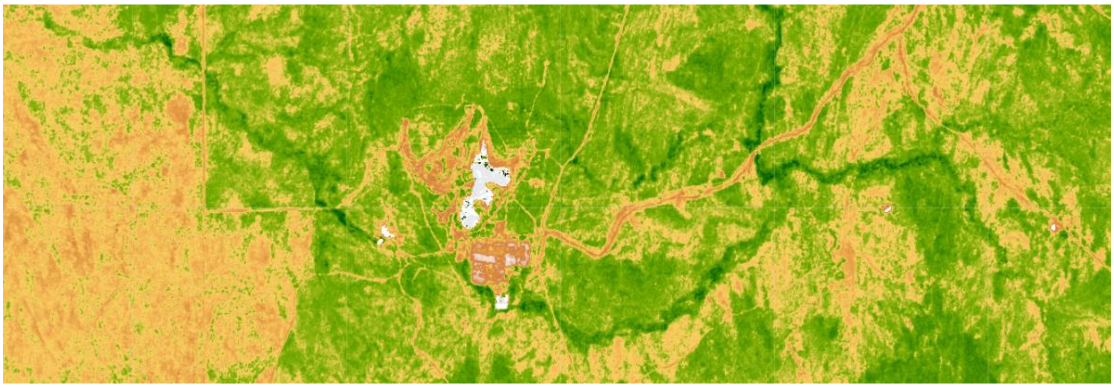
4.4.3 Mapping Riparian GDEs Using Remote Sensing

As discussed, a limitation regarding the knowledge of GDEs is the coarseness of the existing GDE Atlas representation of potential GDEs. A critical data gap during the development of the GDE Atlas was the lack of detailed vegetation mapping within the Project area, such that an assessment of likely terrestrial GDEs could not be made. To overcome this data gap and enable a more thorough coverage of potential GDEs to be made, remote sensing approaches have been used to identify likely riparian vegetarian and assess their likely groundwater connection.

The approach used a land use classification model (i.e. predictive model) to classify vegetation communities in the landscape. Table 4-1 outlines the steps involved in the remote sensing mapping of potential terrestrial GDEs. Data processing, machine learning and analysis was undertaken using the R Programming Language (R Core Team, 2021). The purpose was to identify points using structural information for vegetation (at the plot scale) to use to develop a landscape scale model for GDEs using Sentinel-2, which has continuous coverage across the landscape.

Table 4-1 Analysis steps for mapping potential terrestrial GDE vegetation

Step	Description
Training dataset using GEDI	The Global Ecosystem Dynamics Investigation (GEDI) produces high resolution laser ranging observations of the 3D structure of the Earth. GEDI's precise measurements of forest canopy height, canopy vertical structure, and surface elevation greatly advance our ability to characterize important carbon and water cycling processes, biodiversity, and habitat. The GEDI instrument is a geodetic-class, light detection and ranging (lidar) laser system comprised of 3 lasers that produce 8 parallel tracks of observations. Each laser fires 242 times per second and illuminates a 25 m plot footprint on the surface over which 3D structure is measured. Each footprint is separated by 60 m along track, with an across-track distance of about 600 m between each of the 8 tracks. GEDI expected to produce about 10 billion cloud-free observations during its nominal 24-month mission length. GEDI produces the first high resolution laser ranging observations of the 3D structure of the Earth and provides a global dataset for plot scale measurements of forest canopy height and structure. GEDI Level 2a collection for relative heigh metrics and GEDI Level 2b collection for canopy cover fraction, plant area index and plant volume. Data was accessed via the LP DAAC User Services portal (USGS). A two-class model was applied to the GEDI plot data, with rules developed using the field observations provided by the ecologist survey on site and analysis of the GEDI data for known GDEs in the area (with reference to the BOM GDE atlas). GEDI plots were selected and assigned as 'potential GDE' if they meet the following conditions: RH95 (relative heigh at 95%) was greater than 12m above ground level AND Canopy cover index was greater than 0.3. The sample size of plots used for classification was potential GDE (n = 4,625) and non-GDE (n = 8,000). The insert below shows the distribution of plats in the landscape, and the plot classification across a riparian area (purple are potential GDEV; yellow are non-GDE). The model domain was extended beyond the immediate vicinity of the proposed drawdown to create a larger dataset of GEDI plots for training the classification model. The model domain extended from SW: -13.5, 131.1 to NE: -12.7, 131.9. 

Step	Description
Sentinel-1 and Sentinel-2 imagery	The Google Earth Engine (code.earthengine.google.com; Gorelick et al (2017)) was used to generate a data cube of remote sensing products for developing a landscape scale classification model. Satellite imagery was selected from the late dry season period in 2019 (i.e. August, September and October). 2019 was selected due to below average rainfall (and hence a potentially stronger signal from vegetation with access to groundwater. The goal here was to find a period when shallow rooted vegetation (i.e. grass) would sufficiently have died off to create a stronger contract in spectral signals between shallow and deeper-rooted vegetation (and hence a potentially stronger signal from vegetation with access to groundwater). The Sentinel-1 mission provides data from a dual-polarization C-band Synthetic Aperture Radar (SAR) instrument at 5.405GHz (C band), at which frequency interacts with vegetation canopies, and backscatter provides information about canopy moisture and structure. The Sentinel-1 collection was processed using the workflow provided by Mullissa et al (2021). Sentinel-2 is a wide-swath, high-resolution, multi-spectral imaging mission supporting Copernicus Land Monitoring studies, including the monitoring of vegetation, soil and water cover. The Sentienl-2 collection was processed to generate median value across all bands for each grid cell was selected, and the 95th NDVI band was also calculated. All images were masked for cloud (maximum cloud probability = 20%) and filtered for pixels from the scene classification layer marked as vegetated, non-vegetated and unclassified. For both S1 and S2 outputs, a 20m grid cell was selected to approximate the width of the GEDI plots. A sample extract for the NDVI is shown below, where darker green indicates a higher NDVI value, which as expected are located along drainage lines. 
Pre-processing and feature engineering	Feature engineering consists of creation, transformation, extraction, and selection of variables that are most conducive to creating an accurate machine learning algorithm. Here, this refers to the individual bands and was undertaken using the TidyModels framework (Kuhn et al, 2020). Input bands were centred, scaled and normalised. From this, the following independent variables (bands) were selected for analysis: - Sentinel-1: s1dry2019_VV_p95, s1dry2019_VH_p95 - Sentinel-2: s2dry2020_B1, s2dry2020_B5, s2dry2020_B6¸s2dry2020_B9, s2dry2020_B11, s2dry2020_B12, s2dry2019_NDVI_p95

Step	Description
Model selection	CART models were selected as they generally provide good results for ecological applications using remote sensing data due to their ability to identify non-linear relationships the data and threshold and voting systems. The three CART models were compared: - randomForest (Liaw and Wiener, 2002), which implements Breiman's random forest algorithm (based on Breiman and Cutler's original Fortran code) for classification and regression. - Ranger (Wright and Ziegler, 2017), which is a fast implementation of random forests (Breiman 2001) or recursive partitioning, particularly suited for high dimensional data. Classification and regression forests are implemented as in the original Random Forest (Breiman 2001), survival forests as in Random Survival Forests (Ishwaran et al. 2008). - Rparts (Therneau and Atkinson, 2019), which implements recursive partitioning for classification, regression and survival trees. An implementation of most of the functionality of the 1984 book by Breiman, Friedman, Olshen and Stone The workflow defines a model that creates a large number of decision trees (n = 1,000), each independent of the others, and using bootstrap sampling (n=10). The final prediction uses all predictions from the individual trees and combines them. Optimisation was performed using the grid search methods outlined by Kuhn et al (2020), using tuning parameters for the number of splits at each branch (min_n), the number of predictors that will be randomly sampled at each split when creating the tree models (mtry) and tree depth (maxdepth). A 75%/25% split was used for the training / testing data set. Models were built and compared using the parsnip package (Kuhn and Vaughn, 2021) which is part of the Tidy Models framework (Kuhn et al 2020). This framework simplifies the comparison and select of the optimal final tree.

4.4.4 Results

The model outputs were ranked according to the accuracy metric, which is a suitable performance metric for predicting classes. Overall, random Forest and ranger performed best, with the best performing a range model a mean accuracy of 0.851 (std_err = 0.0016). Results for the best model and hyperparameter values, which compares the model classification between the testing and training datasets. The results indicate classification was accurate around 80% of values, which is a good result and indicates the outputs from this model can be used as a spatial layer for mapping potential GDEs in this landscape.

Table 4-2 Vegetation Patch Types for Remote Sensing Monitoring

		Actual	
		Potential GDE	**Non-GDE**
Prediction	**Potential GDE**	863	194
	Non-GDE	270	1797

Using the final tree, the predict function though the terra package (Hijmans, 2021) was used to generate a spatial prediction using the pre-processed Sentienel-2 image to generate a land use classification raster for the three vegetation classes across the landscape (Figure 4-3).

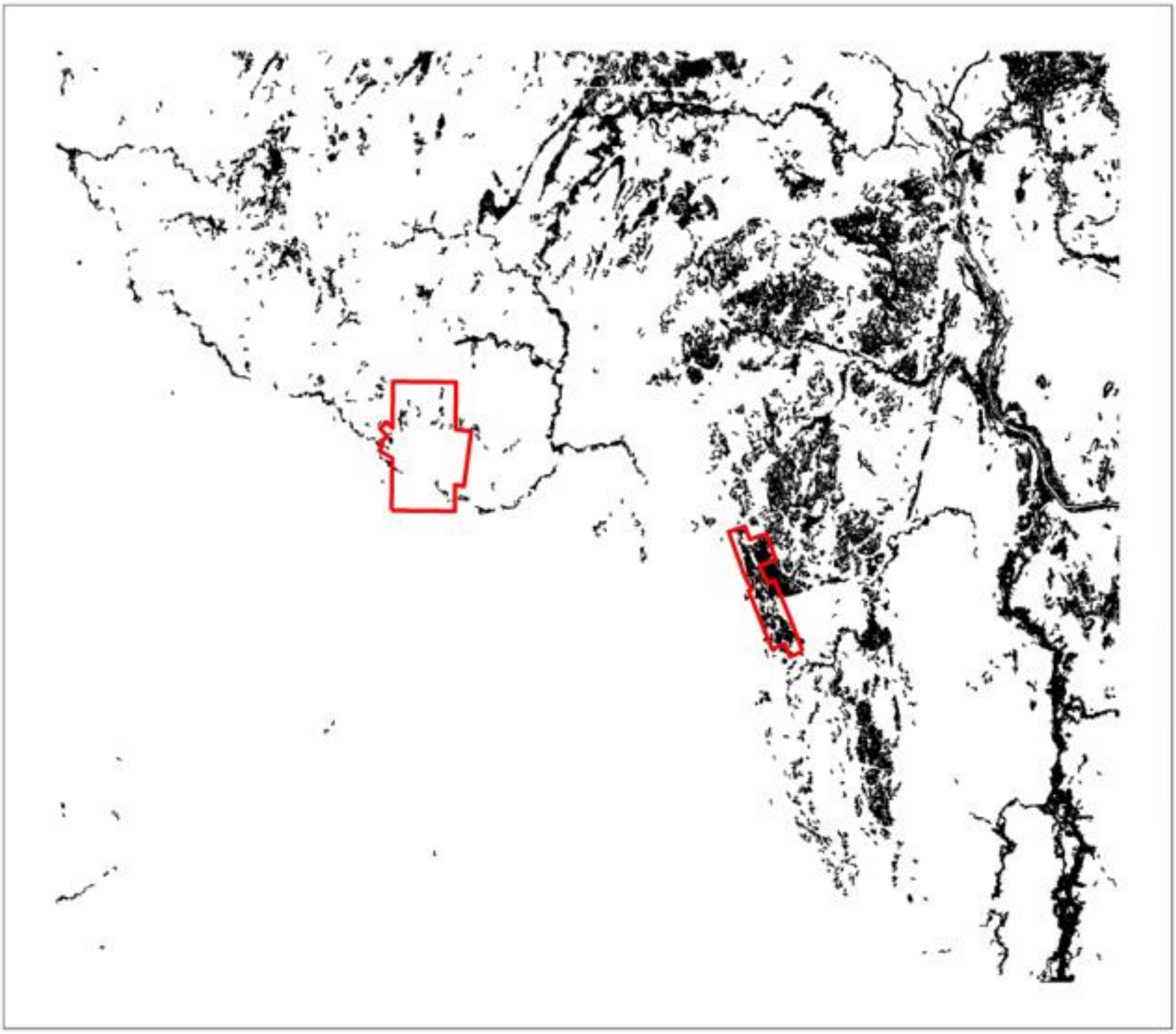


Figure 4-3 **Areas (shown in black) of vegetation with water use signatures which indicate potential terrestrial GDE vegetation. Site boundaries shown in red**

Section 5 Risk Characterisation

A risk assessment has been developed to identify GDEs that are at risk of impacts from mining activities, so that management actions can be prioritised. The IESC position is that impacts on GDEs should be avoided where possible and, if unavoidable, followed by appropriate monitoring and mitigation strategies. The terrestrial GDE risk assessment presented here is designed to address this requirement. As noted in earlier sections there are no Surface Expression GDEs (Type 2) identified in the Project area, and Subterranean GDEs (Type 1) have yet to be classified. Therefore, the focus of this risk assessment is the Type 3 terrestrial vegetation GDEs.

The underpinning reasoning for undertaking a GDE impact assessment is that groundwater drawdown leads to changes in three categories of ecological response in terrestrial GDEs: productivity, biodiversity and recruitment. In the short term (within three years), reduced productivity is expressed as reduced leaf biomass (measured by litterfall and percentage of crown cover) and in the medium term as an absence of saplings (measured by fewer occurrences of smaller size classes). In the longer-term biodiversity is lost, and the vegetation community structure and composition alter.

Risk assessments provide a mechanism to make an indicative evaluation, via a threat analysis, of how the current GDEs might change if groundwater conditions change (Richardson et al., 2011). To assess the risk of mining activities affecting GDEs, risk assessments need to define relationships for each threat between:

- The consequences to the GDE, spatially and temporally, as a function of the severity of the threat;
- The likelihood of the threat affecting each GDE; and
- The significance (Risk) of impacts in a regional/state/national context.

A threat pathway is defined here as a possible chain of events that is initiated by the stressor and could result in an impact to a terrestrial GDE. In the context of assessing the impacts of the proposed mining development, the impact of changes to plant water availability is the primary concern.

Figure 5-1 summarises the threat pathways associated with the key drivers that influence soil water availability and the associated ecological effects for the vegetation. Climatic drivers exert a strong influence on soil water availability and therefore vegetation water status. By comparison, the response of the trees to changes in groundwater conditions will be muted, and potentially highly episodic. The impacts associated groundwater drawdown and the exposure of the vegetation to additional water stress will be difficult to detect, given the background influence of climate, landuse pressures and the current poor condition of remnant riparian vegetation

Soil water availability is influenced by a number of processes, which include rainfall, flooding events and evapotranspiration. Rainfall and flooding replenish the soil water reserves and are important for the tree recruitment, flowering and reproductive processes, and for ongoing transpiration and nutrient uptake.

Evapotranspiration is a control on the rate that soil water reserves are depleted. The capillary fringe above the watertable provides a potential water source for trees during dry periods. Threats associated with changes to groundwater levels are therefore most relevant for established trees.

As indicated in these descriptions of threat pathways, some factors related to existing hydrological conditions stand out as being critical to whether or not a threat pathway exists and will also influence the significance of the potential threat. For Terrestrial Vegetation GDEs the threat pathway is influenced by the groundwater level relative to the root zone (if the capillary fringe above the watertable is inaccessible to roots, changes in groundwater levels do not pose a threat).

Groundwater levels within alluvial aquifers within the Project area rise and fall depending on the frequency of large rain and flood events, gradually declining until the system is replenished. Therefore, the potential threat alters depending on if the system is undergoing a rising or falling climate trend.

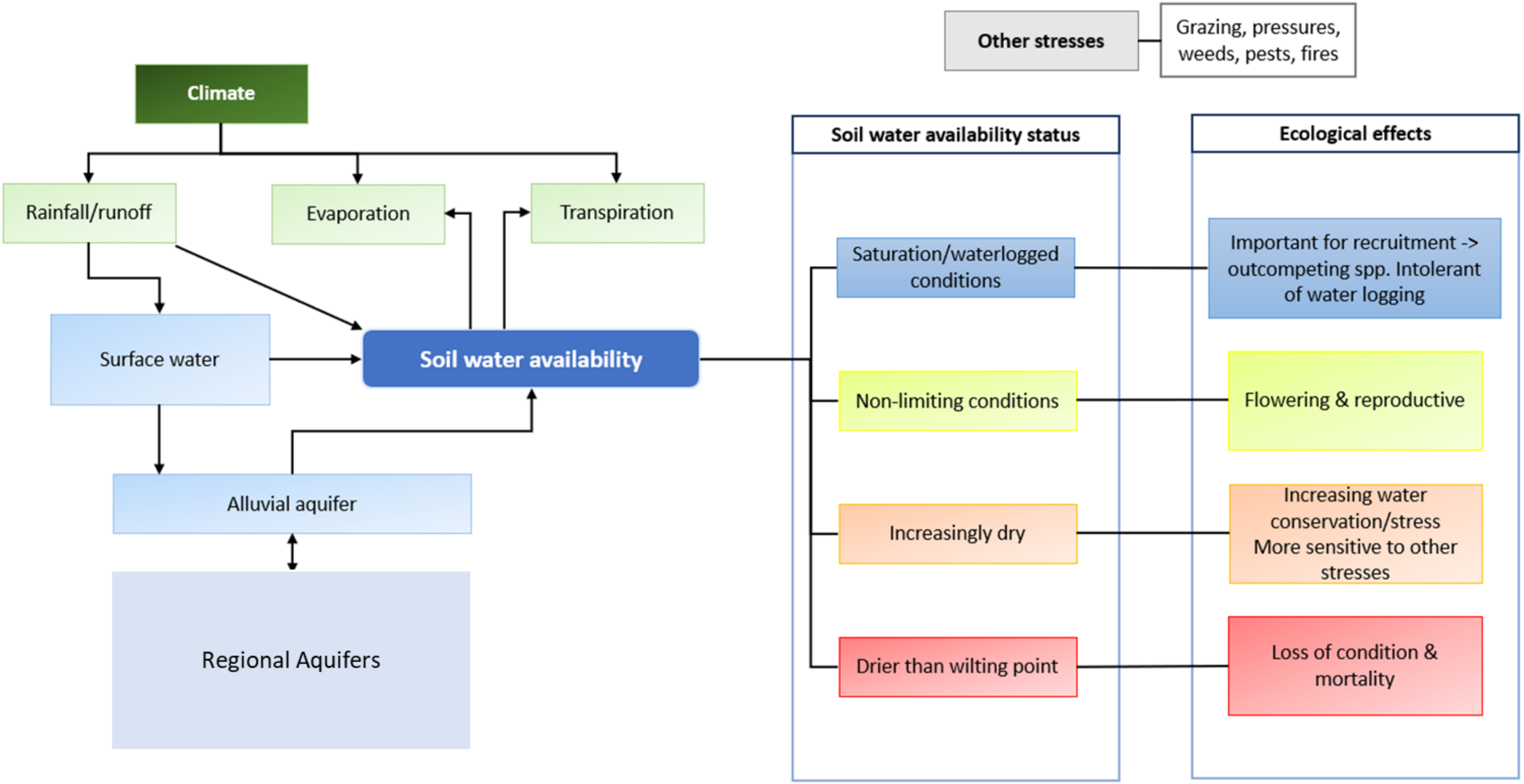


Figure 5-1 **Control-stressor Diagram**

5.1 Risk Matrix

The GDE risk assessment is consistent with the Australian / New Zealand Standard ISO 31000:2009 Risk management principles and guidelines.

This risk assessment has been undertaken considering the critical elements of the conceptualisation relating to how GDEs interact with the unconfined groundwater system. These elements are summarised as follows:

- It is likely existing trees are able to connect with the underlying water table;
- Terrestrial vegetation uses soil water from its rootzone, as well as groundwater;
- Rainfall and surface water most likely provides the biggest inputs to replenish soil water storage;
- During extended dry periods where vegetation is conserving water use and shallow soil water reserves may be depleted, the capillary fringe of the watertable provides a potential alternative water source;
- Soil moisture storage and groundwater levels in the alluvial aquifer are dynamic, likely rising with large rainfall events and receding during dry periods. Changes in soil moisture are very dynamic, with smaller rainfall events providing some replenishment to the soil storage and these may or may not induce recharge (there is no temporal data on soil moisture contents, or LWP, but cycles are likely to be seasonal). These smaller wet events do not materially affect the watertable level; and
- Given the above, management of this risk is warranted.

This risk assessment is considered conservative and through detailed ongoing monitoring and future work programs, that will continue to enhance the conceptual understanding and in doing so, reduce the risk uncertainty.

The level of risk is assigned and calculated as the intersection of likelihood and consequence assignment, as shown below in Table 5-1. Table 5-2 summarises the descriptions of the risk matrix severity ratings, acceptability and treatment of a risk event. For the purposes of assessing risk against Table 5-1 the following spatial layers were used:

- **Likelihood**. Depth to groundwater (in meters below ground level (mbgl), with likelihood ratings based on vegetations ability to access groundwater from depth (Figure 5-2); and
- **Consequence**. Proposed depth to groundwater with drawdown (based on steady state modelling as described in Section 2), with consequence ratings based on the degree of change of groundwater depth (Figure 5-3).

Table 5-1 GDE risk matrix for changes to water levels

Risk matrix		Consequence				
		Slight	**Minor**	**Moderate**	**Major**	**Severe**
		No change in groundwater level due to drawdown	**Up to 1m (95th) drawdown**	**1m to 5m (95th) drawdown**	**5m to 10m (95th) drawdown**	**Greater than 10m (95th) drawdown**
Likelihood	**Highly likely** **Depth to groundwater less than 2 mbgl.**	Low	Low	Medium	High	High
	Likely **Depth to groundwater between 2 mbgl to 5 mbgl.**	Low	Low	Medium	High	High
	Possible **Depth to groundwater between 5 mbgl to 10 mbgl.**	Low	Low	Medium	Medium	Medium
	Unlikely **Depth to groundwater greater than 10 mbgl; groundwater levels below the root zone**	Low	Low	Low	Low	Low

Table 5-2 Risk rating - acceptability and treatment of a risk event

Risk rating	Acceptability	Treatment / Management
High	High indicates a potential unacceptable level of risk and a potential requirement for control measures to be put in place to reduce the risk profile to medium or low with ongoing monitoring.	Risk event may be tolerated and may be subject to multiple regulatory controls. Addition investigations will be required to define what this risk means to the water requirements of the vegetation. This may include both outcome-based and management conditions.
Medium	Medium indicates a partial acceptance of risk but only with detailed and frequent monitoring of the activity in place to check that the risk remains tolerable.	Addition monitoring will be required to define what this risk means to the water requirements of the vegetation
Low	Low indicates an acceptable level of risk with ongoing monitoring of the activity required to check that the risk remains low.	Not required

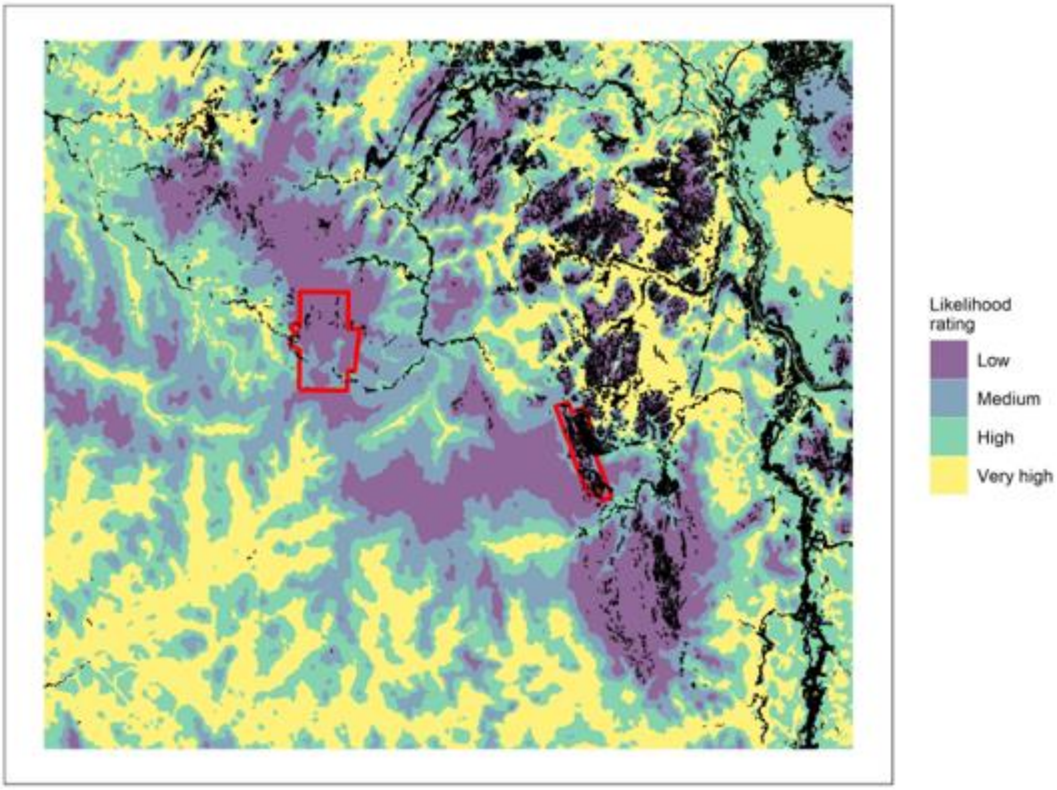


Figure 5-2 Likelihood rating – depth to water (based on vegetations ability to access groundwater from depth)

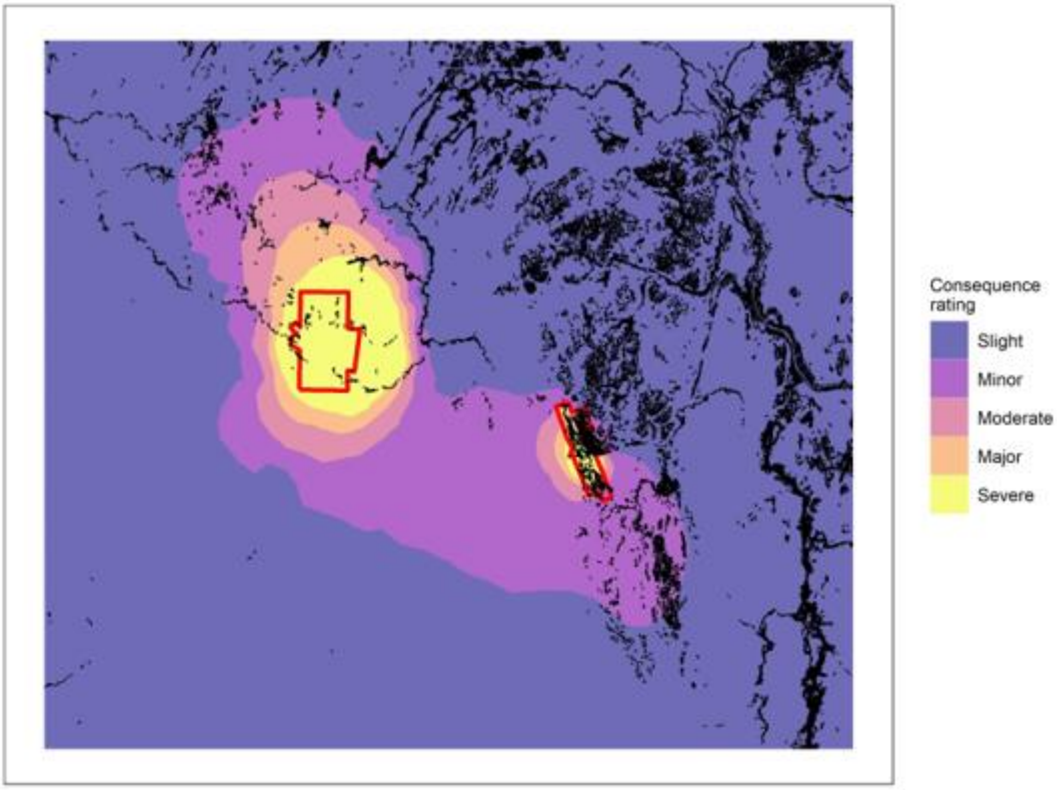


Figure 5-3 Consequence rating - drawdown (based on the degree of change of groundwater depth)

5.2 Risk Rating

The combination of the likelihood and consequence spatial layers is intersected with the potential GDE layer to identify vegetation patches risk ranking (Figure 5-4). This figure indicates there are areas where the risk to riparian vegetation is medium and high.

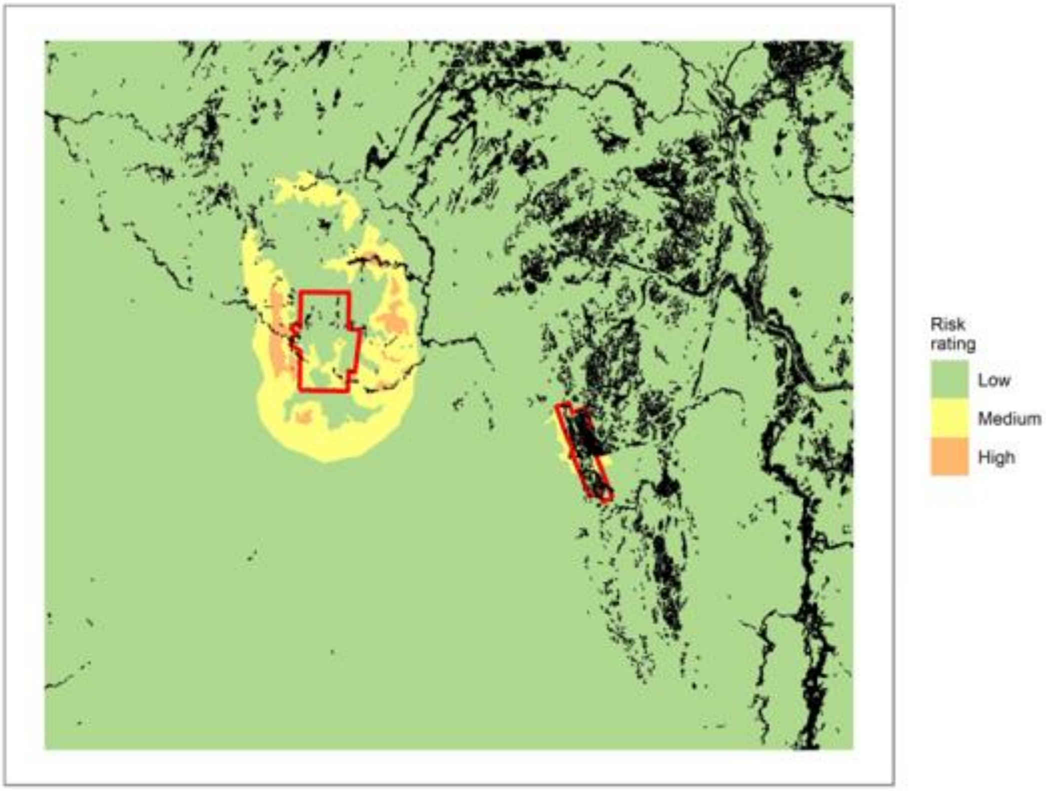


Figure 5-4 Risk rating (with potential terrestrial GDEs shown)

Section 6 Conclusions and Recommendations

The updated GDE assessment has concluded the following:

Aquifer and Cave Ecosystems (Subterranean GDEs)

There is no data available on subterraneous GDEs for the area. Given the regional nature of the groundwater system, species present are likely to be ubiquitous across the Project area, with no particular species occurring within isolation to other species with geographic boundaries.

Ecosystems Dependent on the Surface Expression of Groundwater (Aquatic GDEs)

It is unlikely aquatic GDEs exist within the area of predicted drawdown. While no future work is recommended regarding aquatic GDEs, additional monitoring with respect to Terrestrial GDEs will provide confirmation of this conclusion.

Ecosystems Dependent on the Subsurface Presence of Groundwater (Terrestrial GDEs)

Additional mapping of terrestrial GDEs has identified that there is a likelihood that riparian vegetation within the areas of drawdown exist. These are likely restricted to narrow zones of riparian vegetation, dominated by the presence of medium sized trees *Eucalyptus bigalerita*, and *Lophostemon grandifloras.*

These areas are considered likely to be using groundwater due to their persistent high NDVI trend and the presence of shallow water tables. However, it is largely unknown at this stage if these trees, present across the study area have the root structure to access deeper soil moisture from the capillary fringe above the water table, and if indeed they require groundwater as part of their annual water requirements.

Irrespective of the uncertainty regarding their groundwater use patterns, a conservative risk assessment has been conducted. The risk assessment has identified areas of potential high risk is associated with areas of initial depth to water table of less than 5 metres and a change to that water depth due to mining of greater than 5 meters.

As a result of the risk assessment the development of a Groundwater Dependent Ecosystem Monitoring Program (GDEMP) is recommended. The objective of the monitoring program is to protect the ecological condition of the Type 3 GDEs in the Project area:

- Data collected will be used to monitor the degree of hydro(geo)logical change and influencing factors (informing the likelihood component of the risk assessment);
- Data collected will be used to monitor the condition of the GDEs and their sensitivity to changes and influencing factors (informing the consequence component of the risk assessment); and
- A key component of this summary is the acknowledgment there remains uncertainty within the current system – and with this consideration a future works program has been developed.

The proposed monitoring program is driven by the GDEMP objective that aims to protect the ecological condition of the Type 3 GDEs in the Project area. The monitoring data provides the backbone of the GDEMP and will occur as an array of monitoring components that will track the conditions during the construction, operational and post-operational phases of the Project.

The data collected will be used to address a series of monitoring objectives which are aligned with the risk assessment methodology, as detailed below.

1. Monitor the degree of hydro(geo)logical change and influencing factors, including background influences (which informs the likelihood element of the risk assessment), by:
    a. Monitoring groundwater levels in the alluvial aquifer in areas of probable drawdown and in areas outside of the predicted zone of influence;
    b. Monitoring groundwater levels in regional aquifers to monitor the predicted drawdown at depth, its propagation towards the surface and the relationship / hydraulic gradient to groundwater levels within the alluvial aquifer supporting the GDEs;

    c. Monitoring streamflow;
    d. Monitoring soil moisture levels using leaf water potentials as a surrogate; and
    e. Monitoring climatic conditions (rainfall, temperature).

2. Monitoring the condition of GDEs, their sensitivity to hydro(geo)logical change, and other influencing factors including background influences (which informs the consequence element of the risk assessment), by:
    a. Monitoring the condition of GDEs by:
        i. Leaf water potential monitoring; to identify likely depth of water use by the vegetation, this can be related to the existing depth of the water table at each site.
        ii. Remote sensing; Using high resolution temporal data develop a time series of NDVI response to climate to observe any trends that may be related to changes in groundwater levels.
        iii. Vegetation surveys; to assess the condition of the vegetation and assess any trends against changes in groundwater levels.
    b. Monitoring other threats to GDEs (e.g. weeds and pests, grazing pressure, soil erosion, storms, fire) by vegetation surveys.

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