



Appendix K

Groundwater Dependent Ecosystems Risk Assessment





TNG Limited
Mount Peake EIS Supplement
Groundwater Dependent Ecosystems Risk Assessment

March 2017

Executive summary

TNG Limited (TNG) is proposing to develop the Mount Peake Project (the project), located approximately 235 kilometres (km) north-west of Alice Springs and approximately 50 km west of the Stuart Highway. Baseline vegetation and flora assessments conducted for the project identified the occurrence of potential Groundwater Dependent Ecosystems (GDEs) within the project area. Mining activities for the proposed project include groundwater extraction activities that have a potential to impact GDEs.

GHD was engaged by TNG to assess potential impacts to GDEs from groundwater extraction activities associated with the project. This assessment uses existing groundwater assessments for the project, and specifically makes use of the groundwater drawdown models. The assessment covers the impacts of groundwater extraction from the mine pit and borefield during operation and following closure.

Key conclusions

- The project has the potential to reduce groundwater levels and modify the frequency/timing of water table level fluctuations. The project may also alter the natural groundwater chemistry and/or chemical gradients as a result of changes to water levels.
- A groundwater model developed for the project predicts a maximum groundwater drawdown at the borefield of less than 5 m at Stage 1 (year 4), peaking at approximately 12 m at the end of mining (Stage 2: year 17). Predictions at 100 years shows groundwater levels rebounding with maximum drawdown less than 5 m.
- Potential impacts of predicted groundwater drawdown as a result of the project include mortality of facultative phreatophytes such as River Red Gum, Ghost Gum, Bean Tree and Desert Bloodwood.
- A conservative threshold of 20 meters below ground level (mbgl) was selected as the maximum depth at which facultative phreatophytes would access and rely upon groundwater resources to meet water requirements. Below 20 mbgl it was considered unlikely that River Red Gum, Ghost Gum, Bean Tree and Desert Bloodwood would be reliant on groundwater resources.
- Along the Hanson River palaeochannel within the borefield, predicted groundwater drawdown of 10 m or more (resulting in an overall groundwater depth of 20+ mbgl) would trigger the threshold value and likely result in an impact to facultative phreatophytes. In this worst-case scenario it is estimated no individual trees at year 4 (as predicted drawdown is <5 m) and 2,209 individual trees at year 17 could be impacted.
- Drilling completed to 35 and 36 m on the eastern bank of Murray Creek (near the mine pit) did not identify the presence of groundwater. This indicates that facultative phreatophytes within the area are unlikely to access and/or rely on groundwater resources. No impacts to GDEs in the Murray Creek area are anticipated through groundwater extraction activities associated with dewatering of the pit.
- Opportunities to mitigate impacts to GDEs are limited, however, a monitoring program has been proposed to allow quantification of impacts over the duration of the project.
- Modelling predicts that no groundwater drawdown for any scenario is expected at or near the three sites of conservation significance - Mud Hut Swamp, Anmatyerr North (including Stirling Swamp) and Wood Duck Swamp.

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1. Introduction

1.1 Background

TNG Limited (TNG) is proposing to develop the Mount Peake Project (the project), located approximately 235 kilometres (km) north-west of Alice Springs and approximately 50 km west of the Stuart Highway. The project will consist of:

- The mining of a polymetallic ore body through an open-pit truck and shovel operation
- Processing of the ore to produce a magnetite concentrate
- Road haulage of the concentrate approximately 100 km to a new railway siding and loadout facility on the Alice Springs to Darwin railway near Adnera
- Rail transport of the concentrate to TNG's proposed Darwin Processing Facility at Middle Arm.

Baseline vegetation and flora assessments conducted for the project identified the occurrence of potential Groundwater Dependent Ecosystems (GDEs) within the project area (GHD 2015a, 2017a). Mining activities for the proposed project include groundwater removal from within the pit to allow mining and from the borefield for process and potable water. Based on these extraction activities, there is potential for impacts to GDEs.

1.2 Objectives of the assessment

GHD was engaged by TNG to assess potential impacts to GDEs from groundwater extraction activities associated with the project. The objectives of this report are to:

- Outline the predicted changes to groundwater levels from groundwater extraction based on modelling results
- Identify, describe and map potential GDEs within the project area
- Identify the potential areas where groundwater extraction activities could impact GDEs
- Propose a monitoring program to allow project related impacts to GDEs to be quantified.

This assessment uses existing groundwater and surface water assessments for the Project (GHD 2016, 2017b), and specifically, makes use of the groundwater drawdown models. The assessment covers the impacts of groundwater extraction from the mine pit and borefield during operation and following closure.

1.3 Project definitions

For the purposes of this assessment, the following definitions are employed:

- Mining area – refers to the area where mining and processing will occur and contains all mining facilities
- Mine pit – is located within the mining area and is approximately 77 ha. Once mining is complete, the mine pit will be approximately 2,000 metres (m) long and 600 m wide with a maximum depth of 125 m
- Borefield – the borefield will be established within the alluvial aquifer of the Hanson River and will comprise six supply bores for the first four years of operations, and an additional three bores installed from year 5. The bores will be spaced approximately 1.8 km apart (extending approximately 16 km) and will be connected to the mining area via a water supply pipeline.

1.4 Limitations and assumptions

This report has been prepared by GHD for TNG and may only be used and relied on by TNG for the purpose agreed between GHD and the TNG as set out in section 1.2 of this report.

GHD otherwise disclaims responsibility to any person other than TNG arising in connection with this report. GHD also excludes implied warranties and conditions, to the extent legally permissible.

The services undertaken by GHD in connection with preparing this report were limited to those specifically detailed in the report and are subject to the scope limitations set out in the report.

The opinions, conclusions and any recommendations in this report are based on conditions encountered and information reviewed at the date of preparation of the report. GHD has no responsibility or obligation to update this report to account for events or changes occurring subsequent to the date that the report was prepared.

The opinions, conclusions and any recommendations in this report are based on assumptions made by GHD described in this report. GHD disclaims liability arising from any of the assumptions being incorrect.

This assessment is based upon the mining area and bore locations (within the borefield) developed by TNG and provided to GHD

GHD has prepared this report on the basis of information provided by TNG and others who provided information to GHD (including Government authorities), which GHD has not independently verified or checked beyond the agreed scope of work. The following technical studies have assess particular environmental aspects and are therefore relied upon for inclusion in this report:

- Mount Peake Project, Flora and Vegetation Assessment Report (GHD 2016a)
- Mount Peake Project, Groundwater and Surface Water Assessment Report (GHD 2016b)
- Mount Peake Project, Flora and Fauna Assessment Report, Additional Works (GHD 2017a)
- Mount Peake Project, Groundwater Supplementary Report (GHD 2017b).

2. Proposed groundwater extraction

2.1 Baseline groundwater levels

Interrogation of the NRETAS bore database highlighted a lack of bores close to the project with current and historic groundwater levels. Groundwater and resource drilling undertaken for the project has provided additional groundwater level data along the Hanson River palaeochannel, within the proposed pit area and along the eastern banks of Murray Creek immediately east of the mining area. The drilling indicates groundwater levels to be relatively consistent at a depth of around 10 metres below ground level (mbgl) along the Hanson River palaeochannel and typically 20 to 22 mbgl in the pit area (GHD 2017b). Drilling was also completed to 35 m and 36 m at two locations on the eastern bank of Murray Creek; no groundwater flow was identified at either location.

2.2 Recharge

Aquifer recharge predominantly occurs from direct infiltration of rainfall. Due to the sporadic and minimal amount of rainfall typical of the region, this volume is quite low. Previous studies in the region, most notably for the Ti Tree Basin, have used an average long-term recharge of 2 mm per year (Wischusen *et al.* 2012).

Whereas regional recharge is relatively low, large rainfall and subsequent flood events are known to significantly increase groundwater levels in areas close to active flow channels. However, a lack of monitoring data for the Hanson River channel means that recharge volumes for this system cannot be accurately quantified (GHD 2017b).

2.3 Proposed extraction

2.3.1 Borefield

Borefield operation will be at an abstraction rate of 1.6 GL/year (51 L/s) from 6 active bores during Stage 1 (years 1 to 4) and at an abstraction rate of 2.6 GL/year (82 L/s) from a total of 9 active bores during Stage 2 (from years 5 to 17).

2.3.2 Mine pit

Dewatering within the pit will be facilitated through use of in-pit sumps.

2.4 Modelled drawdown

A groundwater model was developed and used to model cumulative impacts from the bore field operation and mine pit development (GHD 2017b). Three scenarios were simulated:

- Stage 1 (year 4) (Figure 6-1 in GHD 2017b)
- Stage 2 (year 17) (Figure 1, Appendix A) (Figure 6-3 in GHD 2017b)
- Post mining (year 100) (Figure 2, Appendix A) (Figure 6-8 in GHD 2017b).

2.4.1 Borefield

The models indicate that across the borefield area, a maximum groundwater drawdown of less than 5 m is predicted to occur at Stage 1 (year 4), peaking to approximately 12 m at the end of mining (Stage 2: year 17). The maximum drawdown at Stage 2 is localised to the operating bores in the centre of the borefield. The extent of drawdown at the end of Stage 1 is limited to the palaeovalley, with up to 1 m drawdown extending to approximately 1.5 km north and 1.8 km south of the borefield. At Stage 2, the 1 m drawdown contour extends to approximately 4.8 km north and 6.5 km south of the borefield (Figure 1, Appendix A). However, drawdown decreases significantly with distance away from the palaeovalley.

Modelling of the groundwater drawdown at year 100, 83 years following cessation of mining/abstraction, shows groundwater levels rebounding with maximum drawdown less than 5 m. The 1 m drawdown contour extends approximately 12.6 km north and 16.8 km south of the borefield (Figure 2, Appendix A).

2.4.2 Mine pit

The models indicate that at the end of Stage 2 (year 17), due to the depth of excavation within the mine pit, mining dewatering will result in drawdown of up to 80 m in the area immediately around the areas of the deepest part of the pit (Figure 1, Appendix A). Dewatering within the pit will be through use of in-pit sumps, therefore the areas of dewatering impact will largely mimic the outline of the pit. The modelled extent of drawdown resulting from pit dewatering is relatively limited to areas close to the pit, with drawdown more than 1 m modelled to occur to a maximum distance of approximately 1.3 km east and west of the pit. This includes drawdown of up to 10 m at the western side of Murray Creek.

Modelling of the groundwater drawdown at year 100, 83 years following cessation of mining/abstraction, shows a slight increase (to approximately 84 m) with respect to the Stage 2 drawdown. The 1 m drawdown contour extends approximately 4 km from the mine pit (Figure 2, Appendix A).

2.5 Sites of conservation significance

There are three sites of conservation significance located in the vicinity of the project:

- Mud Hut Swamp – This site is located approximately 7.7 km north of the proposed mine pit and encompasses a large, isolated, Smooth-barked coolabah (*Eucalyptus victrix*) swamp that is fed by Bloodwood and Murray Creeks in the south-east, and runoff from low hills and rises to the north and west (NRETAS 2009a).
- Anmatyerr North – This site is located approximately 37 km east to southeast of the borefield and includes Stirling Swamp, a large wetland complex comprised of claypans, lignum swamp, semi-saline samphire and temporary open water as well as parts of the adjacent Hanson River (upstream of the borefield) (NRETAS 2009b)
- Wood Duck Swamp – This site is located approximately 80 km south-east of the borefield and is an ephemeral swamp dominated by Smooth-barked Coolibah. The Swamp may hold water for many months in an otherwise dry landscape and fills periodically after heavy rain (NRETAS 2009c).

The groundwater model predicts that no groundwater drawdown for any scenario is expected at or near the three sites of conservation significance (GHD 2017b).

3. Groundwater Dependent Ecosystems

3.1 Overview

GDEs are ecosystems that require access to groundwater to meet all or some of their water requirements to maintain the communities of plants and animals, ecological processes they support, and ecosystem services they provide (Richardson *et al.* 2011). Groundwater supply to ecosystems is particularly important in arid and semi-arid regions due to low precipitation rates and high evaporation rates resulting in scarce supply of surface water (Eamus *et al.* 2006).

GDEs can be divided in three distinct classes (Eamus *et al.* 2006; Richardson *et al.* 2011):

Type 1: Aquifer and cave ecosystems – “These ecosystems typically include karst aquifer systems, fractured rock and saturated (consolidated and unconsolidated) sedimentary environments. The hyporheic zones of rivers, floodplains and coastal environments are also included in Type 1. The deep subsurface groundwater environment provides relatively stable, lightless environmental conditions with restricted inputs of energy and low productivity, which allows a particular suite of subsurface ecosystems to prosper. The ecological diversity is created from variable geology, oxygen, carbon and nutrient gradients (linked to the dynamics of water flow) and physico-chemical conditions. Subsurface ecosystems provide an important supporting service of bioremediation of contaminated groundwater, and provide an important role in carbon and nutrient cycling” (Richardson *et al.* 2011).

Type 2: Ecosystems dependent on the surface expression of groundwater – These “include wetlands, lakes, seeps, springs, river baseflow, coastal areas and estuaries that constitute brackish water and marine ecosystems. In these cases, the groundwater extends above the earth surface, as a visible expression. In these situations, groundwater provides water to support aquatic biodiversity by providing access to habitat (especially when surface runoff is low) and regulation of water chemistry and temperature” (Richardson *et al.* 2011).

Type 3: Ecosystems dependent on subsurface presence of groundwater – This includes terrestrial vegetation that depends on groundwater fully or on a seasonal or episodic basis in order to prevent water stress and generally avoid adverse impacts to its condition. In these cases, and unlike Type 2 systems, groundwater is not visible from the earths surface. These types of ecosystem can exist wherever the water table is within the root zone of the plants, either permanently or episodically.

A sub-class of Type 3 GDEs includes **facultative GDEs**, which require groundwater in some locations but not in others, particularly where an alternative source of water can be accessed to maintain ecological function (Clifton *et al.* 2007; O’Grady *et al.* 2007). Dependence on groundwater for facultative GDEs can range from opportunistic to being highly dependent. Ecosystems with a proportional dependence on groundwater do not generally exhibit the threshold type response of the more dependent ecosystems. As a change occurs in a groundwater attribute; e.g. level, a proportional response generally occurs within the ecosystem, (Hatton and Evans 1998). Opportunistic dependency occurs when ecosystems use groundwater as required. For example, this may occur when surface water / soil moisture is unavailable, such as at the end of a dry period. Minor changes to the groundwater regime may not have any adverse impacts, but these ecosystems can die if a lack of access to groundwater is prolonged. It is however difficult to distinguish between proportional and opportunistic dependency.

3.2 Groundwater dependency

It is a basic tenet of ecology that ecosystems will generally use resources in proportion to their availability. It is therefore assumed that if groundwater can be accessed, ecosystems will generally develop some degree of dependence and that dependence will likely increase with increasing aridity (Hatton and Evans 1998).

For many communities, depth to groundwater is an important parameter controlling the availability of groundwater to a plant (Hatton and Evans 1998; Eamus *et al.* 2006; Froend and Loomes 2006). Groundwater dependent communities require that groundwater levels be episodically or periodically within their root zone for use when soil water availability is low to satisfy demands for water and nutrients (Hattermann *et al.* 2008; Groom *et al.* 2000).

Information on root depth and morphology can therefore be used to determine dependency. However, little is known about the rooting depths of plants and reliance on groundwater when surface water is unavailable.

The groundwater dependence of many ecosystems can be inferred from their position in the landscape, their response to altered water regimes and the occurrence of vegetation or species associated with shallow groundwater (Froend *et al.* 2004). The groundwater dependency of many ecosystems is self-evident; e.g. cave and aquifer ecosystems, base flow dependent ecosystem. Groundwater dependency of wetlands and terrestrial vegetation can be inferred through the impact of altered water regimes on the distribution and composition of species. The importance of groundwater on more xeric or opportunistic species, such as the semi-arid areas of this study area, may be more difficult to infer.

In ecosystems that only rely on groundwater during extreme climatic conditions (i.e. droughts) such as terrestrial vegetation communities, there may have to be a large change to warrant a response or the response may have a significant time lag from the disturbance event. Different elements of an ecosystem will have different reaction times and responses to a particular impact.

The reliance of central Australian vegetation on groundwater is poorly known. Vegetation that may be most likely to be reliant on groundwater are River Red Gum, Coolabah, Bloodwood and Bean Tree (O'Grady *et al.* 2009; Santini *et al.* 2016). Ghost Gums may also possibly access groundwater resources, but this has not been examined in central Australia. Tree height and tree basal area are considered good indicators of available water resources for tree growth (Zolfhager 2013).

River Red Gum (*Eucalyptus camaldulensis*)

River Red Gum is considered a facultative phreatophyte, with the capacity to utilise water from a range of different sources including rainfall, floodwater, stored soil water and groundwater (Mensforth *et al.* 1994).

River Red Gums support a large root system consisting of vertical tap roots with lateral roots branching off at right angles at several levels, and sinker roots extending downwards from laterals. Vertical sinkers provide support for the aboveground part of the tree and deep penetration of soil over a wider area than would be possible via a single taproot. Extension of the root system also allows for access to oxygen from unsaturated portions of the soil profile during periods of inundation, enhancing flood tolerance. Mature trees are thought to have roots to depths of at least 9 m to 10 m and possibly as deep as 30 m (Davies 1953, cited in Colloff 2014). Adventitious roots can grow out from boles or branches in response to flooding, for increased oxygen uptake and also as a form of vegetative propagation. Woody roots of this species are known to have large xylem vessels for fast, efficient rates of water transport and rapid recovery following water stress (Heinrich 1990, cited in Colloff 2014).

River Red Gum water requirements exceed those provided by rainfall alone, and are met by the trees accessing groundwater (Feikema *et al.* 2010; Doody *et al.* 2009, 2014a). As an adaptation to arid and semi-arid environments, it is opportunistic in its water use, sourcing water according to osmotic and matric water potential (Thorburn *et al.* 1993; Mensforth *et al.* 1994; Holland *et al.* 2006; Doody *et al.* 2009). Water sources include fresh to moderately saline groundwater, lateral bank recharge and overbank flooding which replenishes floodplain groundwater (Thorburn *et al.* 1993; Mensforth *et al.* 1994; Holland *et al.* 2006; Doody *et al.* 2009; 2014b; Holland *et al.* 2009; Feikema *et al.* 2010). In areas with low rainfall and infrequent flooding, groundwater may provide the most temporally stable water resource (Mensforth *et al.* 1994; Burges *et al.* 2001).

Currently, quantitative information suggests reduced importance of groundwater to vegetation where depths to groundwater exceed 10 m. However, it is assumed that at depths of 10–20 m there is a possibility of vegetation groundwater use, although it is thought to be negligible in terms of total plant water use, and that at depths of over 20 m the probability of groundwater use is low (Froend and Zencich 2001).

Ghost Gum (*Corymbia aparrerinja*), Desert Bloodwood (*Corymbia opaca*) and Bean Tree (*Erythrina vespertilio*)

Ghost Gum, Desert Bloodwood and Bean Tree are known as facultative phreatophytic species (O'Grady *et al.* 2009; O'Grady *et al.* 2006; Loomes 2010). The species are deep rooted and tap into groundwater, via the capillary fringe, to satisfy at least some portion of their environmental water requirements. However, the species will also inhabit areas where their water requirements can be met by soil moisture reserves alone (Pritchard *et al.* 2010).

Limited/no information is available on Ghost Gums and Bean Trees in central Australia, however, Desert Bloodwood is reported to draw water from as far as 20 m below ground level (Department of Natural Resources, Environment, the Arts and Sport 2009).

Smooth-barked Coolibah (*Eucalyptus victrix*)

Smooth-barked Coolibah is regarded as being a facultative phreatophyte that most likely draws the majority of its water requirement from the unsaturated zone, but can use groundwater opportunistically as required.

Mature Smooth-barked Coolibah trees commonly support a large dimorphic root system, consisting of prominent tap roots and a network of laterally expansive roots near the soil surface and in the top 1 m to 2 m of the soil profile. The lateral roots can extend to at least 10 m to 12 m away from the main stem, from which vertical sinker roots can also develop and potentially extend tens of metres to water table depth (Florentine 1999).

Previous studies have shown that when provided with access to groundwater, Smooth-barked Coolibah can maintain high leaf water potentials and high rates of tree water use during times of drought (O'Grady *et al.* 2009; Pfautsch *et al.* 2011; Pfautsch *et al.* 2014). However, Smooth-barked Coolibah also demonstrates a strong ability to regulate water losses when water supplies are limited via regulation of stomatal conductance (Pfautsch *et al.* 2014) and structural modifications including leaf die-off crown defoliation and adjustment of leaf area to sapwood area ratio, which enables trees to maintain constant water use despite increasing evaporative demand if sufficient water is available (O'Grady *et al.* 2009). In general, the water use strategy of Smooth-barked Coolibah appears to be highly plastic and opportunistic, enabling survival in a wide range of ecohydrological settings (Pfautsch *et al.* 2014). However, despite being a relatively plastic species, major adjustments to hydraulic architecture in large trees take time such that large changes in hydrology are likely to affect trees growing over historically shallow groundwater to a greater extent than trees that have developed over historically deeper groundwater, as highlighted in a recent study by Pfautsch *et al.* (2014).

From an assessment of water level ranges of Pilbara riparian species, it was found that the mean minimum water level depth of Smooth-barked Coolibah was greater than that for River Red Gum, providing some support for the view that Smooth-barked Coolibah is found in slightly drier areas than River Red Gum and may not be as responsive to water table fluctuations (Loomes 2010)

Mature Smooth-barked Coolibah trees display a moderate level of flooding tolerance. Mature trees are able to tolerate temporary inundation (days to weeks). The presence of adventitious roots and stem hypertrophy (the ability to increase the size of component cells) provides a level of tolerance to waterlogging in seedlings and saplings, allowing them to survive in flood-prone areas (Florentine 1999; Florentine and Fox 2002a). In fact, flooding events are believed to play a major role in the reproductive cycle of Smooth-barked Coolibah, particularly for seedling establishment (Florentine and Fox 2002b).

3.3 Project-specific GDEs

Three vegetation communities mapped for the project have been identified as potential GDEs. These communities are associated with ephemeral / episodic waterways and run-on areas of alluvial floodplains, and include:

- Riparian woodland along watercourses and drainage channels (VT3) (Figure 3)
- Low *Corymbia* woodland on loamy alluvial plains (VT4) (Figure 3)
- Floodplains dominated by *Eucalyptus victrix* (VT5).

Vegetation types 3 and 4 also support woody species Whitewood (*Atalaya hemiglauca*), which commonly co-occurs with the above described facultative phreatophytes (e.g. River Red Gum and Ghost Gum). Very little is known about the water use, water sources or rooting depths of Whitewood, and while some of the larger individuals (> 5 m in height) may opportunistically use groundwater, the majority are considered unlikely to access/use groundwater.

Riparian woodland along watercourses and drainage channels (VT3)

Woodland containing Red River Gum (*Eucalyptus camaldulensis* subsp. *obtusata*), Bean Tree and Ghost Gum has been mapped on the banks of the Hanson River as well as smaller creeks and drainage channels including Murray Creek.

Baseline vegetation and flora assessments (GHD 2017a) have estimated 17 River Red Gum individuals, three Bean Tree individuals and one Ghost Gum individual per hectare along the Hanson River. Estimates included 39 River Red Gum individuals, two Bean Tree individuals and one Ghost Gum individual per hectare along Murray Creek. Density estimates have been calculated based on individual tree counts within standard sized plots (100 x 100 m) located across the proposed borefield and adjacent to the mining area, and extrapolated based on total area.

VT3 occurs within the predicted groundwater drawdown contours for the borefield and mine pit.

Low Corymbia woodland on loamy alluvial plains (VT4)

This open woodland occurs on alluvial floodplains surrounding creek lines and drainage channels (such as the Hanson River and Murray Creek) where moisture availability is greater. Dominant canopy species include Desert Bloodwood.

Baseline vegetation and flora assessments (GHD 2017a) have estimated two Desert Bloodwood individuals per hectare along the Hanson River and along Murray Creek.

VT4 occurs within the predicted groundwater drawdown contours for the borefield and mine pit.

Floodplains dominated by Eucalyptus victrix (VT5)

This vegetation community occurs on flood out areas of the Hanson River and Bloodwood Creek including Mud Hut Swamp. The canopy layer is dominated by Smooth-barked Coolibah with River Red Gum also present in low abundance.

VT5 does not occur within the predicted groundwater drawdown contours for the borefield or the mine pit. This vegetation type is not considered further in this assessment.

4. Identification and assessment of impacts

4.1 Potential impacts of groundwater changes to GDEs

A checklist of impacts on the GDEs is provided in Table 1, indicating likely and unlikely changes to groundwater from the project (in accordance with Serov *et al.* 2012). The main predicted changes are:

- Water quantity impacts:
 - Alteration to the water table levels (dropping water tables)
 - Alteration of the frequency/timing of water table level fluctuations
- Water quality impacts:
 - An alteration to the natural groundwater chemistry and /or chemical gradients—possibly may occur as a result of changes to water levels.

Potential impacts of groundwater drawdown on facultative phreatophytes such as River Red Gum, Ghost Gum, Bean Tree and Desert Bloodwood may include:

- Partial or complete mortality: The disconnection of roots from its aquifer by a rapid drop in the water table can cause severe stress and/or partial or complete mortality in large trees (Le Maitre *et al.* 1999). The impact of a rapid or an extended drawdown can be exacerbated if it occurs during periods of environmental stress such as drought.
- Ecosystem decline: A prolonged period of drawdown can result in the disconnection of the root zone from the water table, resulting in the subsequent drying out of the ecosystem over time. The loss of species and changes in the vegetation community structure may have time lags of years to decades before becoming evident as different species of plants within a community have varying groundwater dependency and stress thresholds (Le Maitre *et al.* 1999; Froend and Sommer 2010).

4.2 Assessment of potential impacts

An assessment of the potential for the project to impact facultative phreatophytes was undertaken based on the estimated baseline groundwater levels (section 2.1), modelled groundwater drawdown for the project (section 2.4), known water requirements of facultative phreatophytes (section 3.2) and estimated species densities (section 3.3). The assessment focuses on the modelled drawdown at Stage 2 (year 17) and post mining (year 100), as at Stage 1 (year 4) predicted drawdown within the borefield is less than 5 m, and there is no drawdown predicted for the mine pit.

The assessment has also established a conservative threshold at the maximum depth at which facultative phreatophytes would access and rely upon groundwater resources to meet water requirements. A threshold value of 20 mbgl was selected based on reviewed published literature describing River Red Gum and Desert Bloodwood water requirements. Below 20 mbgl it was considered unlikely that these species (and other identified facultative phreatophytes) would be reliant on groundwater resources.

Table 1 GDE checklist for a proposed activity (adapted from Serov *et al.* 2012)

GDE impact assessment checklist		Likely	Unlikely	Insufficient data
Water quantity impacts				
Will there be an alteration to the water table levels (rising or dropping water tables)?		X		
Will there be any alteration to the aquifer flow paths?			X	
Will there be any alteration of aquifer discharge volume to off site GDEs?			X	
Will there be an alteration of the frequency/timing of water table level fluctuations?		X		
Will there be any alteration of river base flow in the karst / cave?			X	
Will there be an alteration of surface river base flow?		X		
Will there a reduction in artesian/spring water pressure?			X	
Water quality impacts				
Will there be an alteration to the natural groundwater chemistry and / or chemical gradients?			X	
Will acid sulfate soils be exposed, resulting in the acidification of aquifer and acid runoff?			X	
Will there be an alteration in nutrient loads?			X	
Will there be an alteration in sediment loads?			X	
Will there be an alteration in groundwater salinity levels?				X
Will there be an alteration in groundwater temperatures?			X	
Will there be any bioaccumulation of heavy metals?			X	
Aquifer Integrity impacts				
Will there be any substrate alteration compaction; e.g. aquifer, river gravel bed compaction by heavy machinery or over extraction of water?			X	
Will there be any cracking or fracturing of the bedrock?			X	
Biological integrity impacts				
Will there be an alteration to the number of native species within the groundwater dependent communities (fauna and flora)?				X
Will there be an alteration to the species composition of the groundwater dependent communities (fauna and flora)?				X
Will exotic flora or fauna be introduced?			X	
Will there be any removal or alteration of a GDE type / subtype habitat; e.g. quarrying of limestone around karsts, tramping of cave habitats, sand and gravel extraction?			X	

Along the Hanson River palaeochannel, groundwater depth is around 10 mbgl. Groundwater drawdown of 10 m or more (resulting in overall groundwater depth of 20+ mbgl) would trigger the threshold value within the borefield and potentially result in an impact to facultative phreatophytes. Groundwater drawdown contours overlaying vegetation type is shown in Figure 3. In this worst-case scenario it is estimated no individual trees at Stage 1 (as predicted drawdown is <5 m) and up to 2,209 individual trees at Stage 2, specifically 1,762 River Red Gums, 272 Bean Trees, 136 Ghost Gums and 39 Desert Bloodwoods, could be impacted (Table 2).

Table 2 Drawdown and calculated vegetation impacts for the borefield

Aspect	Stage 2 (year 17)	Post mining (year 100)
Groundwater drawdown		
Maximum drawdown extent:	15,801.74 ha	39,675.00 ha
0-5 m	9,036.76 ha	39,675.00 ha
5-10 m	6,643.49 ha	-
>10 m	121.64 ha	-
Calculated vegetation impacts at >10 m		
Riparian woodland (VT3):	101.64 ha	-
River Red Gum	1,762 individuals	-
Bean Tree	272 individuals	-
Ghost Gum	136 individuals	-
Low <i>Corymbia</i> woodland (VT4):	19.33 ha	-
Desert Bloodwood	39 individuals	-

Groundwater drawdown following cessation of mining/abstraction for 83 years (modelling at year 100) shows groundwater levels rebounding within the borefield with a maximum drawdown of less than 5 m) (Figure 4). However, the impacts of a prolonged period of drawdown and subsequent drying out of the ecosystem over time are uncertain. The potential loss of key species may lead to irreversible changes in vegetation structure and further decline, or alternatively, the ecosystem may slowly recover.

Dewatering within the mine pit will result in groundwater drawdown of up to 80 m at Stage 2 and approximately 84 m post mining (year 100). In the Murray Creek area, this is substantially less with groundwater drawdown approximately 5 m at the end of Stage 2 and 23 m at 100 years. Drilling completed to 35 and 36 m on the eastern bank of Murray Creek did not identify the presence of groundwater. This indicates that facultative phreatophytes within the area are unlikely to access and/or rely on groundwater resources. No impacts to GDEs in the Murray Creek area are anticipated through groundwater extraction activities associated with the project.

5. Monitoring

As identified in Section 4.2 there is the potential that some groundwater dependent vegetation will be impacted by groundwater drawdown, specifically in areas where drawdown exceeds 10 m. Opportunities to mitigate impacts are limited and a monitoring program is proposed to allow quantification of impacts. The monitoring program should include the following aspects:

- Vegetation monitoring of GDEs at the borefield (along the Hanson River) and near the mine pit (along Murray Creek). Monitoring sites should be established at varying distances from the centre of the groundwater drawdown zone, as well as upstream and downstream of the borefield and mine.
- A combination of permanent transects and quadrats should be established to monitor facultative phreatophytes (e.g. River Red Gum, Ghost Gum, Bean Tree, Desert Bloodwood and Smooth-barked Coolibah) and understorey species (as part of overall GDE health).
- The use of standard or generally accepted methods. Transect monitoring parameters (for each phreatophytic tree) may include species ID, height, diameter at breast height, visual health ranking (through % cover alive canopy foliage, health score and photographs). Quadrat monitoring parameters may include a list of all species, height, number and % cover of live and dead plants.
- Other optional transect monitoring parameters to be considered include isotopic analysis to quantitatively measure tree stress, and heat pulse test to measure tree water use.
- Annual monitoring to enable a local dataset of GDE health to be established that will include temporal fluctuations. This information should be coupled with climatic data, groundwater bore levels, water table levels and water table quality data. Monitoring should commence prior to extraction occurring and continue during mine operations.

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Appendices

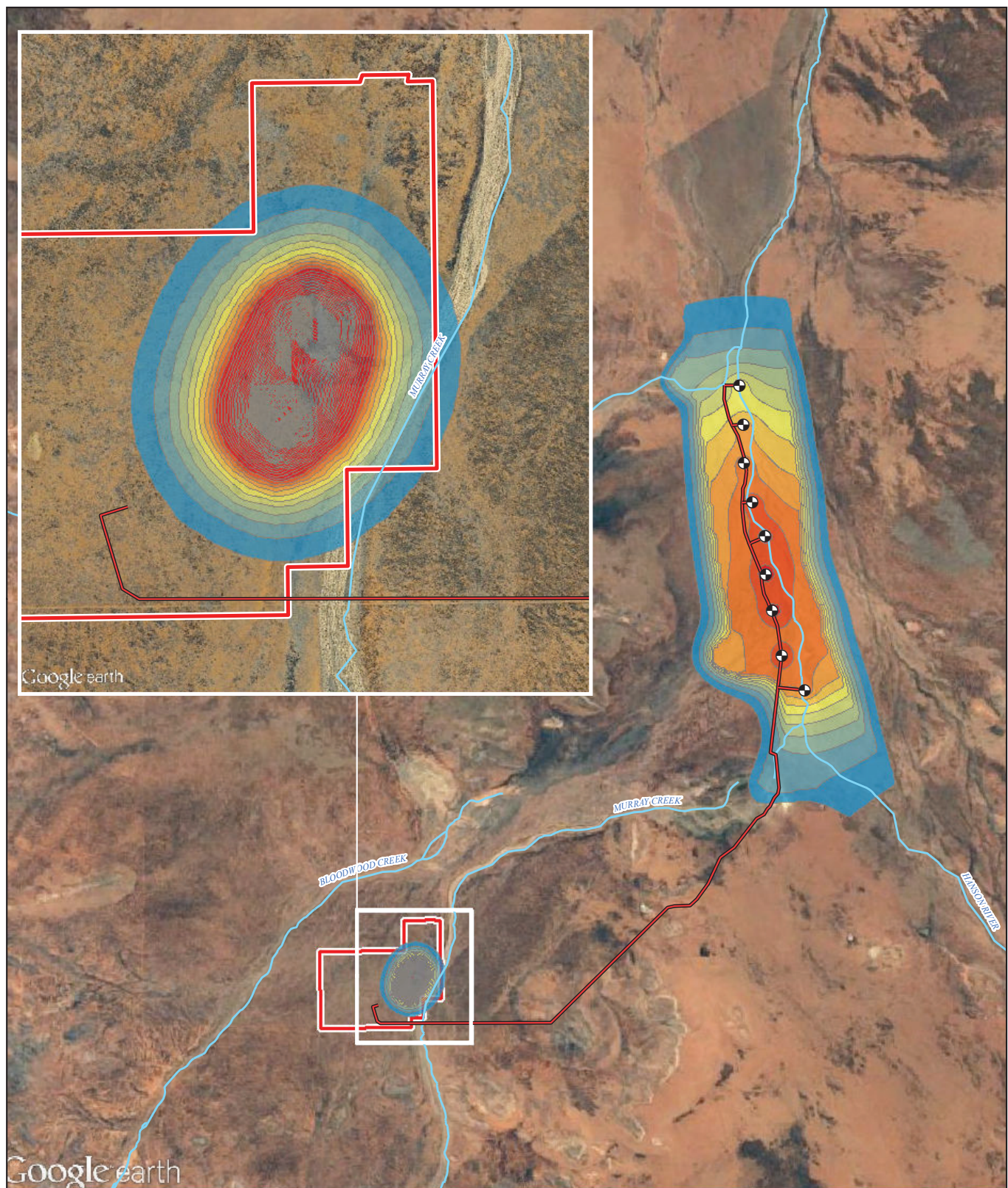
Appendix A – Figures

Figure 1 17 year predicted maximum drawdown

Figure 2 100 year predicted maximum drawdown

Figure 3 17 year predicted maximum drawdown and GDEs

Figure 4 100 year predicted maximum drawdown and GDEs



LEGEND

	Bore Location (Indicative)		Major Watercourse	Maximum Drawdown (m)		3		6		9		
	Borefield Pipeline		Mount Peake Mining Area			1		4		7		10
						2		5		8		>11

Paper Size A4
0 2 4 6 8 10
Kilometres
Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 53



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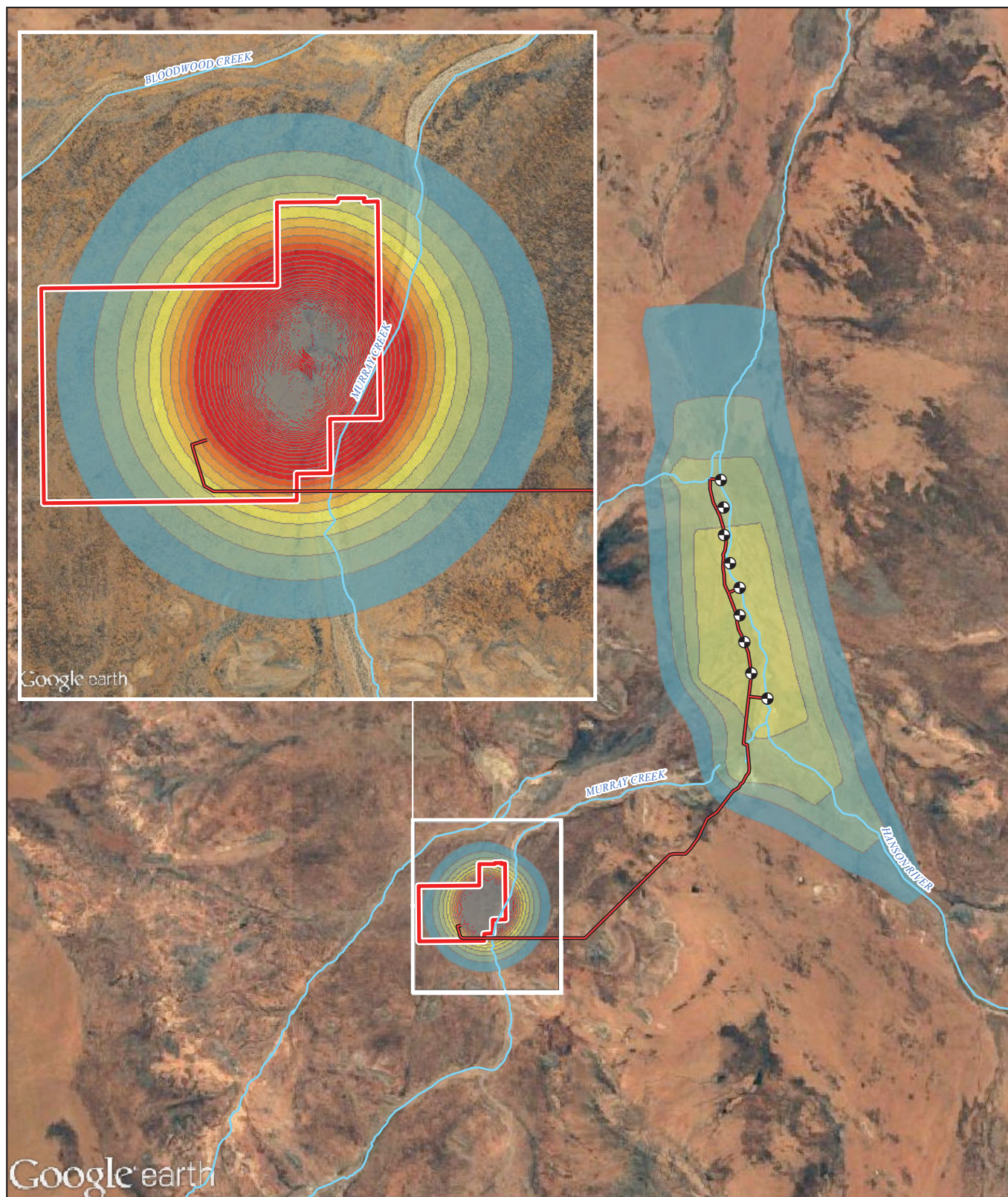
17 Year Predicted Maximum Drawdown

Figure 1

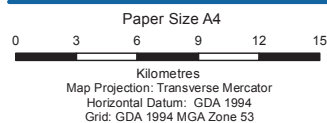
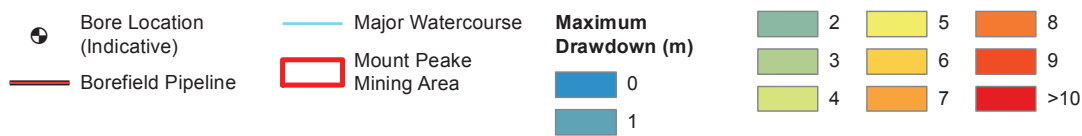
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LEGEND

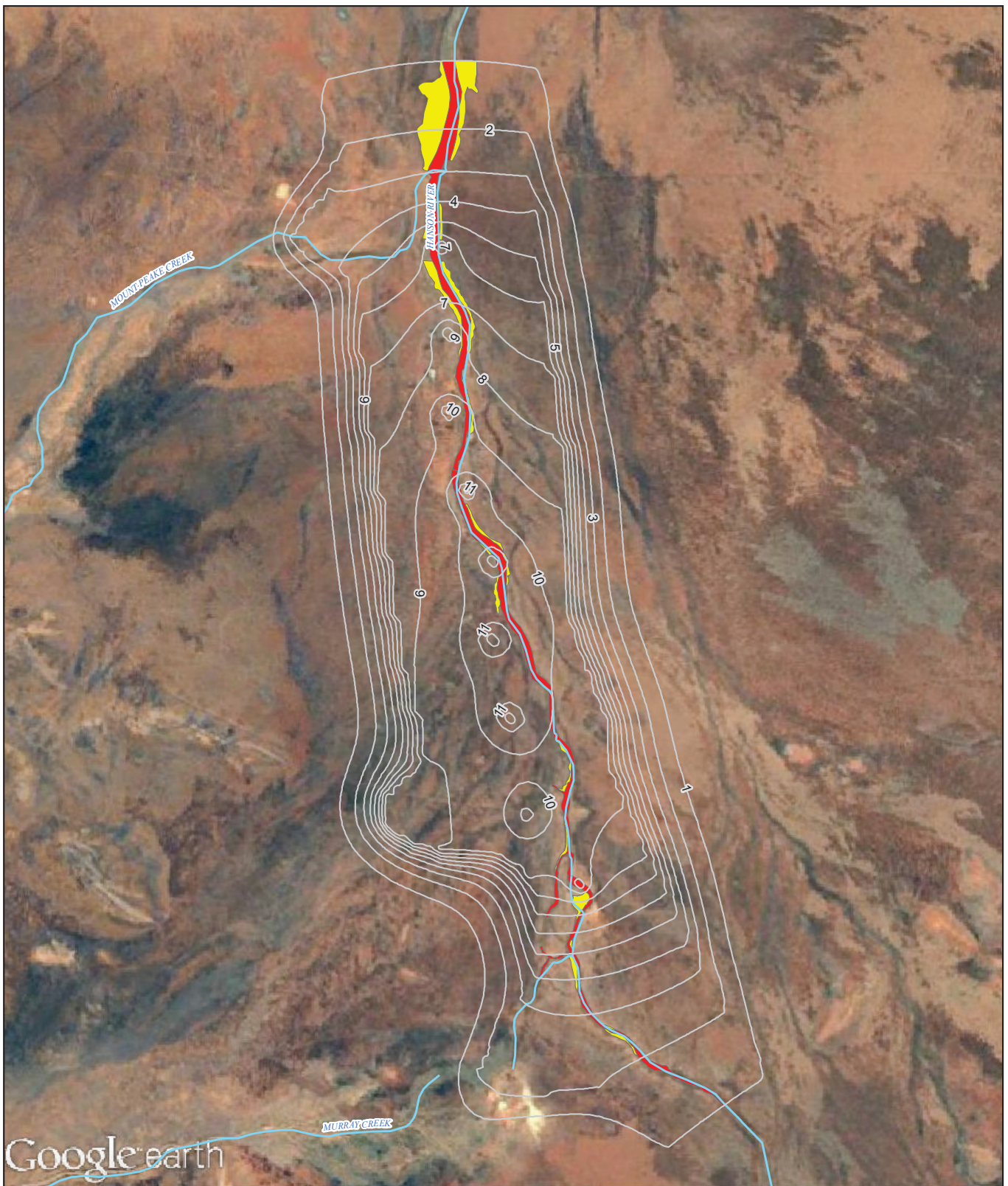


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100 Year Predicted Maximum Drawdown

Figure 2



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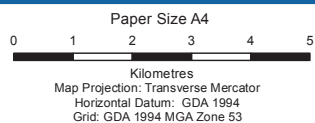
— Major Watercourse

— Maximum Drawdown Contour (1m)

Riparian Vegetation

■ 3 Riparian woodland along watercourses and drainage channels

■ 4 Low Corymbia open woodland on loamy alluvial plains



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17 Year Predicted Maximum Drawdown
and GDEs

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Figure 3



LEGEND

- | | |
|---|--|
|  Major Watercourse | Riparian Vegetation |
|  Maximum Drawdown Contour (1m) |  3 Riparian woodland along watercourses and drainage channels |
| |  4 Low Corymbia open woodland on loamy alluvial plains |

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