pitt&sherry

Notice of Intent

Savage River Mine:
North Pit Underground Operations

Prepared for

Grange Resources (Tasmania) Pty Ltd

Client representative

Tony Ferguson

Date

2 March 2020

Rev 03

Table of Contents

List of figures

Appendices

Appendix A – Natural Values Assessment

Appendix B – Mine Water Management

Prepared by — David Lenel		**Date —** 2 March 2020
Reviewed by — Leigh Knight		**Date —** 2 March 2020
Authorised by — David Lenel		**Date —** 2 March 2020

Revision History

Rev No.	Description	Prepared by	Reviewed by	Authorised by	Date
00	Final for client review	D Lenel	L Knight	D Lenel	06/12/2019
01	Revised for EPA submission	D Lenel	L Knight	D Lenel	13/02/2020
02	Revised for EPA submission	D Lenel	L Knight	D Lenel	02/03/2020
03	Revised for EPA submission	D Lenel	L Knight	D Lenel	02/03/2020

1. The name and contact details of the person lodging the application.

Applicant contact: Tony Ferguson
A: Grange Resources (Tasmania) Ltd (Grange), 34A Alexander St, Burnie, TAS 7320
P: 03 6430 0222
E: Tony.Ferguson@grangeresources.com.au

Consultant contact: David Lenel
A: Level 1, 199 Macquarie Street, Hobart, TAS 7000
P: 0419 249 748
E: dlenel@pittsh.com.au

2. The name of the proposed project and its location.

Project title: Savage River Mine: North Pit Underground Operations

Project location: Savage River Mine is located in north-west Tasmania (latitude 41°29’25”S, longitude 145°12’03”E), 45 km west of the Murchison Highway (figure 3). The nearest localities are Corinna 24 km to the south-west and Waratah 38 km to the north-east. The general location is shown in Figure 1 below.

Figure 1: Savage River Mine Location

3. Background of the project proponent, including details of the proponent's experience and financial capacity to undertake the project and his, her or its contact details.

Grange Resources (Tasmania) Pty Ltd (Grange) owns and operates an integrated iron ore mining and pellet production business located in the northwest region of Tasmania. The company is Australia's oldest and most experienced magnetite producer, and a proven and reliable commercial producer of magnetite pellets in Australia combining both mining and pellet production expertise.

Open cut magnetite mining has been undertaken at the Savage River Mine site since 1967. This was initially operated by Savage River Mines (SRM) which, between 1990 and 1996, was owned and operated by Pickands Mather & Co. International (PMI) and Cleveland Cliffs. In April 1996, all mining ceased except for disestablishment and rehabilitation. Goldamere Pty Ltd, trading as Australian Bulk Minerals (ABM) and later to become Grange Resources (Tasmania) Pty Ltd, recommenced mining in 1997 with cutbacks to South Lens, North Pit, Centre Pit North and Centre Pit South, and a new pit at South Deposit commencing in 2001.

The Savage River ore body strikes north-south. At the bottom of the life-of-mine North Pit (floor at RL -235m) the orebody is approximately 1,200 m long and 140 m wide but open pit mining only extracts along approximately 500 m of the length.

The Savage River magnetite iron ore mine, 100 km southwest of the city of Burnie, is a long-life mining asset set to continue operation to beyond 2034. At Port Latta, 70 kms northwest of Burnie, is Grange Resources' wholly owned pellet plant and port facility producing approximately two million tonnes of premium quality iron ore pellets annually with plans to increase annual production in the coming years to 2.7 million tonnes. Grange holds long term supply contracts for one million tonnes of its annual production and offers the balance of its production to market via a spot sales tendering/contracting process. All production is shipped to major steel producers in Australia and internationally.

Grange can be contacted through Tony Ferguson (contact details are in section 1 above).

4. A description of the proposed project including its key physical components.

The proposed underground operations will proceed in two phases; first, a trial mine will be developed using Sub-Level Caving (SLC) mining methods. If the data gained through the trial mine is favourable, the second phase would be to pursue block caving. An exploration decline is currently being developed under and to the East of North Pit (approved under EPN No. 10006/2). Drilling will be undertaken from key locations along the decline to define the underground resource and optimize the mining method. Grange ultimately plan to develop an underground resource through block cave mining. The proposed mining operations would operate 24 hours per day, 365 days per year.

4.1 Phase 1 - Underground Trial Mine

The purpose of the trial mine is to provide valuable information to optimise the design of the block cave. The trial mine will enable in-situ examination of ground conditions and bulk sampling of the ore and waste to generate data for geotechnical studies and resource definition and scheduling of the block cave. The trial mine will be initiated with a resource definition drilling campaign. The trial mine will then be developed through one or more progressively deeper levels of multiple parallel drives into the orebody beginning from the northern end of the exploration decline. This in generally known as Sub-Level Caving. Once the drives have been excavated and reinforced, a series of blast hole fans will be drilled vertically or near vertically from the drives and into the overlying rock. Material will then be produced from each of the drives by blasting out cuts of the overlying rock and excavating the resulting broken and caved ore.

In summary, the following aspects of Phase 1 – Trial Mine (SLC) will be analysed to optimise the design for Phase 2 – Block Cave.

- Gain early understanding of rock mass behaviour, critical for the block cave design
- Stability of workings through Eastern Contact Fault and ore body
- Interaction between cave and faults
- Brow wear, stability of brow and pillars
- Risk assess potential challenges associated with drill and blast in poor ground
- Calibrate recovery models associated with fragmentation and recovery
- Optimise methods of ore handling, i.e. fines, mud, water, inrush potential etc.; and
- Mine dewatering –understand water inflow and dewatering requirements.

4.2 Phase 2 - Block Cave

If the information gained through the trial mine is favourable, the mine will be further developed as a block caving operation. A block cave is initiated by undercutting a large section of rock. The rock section collapses under its own weight into the undercut, creating an underground cave filled with rubble. The rubble then flows through a series of preconstructed funnels and tunnels underneath the cave before it is collected by loaders, potentially crushed (for oversize material) and transported to the surface. As the broken rock is removed from the cave, the support the broken rock provided to the top of the cave is also removed. Consequently, the cave progressively collapses upwards as the rock is removed and eventually reaches the surface. The block cave design proposed for Savage River mine will target a significant proportion of the ore body and could increase mine life and reduce operating cost, securing a long-life operation.

4.3 Mining Waste

The two main waste streams resulting from mining operations are tailings and waste rock. Grange has undertaken a long-term mine planning exercise based on known resources and exploration drilling. Regardless of whether this proposal is approved, the mine production rate is not expected to vary. The following information has been ascertained:

Tailings

Grange's forecast tailings production, which is based on current operations and projected open pit mining only, equates to approximately 61 Mt between 2020 and 2040. In the event this proposal is approved, and the SLC and Block Cave are developed, it is anticipated that approximately 44 Mt of tailings will be produced within the same period. This volume can be accommodated within the operation's current and projected tailings capacity schedule.

Waste Rock

Current projections of waste rock production from the mining of Center Pit and North Pit equate to approximately 358 million BCM between 2020 and 2038. In the event this proposal is approved, waste rock production is expected to continue at approximately the current rate throughout Phase 1 – Trial mine (SLC). However, it is anticipated that this rate will significantly decline upon commencement of Phase 2 – Block Cave. The site's existing waste rock storage facilities are also expected to provide sufficient storage capacity.

5. An outline of the proposed location of the project and a general site location map.

The main entry into the Phase 1 – Trial Mine (SLC) will be developed from the existing portal used for the Exploration Decline at the south-eastern extent of North Pit shown in Figure 2 and Figure 3. Phase 2 – Block Cave will also use the existing Exploration Decline portal. Figure 4 shows the conceptual mine design for both Phase 1, shown in green, and Phase 2 shown in red. The ventilation shafts for both phases are currently shown to daylight from the upper benches of the Eastern side of North Pit.

Figure 2: North Pit looking north, portal to south-east

It should be noted that the existing exploration decline was approved (EPN 10006/1) on 26 November 2018, to extend to a distance of 1.3 km from the portal. An application to extend this exploration decline was submitted to the EPA on 16 December 2019, the EPA responding on 10 January 2020 by issuing EPN 10006/2. This permitted Grange to extend the decline by an additional a) 500 m to the north to allow the northern vent rise and exploration rill targets, and b) 1,700 m to the south to reach the southern and block cave lift 2 exploration targets. The proposal for activities associated with the North Pit Underground Mine will commence from the furthest distance achieved under approval from the Director, EPA, this being a lateral distance of 3,000 m from the decline, with the 500 m extension to the north.

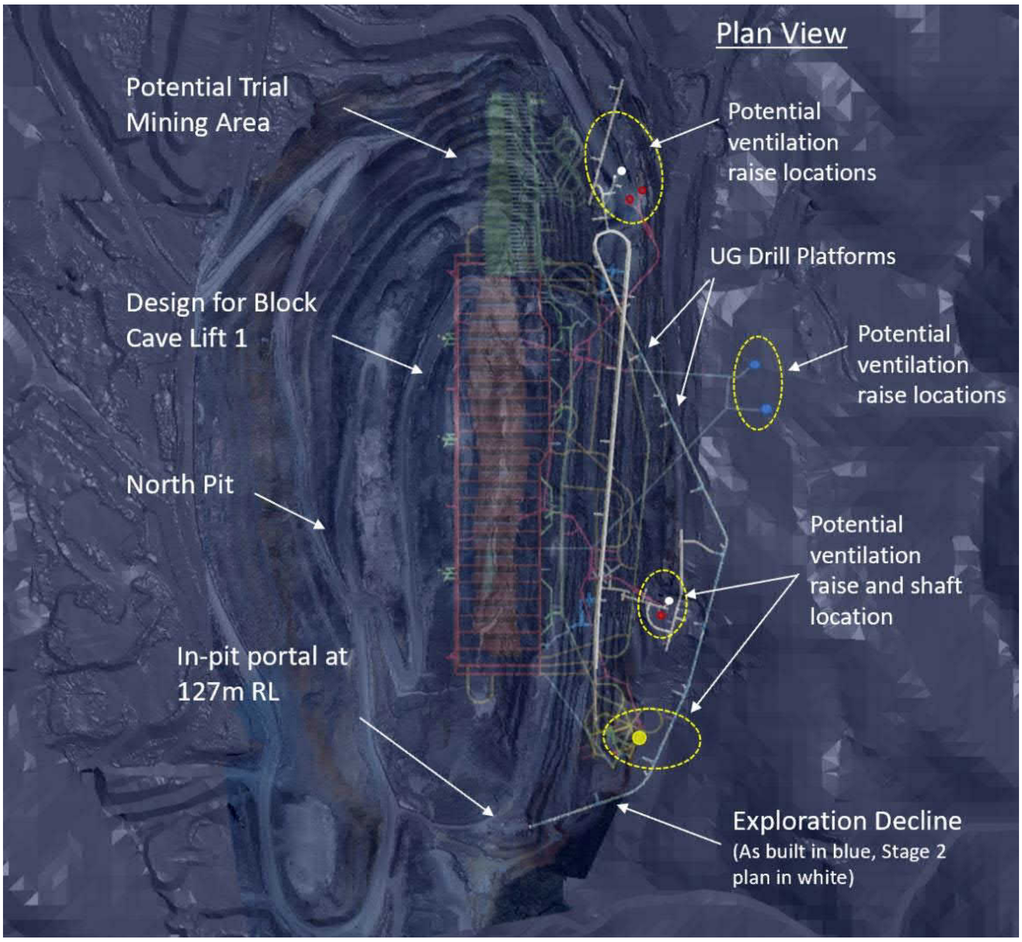

Figure 3: Plan view of North Pit, decline and location and access to Stages 1 and 2

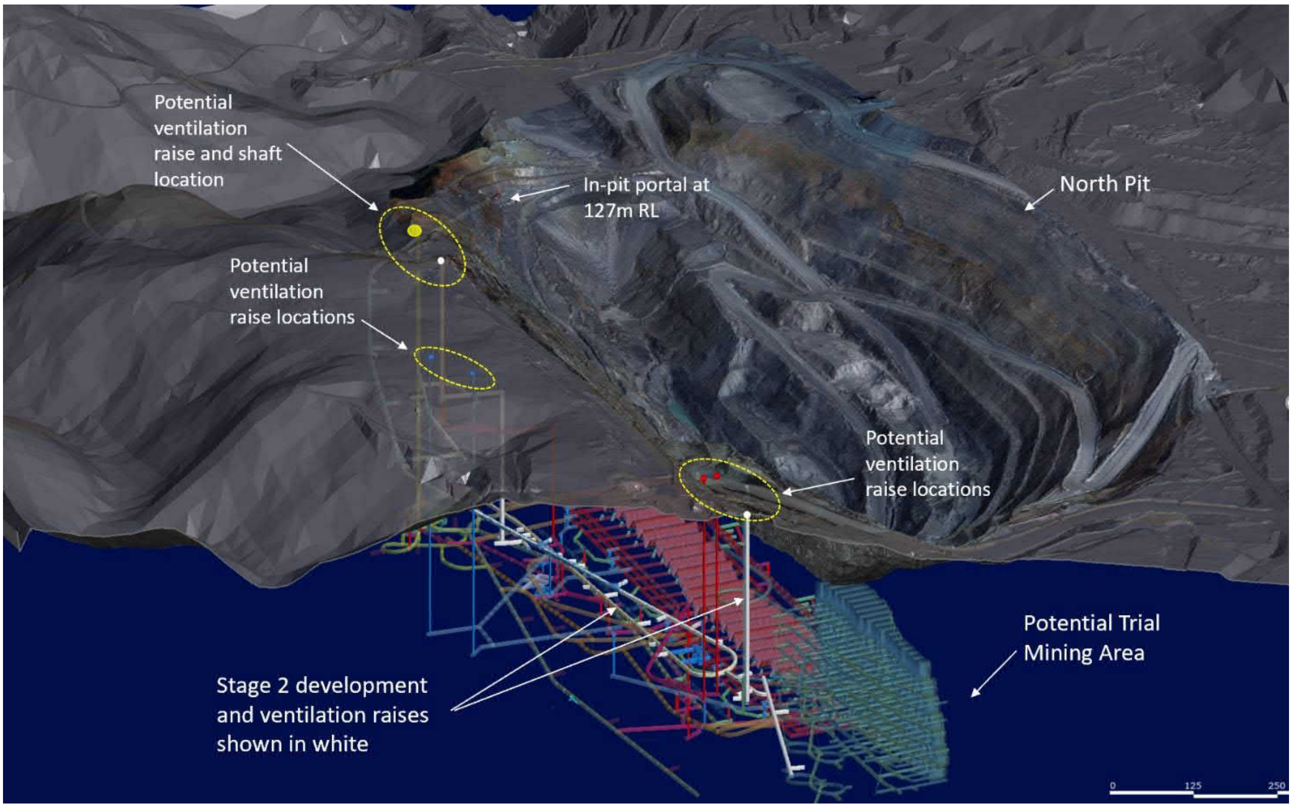

Figure 4: North Pit (looking south) undercut with Stage 1 (green) and Stage 2 (white) of the exploration decline

6. An outline of the stakeholder consultation process undertaken or proposed to be undertaken, including the consultation method, stakeholders consulted or to be consulted and the issues raised or to be raised.

Grange understands the importance of stakeholder consultation. Through the company's Social Responsibility Policy, Grange is committed to consulting the community on its concerns, aspirations and values regarding the development, operational and closure aspects of mineral projects, recognising that there are links between economic, social and cultural issues.[1]

It is proposed to consult with the following stakeholder groups through the EPA approvals process:

- Community members and interest groups
- Adjoining landowners
- Local government
- State government, agencies and NGOs; and
- Federal government, for any Commonwealth-related issues, that may arise during the project.

7. A general description of the physical environment that may be affected by the project.

The Savage River Mine is accessed by sealed road that branches off the main north-south Link Road from Burnie to Rosebery. Savage River Mine is in North West Tasmania at an elevation of 100 – 350 m. The terrain is rugged and mountainous, and covered with dense rain forest. The mine and concentrating plant are both in the Savage River valley, with the Savage River flowing through the mine site and ultimately discharging into the Pieman River, which then flows westwards to the coast. The climate of the area is characterised by cool temperatures, and high and consistent annual rainfall. The average annual rainfall at Savage River is 1,953.9 mm.

The proposed underground operations are located on the eastern edge of the North Pit. The area is bounded in the west by North Pit and by Armstrong Creek in the east. The site is very steep (~30°), west facing, and ranges from 130 to 340 m above sea level. Ventilation shafts associated with the development will be exposed in this area requiring only limited vegetation clearing in a number of area of approximately 50 m x 50 m (0.25 ha). While the precise location of the vent shafts is to be advised, most of the ventilation shafts will be situated within previously cleared areas on benches within the pit, or currently accessible areas to the east of North Pit.

[1] The Social Responsibility Policy can be viewed here: SR Policy.

8. The key environmental, health, economic and social issues identified for the project to date.

8.1 Environmental issues

Ecology

Grange is committed to environmental sustainability through its Environmental and Social Responsibility Policy - June 2016[2] and its Sustainable Development Policy[3]. With this in mind, the Natural Values Assessment at Appendix A of this report was prepared in June 2018 in support of the Exploration Decline application. While the potential impact areas for this proposal differ slightly form the June 2018 survey, it can be expected that any ecological surveys (including pre-clearance and targeted surveys) will be undertaken. The summary of the EPBC Protected Matters Search Tool and Natural Values Atlas Search Tool referenced in Appendix A remains current.

Targeted surveys will be required to determine the extent that threatened species utilise the site and to confirm the likely impacts. The proposed area of disturbance is very limited due to the siting of both Phase 1 and Phase 2, both being directly underneath the existing North Pit and will only be required for any surface infrastructure such as ventilation shafts which are unable to be located within the existing footprint. Therefore, potential impacts to natural values will be very limited.

The project site falls within the climatic zone favourable for *Phytophthora cinnamomi*. However, no evidence of infection was observed during June 2018 site survey. Given this, efforts to mitigate the impacts of the development should focus on reducing the risk of introduction and spread of plant pathogens, and declared and environmental weeds, during and after works, by implementing appropriate weed and hygiene management plans. Further, reducing the clearance and impact on riparian vegetation on the Savage River should be considered.

Based on the June 2018 survey area, and its proximity to the proposed potential impact areas, it is not expected to trigger the Tasmanian Nature Conservation Act 2002.

Water management

AQ2 was commissioned by Grange in August 2019 to investigate and prepare a report pertaining to predicted water flows and potential impacts to the hydrodynamic activity during the proposed block cave project. The report summarised the Broderick Creek Flow Through System (BCFT) as follows:

- The BCFT was developed in 1998 to convey stream flow from the Upper Broderick Creek beneath the western waste dump to a discharge point on Lower Broderick Creek close to its confluence with the Savage River. In summary, the BCFT comprises:
    - Selectively placed, high permeability coarse fill along the base of the Broderick Creek flow channel. The fill (referred to as Type A fill – alkaline rock sourced from the magnesite schists in the West Wall Block aquifer zone) was placed directly onto weathered basement within the creek valley
    - The Type A fill (essentially an alkaline high flow medium) is up to 30m thick along the deepest part of the creek valley. Clay material was placed along the top and sides of the Type A fill and then covered by various other types of waste rock; and
    - The BCFT conveys flows of up to 1,800 L/s in winter, depending on rainfall patterns and the water level upstream of the BCFT in Upper Broderick Creek. In summer, flows decline to around 20 L/s, depending on the dry season water level in Upper Broderick Creek.

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[2] The Environmental and Social Responsibility Policy - June 2016 can be viewed here: ESR Policy.
[3] The Sustainable Development Policy can be viewed here: SD Policy.

The AQ2 report has been attached as Appendix B, with the findings of the report summarised below:

- Rainfall runoff to the pit (and then underground) will be no more than currently experienced
- Runoff to the pit (and underground) will be returned to Savage River via South Lens Pit and so runoff interception by mining will have little to no impact on regional river flows
- Groundwater inflows from surrounding aquifers will be sustained by leakage from the aquifer boundaries (Savage River, Broderick Creek, Upper Broderick Creek and Armstrong Creek). Groundwater inflows will also be returned to the Savage River via South Lens Pit and so groundwater inflows will have little to no long-term impact on regional river flows
- Drawdowns in groundwater levels as a result of mine inflows will be constrained to the immediate mine area and are not likely to be measurable beyond the aquifer recharge boundaries (Savage River, Broderick Creek, Upper Broderick Creek and Armstrong Creek)
- Overflows from the Broderick Creek Flow Through System to the pit (and underground) will also be returned to Savage River via South Lens Pit and so runoff interception by mining will have little to no impact on regional river flows
- Any water pumped from the Broderick Creek Diversion Scheme (if required) will be returned directly to the Savage River at the existing Broderick Creek Flow Through System discharge point and will have little to no impact on regional river flows
- Discharge from the Broderick Creek Diversion Scheme will have the same water quality as the Upper Broderick Creek. This will be somewhat different to current discharge from the Broderick Creek Flow Through System which is slightly alkaline due to passage through the magnesite material that makes up the Type A fill (main flow pathway). As such, the pH of overall discharge from Broderick Creek to the Savage River will be closer to neutral. This is not considered to be an impact, but merely a change; and
- Overall, the potential impacts of the mine water management scheme are considered to be negligible.

8.2 Health Issues

Onsite operation activities will be managed in accordance with industry standards and Grange's policies for Occupational Health and Safety[4] and Risk Management[5]. Further, the company has an Audit and Risk Committee Charter to help ensure Grange maintains policies that ensure compliance with laws and safety, health and environment matters[6]. As such, onsite risk to human health from the proposed mining activities will be satisfactorily managed. With regard to potential offsite health impacts, there are no residences within 5km of the site. Given this, the proposed mining activities are unlikely to impact human health as a consequence of noise or air emissions.

8.3 Economic Issues

Expanding mining operations will enable the proponent to supply more material to clients, and provide for the efficient and timely construction and maintenance of assets. In doing so, the proposal will help sustain the economic viability of the business at this location. The expanded operations, in particular the block cave phase, will likely result in lower operating numbers.

8.4 Social issues

The nearest settlement is Savage River, approximately 4.5 km south of the development area. As the mine is in an isolated location with significant separation distances from residential development, the proposed mining activities are unlikely to result in significant adverse social impacts.

[4] Operational Health and Safety Policy: OH&S Policy.
[5] Risk Management Policy: RM Policy.
[6] Audit and Risk Charter: AR Charter.

The proposal would also enable to the mine to continue to provide for local employment opportunities and associated social benefits.

As it is not expected that a significant increase in employees would be required for the expanded mining operations, the site will not generate a significant increase in vehicular traffic to the site, or associated impacts.

9. The surveys and studies proposed or underway in relation to the key issues for the project.

The following surveys and studies have or will likely be prepared:

- Natural Values Assessment, when potential impact areas from the ventilation shafts and/or portal have been confirmed
- Desktop Heritage Assessment, when potential impact areas from the ventilation shafts and/or portal have been confirmed
- Geological mapping; and
- Conceptual decline closure design.

It is also proposed to carry out targeted surveys for the following, in the event it is considered necessary:

- Spotted-tailed quoll
- Tasmanian devil
- Grey goshawk; and
- Hydrobiid snails.

10. The proposed timetable for the project.

It is anticipated that development of Phase 1 - Trial mine (SLC) will commence in late 2020, subject to statutory approval. During its development, it is intended to continue mining the Centre Pit. The timing for the commencement of Phase 2 – Block Caving is currently scheduled for 2025, as shown in Figure 5 below.

However, several factors associated with material characteristics and water management may influence the scheduling of the transition between Phase 1 – Trial Mine (SLC) into Phase 2 – Block cave. These factors are expected to become clearer as Phase 1 develops.

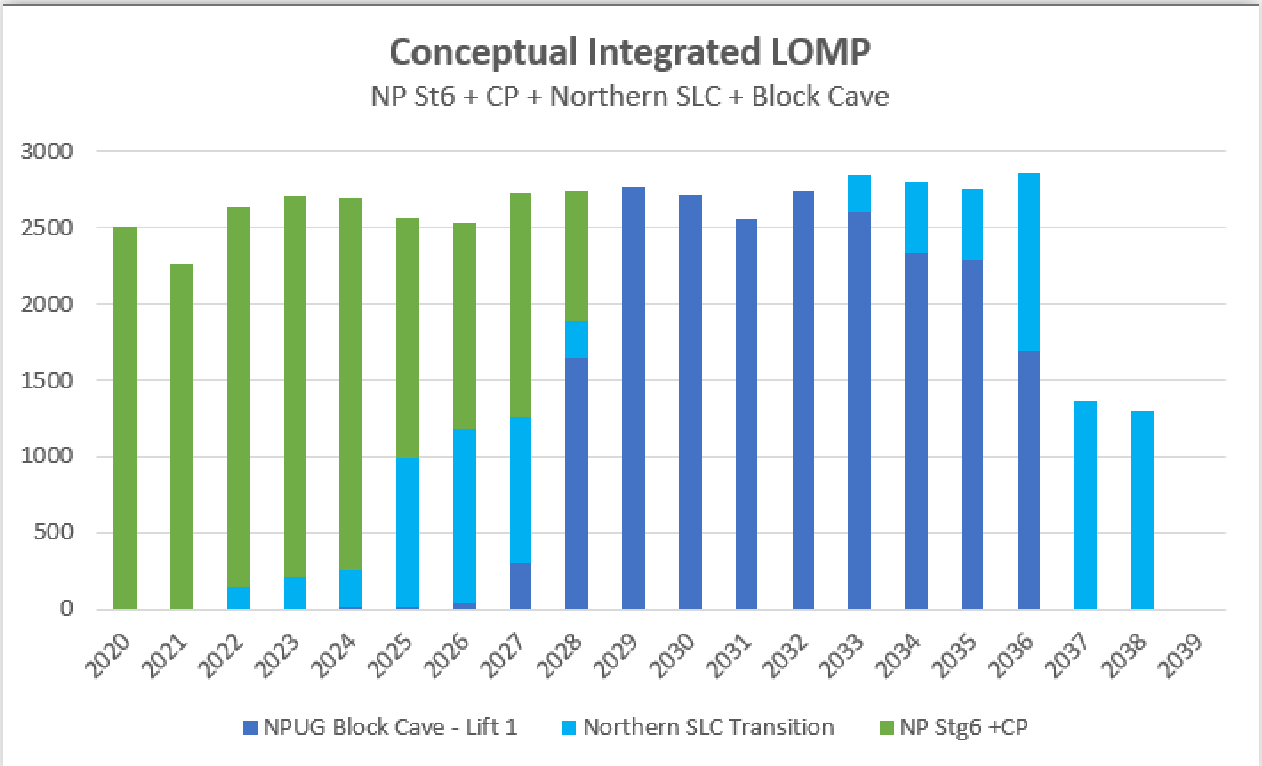


Figure 5: Preliminary ore development transition

Referring to Figure 5, NPUG = North Pit Underground, SLC = Sub Level Cave, NP = North Pit, CP = Center Pit.

11. For the purposes of section 27B(2)(k) of the EMPC Act, the Board has determined that a NoI is to contain the following additional details:

a) Whether the project requires or is likely to require approval under the Environment Protection and Biodiversity Conservation Act 1999 (which will be determined by the project's potential to impact upon matters of national environmental significance or upon Commonwealth land).

Species listed under the EPBC Act may be present in the proposed development area and potential habitat is present. Spotted-tailed quolls and Tasmanian devils are likely to forage in the area. However, the extent of the development area is less than 10 ha, which is considerably less than the suggested area for a single quoll (300 ha) or devil (800ha to 2,000 ha). While it may be reasonably assumed that animal density can exceed this in optimum habitat, the impact to these species by the development is likely to be negligible. Pre-clearance den surveys for the quoll and devil can provide a baseline to implement appropriate avoidance measures. Taking all these matters into consideration, the proposed mining operations are unlikely to have significant impacts to species listed under the EPBC Act.

b) Whether the proponent has or intends to refer the project to the Commonwealth Government for a determination on whether approval under the Environment Protection and Biodiversity Conservation Act 1999 is required.

Given that the proposed mining operations are unlikely to result in significant impacts to species listed under the EPBC Act, there is no requirement or intention to refer the project to the Commonwealth Government.

12. For the purposes of section 27B(2)(k) of the EMPC Act, the Board has determined that a NoI is to contain the following additional details.

12.1 The status of the proposal under the Land Use Planning and Approvals Act 1993 (the LUPA Act). This must include:

a. Whether or not the relevant Council will require a LUPA Act permit application.

Waratah-Wynyard Council will require a new Development Application for this activity. The site has been in operation since 1967 with planning permits renewed in 1996-1997 and is considered to be an existing use. However, the provisions which allow existing uses to continue operating without approval do not extend to include substantial intensification of the use. Extractive Industry is a Permitted use in the Rural Resource zone where not relying on Performance Criteria. A development application will be required for the proposed expansion.

b. Whether a single permit application or multiple applications will be required.

Single application.

c. The division of the LUPA Act under which the application will be made.

The permit application will be made under Part 4 – Enforcement of Planning Control Division 2 – Development control

d. Zoning of the proposal site(s), and whether or not rezoning will be required.

The land is in the Rural Resource Zone. Extractive Industry is a Permitted use in the Rural Resource zone.

12.2 If the proposal is for intensification or alteration of an existing activity, the status of the existing activity under the LUPA Act; and

The mine has been in operation since 1967, ceasing extraction for one year only, between 1996 and 1997, and benefits from the existing use rights provisions under Section 12 (1) of the LUPA Act. This section allows existing uses to continue without the need for planning approval. However, Section 12 (7) provides that Subsection (1) does not apply to, or in relation to, a use, of any land, building or work, that is substantially intensified.

a. If the proposal is for intensification or alteration of an existing activity, whether or not the council regards the proposal as a substantial intensification for the purposes of subsection 12(7) of the LUPA Act.

Waratah-Wynyard Council will require a new Development Application for this activity.

13. In the event that the proposal has a reasonable likelihood of requiring approval from the Commonwealth Government under the Environment Protection and Biodiversity Conservation Act 1999 (Cth), a statement is to be provided as to whether or not the proponent elects for the proposal to be assessed pursuant to the Bilateral Agreement made under section 45 of the Environment Protection and Biodiversity Conservation Act 1999 (Cth) between Tasmania and the Australian Government (dated 22 October 2014).

Not applicable.

Natural Values Assessment

Appendix A

northbarker
ECOSYSTEM SERVICES

Savage River Mine - North Pit Exploration Decline
Savage River

Natural Values Assessment

28th June 2018

For pitt&sherry OBO Grange Resources
GRA005

Andrew North anorth@northbarker.com.au **Philip Barker** pbarker@northbarker.com.au
163 Campbell Street Hobart TAS 7000 Telephone 03. 6231 9788 Facsimile 03. 6231 9877

Contributors:

Field Assessment: Grant Daniels and Richard White – date of survey: 1st and 2nd May 2018

Report: Richard White

Mapping: Richard White

Review: Andrew North

Photos: Richard White

Summary

Natural Values

Impact on threatened vegetation	Nil
Impact on threatened flora	Nil
Impact on threatened fauna	Negligible impact to threatened species that may use the area. Potential impact on *Beddomeia* spp., and Grey Goshawk can only be quantified through targeted surveys
Environment Protection and Biodiversity Conservation Act 1999	No Matters of National Environmental Significance occur in the study areas
Tasmanian Threatened Species Protection Act 1995 (TSPA)	*Beddomeia* spp., and grey goshawk may be impacted if confirmed from the area
Weed Management Act 1999	No declared weeds in the study area but one declared weed occurs just outside the northern study area
Tasmanian Nature Conservation Act 2002 (NCA)	No part of the development is likely to trigger this act

Table of Contents

1 Introduction

1.1 Background

Grange Resources (Grange) are planning to undertake underground mining activities at North Pit at the Savage River Mine in Western Tasmania. The EPA has suggested that Grange notify the Waratah-Wynyard Council (Council) of the proposed activities. To this end, pitt&sherry have been engaged to prepare a 'Project Description' for submission to Council. Part of this submission is an assessment of the potential impact on the natural values in the impact areas; North Barker Ecosystem Services have been engaged by pitt&sherry to provide this information.

The natural values in the area will be impacted by the clearance of vegetation for aboveground works associated with the underground mining activities. These works involve: 1) the emergence of a vent shaft (50 x 50 m) from the underground mine to the surface, and 2) a road and entry point to the underground mine.

This report documents the results and recommendations of our findings in accordance with the *Guidelines for Natural Values Surveys* by the Tasmanian Department of Primary Industries, Parks, Water and Environment (DPIPWE)[1].

1.2 Study area

Savage River is located within the Tasmanian 'West' bioregion[2], approximately 100 km from Burnie, and within the municipality of Waratah-Wynyard. The proposed development will have two impact areas (Figure 1); these were conceptual at the time of the publication of this report.

1. <u>Northern study area</u>: this site is east of north pit, and bounded in the west by pipeline road and by Armstrong Creek in the east. The site is very steep (~30°), east facing, and ranges from 170 to 340 m above sea level. A vent shaft associated with the development will be exposed in this area requiring vegetation clearing in an area of approximately 50 m x 50 m (0.25 ha). While the precise location of the vent shaft is to be advised, it will be within the northern study area.
2. <u>Southern study area</u>: this site is immediately east of the southern end of north pit. It is bounded in the south by the Savage River. The slope is south-facing, steep in places (~20°), and ranges from 110 to 180 m above sea level. In this area vegetation will be cleared for the development of a road and access the underground mine (Figure 1).

Savage River receives a mean of 1,957 mm of rain per annum with a mean of 186 rain days per year (days with > 1 mm). The mean monthly maximum varies from 9.4 °C (July) to 20.1 °C (February) with the mean minimum temperature varying from 3.3 °C to 9.9 °C in equivalent months[3].

The site occurs within the West Coast mineral belt, in the Bowry Formation of the Proterozoic Arthur Metamorphic Complex. This complex is 10 km wide. In the Savage River area it is dominated by Whyte schist consisting mainly of quartz-mica rocks, including thin micaceous quartzite beds, schist and phyllite.

[1] DPIPWE 2015
[2] IBRA 5 (Peters & Thackway 1998)
[3] Australian Bureau of Meteorology

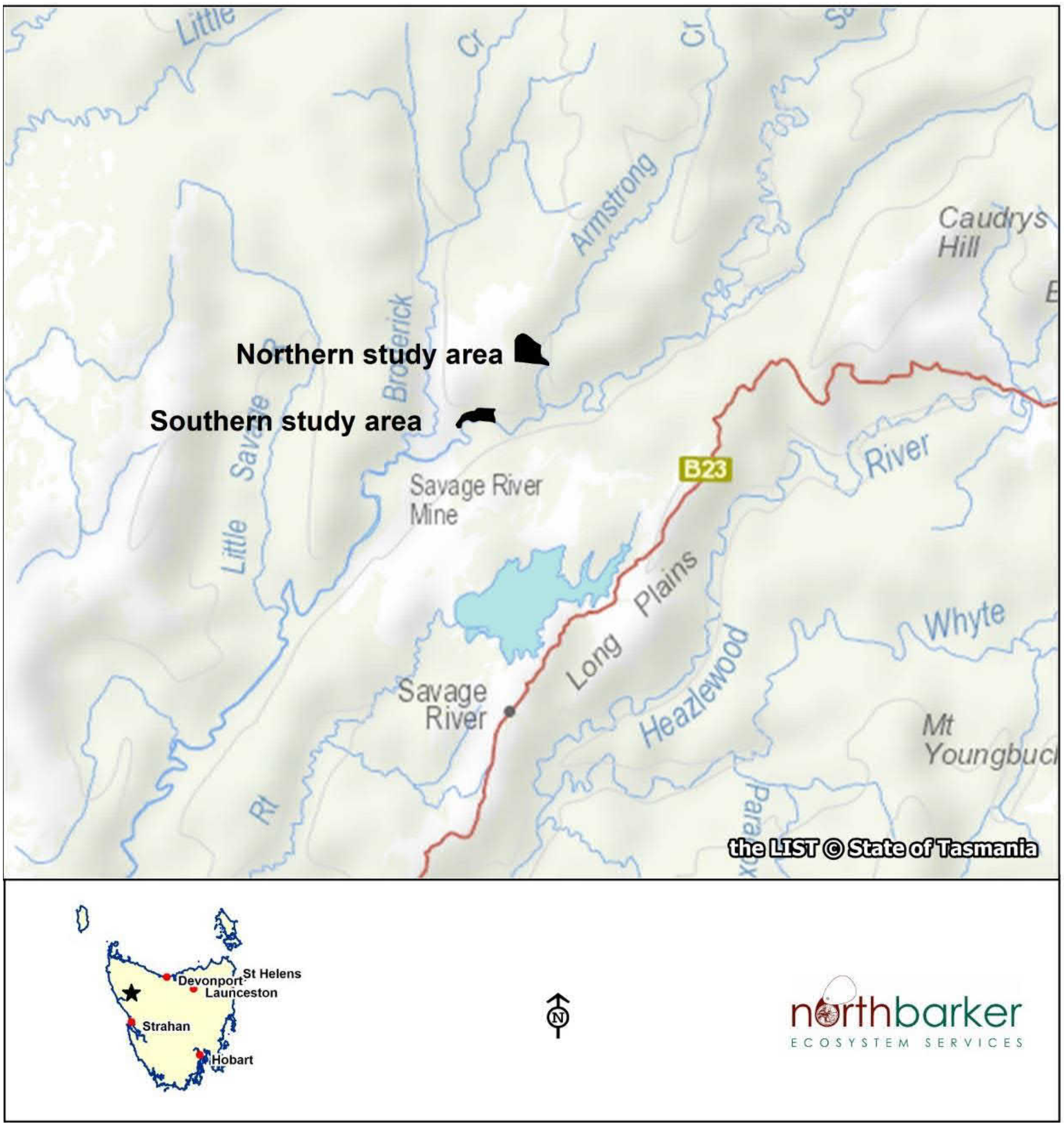


Figure 1: Location of the northern and southern study areas

2 Methods

The following sources were used for biological records for the region:

- TASVEG version 3.0 digital layer[4];
- Natural Values Atlas (NVA) - all threatened species records within 5 km of the study area and threatened fauna considered possible to occur in suitable habitat[5];
- EPBCA Matters of National Environmental Significance database - a 5 km buffer was used to search for potential values[6]; and
- Previous work by NBES, specifically flora and fauna habitat surveys of adjacent and nearby sections of the Savage River mine.

[4] Kitchener and Harris 2013

[5] Natural Values Atlas Report, May 2018

[6] Commonwealth of Australia, EPBC Protected Matters Search Tool Report, May 2018

2.1 Botanical Survey

This assessment was undertaken in accordance with the *Guidelines for Natural Values Surveys*[7]. Field work was carried out by two observers on foot on the 1st and 2nd of May 2018. Native vegetation was mapped in accordance with units defined in TASVEG 3.0[8]. Vascular plants were recorded in accordance with the current census of Tasmanian plants[9]. The mine site was mapped using a meandering area search technique[10]. Particular attention was given to habitats suitable for threatened species (under Tasmanian TSPA and/or the Commonwealth EPBCA), and to 'declared' weeds. Botanical nomenclature follows the current census of Tasmanian plants[11]. All location data were recorded with a handheld GPS.

2.2 Fauna survey

A search was made for sign (e.g. scats, tracks) and presence of potential threatened fauna concurrently with the botanical survey. A search for nests was done from the ground only. The survey was carried out in accordance with DPIPWE's 'Survey guidelines and management advice for development proposals that may impact on the Tasmanian devil (*Sarcophilus harrisii*)'. According to those guidelines the scale of the proposed development is medium (vegetation clearance is between 1 and 100 ha).

2.3 Limitations

Due to various limitations (e.g. variations in species presence and detectability), no biological survey can guarantee that all species will be recorded during a single visit. The field survey was undertaken in autumn, so seasonal and ephemeral species may have been overlooked or are seasonally absent, including spring flowering herbs and orchids. The present study area is variably steep and includes dense forest that inhibits access and limits opportunities for complete coverage. It is thus possible that the study area contains additional species and species habitats that could be recorded by repeated visits. Nevertheless, we are confident the present survey sufficiently captured community level diversity. Furthermore, given the relative homogeneity of forest communities in the region, it can be assumed that we have captured most of the species diversity. Finally, we compensate for survey limitations by considering all listed threatened species from data from the Tasmanian *Natural Values Atlas* (NVA)[12] and an EPBCA Protected Matters Report[13]. These data include records of all threatened species known to occur, or with the potential to occur, up to 5 km from the study area.

3 Results - Biological values

3.1 Vegetation

Nothofagus-Atherosperma rainforest (RMT) was the only TASVEG community recorded in the study areas (Plates 1-4). While the southern study area is floristically more diverse, there is much floristic and structural overlap between the two areas, and they will therefore be considered together. RMT in the area is best described as thamnic rainforest, with medium to tall rainforest trees, and a shrubby understorey. The canopy is 15 to 20 m in height, dominated by *Nothofagus cunninghamii* with *Eucryphia lucida*, *Atherosperma moschatum* and *Acacia melanoxylon* occasional. The shrub/small tree layer comprises a range of species, with *Anodopetalum biglandulosum* dominant in

7 DPIPWE 2015
8 Kitchener and Harris 2013
9 de Salas and Baker 2017
10 Goff *et al.* 1982
11 Tasmanian State Government 1995; Commonwealth of Australia 1999
12 Natural Values Atlas Report, May 2018
13 Commonwealth of Australia, EPBC Protected Matters Search Tool Report, May 2018

places. *Olearia argophylla*, *Nematolepis squamea, Anopterus glandulosus* and *Pimelea cinerea* occur regularly. The ground cover is sparsely vegetated with ferns including *Polystichum proliferum* and *Blechnum wattsii*. Several epiphytic fern species are also present; most common are *Grammitis billardierei*, and *Hymenophyllum rarum*.

The RMT mapping unit does not correspond to any threatened community listed under the NCA or the EPBCA.

Plate 1: Northern study area RMT rainforest

Plate 2: Northern study area understorey of RMT rainforest

Plate 3: Southern study area RMT rainforest (background) and the riverine strip (foreground)

Plate 4: Southern study area understorey of RMT rainforest

3.2 Plant species

Forty-six and sixty-two species of vascular plant were recorded in the northern and southern study areas respectively, comprising a total of seventy-eight species. A complete species list from the field survey is presented in Appendix A. No threatened flora listed under the TSPA and EPBCA, or any declared weeds listed under the Tasmanian *Weed Management Act 1999*, were recorded in the study areas. Notably, pampas grass (*Cortaderia* sp.), occurs in scattered locations at the mine site, and was found in several locations on the Pipeline Road just beyond the northern study area (Figure 2). While the occurrences of this species are outside the study area, this is a declared weed requiring management.

In previous surveys in the area NBES have recorded *Persoonia muelleri subsp. angustifolia* on the Pipeline Road, none were found during the present survey.

According to data within the Tasmanian Natural Values Atlas[14], no observations of threatened flora are known within 500 m of the site, and only four species are known within a 5 km radius. No further threatened species are considered to have potential habitat in the region according to the EPBCA Protected Matters Search Tool[15].

Each threatened flora species known from the area is presented in **Table 1** in context of the suitability of habitat within the study area, and the likelihood of occurrence. Of these species, *Persoonia muelleri subsp. angustifolia* (narrowleaf geebung) has a low potential to occur, and while there is potential habitat, it is unlikely to have been overlooked. The chances of the remaining three species occurring are very low to nil, primarily due to a lack of suitable habitat in the study areas.

Table 1: Flora species of conservation significance known within a 5 km radius of the study areas

Species	Status[16] TSPA / EPBCA	Potential to occur in both study areas	Observations and Preferred Habitat[17]
Epacris curtisiae northwest heath	Rare/ -	Very low	*Epacris curtisiae* (northwest heath) is a slender shrub restricted to peaty soils in undulating terrain in association with locally common heathlands, graminoid heaths and scrub in the northwest in altitudes below 300 m. There is no suitable habitat in the study area.
Micrantheum serpentinum western tridentbush	Rare/-	None	*Micrantheum serpentinum* is a straggly shrub in the Euphorbiaceae (spurge) family, restricted to ultramafics (Cambrian serpentinite) in Tasmania's northwest. Habitat includes low open eucalypt woodland, shrubland and heathland, generally on lateritic soils[18], as well as shaded riparian areas. Observed geology within the study area is entirely unsuitable for this species.
Persoonia muelleri subsp. angustifolia narrowleaf geebung	Rare/-	Low	This species occurs in central and western Tasmania in rainforest and dense scrub (and perhaps sub-alpine heath) in a variety of sedimentary and metamorphic substrata. It typically occurs in the ecotone between dry scrub and rainforest, particularly where high light levels occur on the ground due to a short and open canopy. It is known from between 50 to 700 m altitude[19]. This species has been recorded in a previous NBES survey approximately 5 km north of the mine on the Pipeline Road. Its occurrence there was likely a result of clearing for the road allowing light levels to allow recruitment. The field survey was undertaken during the potential time for identification, and while there is suitable

[14] Natural Values Atlas Report, May 2018
[15] EPBC Protected Matters Search Tool Report, May 2018
[16] Tasmanian State Government 1999
[17] Lazarus *et al.* 2003; Jones *et al.* 1999
[18] Threatened Species Section (2018A)
[19] Threatened Species Section (2018B)

Species	Status[16] TSPA / EPBCA	Potential to occur in both study areas	Observations and Preferred Habitat[17]
			habitat in the study area, this is a conspicuous species that is unlikely to have been overlooked.
Rhodanthe anthemoides chamomile sunray	Rare/-	None	*Rhodanthe anthemoides (*chamomile sunray) *is* perennial herb with a woody rootstock. The Tasmanian distribution of this species includes montane grasslands, heath and heathy scrub in central and north-western Tasmania[20]. There is no suitable habitat for this species in the study area.

[20] Threatened Species Section (2018C)

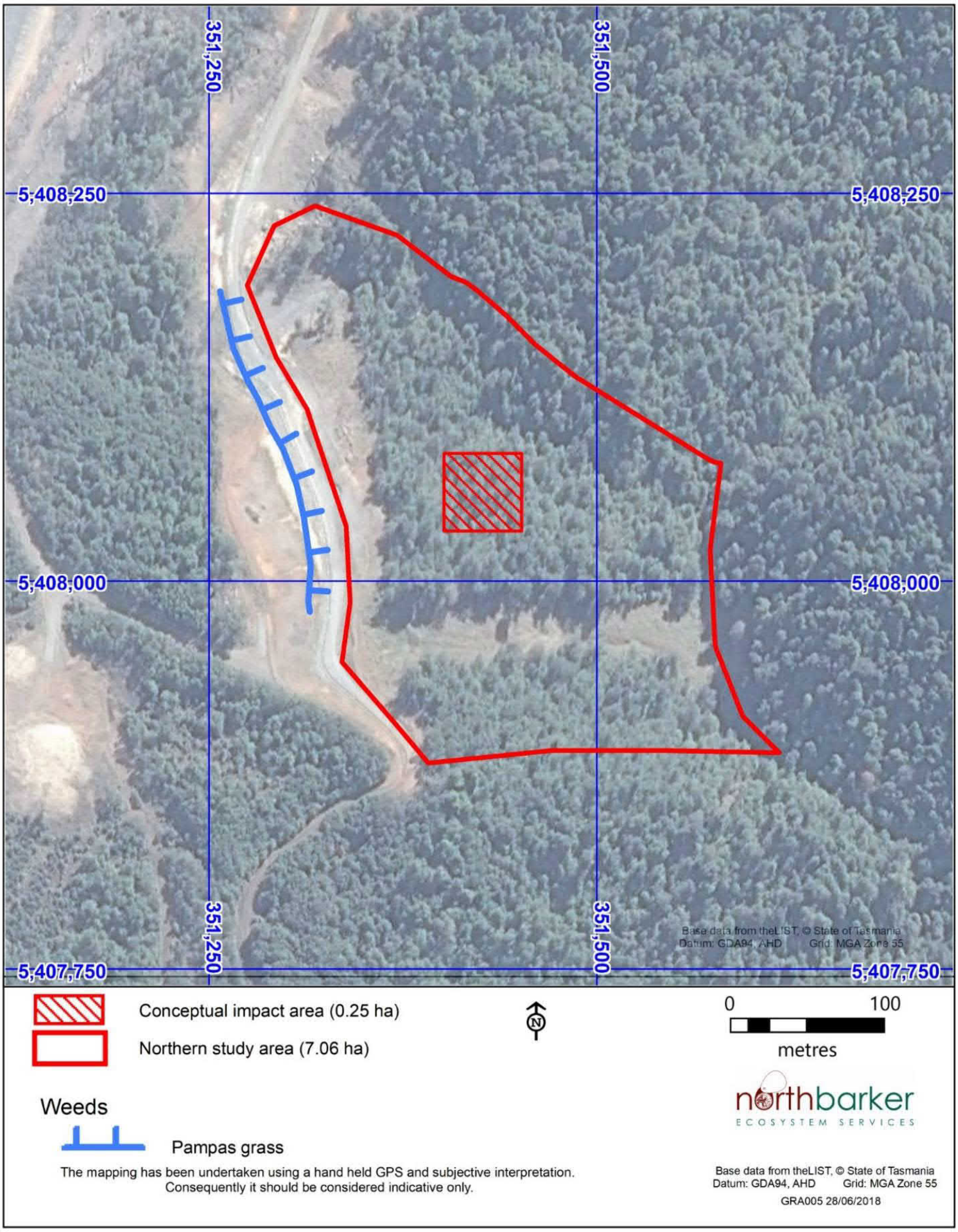


Figure 2: Northern study area with conceptual impact zone and location of pampas grass

3.3 Fauna conservation values (including habitat trees)

During our field survey, no species of listed threatened fauna were observed. However, the study areas do offer potential habitat for several species:

1. Spotted-tailed quoll (*Dasyurus maculatus ssp. maculatus*, TSPA rare and EPBCA vulnerable): rainforest in this area is considered to have a high likelihood of supporting this species.
2. Grey goshawk (*Accipiter novaehollandiae*, TSPA endangered): the southern study area is within 100 m of potential priority nesting habitat for this species (Figure 2).
3. Hydrobiid snails (*Beddomeia bowryensis,B. hullii, B. trochiformis* and *Phrantela marginata,* all TSPA rare): based on previous surveys in the area[21], and range boundaries in the Natural Values Atlas, there is potential for four species of these snails to occur in two creeks in the southern study area (Figure 2). Images and the core characteristics of each of the two creeks are presented in Table 2.
4. Tasmanian devil (*Sarcophilus harrisii*, TSPA and EPBCA endangered): While areas of suitable foraging habitat occur, no suitable denning sites were observed.

[21] North Barker Ecosystem Services report: "Savage River Mine North Pit Extension, Botanical Survey and Fauna Habitat Assessment for Grange Resources, GRA003, 11th November 2015" & North Barker Ecosystem Services report: "Savage River Mine South Deposit Tailings Storage Facility, Botanical Survey and Fauna Habitat Assessment for Caloundra Environmental obo Grange Resources, CAL005, 22nd March 2013"

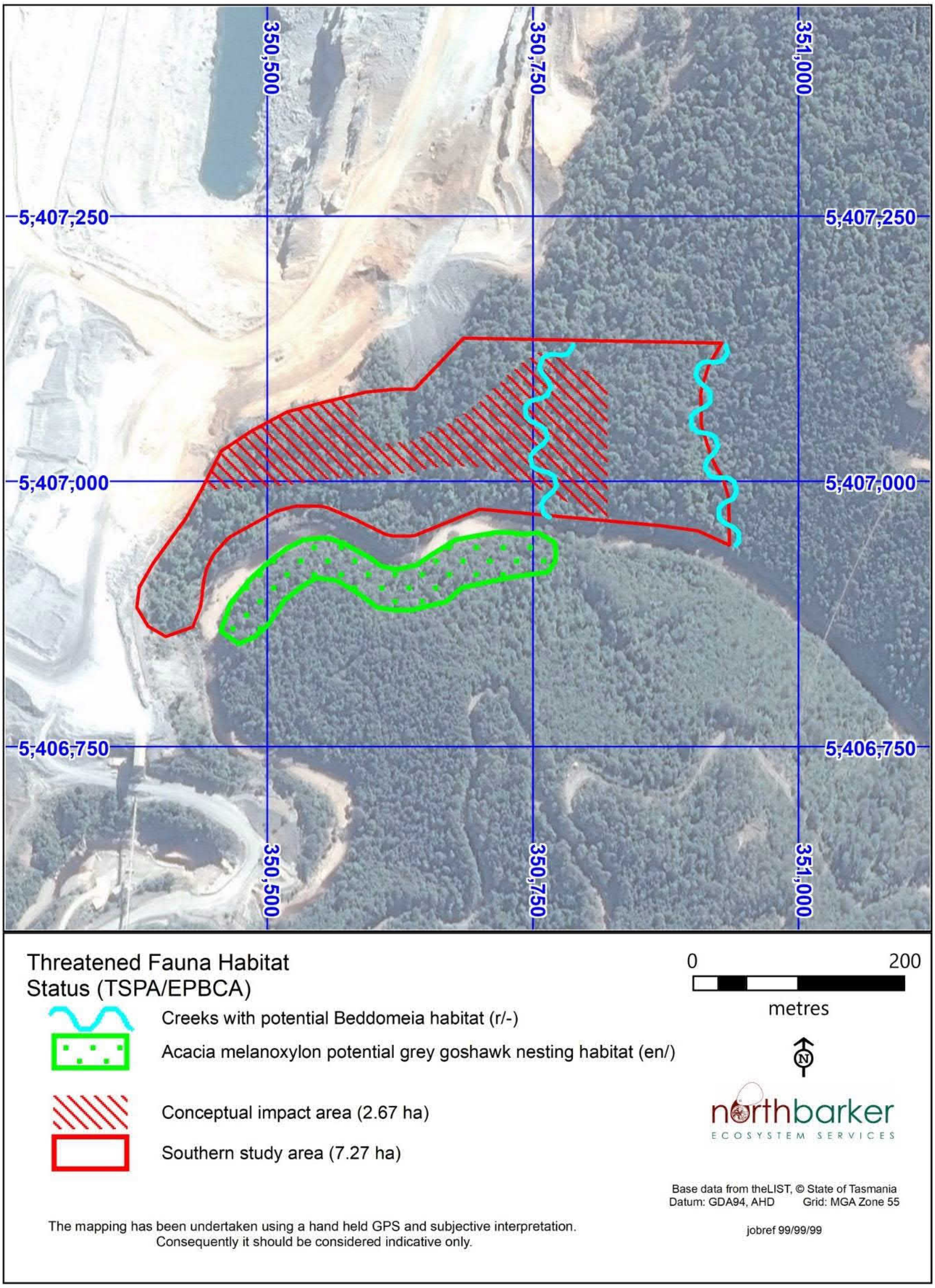


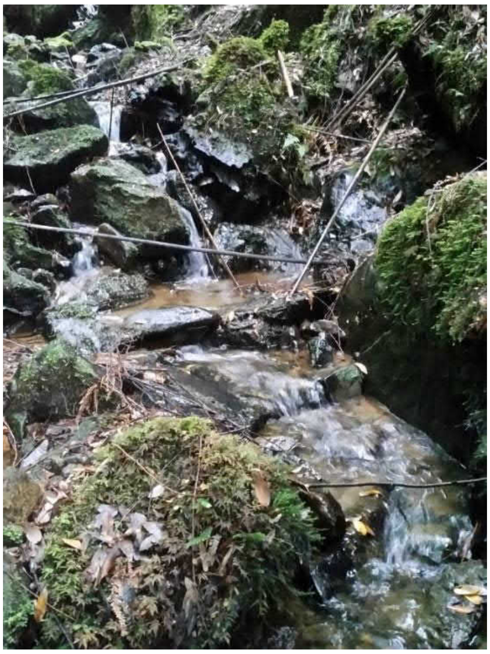
Figure 3: Southern study area with conceptual impact area and potential threatened fauna habitat

Table 2: Creeks with potentially suitable habitat for Hydrobiid snails in southern study area

CREEK ON THE EASTERN BOUNDARY OF THE SOUTHERN STUDY AREA

Image	Components	Description
	**leaf litter:** 50-75% **coarse woody debris:** 25% **moss:** 5% **rock/pebbles:** 10-15 %	A low energy, rocky creek with patches of still/slow moving water connected by narrow runs. The substrate is a mix of sandy and rocky patches, leaf litter and course woody debris.

CREEK IN THE CENTRE OF THE SOUTHERN STUDY AREA

Image	Components	Description
	**leaf litter:** 30-40% **coarse woody debris:** 5-10% **moss:** 5% **rock/pebbles:** 30-40 %	As per the above creek. However due to a steeper gradient, this is a higher energy creek with faster flowing water.

In previous NBES and other surveys, several listed species have been recorded within 5 km of the study area. None have been recorded within 500 m. An annotated list of these previously recorded species, and those with the potential to occur within 5 km of the study area is presented in Table 3 (note: marine, coastal and estuarine species are included in the *EPBC Act Protected Matters Report* – these are not considered here).

Table 3: Fauna species of conservation significance previously recorded, or which may potentially occur, within 5 km of the study area[22]

Species	Status TSPA/ EPBCA	Potential to occur in both study areas	Observations and preferred habitat[23]
Accipiter novaehollandiae grey goshawk	Endangered/ -	Northern study area : lower priority, mainly foraging habitat Southern study area : lower priority, mainly foraging habitat, but within 100-200 m of potential priority nesting habitat	Inhabits large tracts of wet forest and swamp forest, particularly patches with closed canopies above an open understorey, but with dense stands of prey habitat nearby. Mature trees provide the best nesting sites. The forest in both study areas may be considered as low priority, primarily offering potential foraging habitat. Nesting opportunities in the areas are limited due to the high degree of canopy connectivity, and the paucity of large 'habitat' canopy trees[24]. Dense stands of *Leptospermum* or *Melaleuca* are preferred foraging habitat; these were not evident in the study area. Vegetation of this type mapped in TASVEG 3.0 occurs within 500 m of the northern study area, but this area has largely been cleared for existing mining operations. The next closest patch is > 1 km away from both sites. The RMT in the area does have some potential to support prey species, however this habitat is not as desirable as *Leptospermum* or *Melaleuca*. No nests were observed and no individuals were seen or heard. Large *Acacia melanoxylon* occur within 100 m of the southern study area on the south bank of the Savage River – this is a preferred species for nesting tree for grey goshawk. This vegetation was not surveyed, but the presence of large *Acacia melanoxylon in* this area suggests there is potential high priority nesting habitat.
Alcedo azurea ssp. *diemenensis* azure kingfisher	Endangered/ ENDANGERED	Very low	Has undergone a large range contraction in Tasmania and occurs on major rivers in the western half of the State. Requires native riparian vegetation, typically with a eucalypt component[25]. No nest sites or observation records are known from within 5 km of the study area. Watercourses in the study area do not constitute major rivers, and while it is possible this species may occasionally be present on the Savage River, this is highly unlikely.

[22] DPIPWE 2018, nvr_1_09-Jan-2018, Commonwealth of Australia, EPBC Protected Matters Report # PMST_NXNLQ7
[23] Bryant & Jackson 1999
[24] Forest Practices Authority 2011A
[25] Wapstra *et al.* 2010

Species	Status TSPA/ EPBCA	Potential to occur in both study areas	Observations and preferred habitat[23]
Beddomeia bowryensis hydrobiid snail *Beddomeia hullii* Hulls freshwater snail *Beddomeia trochiformis* Savage River Mine freshwater snail *Phrantela marginata* Heazlewood River hydrobiid snail	All species: Rare/-	Northern study area: None Southern study area: Likely	Hydrobiid snails live in sheltered habitats such as under rock slabs in streams, and each species has an extremely limited distribution often being found in only one stream. Their distribution in Tasmania occurs in the northern and western parts of the state. They have been observed within 5 km of the study area in suitable habitat. The very steep forested slopes at the northern study area are not conducive to stream formations suitable for these species. At the southern study area two streams were notable as potential habitat for one or more of these species; these are dealt with in more detail below.
Aquila audax subsp. *fleayi* wedge-tailed eagle	Endangered/ ENDANGERED	Very low (foraging) Very low (nesting)	Requires large sheltered trees for nesting and is highly sensitive to disturbance during the breeding season. Use of rainforest tree species for nesting is extremely rare. However, a single nest from 1993 is known from the Savage River approximately 5 km from the study area. It is not known what tree species was used for this nest. Regardless, neither site has large eucalypt trees in sufficiently sheltered locations to support nests. The survey areas are likely to be infrequently utilised for hunting and foraging only.
Apus pacificus fork-tailed swift	- / MIGRATORY	None	Most records of the Fork-tailed swift are from Bass Strait Islands with fewer on mainland northern Tasmania. Almost exclusively an aerial species, with no likelihood of roosting in the survey areas.
Ardea alba great egret	- / MIGRATORY	None	The great egret breeds in northern Australia only. It is a regular visitor to Tasmania where it favours freshwater wetlands, farm dams and brackish lagoons. There is no suitable habitat present.
Ardea ibis cattle egret	- / MIGRATORY	None	The cattle egret breeds mostly along the central eastern coast of Australia and not in Tasmania. Non-breeding individuals in Tasmania favour pasture and freshwater wetlands along the north coast and southeast. There is no suitable habitat present.
Dasyurus maculatus subsp. *maculatus* spotted-tail quoll	Rare/ VULNERABLE	High	This naturally rare forest-dweller most commonly inhabits rainforest, wet forest and blackwood swamp forest. It forages and hunts over distances of up to 20 km at night. During the day it shelters in logs, rocks or thick vegetation. This species has been recorded in surveys within 5 km of the study area. Based on the extent of suitable habitat in the region and the broad home

Species	Status TSPA/ EPBCA	Potential to occur in both study areas	Observations and preferred habitat[23]
			range size of this species, we do not consider it likely that the site contains any traits that could be critical to the local survival of the species at a population level.
Dasyurus viverrinus eastern quoll	- / ENDANGERED	Very low	Potential habitat for the eastern quoll includes rainforest, heathland, alpine areas and scrub. However, this species favours dry forest and native grassland mosaics which are bounded by agricultural land. There is no suitable core habitat in the survey areas.
Haliaeetus leucogaster white-bellied sea-eagle	Vulnerable/ -	Very low (foraging) None (nesting)	Occurs in coastal habitats and large inland waterways. May hunt over the site, and staff at the mine have reported this species once (pers. comm. Tony Fergusson). However, this species is highly unlikely to be a regular visitor to the area. Nesting habitat is tall eucalypt trees in large tracts (usually more than 10 ha) of eucalypt or mixed forest. No known nests known within 5 km.
Hirundapus caudacutus white-throated needletail	-/MIGRATORY	None	Almost exclusively an aerial species, with no likelihood of roosting in the study area.
Lathamus discolor swift parrot	Endangered/ CRITICALLY ENDANGERED	None	This migratory species is more frequent in eastern Tasmania, but is occasionally recorded on the west coast and does have a semi-regular population in the northwest around Devonport. Records in western Tasmania tend to be during post-breeding dispersal, where a broader diversity of *Eucalyptus* species are utilised for foraging. Based on the lack of *Eucalyptus* spp., there is no chance of this species occurring in the survey areas. No observations are known within 5 km of the study area.
Limnodynastes peronii striped marsh-frog	Endangered / -	None	Potential habitat for the striped marsh frog is natural and artificial coastal and near-coastal wetlands, lagoons, marshes, swamps and ponds (including dams), with permanent freshwater and abundant marginal, emergent and submerged aquatic vegetation. There is no suitable habitat in the study area.
Myiagra cyanoleuca satin flycatcher	- / MIGRATORY	Very low	There are no NVA records of the satin flycatcher within 5 km of the study area. The species is relatively widespread across Tasmania, but is more frequent within wet sclerophyll than in rainforest, and is least common in western Tasmania.

Species	Status TSPA/ EPBCA	Potential to occur in both study areas	Observations and preferred habitat[23]
Prototroctes maraena australian grayling	vulnerable/ VULNERABLE	Very low	Inhabits the middle and lower reaches of unpolluted rivers and streams that open to the sea. The southern study area extends to the Savage River, this area is relatively far from coastal waters, and likely includes several downstream impediments to the presence of the species, including small waterfalls. This species was not specifically targeted in our survey but it is considered highly unlikely that this species occurs in the study area.
Pseudemoia pagenstecheri tussock skink	vulnerable/ -	None	Inhabits tussock grassland habitats (with at least 20 % native species), where trees are absent, or occasional. No suitable tussock grassland present.
Sarcophilus harrisii Tasmanian devil	Endangered/ ENDANGERED	Low	Potential habitat for the Tasmanian devil is all terrestrial native habitats, forestry plantations and pasture. Devils require shelter (e.g. dense vegetation, hollow logs, burrows or caves) and hunting habitat (open understorey mixed with patches of dense vegetation) within their home range (4-27 km^2). Known within 5 km; however both the north and southern study areas are largely unsuitable for this species due to the dense canopy, complex topography and very steep terrain, factors that limit their occurrence[26]. Areas of suitable foraging habitat occur, but no suitable denning sites were observed, or are considered likely to occur given the steepness of the terrain. We consider that the site has a low probability of containing refuges that can be considered as potential devil dens on the weight of observable evidence. The site does not therefore qualify as significant habitat in accordance with the definition from FPA guidelines.
Tyto novaehollandiae masked owl	Endangered/ VULNERABLE	Very low (foraging) None (nesting)	Primary habitat is lowland dry forest and woodland, with nesting occurring in old growth eucalypts with large main-stem hollows. The vegetation within the study area is considered unsuitable for nesting and of very low suitability for foraging.

3.4 Plant Pathogens

3.4.1 Root rot fungus (*Phytophthora cinnamomi*)

Phytophthora cinnamomi (PC) is a pathogen which affects a wide range of species, (notably those in the Epacridaceae and Proteaceae families). It is a soil borne fungal

[26] Forest Practices Authority 2011B

pathogen that invades the roots of plants and starves them of nutrients and water. Nearly 50 % of rainforest species which occur in the climatic range of PC are susceptible to infection. However, due to the cool nature of most rainforest communities, this species susceptibility does not generally translate into the rainforest communities being highly susceptible. This soil borne fungus moves naturally through the soil, more rapidly with drainage, and more slowly upslope. It is transported long distances by animals and humans.

PC can be accidentally introduced through the transportation of soil on vehicles, construction machinery and walking boots. The establishment and spread of Phytophthora is favoured in areas that receive above 600 mm of rainfall per annum and are below about 800 m altitude. The project site falls within this climatic zone. Rainforests are generally only susceptible to infection when severely disturbed so that the soil temperature can be raised by sun exposure to a temperature suitable to sustain PC. No symptomatic evidence of PC was noted in the study area. However, it should be noted that PC was located in a previous NBES survey north of the study site on Pipeline Road.

3.4.2 Myrtle wilt fungus (*Chalara australis*)

Chalara australis is a naturally occurring fungus that causes a disease in older myrtle beech (*Nothofagus cunninghamii*) regeneration (40-60 years), as well as mature myrtle, which results in death of the trees. This disease is commonly referred to as 'myrtle wilt'. Symptoms are wilting, followed by leaf death with the dead leaves being retained on the tree for some time. Myrtle wilt is the main cause of disease in undisturbed stands of rainforest and mixed forest. Disturbance within the stand exacerbates the effect of myrtle wilt. Disease incidence has been shown to be higher in callidendrous than in thamnic or implicate rainforests; higher in mixed forests the greater the myrtle densities; higher at lower altitudes; higher with increased diameter of tree; and higher where there is stem and crown damage[27].

No symptomatic evidence of myrtle wilt was observed within the present study area.

4 Assessment of Impact and Mitigation

4.1 Vegetation

There are 14.33 ha of RMT vegetation within the two study areas. The design is conceptual, but it is expected that < 10 ha will be impacted. No impact to vegetation communities listed on the EPBCA or the Tasmanian NCA is anticipated.

4.2 Threatened Flora

No threatened flora species listed on the EPBCA or TSPA were observed within the study area, and so no impact is expected on threatened flora.

4.3 Threatened fauna habitat

No threatened fauna species listed on the EPBCA or TSPA were observed within the study areas. It is however likely that spotted-tailed quoll and Tasmanian devil forage in the study areas, although no impact on denning habitat is expected. Works in this area have the potential to impact on grey goshawk due to the presence of potential priority breeding habitat within 100 -200 m of the southern study area. If hydrobiid snails occur in the creeks in the southern study area, the development may have an impact on one or more of these species.

[27] Packham, 1990

4.3.1 Spotted-tailed quoll (*Dasyurus maculatus maculatus*)

The known threats to the spotted-tailed quoll include the following:

- **Habitat loss and modification:** Considered the greatest threat to the species. In Tasmania 50 % of the species core habitat has been removed by logging or agriculture. Of the remaining 50 %, half has been subject to logging in the past 20 years – particularly in the north and northwest regions of the State where clearance has occurred for plantations.
- **Fragmentation:** In many areas their habitat is fragmented, resulting in isolated populations. This leads to breeding complications, including difficulty in locating breeding partners and a lack of genetic diversity. The species naturally occurs in low population densities (breeds only once a year) meaning isolated populations have inherent breeding difficulties. Isolated populations are also vulnerable to stochastic events and the species is slow to recolonise following local extinction.
- **Timber harvesting:** Research suggests that forestry practices that remove or reduce prey or critical habitat (including trees with hollows, hollow logs and complex vegetation structure) may render habitat unsuitable.
- **Poison baiting:** In the past, 1080 baiting (used to control red fox, wild dogs and rabbit) has been blamed. However, recent research indicates that 1080 baiting is in fact not a threat.
- **Competition and predation:** On the mainland, habitat preferences of the European red fox overlap with much of the spotted-tailed quoll. If foxes become established in Tasmania they could displace native carnivores. Not only would they be direct competition, they are also likely to predate on younger quolls.
- **Deliberate killing and dog attacks**.
- **Road mortality**: Road mortality is believed to be a significant factor in the decline of some populations. It is estimated that 1–2 individuals are killed daily on the main road between Hobart and the northwest of the state. Juvenile males are most at risk due to extensive range. The full impacts of road mortality on the species are not well known, although local studies have demonstrated this to be significant at Cradle Mountain and near Arthur River.
- **Wildfire and prescription burning:** The impacts of wildfire and prescription burning are not well known but it may reduce prey and habitat. However, recent research found that fire may be beneficial as it can increase the formation of tree hollows used by the species and its prey.

Habitat loss

The exact extent of loss from the current proposal is not yet known but is unlikely to exceed 10 ha. However, any removal of habitat for this species will reduce the effective carrying capacity of the forests in the area. It is unknown exactly how many quolls could be displaced by the expected loss of habitat, but a rough estimate of density in non-core habitat is approximately 1 animal per 300 ha. A viable population of about 50 quolls is thought to require about 15,000 ha of continuous habitat. Given the extent of habitat in the region (large tracts of continuous native vegetation) it is likely that the area for a minimum viable population of 50 individuals is exceeded and that a small decline in the overall carrying capacity is negligible (the suitable habitat in the study site is well below 100 ha).

The species is considered to be distributed throughout mainland Tasmania[28]. Key sites for the spotted-tailed quoll in Tasmania according to the Tasmanian Threatened Fauna Handbook[29] include:

- northern forested areas bounded by Wynyard, Gladstone and the central and north-eastern highlands,

[28] TMAG 1990
[29] Bryant & Jackson 1999

- the north-western wet forests; including the catchments of the Arthur and Montagu Rivers,
- the Dry eucalypt forests in the central north coastal regions bounded by the Tamar, Devonport and Western Tiers,
- patches between the King River and Strahan, the Gordon River and Huon River Catchments as well as the coastal strip from Strahan to Temma.

The Draft National Recovery Plan[30] identifies "important populations" for the spotted-tailed quoll in Tasmania. These are identified in Table 5.

Table 5: Important populations identified in the Draft National Recovery Plan

Population	Basis for 'importance' classification
Freycinet National Park	research population
Central-north Tasmania (including Great Western Tiers to Narawntapu)	stronghold & research population
Cradle Mountain National Park	stronghold & research population
Far north-western Tasmania (including the Smithton and Marrawah regions)	stronghold & research population
Eastern Tiers/northern Midlands (including Nugent and Ross regions)	stronghold population
Southern forests/South Coast (including the Hastings region)	stronghold population
Gordon River system	stronghold population
South-west Cape	stronghold population

Figure 4 presents a composite map of the likely areas occupied by the above two sets of definitions of key sites and important populations in relation to the location of the study area.

Habitat modification

Construction works will bring a heightened level of disturbance from noise and vibrations. These will tend to disperse sheltering animals greater distances from the site. There is thus a small possibility that any dens being utilised in close proximity to the development could be abandoned.

Fragmentation

The extensive interconnected expanse of native vegetation in the broader landscape means that the footprint of the development will not lead to habitat fragmentation.

Road kill

Changes to traffic usage during the construction period may result in increased incidences of road kill, especially if this involves contractors travelling around dusk or dawn. Significant increases in traffic volumes are likely to increase the incidence of road kill unless mitigation measures are adopted. Changes to traffic usage from the proposal is unknown at this stage.

[30] DSEWPC (2012a)

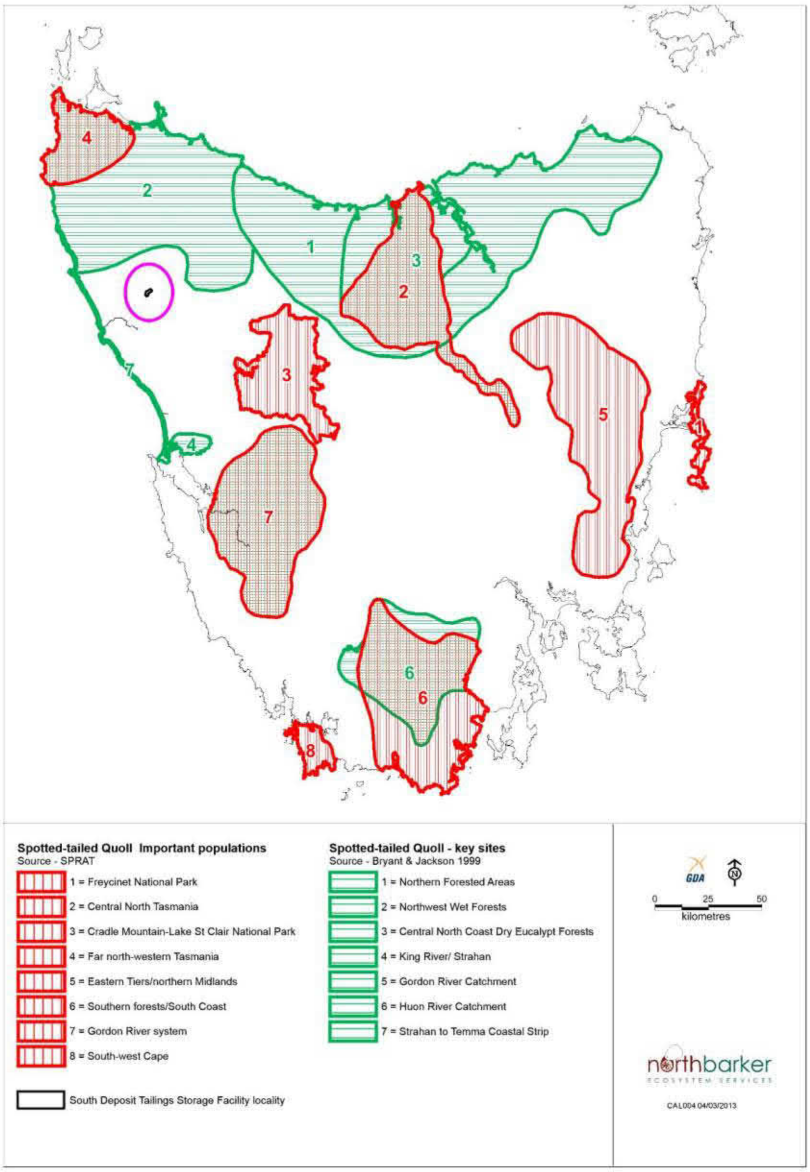


Figure 4: Spotted-tailed quoll key sites and important population

4.3.2 Grey goshawk (*Accipiter novaehollandiae*)

There is currently no listing statement or recovery plan under the TSPA for this species.

The RMT in the study areas may be regarded as lower priority habitat for this species, constituting mainly foraging habitat[31]. However, the presence of large *Acacia melanoxylon* on the south bank of the Savage River, are within 100 m of the southern study area, and this area may qualify as priority nesting habitat[32]. No birds were seen or heard in the area.

Key threats to this species include[33]:

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[31] Forest Practices Authority 2011A

[32] Forest Practices Authority 2011A, Forest Practices Authority 2018

[33] Bryant & Jackson 1999

- Clearing, fragmentation and plantation conversion of old growth and wet forest habitat, especially blackwood swamps and streamside forest;
- Deliberate persecution; and
- Accidental death from poisoning, electrocution, collision etc.

Potential habitat is extensive in the broader region. It could be argued that due to seemingly low population densities, this species is unlikely to be limited by habitat availability in the region; although this may be dependent on territory size which is currently unknown. The study area occurs within this species core habitat range.

Surveys by NBES in January 2012 found an active nest 8.16 km south of the study area in a mature myrtle tree, as well as sightings from motion camera and call back surveys. This nest is well outside any impact from the current proposal. There is extensive undisturbed habitat in the surrounding area, so any impact upon this species is anticipated to be relatively localised assuming the species isn't currently nesting in the area

4.3.3 Tasmanian devil (*Sarcophilus harrisii*)

Known threats to Tasmanian devil include the following:

- Devil Facial Tumour disease: This is the main threat to the species and the reason for its listings as a threatened species.
- Lack of genetic diversity: The Tasmanian devil has been found to have relatively low genetic diversity compared to other marsupials and placental carnivores.
- Competition and predation by foxes: Habitat preferences of European red fox overlap heavily with the Tasmanian devil. If foxes become established they will replace most of the medium and large carnivores. This presents an enormous risk to the species' recovery as foxes could prevent devils' populations from becoming re-established.
- Road kill: Most of the core habitat for the species is in the vicinity of roads. Devils use roads for long distance travel and as a source of food (scavenging carcasses). Most collisions are fatal for the species. A recent study estimated 1700 devils are killed on roads annually. In local areas, where road kill has been measured, the impact on the species has been high (for example a 50 % increase in sightings of road kill when the existing Arthur River Road was sealed, and 50 % of deaths in the local areas being attributable to road kill).
- Persecution: Current illegal culling is considered to be less than in the past but can still be locally intense.

Devil Facial Tumour Disease

Devil facial tumour disease (DFTD) has had a significant impact on the Tasmanian devil population in Tasmania, and is the single most significant cause of mortality for the species.

Based on the current understanding of DFTD, the construction and operation of the proposal will not result in any changes to the environment that could exacerbate the effects of DFTD in the area or increase its prevalence.

Habitat loss

The project will involve the loss of some habitat for the devil. The removal of less than 10 ha of native habitat within the range for this species will reduce the effective carrying capacity of the area.

The listing of the Tasmanian devil on the *TSPA* and *EPBCA* has occurred due to the threat to the species brought about by the Devil Facial Tumour Disease (DFTD) which has ravaged some populations.

Persecuted along with the Tasmanian tiger, the species was in threat of extinction by the early 20th century. However changes in policy allowed the species to recover so that it reached historically high levels by the 1990's. Some estimates suggest the population may have exceeded 150,000 individuals at that time[34].

They have home ranges of 8 to 20 square kilometres (800 to 2,000 ha), although more recent studies suggest smaller ranges[35] probably reflecting higher carrying capacity. The home ranges overlap to a very large extent with other individuals but they forage separately and are antagonistic toward each other on meeting. The average density of pre-disease devils in unmodified habitat ranges between 0.3 and 0.7 per km^2 [36].

The overlapping ranges and high density of animals results in a population of devils that utilises the whole of the landscape as a single entity. Pemberton (1990) showed that for a population of 250 devils occupying about 45 km^2, each devil having a home range of about 15 km^2; then about 30% of animals share a majority of their home range and about 80% have at least some overlap of the home range. The high degree of overlap reflects a myriad range of home range shapes.

As a result of the high degree of shared range, the clearance of an area equal to one home range (15 km^2) can effect up to 80% of the population to some degree. Devils thrive in a landscape mosaic of native habitat and agricultural land. The population uses all of the habitat mosaic but typically does not use areas of pasture more than 500m from continuous habitat. Dense wet eucalypt and rainforest (as within the study area), alpine areas, dense wet heath and open grassland all support only low densities of devils[37] . Devils are more abundant in habitats (open eucalypt forests and woodlands, coastal scrub) that support dense populations of their prey (macropods, wombats, possums)[38]. Devils displaced by habitat loss will move to other home ranges but ultimately the population will decrease due to the limits of carrying capacity. This is likely to be over a period of the lifespan of the displaced animals. If native non breeding habitat is lost, a population can be sustained if the prey abundance and seasonal availability is sustained. If the prey abundance and seasonal availability is not sustained then the carrying capacity and the population size will fall.

<u>Habitat Present:</u>

The survey area was found to be largely unsuitable for denning at the macro scale. Particularly unsuitable macro traits were the dense canopy (resulting in a relatively dark and dank microclimate at ground level) and the very steep contours (which can be relatively slow and difficult to traverse, a factor compounded by high stem density). Caves, rocky outcrops, substantial log piles and the like were not observed and are not likely to have been overlooked. In addition, the prevailing dark conditions (in conjunction with the sites moisture-retentive ferrosols) have led to high soil moisture levels that contrast with the dry and warm soils needed for denning.

At the micro scale, refuges were limited to infrequent hollow and/or rotten tree bases, and infrequent hollow-bearing fallen logs. Without exception, all of the refuges observed and inspected were too shallow and wet or too exposed to be considered suitable den sites. No indications of devil use were observed around refuges.

Subsequently, the site is not considered to contain any refuges that can be considered as potential devil dens on the weight of observable evidence. The site does not therefore qualify as significant habitat in accordance with the above definition from FPA guidelines.

[34] N. Mooney cited in McGlashan *et. al.* 2006
[35] S. Troy *pers. comm.* –" Landscape ecology of the Tasmanian devil and spotted-tailed quoll"
[36] DPIPWE 2010b
[37] Jones et al. 2004
[38] Jones & Barmuta 1998

4.3.4 Tasmanian wedge-tailed eagle (*Aquila audax ssp. fleayi*)

There were no sightings of this species during the survey and the habitat is deemed unsuitable for nesting. Wedge-tailed eagles nest in a range of old growth native forests and the species is dependent on forest for nesting. It nests almost exclusively in mature eucalypts capable of supporting their nests, which can develop after many years of use into massive structures over 2 m in diameter. The eagles choose old growth trees in relatively sheltered sites for locating their nests. Territories can contain multiple nests and up to five alternate nests have been located. Nests within a territory are usually close to each other but may be up to 1 km apart where habitat is locally restricted. Wedge-tailed eagles prey and scavenge on a wide variety of fauna including fish, reptiles, birds and mammals.

The nearest nest record is approximately 5 km to the north-east of Savage River, last confirmed in 1993. This is well beyond the range of likely disturbance. No evidence of large eucalypt trees in sufficiently sheltered locations to support nests was recorded during the survey. Some old growth myrtle trees within the study area near Savage River were noted, however use of myrtle for nesting is extremely rare. Sightings by mine staff are very sporadic and not indicative of breeding nearby. No sightings of the species have been recorded during the various surveys conducted for past projects for the mine.

Modelling of prospective nesting habitat is being developed by the Tasmanian Forest Practices Authority. Figure 5 shows that the forested vegetation, in the vicinity of the study, is of low potential for nesting habitat. The nearest areas of moderate potential as nesting habitat occurs over 1km to the east on the south bank of the Savage River.

The survey area may be utilised occasionally for hunting and foraging, but not for breeding given the paucity of large *Eucalyptus*. Given the relatively small footprint of the development, impact on this species may be considered negligible.

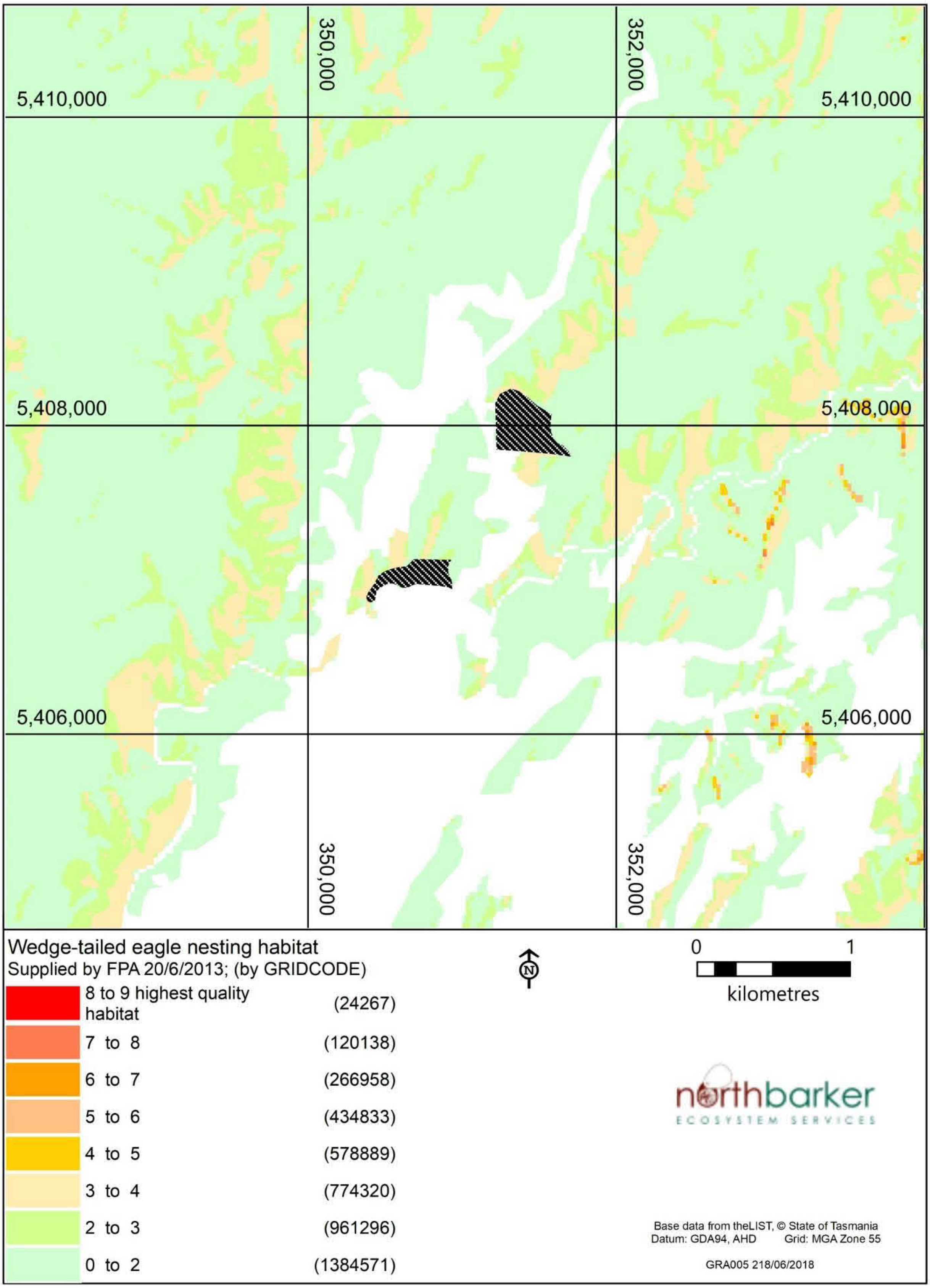

Figure 5: Modelling of Tasmanian wedge-tailed eagle habitat in relation to two study areas (black)

4.3.5 Tasmanian azure kingfisher (*Ceyx azureus diemenensis*)

No suitable waterway habitat has been recorded within the study area and the closest record is a sighting > 10km to the south-west. The nearest habitat occurs on the Donaldson River (> 6 km to the north-west) and the Whyte River (> 5 km south-east). The savage River is likely to have once provided habitat but is likely to be unsuitable due to acid drainage. The Savage River empties into the Pieman River which is known to support a breeding population.

5 Mitigation

5.1 Vegetation Clearance

The site does not contain any vegetation communities listed as threatened under the Tasmanian NCA or the EPBCA. RMT is well reserved at the state and regional level. Consequently, negligible impact is anticipated at the community level, requiring no specific mitigation.

The impacts of vegetation clearance are difficult to mitigate. However, the risk of unnecessary and indirect impacts on vegetation outside the footprint of the development could be minimised by following these protocols:

a) Clearly define the extent of clearance required for the project, and ensure that any additional impacts are considered.
b) The works area should be marked and all works, vehicles and materials should be confined to the works area.
c) Ensure there are appropriate runoff controls to avoid disturbance to the vegetation that falls outside the footprint but is potentially at risk of sediment influx. (Prepare a Sediment and Erosion control Plan).

5.2 Threatened Flora

The site has not been found to support any species of threatened flora, and is not thought to have a high likelihood of doing so. Consequently, no mitigation regarding threatened flora species is required. It is recommended that this report is reviewed post final design to ensure the recommendations are tailored to the final environmental impact.

5.3 Threatened Fauna

5.3.1 Spotted-tailed quoll and Tasmanian devil

While quolls and devils are likely to forage in the area, the extent of the impact area (< 10 ha) is considerably less than the suggested area for a single quoll (300 ha) or devil (800 ha to 2000 ha). While it may be reasonably assumed that density will exceed this in optimum habitat, the impact to these species by the development is likely to be negligible. Final impact is likely to be less than the area surveyed however this should be reviewed post design.

Pre-clearance den surveys for the quoll and devil are recommended as appropriate mitigation measures.

5.3.2 Grey goshawk

A targeted grey goshawk nest survey is warranted to determine if there are any nests of this species within 100 m of the southern study area (100 m is the buffer recommended by the FPA). If no nests are found then impact on this species is considered negligible, and no mitigatory measures will be required.

5.3.3 Hydrobiid snails

A targeted search of these species is recommended for the creeks that are likely to be affected by the development. Mitigatory measures will not be required if snails are not found.

6 Legislative implications

6.1 Commonwealth *Environment Protection and Biodiversity Conservation Act 1999*

The EPBCA is structured for self-assessment; the proponent must determine whether or not the project is considered a 'controlled action' which if confirmed would require approval from the Commonwealth Minister.

Referral under the EPBC Act will be necessary if, as the Act states:

'An action has, will have, or is likely to have a significant impact on an endangered or vulnerable species if it does, will, or is likely to (amongst other things):

modify, destroy, remove, isolate or decrease the availability or quality of habitat to the extent that the species is likely to decline.'

Quoll

The project will not have a significant impact on the 'Vulnerable' spotted-tailed quoll under the significant impact criteria as the area does not support an 'important population' as defined under this legislation.

Devil

The scale of impact to the habitat of the Tasmanian devil is not significant in the context of the extent of habitat in the area and the character of the sub optimal denning habitat being disturbed. While it remains possible that one or more natal dens may be present, this is highly unlikely given the steepness of the terrain and paucity of suitable sites; also no obvious preferred structure was identified during targeted surveys.

6.2 Tasmanian *Threatened Species Protection Act 1995*

No threatened species were recorded within the impact area. The TSPA definition of "take" does not usually extend to the disturbance of foraging habitat for fauna, but does include nests and dens, which are "products of wildlife".

No potential dens for spotted-tailed quoll or devil were found. No direct impact could be quantified sufficiently to require a permit under this legislation.

No raptor nests were observed within the study area, although there is potential nesting habitat for the grey goshawk within 100 m of the southern study area. A grey goshawk nest survey is recommended to fully quantify the potential for impact on this species.

No other nests of fauna listed under the TSPA were recorded and it is unlikely that nesting habitats will be impacted.

6.3 Tasmanian *Forest Practices Act 1985*

Under the *Forest Practices Act 1995*, a Forest Practices Plan is required for clearing of land. However, Section 6 states that this does not apply in prescribed circumstances. The prescribed circumstances are defined in the *Forest Practices Regulations 2007*.

Section 4 of the Regulations states under what circumstances a Forest Practices Plan is not required. These circumstances include mineral exploration activities or mining activities that are authorised under:

(i) a permit granted under the Land Use Planning and Approvals Act 1993; or

(ii) an exploration licence within the meaning of the Mineral Resources Development Act 1995; or

(iii) a retention licence within the meaning of the Mineral Resources Development Act 1995; or

(iv) a mining lease within the meaning of the Mineral Resources Development Act 1995;

If the activity has been authorised under a retention licence granted under the *Mineral Resources Development Act 1995*, a Forest Practices Plan is not required.

6.4 Tasmanian *Land Use Planning and Approvals Act 1993*

LUPAA states that 'in determining an application for a permit, a planning authority must (amongst other things) seek out the objectives set out in Schedule 1. [39]

Schedule 1 includes 'The objectives of the Resource Management and Planning System of Tasmania' which are (amongst other things) 'To promote sustainable development of natural and physical resources and the maintenance of ecological processes and genetic diversity'.

Sustainable development includes 'avoiding, remedying or mitigating any adverse effects of activities on the environment'[40].

Over and above threatened species and forest clearance issues, it should be incumbent on the proponent to demonstrate that the works will include measures to fulfil the aims of LUPPA by:

- incorporating measures to prevent environmental weeds and plant pathogens; and
- maintain general environmental quality through the proper management of erosion and drainage.

6.5 Tasmanian *Weed Management Act 1999*

No declared weeds were located in the study areas.

7 Conclusion

The areas for the proposed development of areas to the east of north pit is situated in a topographically steep area dominated by myrtle beech rainforest. This vegetation is typical for the region and is not listed as threatened.

No threatened flora or fauna species were observed. The study area offers potential habitat of varying quality for several fauna species: the spotted-tailed quoll, Tasmanian devil, and the grey goshawk, Hydrobiid snails

For the spotted-tailed quoll and the Tasmanian devil the impact of the development is not considered to have a significant impact on a population of either species. The potential impact on the snails and the goshawk cannot be quantified until targeted surveys are carried out. Additional threatened fauna identified in the Natural Values Atlas report are considered unlikely to be impacted. A review of this report should be undertaken post final design.

The extent of vegetation in the study area is approximately 14.33 ha; a small area in the context of the surrounding environment – a large tract of native vegetation including the

39 section 51(2) (b) – Part 4 Enforcement of Planning Control – Division 2 Development Control LUPA 1993

40 pp56 LUPA 1993

Tasmanian Wilderness World Heritage Area, National Parks, Regional Reserves and State Forest. Consequently, considerable alternative habitat will remain in the surrounding vegetation.

Efforts to mitigate the impacts of the development should focus on reducing the risk of introduction and spread of plant pathogens, and declared and environmental weeds, during and after works, by implementing appropriate weed and hygiene management plans. Furthermore, reducing the clearance and impact on riparian vegetation on the Savage River should be considered. A pre-clearance den survey for devils and quolls should also be included.

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Appendix A: Vascular Plant Species list

Status codes:

ORIGIN	NATIONAL SCHEDULE	STATE SCHEDULE
i - introduced	EPBC Act 1999	TSP Act 1995
d - declared weed WM Act	CR - critically endangered	e - endangered
en - endemic to Tasmania	EN - endangered	v - vulnerable
t - within Australia, occurs only in Tas.	VU - vulnerable	r - rare

Sites:

8	Northern study area - E351357, N5407770	1/05/2018
9	Southern study area - E350558, N5407043	2/06/2018

Site	Name	Common name	Status
DICOTYLEDONAE			
	APIACEAE		
8 9	*Hydrocotyle hirta*	hairy pennywort	
	ASTERACEAE		
8 9	*Cassinia aculeata subsp. aculeata*	dollybush	
8 9	*Cirsium vulgare*	spear thistle	i
8	*Cotula australis*	southern buttons	
9	*Euchiton involucratus*	star cottonleaf	
8 9	*Euchiton japonicus*	common cottonleaf	
8	*Helichrysum luteoalbum*	jersey cudweed	
9	*Olearia lirata*	forest daisybush	
9	*Senecio minimus*	shrubby fireweed	
9	*Senecio sp.*	groundsel	
	ATHEROSPERMATACEAE		
8 9	*Atherosperma moschatum subsp. moschatum*	sassafras	
	CUNONIACEAE		
8 9	*Anodopetalum biglandulosum*	horizontal	en
	ELAEOCARPACEAE		
9	*Aristotelia peduncularis*	heartberry	en
	EPACRIDACEAE		
8 9	*Leptecophylla juniperina*	pink or crimson berry	
9	*Monotoca glauca*	goldey wood	
	ERICACEAE		
9	*Gaultheria hispida*	copperleaf snowberry	en
	ESCALLONIACEAE		
8 9	*Anopterus glandulosus*	tasmanian laurel	en
	EUCRYPHIACEAE		
8 9	*Eucryphia lucida*	leatherwood	en
	FAGACEAE		
8 9	*Nothofagus cunninghamii*	myrtle beech	
	GENTIANACEAE		
9	*Centaurium erythraea*	common centaury	i
	GERANIACEAE		
8	*Geranium potentilloides var. potentilloides*	mountain cranesbill	
	HALORAGACEAE		
9	*Gonocarpus teucrioides*	forest raspwort	
	LAMIACEAE		
8	*Prostanthera lasianthos var. lasianthos*	christmas mintbush	
	MIMOSACEAE		
9	*Acacia melanoxylon*	blackwood	
9	*Acacia mucronata*	variable sallow wattle	
	MYRTACEAE		
9	*Leptospermum lanigerum*	woolly teatree	
9	*Leptospermum nitidum*	shiny teatree	en
8	*Leptospermum scoparium*	common tea-tree	
	ONAGRACEAE		
8	*Epilobium sp.*	willowherb	
	OXALIDACEAE		

8 9	*Oxalis magellanica*	snowdrop woodsorrel	
	PITTOSPORACEAE		
8	*Pittosporum bicolor*	cheesewood	
	PROTEACEAE		
8 9	*Cenarrhenes nitida*	native plum	en
	RANUNCULACEAE		
8 9	*Clematis sp.*	clematis	
	RHAMNACEAE		
8 9	*Pomaderris apetala*	common dogwood	
	ROSACEAE		
9	*Acaena novae-zelandiae*	common buzzy	
	RUBIACEAE		
9	*Coprosma hirtella*	coffeeberry	
8	*Coprosma quadrifida*	native currant	
	RUTACEAE		
8	*Nematolepis squamea*	satinwood	
	THYMELAEACEAE		
9	*Pimelea cinerea*	grey riceflower	en
8 9	*Pimelea drupacea*	cherry riceflower	
9	*Pimelea linifolia*	greater slender riceflower	
	VIOLACEAE		
8 9	*Viola hederacea subsp. hederacea*	ivyleaf violet	
	WINTERACEAE		
8 9	*Tasmannia lanceolata*	mountain pepper	
	GYMNOSPERMAE		
	PHYLLOCLADACEAE		
9	*Phyllocladus aspleniifolius*	celerytop pine	en
MONOCOTYLEDONAE			
	CYPERACEAE		
8 9	*Carex appressa*	tall sedge	
8 9	*Gahnia grandis*	cutting grass	
9	*Isolepis fluitans*	floating clubsedge	
9	*Isolepis sp.*	club rush	
8 9	*Uncinia tenella*	delicate hooksedge	
	IRIDACEAE		
8 9	*Libertia pulchella*	pretty grass-flag	
	JUNCACEAE		
8 9	*Juncus bassianus*	forest rush	
8	*Juncus pallidus*	pale rush	
8	*Juncus pauciflorus*	looseflower rush	
8 9	*Luzula sp.*	luzula	
	LILIACEAE		
8	*Dianella tasmanica*	forest flaxlily	
	POACEAE		
9	*Aira caryophyllea*	silvery hairgrass	i
8	*Ehrharta stipoides*	weeping grass	
9	*Ehrharta tasmanica var. tasmanica*	tasmanian ricegrass	en
9	*Poa tenera*	scrambling tussockgrass	
	TYPHACEAE		
9	*Typha sp.*		
	PTERIDOPHYTA		
	ASPIDIACEAE		
9	*Lastreopsis hispida*	bristly shieldfern	
9	*Polystichum proliferum*	mother shieldfern	
8	*Rumohra adiantiformis*	leathery shieldfern	
	ASPLENIACEAE		
8	*Asplenium appendiculatum subsp. appendiculatum*	narrow spleenwort	
	BLECHNACEAE		
9	*Blechnum nudum*	fishbone waterfern	
8 9	*Blechnum wattsii*	hard waterfern	
	DENNSTAEDTIACEAE		
8 9	*Histiopteris incisa*	batswing fern	
8 9	*Hypolepis rugosula*	ruddy groundfern	
	DICKSONIACEAE		

8 9	*Dicksonia antarctica*	soft treefern	
	GLEICHENIACEAE		
9	*Sticherus tener*	silky fanfern	
	GRAMMITIDACEAE		
9	*Notogrammitis billardierei*	common fingerfern	
9	*Notogrammitis heterophylla*	gypsy fern	
	HYMENOPHYLLACEAE		
9	*Hymenophyllum australe*	southern filmyfern	
8 9	*Hymenophyllum flabellatum*	shiny filmyfern	
9	*Hymenophyllum peltatum*	alpine filmyfern	
8 9	*Hymenophyllum rarum*	narrow filmyfern	
8	*Hymenophylum applanatum*	skeleton filmyfern	en
	POLYPODIACEAE		
8 9	*Microsorum pustulatum subsp. pustulatum*	kangaroo fern	

Mine Water Management

Appendix B

pitt&sherry

NORTH PIT UNDERGROUND PROJECT PFS

MINE WATER MANAGEMENT

Prepared for

GRANGE RESOURCES

August 2019

AQ2

AQ2 Pty Ltd
Level 4, 56 William Street
Perth 6000

T: 08 9322 9733
www.aq2.com.au

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Prepared by:	**AQ2 Pty Ltd (ABN 38 164 858 075)**	**Prepared for:**	**Grange Resources**
T:	(08) 9322 9733	T:	
E:	Jon.Hall@aq2.com.au	E:	Uday.Singh@grangeresources.com.au
W:	www.aq2.com.au	W:	www.grangeresources.com.au
Author:	JWH		
Reviewed:	JLJ		
Approved:	JWH		
Version:	a		
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EXECUTIVE SUMMARY

Potential inflows of water to the proposed underground mining operations have been assessed and a concept level mine water management plan has been developed. For the purposes of the PFS, and given that there remains some uncertainty as to the long-term mine plan, this assessment has been restricted to the end of Lift 1 of the current Block Cave mine design (i.e. to Year 24).

Predicted water inflows are as follows:

- Groundwater inflows – up to 100L/s including groundwater inflows from the surrounding low permeability basement rocks and some enhanced leakage from the Broderick Creek Flow Through system (via minor connected cracking above the predicted Block Cave subsidence zone). Groundwater inflows will be relatively constant once the Block Cave subsidence zone breaks through to the surface.
- Rainfall runoff to the North Pit and then directly to the Lift 1 extraction level, through the Block Cave subsidence zone – this will fluctuate on a daily basis depending on rainfall and rainfall patterns, but probabilistic analysis indicates:
    - 50% probability of inflow exceeding 1,300L/s.
    - 25% probability of inflow exceeding 1,400L/s.Maximum possible inflow of 2,500L/s.
- There is also the possible risk that, should deformation above the Block Cave result in a much higher degree of connected cracking sub-cropping beneath the Broderick Creek Flow Through system (or other water sources) than is currently predicted, there could be significantly higher inflows to the underground mine workings.

The concept water management plan to account for the above includes the following:

- The use of underground void space below the Lift 1 active mine levels to create buffer storage, which will smooth out dewatering pumping requirements. Probabilistic water balance modelling indicates that the inclusion of the following buffer storage volumes would reduce total pumping requirements (for a probability of exceedance of 25%) as follows:
    - 30ML storage – 1,150L/s pumping capacity.
    - 60ML storage – 800L/s pumping capacity.
    - 90ML storage – 540L/s pumping capacity.
- Upgrading of the existing West Wall Dewatering System to cushion it against minor settlement and to reduce the potential for erosional scouring, so that it can continue to divert overflows (up to around 600L/s as was experienced in 2018) from the Broderick Creek Throughflow System.
- Installation of the Upper Broderick Creek Diversion Scheme to reduce flows through the Broderick Creek Flow Through System if/when the West Wall Dewatering System fails, or deformation results in much higher (than currently predicted) levels of connected cracking beneath the Broderick Creek Flow Through System.

The predicted rainfall runoff volumes to the underground mine workings are largely insensitive to the degree and extent of deformation above the block cave. However, predicted groundwater inflows and possible overflows, and/or additional leakage, from the Broderick Creek Flow Through System are very sensitive to deformation, connected cracking and the consequent increases in the level of hydraulic connection. These components of the water balance will need to be re-evaluated as/when modified mine plans or deformation modelling results come to hand.

There are no predicted impacts of mine inflows and dewatering on groundwater and surface water outside the immediate mine area.

TABLE OF CONTENTS

Tables

Figures

Appendices

1 INTRODUCTION

1.1 Project Background

Grange Resources Ltd, owners and operators of the Savage River magnetite mine in north-western Tasmania, is currently undertaking feasibility studies into the development of an underground mining operation below the North Pit (North Pit Underground Project – NPUG). The plan under consideration is to develop a block cave mining operation down to around 400m below the current pit base, with some sub level cave mining targeting selected areas to the north of, and at a similar depth as, the current pit.

The current phase of assessment is a Preliminary Feasibility Study (PFS), which is considering the main Block Cave mining via two lifts, commencing in 2020 with Lift 1 being completed in 2034 and Lift 2 being completed in 2044.

AQ2 Pty Ltd were commissioned by Grange Resources to assist them with investigating potential water inflows to the underground mining operations, developing a concept mine water management plan and assessing the net impacts on the local hydrogeological environment of the mine water management plan.

1.2 Key Water Management Issues

The key water management issues, identified during a preliminary assessment of water risks to the Project, are:

- Significant volumes of rainfall runoff to the pit, which will then rapidly make its way down into the underground mine workings through the cave zone (sometimes referred to as the subsidence zone), which will develop below the pit base and adjacent to the pit walls.
- Groundwater inflows from the fractured basement rock aquifers, which host and surround the magnetite orebody. These are not expected to be as large as rainfall runoff volumes, but will contribute to total dewatering requirements.
- Possible inflows from the Broderick Creek Flow Through System, a specially designed high flow channel at the base of the western waste rock dumps to convey river flow from upstream reaches of Broderick Creek in the north to the Savage River in the south. Identified potential inflow pathways included direct seepage to the west wall of the pit (where the pit intersects the flow channel) during high flow periods, and leakage through cave zone cracks if these extend beneath the flow channel.

Other identified water management issues relating to the overall Savage River mine water management plan, included:

- Maintenance of flows from the upper Broderick Creek to the Savage River, which have beneficial influence on water quality in the Savage River.
- Maintenance of discharge of all mine dewatering volumes to the South Lens pit for treatment and polishing before discharge to the Savage River.

1.3 This Report

This report describes the hydrological and hydrogeological investigations undertaken and presents the results. The rest of the report is structured in sections as follows:

- Section 2: Conceptual Hydrological Models
- Section 3: Surface Water Inflows
- Section 4: Groundwater Inflows
- Section 5: Inflows from Broderick Creek Flow Through System
- Section 6: Mine Inflow Management Plan
- Section 7: Potential Impacts of Mine Inflow Management Plan
- Section 8: Summary

2 CONCEPTUAL HYDROLOGICAL MODELS

2.1 Surface Water

The following conceptual hydrological model is based on current mine survey data and on information and data included in a number of historical reports (see Section 8 – References).

2.1.1 Local Hydrology and Mine Inflows

It has been assumed that the surface water catchment which currently reports to the North Pit will report to the underground mine workings in the future, via subsidence cracking. The catchment area of the North Pit has been estimated from site topography information (digital terrain model) and site observations. The catchment is shown in Figure 1 and has an estimated area of 1.7km^2. The majority of the catchment is the pit footprint (85%), with the remainder being a small amount of ex-pit catchment located to the north of the pit. Runoff to the pit is expected to be dominated by responses to winter rainfall events.

2.1.2 Existing Dewatering System

An in-pit sump pumping system is currently used to manage the inflow of surface water to the pit by pumping to the South Lens Pit, which is used to store and treat all mine inflows, prior to discharge to the Savage River.

Water levels within the Broderick Creek Flow Through System also respond to seasonal rainfall events. As discussed in Section 2.3, water levels in the Broderick Creek Flow Through System can increase to the point that seepage into the pit occurs. The existing West Wall Dewatering System captures this seepage and transfers it out of the pit to the South Lens Pit via a gravity drainage pipeline.

2.1.3 Key Hydrological Parameter

Apart from defining the catchment areas for future pit and underground inflows, which will be confirmed by parallel studies (e.g. geomechanical/deformation modelling), the key parameter for runoff and inflow prediction is the adopted runoff coefficient.

The following annual runoff coefficients have been adopted for this study (based on estimates by WRM 2007) for different areas of the pit catchment:

- Pit walls – 90%
- Ex-pit catchment – 77%

2.2 Groundwater

The following conceptual hydrogeological model is based on information and data included in a number of historical reports and investigation data sets (see Section 8 – References).

2.2.1 Local Hydrogeology

The hydrogeology in and around Savage River is complex. Apart from shallow river alluvium and some Tertiary basalts, the aquifers are generally low permeability basement rocks where aquifer properties are associated with fractures/joints/shears and some deep weathering of carbonate rocks along fracture planes.

In general, these aquifers are recharged by infiltration of rainfall runoff where fractures/joints outcrop or sub-crop beneath surface water drainages (streams, creeks and rivers). The aquifers naturally discharge as baseflow to the major creeks and rivers. The aquifers also discharge as groundwater inflows to the pit(s) with inflows then being pumped to the South Lens pit (for treatment/polishing) before discharge to the Savage River.

2.2.2 Project Specific Hydrogeology

For the purposes of assessing groundwater inflows to the Project, the hydrogeology in around North Pit can be represented by a simple block model. The key components (aquifer units) of this block model are:

- East Wall Block – largely competent chlorite-carbonate schists that form the east wall of the North Pit. Available information suggests that bulk permeability is low and aligned along strike (north-south), although there is reference to some enhanced permeability in places associated with structure and weathering.
- Eastern Contact Fault Zone – which includes the EC Fault East and EC Fault West. Historical reports suggest that these faults are likely to form flow barriers, although anecdotal information indicates that there have been consistent (if only minor) groundwater flows from the exposure of these faults in the west wall.
- Ore Zone Block – interbedded mafic intrusives and magnetite ore. It is reported that the rock mass itself is tight, but that there is some permeability associated with north-south oriented structures.
- Western Boundary Fault Zone – this includes the Magnesite-Siderite Fault. The fault zone is reported to be sheared and clay filled, although significant short-term inflows (up to 100L/s) have been observed when this zone has been mined through, but that flows have largely ceased after a short time. This suggests that the fault zone may be acting as a partial barrier to the release of stored water behind the faults but there is only limited groundwater storage and permeability.
- West Wall Block – largely magnesite and chloritic schists. Like the East Wall Block, it is reported that permeability is low and aligned along strike.
- LeFroy Fault Zone – there is only minor available hydrogeological information for this fault zone. It is suspected that the fault zone acts as a flow barrier. However, for the purposes of the current assessment it will be assumed to have similar aquifer properties to the units either side of it.
- Broderick Creek Block – largely metasediments (sandstones and slates) and meta-basalt. Again, there is little to no available hydrogeological information for this unit. However, as outlined in Section 3, the unit largely lies to the west of an interpreted aquifer recharge boundary and so will have no influence of groundwater inflows to the SLC or Block Cave.

Figures 2 and 3 show the conceptual aquifer block model in plan and oblique section.

2.2.3 Aquifer Hydraulic Parameters

Based on data reported in historical reports and from the recent geotechnical drilling/testing programme for the North Pit (refer Section 8 – References), and calibration of an analytical groundwater inflow model (refer Section 4), estimates of bulk aquifer permeability for each aquifer unit have been derived.

As permeability appears to be strongly controlled by strike oriented structures, it is assumed that there is a strong X-Y aquifer anisotropy with north-south oriented permeability in broad aquifer units being one order of magnitude higher than east-west oriented permeability. It has also been assumed that the permeability in the Ore Zone Block is higher than in the East Wall and West Wall Blocks. The analytical groundwater inflow model (calibrated to dry season pit inflows) also adopted such north-south anisotropy.

The measured, calibrated and adopted bulk permeability for each aquifer unit is listed in Table 1. A higher permeability for the ECF Fault Zone (than has been measured in limited tests) has been adopted to account for observed preferred flows along this structure.

Table 1: Adopted Bulk Permeability for Aquifer Units

Aquifer Unit	Derived Permeability (m/d)		Adopted Permeability (m/d)	
	Range of Reported Test Results	Bulk K derived from Calibrated Pit Model	North-South	East-West
East Wall Block	0.001 to 0.8	0.01 (north-south) 0.001 (east-west)	0.005	0.001
ECF Fault Zone	0.008 (?)		0.05	0.005
Ore Zone Block	0.003 to 0.1		0.01	0.001
WBF Fault Zone	NA		0.01	0.001
West Wall Block	0.001 to 0.8		0.005	0.001
LeFroy Fault Zone	0.004		0.005	0.005
Broderick Creek Zone	NA		0.005	0.001

In terms of aquifer storativity, a bulk specific yield (unconfined storativity) of 0.5% has been adopted for all units. Confined storativity is likely to be in the range 10^{-5} to 10^{-3}, however, this parameter has less influence on dewatering and a precise estimate is not required.

2.2.4 Aquifer Boundary Conditions

Aquifer recharge boundaries are important in that they can control the lateral extent of groundwater level drawdowns around the pit/underground and can also be the key driver of mine inflows. Recharge boundary conditions at Savage River are complex, as a result of the generally low bulk permeability. Prior to mining, the main aquifer boundaries would have been the Savage River (constant head recharge boundary to the south) and various groundwater flow divides beneath topographic ridges (no-flow boundaries to the north, east and west. The boundary heads at the no-flow boundaries would have been maintained by recharge.

However, boundary conditions will have changed since the commencement of mining and will likely change further (significantly) if there is any development of connected cracking in the subsidence zone above with SLC and Block Cave mining. From parallel rock mechanics and rock deformation modelling studies, it is predicted that minor connected cracking (which will develop on the margins of the main subsidence zone) will sub-crop beneath some potential recharge sources.

In terms of prediction of inflows (refer Section 4), the following aquifer boundaries were adopted:

- Savage River and South Lens Pit lake to the south – with recharge heads based on the elevation of the river bed and the spillway level of South Lens Pit.
- Broderick Creek Flow Through System to the west – with recharge heads based on measured groundwater levels in the new monitoring bores in the Broderick Creek Flow Through System (refer Section 2.3).
- Armstrong Creek to the east – with recharge heads base on the elevation of the creek bed up to a maximum head (and then constant head above this to reflect perennial creek flow conditions in the upper catchment).
- Upper Broderick Creek and tributaries of Upper Broderick Creek and Armstrong Creek - with recharge heads base on the elevation of the creek beds up to a maximum head of 260mRL (and then a constant head of 260mRL upstream of this to reflect "perched flow" conditions above the water table in the upper catchments).

Figure 4 shows the proposed recharge boundaries surrounding the pit and SLC/Block Cave and the derived recharge heads.

2.3 Broderick Creek Flow Through System

The Broderick Creek Flow Through System (BCFT) was developed in 1998 to convey stream flow from the Upper Broderick Creek beneath the western waste dump to a discharge point on Lower Broderick Creek close to its confluence with the Savage River. In summary, the BCFT comprises:

- Selectively placed, high permeability coarse fill along the base of the Broderick Creek flow channel. The fill (referred to as Type A fill – alkaline rock sourced from the magnesite schists in the West Wall Block aquifer zone) was placed directly onto weathered basement within the creek valley.
- The Type A fill (essentially an alkaline high flow medium) is up to 30m thick along the deepest part of the creek valley. Clay material was placed along the top and sides of the Type A fill and then covered by various other types of waste rock.
- The BCFT conveys flows of up to 1,800L/s in winter, depending on rainfall patterns and the water level upstream of the BCFT in Upper Broderick Creek. In summer, flows decline to around 20L/s, depending on the dry season water level in Upper Broderick Creek.

Currently, under "normal" rainfall and flow conditions, leakage/seepage from the BCFT into underlying weathered and fresh rocks (of the West Wall Block and Broderick Creek Block aquifer zones) is controlled by the low permeability of these units, and would be minimal. As such, while the Broderick Creek Flow Through System might contribute some seepage to groundwater, it is not likely to form a groundwater recharge boundary. However, as outlined in Section 2.2.4, the BCFT will likely form a recharge boundary (even if only a partial recharge boundary) if/when connected cracking on the flanks of the Block Cave subsidence zone subcrop beneath the BCFT.

It is also noted that, in 2018 following a period of prolonged high rainfall, water levels within the BCFT rose to the top of the Type A fill and significant volumes of water "spilled" to the pit at three low points where the current pit wall cutback intersects the waste dump. It was estimated that up to 600L/s flowed from the BCFT to the pit during this period. The following (West Wall Dewatering System – WWDS) has been implemented to manage the potential for this to occur in the future:

- A flow interception scheme has been implemented to catch any future inflows in large tanks installed at the inflow points and direct water to the South Lens pit by gravity flow through large diameters HDPE pipes. Inflows flow down the pit wall and are initially captured in clay lines dams (constructed on the berm below the inflows points (also referred to as the "waterfalls") which then overflow to the tanks via multiple pipes.
- Six monitoring bores have been installed along the BCFT and water levels monitored on a regular monthly basis.
- A TARP (Trigger Action Response Plan) has been developed, as part of the open pit water management plan, which includes monitoring rainfalls and water levels in the BCFT and readiness checks of the inflow interception scheme.

2.4 Mine Inflow Mechanisms

2.4.1 Current Pit Inflows

Groundwater inflows to the existing pit are largely as a result of pseudo-radial groundwater flow through the low permeability basement rocks and fault structures. As outlined in Section 2.2.3, there is a north-south anisotropy in aquifer permeability, which results in a preferred north-south oriented groundwater flow direction.

Groundwater level drawdowns in response to pit inflows (and the removal of inflows by pit sump pumping) will also have a preferred north-south orientation and will form an elliptical shape. Given the low permeability of the local aquifers, drawdowns will have been constrained to the local mine area only. The influence of potential recharge boundaries is not clear. However, depending on the vertical permeability beneath the potential recharge boundaries (compared with horizontal permeability), drawdowns could extend beneath and beyond some boundaries. Leakage from the potential recharge sources is likely to be occurring, but at rates insufficient to fully constrain the lateral extent of drawdowns.

In calibrating the mine inflow model used in this study (refer Section 4), both scenarios were simulated (i.e. radial flow from infinite aquifer and radial flow from fixed recharge boundaries).

2.4.2 Future Inflows to Block Cave

Following the commencement of block cave mining, a cave/subsidence zone will develop above the mine workings. This cave/subsidence zone will be conical (inverted cone) in shape with the margins roughly parallel to and largely contained within a similar area as the existing pit. The permeability within the main cave/subsidence zone will be very high (likely to be greater than four orders of magnitude higher than the permeability of local aquifers). The hydraulic driver for most future underground mine inflows would be similar to a deep open pit that envelops the main cave/subsidence zone. That is, pseudo-radial flow to a large void extending down to the base of the mine workings. Such psuedo-radial inflows would be somewhat higher than current pit inflows, due to the increased mine depth.

As mentioned in Section 2.2.4, rock mechanics and deformation modelling predicts that minor connected cracking will develop along the margins of the main subsidence zone above the block cave. To the north, east and south this will merely result in a marginal increase in the effective hydraulic radius of the main cave/subsidence zone. However, the modelling predicts that the minor connected cracking will sub-crop beneath parts of the BCFT. Current deformation results suggest that the degree of deformation (strain) could result in an order of magnitude increase in local aquifer permeability in this fringe zone (Beck Engineering, 2016, 2019 and pers.com.).

This increase in permeability is likely to result in an increase in direct leakage of water from the BCFT into the main cave/subsidence zone, at rates sufficient for the BCFT to form an effective constant head recharge boundary and result in a measurable increase in mine inflows. Prediction of future underground mine inflows (refer Section 4), adopted a constant head boundary approach to account for such flow.

There is also the potential for the overflow of water from the BCFT to the pit and then to the cave/subsidence zone, during periods of high rainfall and flow, as was observed in 2018. This is not considered a groundwater inflow (or direct surface water inflow) and is covered separately in the inflow predictions (refer Section 5) and the concept mine water management plan (refer Section 6).

2.4.3 Inflows to Decline

The exploration decline (currently being developed) and future main access and extraction declines will largely be contained within the East Wall Block aquifer zone (in the footwall of the Eastern Contact Fault – ECF), which has an interpreted very low bulk permeability. As such, bulk and long-term inflows are expected to be minimal. However, some measurable inflows could be encountered where the declines and other access workings intersect faults and jointed ground.

3 SURFACE WATER INFLOWS

3.1 Approach

A daily rainfall/runoff model was developed for the North Pit mine area using the following approach:

- Savage River rainfall records were used as an input to the e-Water program SCL (Stochastic Climate Library). The SCL program uses historic rainfall data as an input and produces a synthetic rainfall data set for the required duration, which is a statistical fit to all observed rainfall. For this project, recorded rainfall between 1967 and 2018 was used and a synthetic daily rainfall sequence over 500 years was generated.
- The current pit catchment was derived from the pit topographic plan provided by site (see Figure 1) and site observations. The measured catchment area is 1.7km^2.
- Annual average runoff coefficients were adopted (based on WRM, 2007) as follows:
    - Runoff from pit walls (1.44km^2) – 90%
    - Runoff from catchment areas outside the pit crest (0.26km^2) – 77%.
- Surface water inflows to the pit were calculated within the GoldSim water balance model, which was set up to assess mine water management options (refer Section 6.1 for further information). GoldSim is a probabilistic simulation model (based on Monte Carlo simulation software) that allows users to create customised models based on built-in functions within the software. The software is well suited for water balance projects.
- The model was run for 100 iterations of rainfall-runoff using different, randomly selected 15-year rainfall sequences (equivalent to the mine life of Lift 1 of the Block Cave), from within the synthetic rainfall data set. The rainfall data set was converted to runoff rates using the catchment areas and runoff coefficient described above to simulate possible rainfall runoff sequences over the 15-year period in each model iteration.

It is assumed that the runoff which is currently predicted to report to the base of the North Pit would report to the Block Cave, through the subsidence zone which will develop above the underground workings, with little to no lag time.

3.2 Results

Runoff rates to the underground were simulated in the GoldSim model using Monte Carlos sampling of a synthetic rainfall data set. The GoldSim model uses daily precipitation values to estimate inflow rates to the pit assuming that each day’s rainfall reports to the extraction point within the pit on the day the rain occurs, and the runoff is spread evenly over whole day (i.e. averaged over the day).

The results of runoff predictions are plotted in Figure 5. Figure 5 shows both the maximum inflow rate across all model iterations predicted on each day, plus the mean inflow rate across the model iterations. The maximum instantaneous inflow rates to the Block Cave are predicted to be up to 2,500L/s, with mean inflow rates ranging from 0L/s to 150L/s. Although not shown in Figure 5, the model also predicts that no run-off to the pit may occur on any given day.

The model also predicts that over the 15-year underground mine life, the estimated probability of inflow to mine exceeding different runoff rates is as follows:

- 50% probability that a flow exceeding 1,300L/s will occur
- 25% probability that a flow exceeding 1,400L/s will occur
- Maximum predicted inflow rate of 2,500L/s

4 GROUNDWATER INFLOWS TO BLOCK CAVE

4.1 Approach

A simple analytical modelling approach was adopted to provide PFS level of confidence estimates of groundwater inflows to the underground mine. More complex modelling approaches (e.g. 3D numerical groundwater flow modelling) were considered, especially given that inflows will, in part, be influenced by the complex 3D geometry of the main cave/subsidence zone and potential flows from the BCFT.

However, our experience in recent years has been that there is rarely sufficient data on, or understanding of, specific hydrogeological features (that control groundwater flow) in fractured rock aquifers, to support the potential benefits of using numerical models. That is, while numerical models can simulate spatial and temporal variability in all model parameters and can simulate multiple lateral and vertical flow paths and the development of underground workings, there is insufficient data to validate/calibrate the models for these specific flows. As a result, and particularly where there is dewatering history available to support model calibration (as is the case with the North Pit) the numerical models are often no more reliable that more simplified analytical modelling approaches.

In fact, in a number of cases where limited data exists (as is the case at Savage River) and where both analytical and numerical models have been run, the results were comparable. There is also a wealth of published research data that supports the use of analytical models in fractured rock environments.

Another contributing factor to groundwater model selection was the expected relative proportion of groundwater and surface water inflows to total mine inflows. Historical data (and some preliminary modelling) indicated that surface water inflows would be one to two orders of magnitude higher than groundwater inflows. As such, uncertainties in the magnitude of groundwater inflows would have minimal impact on the reliability of total mine inflows.

The outcome of our assessment was that a lumped parameter analytical model would provide sufficient predictive reliability for the PFS, especially given the available calibration data.

4.2 Groundwater Inflow Model

4.2.1 Description of Model

The model used is a simple analytical groundwater flow model based on the Dupuit-Forcheimer and Theim Equations for groundwater flow to a large diameter well. Key steps in the modelling are as follows:

- The mine, or various sections of the mine, is represented by a large diameter “equivalent well” (or sequence of wells) of similar base area and depth at various time steps, representing various stages of mine development.
- Average aquifer parameters are applied to the equivalent well(s).
- The model is used to calculate the pumping rate required to maintain pumping water levels in each equivalent well at or below the base of each equivalent well (mine base) at the end

of each time step. This is the analogue equivalent of groundwater inflow to a dewatered mine.

- As the total volume of material to be mined and the specific yield (drainable porosity) of the material will be very low in comparison to the other inflows, the contribution of storage in the mined ore/waste can be ignored in this case.

The model makes a number of other simplifying assumptions including lumped (bulk average) aquifer parameters and radial flow from an aquifer of infinite areal extent. Recharge can either be simulated using boundary conditions or as a constant flux. As such, it cannot be considered as an exact model, but the model does allow for good approximations of bulk mine inflows. In this case, model reliability is improved by calibration data from anecdotal North Pit dewatering records.

4.2.2 Modelling Approach

A two phased approach to the inflow modelling was adopted, as follows:

- Phase 1 – Confirmation of bulk aquifer parameters: The model was set up to simulate the existing inflows to North Pit and the model was run to simulate historical groundwater inflow rates. Aquifer parameters were varied (within limits consistent with the conceptual hydrogeological model – refer Section 2.2.3) until a good match between predicted and observed dewatering was achieved. This process is sometimes called "inverse modelling" and is essentially model validation / calibration.

- Phase 2 – Prediction of Future Mine Inflows: Once bulk aquifer parameters had been derived, these were used in the model set-up to simulate inflows to the future underground mine for the development of first section of the planned Block Cave (Lift 1) from 2020 to 2034.

4.3 Phase 1 – Calibration

The calibration model was set-up to simulate observed long-term inflows to the North Pit. Key features of the model set up are:

- The model extends from 200mRL (average pre-mining water table) down to -100mRL (100m below current base of pit and assumed to be the effective base of the aquifer).

- The pit was represented by a large diameter well extending down to 0mRL and with an equivalent well radius of around 320m (calculated from the average area of the current pit below water table).

- A bulk specific yield of 0.5% was adopted.

- The model was run to predict inflows to the pit after 10 years or mining below water table.

- Two model scenarios were considered during calibration:

    - Transient bulk aquifer radial flow model with no influence from recharge boundaries. In this model, drawdowns were free to extend over time to the calculated radius of pumping (i.e. dewatering) influence in the broad aquifer.

    - Steady state, anisotropic model with flows influenced by recharge boundaries. In this model, the maximum extent of drawdown was fixed at the various identified potential aquifer recharge boundaries. This model also considered two flow components:

  - Flow from the northern and southern quadrants of the overall radial flow field influenced by one bulk permeability.
  - Flow from the eastern and western quadrants of the overall radial flow field influenced by a bulk permeability one order of magnitude lower.

- Both models were run for various adopted base case permeability values, until a match between predicted and observed inflows was achieved.
- The long-term pit inflow rate was assumed to be 15L/s based on reported (anecdotally) end of summer pit sump pumping requirements. That is, total dewatering when there was no direct rainfall runoff and only minor (if any) delayed interflow through the unsaturated zone above the water table.

Appendix A shows the model spreadsheet for the inflow calibration model, including schematic sections (plan and vertical sections) through the model.

Good model calibration was achieved with the following adopted bulk permeabilities:

- Transient radial aquifer model (with no recharge boundaries) – 0.01m/d.
- Steady state, anisotropic model (with recharge boundaries) – 0.015m/d (N-S); 0.0015m/d (E-W).

As a result, either model is considered suitable to provide reliable predictions of future pit inflows. Both models are also considered to be suitable to provide reliable predictions of future inflows to a "non-caving" underground mine, where the mine workings could be represented by simple voids within the mining envelope. However, when taking into consideration the development of the cave/subsidence zone above the block cave mine and the predicted deformation on the margins of the cave/subsidence zone (which sub-crops beneath some aquifer recharge boundaries), the transient radial flow model is not considered appropriate for future inflow predictions. The steady state, anisotropic model can account for expected flows from the BCFT to the cave/subsidence zone and this model was carried forward.

4.4 Phase 2 – Inflow Prediction

4.4.1 Lift 1 Inflows

As outlined above, the calibrated steady-state anisotropic model was carried forward for prediction of inflows to the underground mining operation. There remains some uncertainty as the design (and mining method) for the Lift 2 zone (deepest section of underground mining), so only Lift 1 was modelled as part of this study.

The calibration model (refer Appendix A) was modified to simulate the cave/subsidence zone in general and in particular the development of connected cracking beneath the BCFT. The model spreadsheet for the prediction model (including schematic sections) is shown in Appendix B. Key features of the prediction model setup are:

- The base of the Lift 1 mine workings is at -200mRL.
- The margins and the main cave subsidence zone will roughly parallel but extend laterally further than the final pit walls. The radius of the equivalent well (representing the main cave/subsidence zone) was increased to around 730m to cover the larger effective void.
- Connected cracking at the margins of the main cave/subsidence zone was simulated by a zone of enhanced permeability (one order of magnitude higher than surrounding basement rocks and extending over half the aquifer thickness). This has little impact on inflows from the east, but does provide a direct pathway for enhanced flow from the BCFT (i.e. from the west).
- The base of the aquifer remains at -100mRL. That is, the model simulates groundwater inflows to the upper half of the cave zone only. This is considered realistic as permeability in fractured rock aquifers typically decreases with depth and is minimal at depths of 400m below natural surface. However, a check model was also run to simulate possible deeper flows (refer Section 4.4.3).
- In summary, the model simulates the following inflows:
    - West – inflows from the BCFT to the cave/subsidence zone controlled by the permeability of the enhanced permeability zone.
    - East – inflows from the recharge boundary along Armstrong Creek controlled by the bulk E-W basement rock permeability.
    - North – inflows from the assumed constant head boundary to the north of the mine controlled by the bulk N-S permeability of the basement rocks.
    - South - inflows from the Savage River controlled by the bulk N-S permeability of the basement rocks.

The model was run to predict total inflows at the end of Lift 1 (in 2034 or 14 years after commencement of mining). This is considered the worst case, as it takes most of the Lift I mine life for the deformation (and connected cracking) to propogate to beneath the BCFT. The model predicts:

- Around 85L/s inflows to the cave/subsidence zone (which will then rapidly migrate to the draw works and extraction level of Lift 1).

In one sense, the above approach is considered somewhat conservative in that it assumes that there will be direct hydraulic connection (via connected cracking) between the BCFT along most of the western margin of the model area. In practice, such connection is likely to be limited to a much smaller part of the western margin of the cave/subsidence zone.

However, in another sense, it is possible that the degree of deformation in places might result in localised higher permeability beneath the BCFT and/or might result in some enhanced hydraulic connection to the cave/subsidence zone from South lens pit or the Savage River.

4.4.2 Check Model (for deeper base of aquifer)

As outlined in Section 4.4.1, the inflow prediction model assumed that the effective base of the aquifers (surrounding the cave/subsidence zone) was at -100mRL. While this is considered to be appropriate, a simple check model was run to assess the potential inflows if a deeper aquifer base was adopted. The check modelling process was as follows:

- An aquifer base of -400mRL (base of Lift 2) was adopted.
- The calibration model was modified (for the deeper base of aquifer) and run to derive calibrated bulk permeabilities. The model calibrated to proportionally lower permeabilities as follows:
  - around 0.004m/d for the transient model;
  - around 0.006m/d (N-S) and 0006m/d (E-W) for the steady state anisotropic model.

The prediction model was for the deeper base of aquifer and the calibrated permeabilities listed above.

The check model predicts an inflows of around 80L/s at the end of Lift 1. That is, the model results are largely insensitive to the adopted base of aquifer.

4.5 Groundwater Inflows to Declines

A simple analytical flow model was used to predict potential inflows to the current exploration decline. The model is based on the Goodman et all equations for steady state groundwater flow to a tunnel. Based on the aquifer parameters for the East Wall Block and ECF aquifer zones listed in Table 1, and depths below current water table scaled from mine plans, the following maximum inflows were predicted:

- Long-leg decline in the footwall of the ECF (East Wall Block) – up to 9L/s
- Cross cut through the ECF – 3L/s.

However, these are predicted maximum inflows. As outlined in Section 2.4.3, inflows are likely to decline as immediate fault zones become dewatered and/or depressurised as result of inflows to the decline during development and later to the cave/subsidence zone during mining.

Peak inflows to the full Block Cave access and extraction declines might be marginally higher that the above predictions.

5 INFLOWS FROM BRODERICK CREEK FLOW THROUGH SYSTEM

There are two broad inflows mechanisms from the Broderick Creek Flow Through System (BCFT):

- Leakage through the base of the BCFT via deformation and connected cracking along the margins of the cave/subsidence zone. This is included in the prediction of groundwater inflows (refer Section 4).
- Overflow from the upper parts of the BCFT during periods of high rainfall, flow and BCFT water levels. Overflows of around 600L/s were observed in 2018. This likely reflects the upper limit of overflows under current conditions.

However, if deformation above the Block Cave subsidence zone in the area of the BCFT is greater than currently predicted, this could lead to increased inflows from both of the above inflow mechanisms.

6 CONCEPT MINE INFLOW MANAGEMENT PLAN

A concept mine water management plan has been developed for the PFS. This plan will be refined during the subsequent DFS and Detailed Design Stage of the project, and comprises two broad components:

- Managing inflows from rainfall runoff to the pit catchment (and thence into the cave zone) and base groundwater flows to the cave/subsidence zone including some enhanced leakage from the BCFT through minor connected cracking associated with deformation at the margins of the cave/subsidence zone.
- Potential overflows from the BCFT during high rainfall periods and/or high rates of leakage through the base of the BCFT if significant connected cracking develops along the margins of the cave subsidence zone.

6.1 Rainfall Runoff and Base Case Groundwater Inflows

Instantaneous (daily average) surface water inflow rates to the Block Cave range from 0L/s (non-rainfall days) to up to 2,500L/s. It is not practical to design a dewatering system to account for instantaneous inflows of surface water. A “just in time” dewatering pumping system designed to manage peak inflows would require very large capacity pumps that would only operate at design rates for short periods of time. The more practical approach is to design some buffer storage into the underground mine void and use this storage to balance out required pumping rates. That is, the optimum dewatering system would be designed to run at a fixed maximum rate (much lower than the peak “just in time” rate) sufficient to maintain the buffer storage at full or less than full capacity.

A water balance approach was used to develop the optimum dewatering system pumping rates for various assumed buffer storage volumes. For the purposes of the PFS, this assessment was restricted to the Block Cave Lift 1 development (from 2020 to 2034).

6.1.1 Total Inflow Rates

For the purposes of this assessment, total inflows are assumed to be a combination of:

- The variable rainfall runoff as described in Section 3.2.
- Fixed groundwater inflows of 100L/s. This includes the 85L/s predicted groundwater inflows to the cave/subsidence (as described in Section 4.4) and a conservative allowance of 15L/s inflow to the decline and other access workings (refer Section 4.5).

6.1.2 Inflow Water Balance Model

The GoldSim probabilistic water balance model (described in Section 3.1) was used to assess various dewatering options using the inflows discussed above (fixed groundwater inflow plus variable surface water runoff volumes discussed in Section 3.2). The model assumes that inflow to the Block Cave is stored within the nominal storage voids and the volume of water stored is tracked within the water balance. Different model scenarios were run with pump out rates and storage capacity limitations applied. The following scenarios were run:

- No buffer storage in the underground – sufficient pumping capacity is required to remove runoff and dewatering inflow to the underground instantaneously. This is the "just in time" dewatering case and is presented for reference only.
- Lift 2 decline can be flooded – 30,000m^3 buffer storage available underground to run the pump out system.
- Lift 2 decline + 1 stope can be flooded – 60,000m^3 buffer storage available underground to run the pump out system.
- Lift 2 decline + 2 stopes can be flooded – 90,000m^3 buffer storage available underground to run the pump out system.

The water balance was used to determine what pump out rate would be needed to prevent stored water volume exceeding the underground buffer storage capacities for each scenario. Required pump out rates were determined for different rainfall exceedance probabilities (50%, 75% and 95%) over the 15-year mine life.

The results are shown in Table 2, and graphically in Figures 6 to 8. To further explain the meaning of the results, using the 30,000m^3 buffer storage volume as an example:

- A 1,000L/s pump out rate was predicted to result in the 30,000m^3 buffer storage capacity being exceeded during the 15-year mine life in 50% of the model iterations which were run,
- A 1,150L/s pump out rate was predicted to result in the 30,000m^3 buffer storage capacity being exceeded during the 15-year mine life in 25% of the model iterations which were run.
- A 1,950L/s pump out rate was predicted to result in the 30,000m3 buffer storage capacity being exceeded during the 15-year mine life in 5% of the model iterations which were run.

Table 2: Underground Pumping Rates Required to Maintain Buffer Storage Volumes

Buffer Storage Volume (m^3)	Required Pumping Rate (L/s) to Maintain Buffer Storage Below Capacity		
	50% Exceedance Probability	25% Exceedance Probability	5% Exceedance Probability
0	1,260	1,390	2,200
30,000	1,000	1,150	1,950
60,000	670	800	1,600
90,000	470	540	1,250

6.1.3 Dewatering System Requirements

From the data provided in Table 2, the pumping capacity of the dewatering system required to remove the water from the underground with a certain risk of exceedance can be determined. For example, for a 60,000m^3 buffer storage in the underground equipped and an 800L/s dewatering system capacity, there would be a 25% chance of the storage capcity being exceeded (and some flooding of lower active mine workings) being exceeded over the 15-year operating life.

It is noted that AECOM (2019) developed a concept design for the underground dewatering system. The AECOM design assumed a total groundwater inflow of 130L/s to account for groundwater inflows and leakage from the BCFT. The assumed total inflow was based on estimates provided by AQ2 at the time (May 2019) which included 30L/s general groundwater inflows and 100L/s leakage from the BCFT. We have since revised estimates of groundwater inflows (refer Section 4) to account for predicted deformation to 100L/s (including leakage from the BCFT).

The AECOM concept design system included a pumping capacity of 640L/s based on an assumed buffer storage capacity of 180Mm^3 to cater for a 100-year event (which has an approximately 15% probability of occurring over the 15-year operating period). This concept design is consistent with our water balance for the adopted buffer storage and exceedance probability.

6.2 Overflows and/or High Leakage from Broderick Creek Flow Through System

There are two broad inflow risks to the underground operations to the Broderick Creek Flow Through (BCFT) system.

- Overflow to Pit Wall: During high rainfall and high BCFT flow periods, the BCFT can overflow to the pit as it did in 2018 and has recently begun doing in 2019. There is an interception system currently in place – West Wall Dewatering System (WWDS) but there is the possibility that the WWDS might get "damaged" by surface deformation and cannot be repaired because it is inside an exclusion zone. It is also noted that "inflows from the BCFT in 2019 have resulted in the erosion of the pit wall above the WWDS and there has been some erosional undercutting of the lined collection berms.
- High Leakage through Base: The longer-term (and potentially more serious) issue is the potential for moderate to high levels of deformation and connected cracking to sub-crop beneath the BCFT, which could lead to a significant proportion of flow in the BCFT draining directly into the cave/subsidence zone above the Block Cave, and by-passing the West Wall Dewatering System.

Concept level options to manage both broad risks are outlined below:

6.2.1 Overflow to Pit Wall

There are two potential conditions that need to be considered, based on the ongoing performance of the West Wall Dewatering System (WWDS):

- The WWDS is not affected by subsidence and remains effective.
- The WWDS fails.

If WWDS Remains Effective

In this scenario, surface deformation in the area of the WWDS is only minor such that the WWDFS remains largely effective. However, some preparation will be required prior to development of the Block Cave (while safe access is still available) to maintain operation, including:

- Stabilising the pit wall beneath the "waterfalls" to reduce erosion and the potential for undercutting the collection sumps. This could simply involve shotcreting, but might also some increased level of stabilisation (e.g. mesh support to strengthen any shotcreting).
- Cushioning the tanks-pipework system against differential settlement. This would simply include providing adequate pipework and/or flexible couplings, so that any differential settlement does not result in the pipework or the pipe-tank connections parting.

As part of this assessment, other options were also considered including a lined open drain system from the catch sumps to South Lens Pit following a constructed even fall. However, it is considered that, if there is sufficient deformation/settlement to damage the current WWDS, it would also damage any open/lined drain system. In fact, the existing WWDS is considered to be more robust than a lined drain.

If WWDS Fails

If the WWDS fails (due to either settlement or excessive erosion), it is assumed that there will be no safe access for repairs as the Block Cave subsidence exclusion zone would extend to the area of the failed WWDS. If this occur, then some other form of flow interception will be required to reduce the flow of water to the pit and Block Cave during high rain fall/flow periods. Three options were considered, although as outlined below, only two options (Options 1 and 2) are considered practical. It is noted that Options 1 and 2 are really just different levels of the same basic concept. The options considered were:

- Option 1: Pumping from the creeks upstream of the BCFT. This scheme would involve:
    - Extracting water from the natural ponds that form in the two tributaries of Broderick Creek upstream of the two arms of the northern BCFT.
    - Pumping water via a HDPE pipeline (nominally 600mm diameter pipe) up over the western waste-dump to a high point some 3km to the south and then by gravity drainage to the BCFT discharge point on the Savage River around 1km to the south of the high point.
    - Operation of the system would be triggered by water levels in the existing (and new) BCFT monitoring bores and the required pumping rate would fluctuate depending on rainfall/streamflow and the bore water levels. However, the pumping capacity would need to be at least 600L/s based on observed inflows to the west wall of the pit from the BCFT in 2018.
- Option 2: Pumping from Dams at the upstream of the BCFT.
    - This is broadly similar to Option 1, except that dams would be formed by placing low permeability material (compacted clays or synthetic liners) against the upstream batters/berms of the northern BCFT to low-leakage storages.
    - The advantage of Option 2 over Option 1 is that the buffer storage capacity provided by the dams would allow for a lower peak pumping capacity with pumps operating at lower rates, but more constantly (than for Option 1), to maintain water levels in the dams below design levels. Figure 9 shows a concept plan for Option 2.

- Option 3: Installation of interception/dewatering wells into the BCFT adjacent to and just upstream of the “waterfalls”. However, this is considered impractical for the following reasons:
  - The system would need to have a minimum capacity of 600L/s.
  - The practical limit for submersible pumps is around 60 to 70L/s each (and the cost of such pumps, cables and controls is high).
  - This would require nine to ten large diameter bores/wells (300mm diameter cased bores as a minimum). Drilling costs through BCFT material would also be very high.
  - Target bore locations may also be subject to deformation (and damage to bores) in the longer term.

It is noted that that failure of the WWDS is only an issue during high rainfall and flow periods, when water levels within the BCFT rise to above the waterfall levels. However, overflow from the BCFT to the pit has now occurred in the two years since Cutback 5 took place in the pit (2018 and 2019) and has a high probability of occurring multiple times during the life of the underground mine.

6.2.2 High Leakage Through Base of Broderick Creek Flow Through System

If sufficient connected cracking develops beneath the BCFT to allow for large volumes of leakage directly to the Block Cave subsidence zone, the only practical options to control/intercept such flows is Option 2, as described in Section 6.2.1. This is because any flow through the BCFT (even flows at levels below those that would result in overflow to the waterfalls) would leak into the Block Cave.

6.3 Recommended Mine Water Management Plan

The recommended concept mine water management scheme for the proposed underground mining operations scheme includes the following:

6.3.1 Rainfall Runoff and Groundwater Inflows from Surrounding Aquifers:

The recommended scheme to cover all potential inflows from these sources includes:

- The development of buffer storage voids below the level of active ore extraction and movement.
- Dewatering pumps (and reticulation system) operating at semi-constant rates required to maintain water levels below the active mine workings at a confidence level determined by Grange Resources (i.e. what probability of flooding the lower mine workings and for how long, are acceptable following peak storm events).

The detailed design will be critically dependent on the available buffer storage and the level of confidence adopted. These will need to be refined during the DFS as the mine design is further refined.

6.3.2 Broderick Creek Flow Through System:

The recommended scheme to cover all potential inflows from this source includes:

- Current WWDS with some upgrade modifications to make it more robust under minor deformation conditions.
- Upper Broderick Creek Diversion Scheme (Option 2).

Both schemes should be in place prior to the initiation of the Block Cave, although the Upper Broderick Creek Diversion Scheme may not be required to operate until such time as the WWDS cannot manage overflows from the BCFT, or until connected cracking beneath the BCFT leads to uncontrolled leakage.

Monitoring of the BCFT monitoring bores will provide some advanced warning of water level and flow conditions on the BCFT that will lead to overflow, but there would not likely be sufficient lead time to install the Upper Broderick Creek Diversion Scheme based on trigger monitoring data.

It is noted that the results of ongoing deformation modelling for the current (and possibly modified) mine plans will be critical in confirming the options for the water management scheme.

It is also noted that, as part of the DFS, detailed civil engineering assessment would be required to confirm practical options for dam construction (and residual dam leakage to the BCFT) and more detailed hydrological analysis and water balance modelling would be required to confirm the optimum pump and pipeline capacity.

7 POTENTIAL IMPACTS OF MINE INFLOW MANAGEMENT PLAN

The potential impacts of the recommended mine water management scheme on local and regional water resources are as follows:

- Rainfall runoff to the pit (and then underground) will be no more than currently experienced.
- Runoff to the pit (and underground) will be returned to Savage River via South Lens Pit and so runoff interception by mining will have little to no impact on regional river flows.
- Groundwater inflows from surrounding aquifers will be sustained by leakage from the aquifer boundaries (Savage River, Broderick Creek, Upper Broderick Creek and Armstrong Creek). Groundwater inflows will also be returned to the Savage River via South Lens Pit and so groundwater inflows will have little to no long-term impact on regional river flows.
- Drawdowns in groundwater levels as a result of mine inflows will be constrained to the immediate mine area and are not likely to be measurable beyond the aquifer recharge boundaries (Savage River, Broderick Creek, Upper Broderick Creek and Armstrong Creek).
- Overflows from the Broderick Creek Flow Through System to the pit (and underground) will also be returned to Savage River via South Lens Pit and so runoff interception by mining will have little to no impact on regional river flows.
- Any water pumped from the Broderick Creek Diversion Scheme (if required) will be returned directly to the Savage River at the existing Broderick Creek Flow Through System discharge point and will have little to no impact on regional river flows.
- Discharge from the Broderick Creek Diversion Scheme will have the same water quality as the Upper Broderick Creek. This will be somewhat different to current discharge from the Broderick Creek Flow Through System which is slightly alkaline due to passage through the magnesite material that makes up the Type A fill (main flow pathway). As such, the pH of overall discharge from Broderick Creek to the Savage River will be closer to neutral. This is not considered to be an impact, but merely a change.

Overall, the potential impacts of the mine water management scheme are considered to be negligible.

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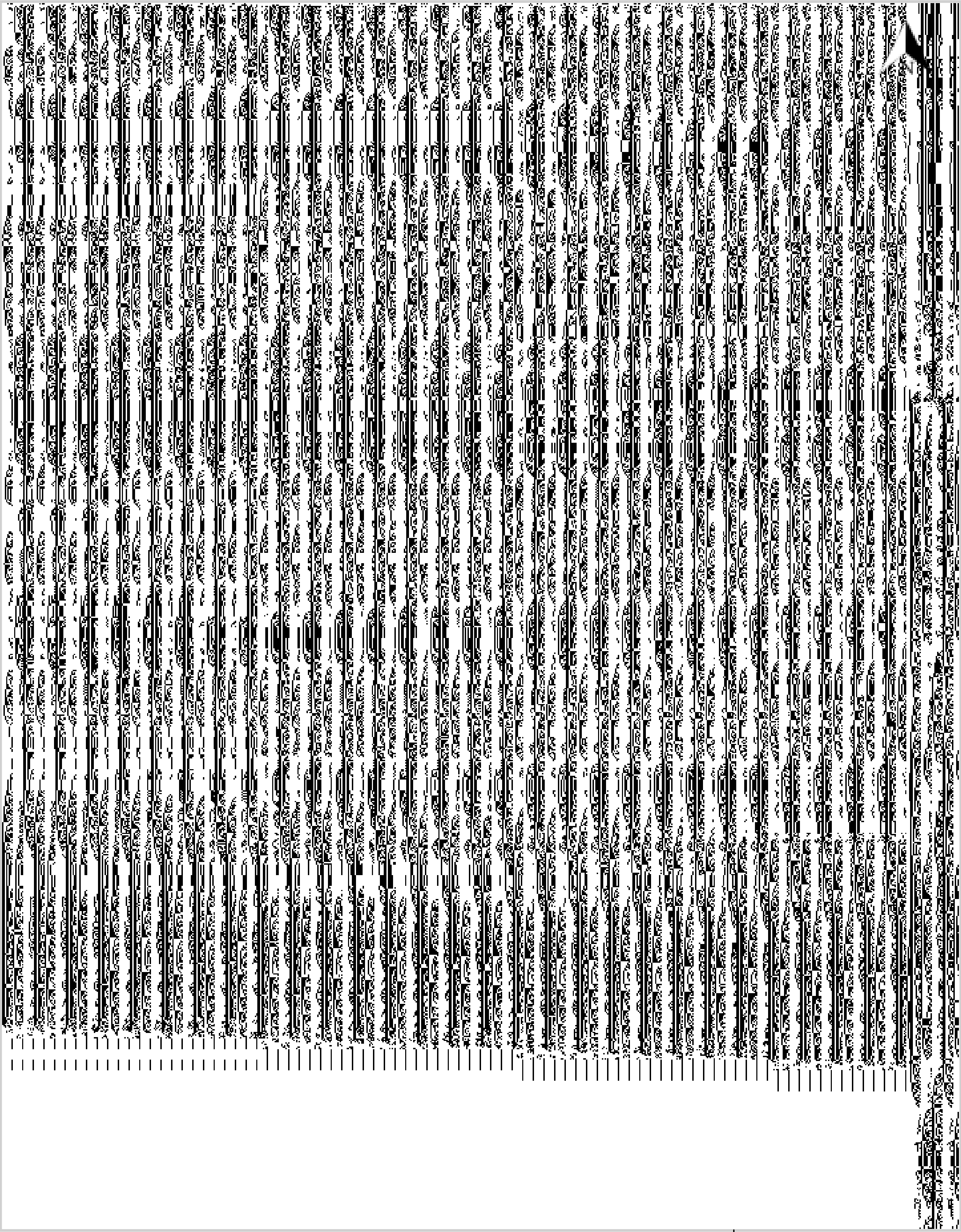
FIGURES



KEY

Elevation (mAHD)

382	351	319	279	232	-12
370	342	307	267	195	
360	333	294	250	150	

FIGURE 1

NORTH DEPOSIT PIT CATCHMENT

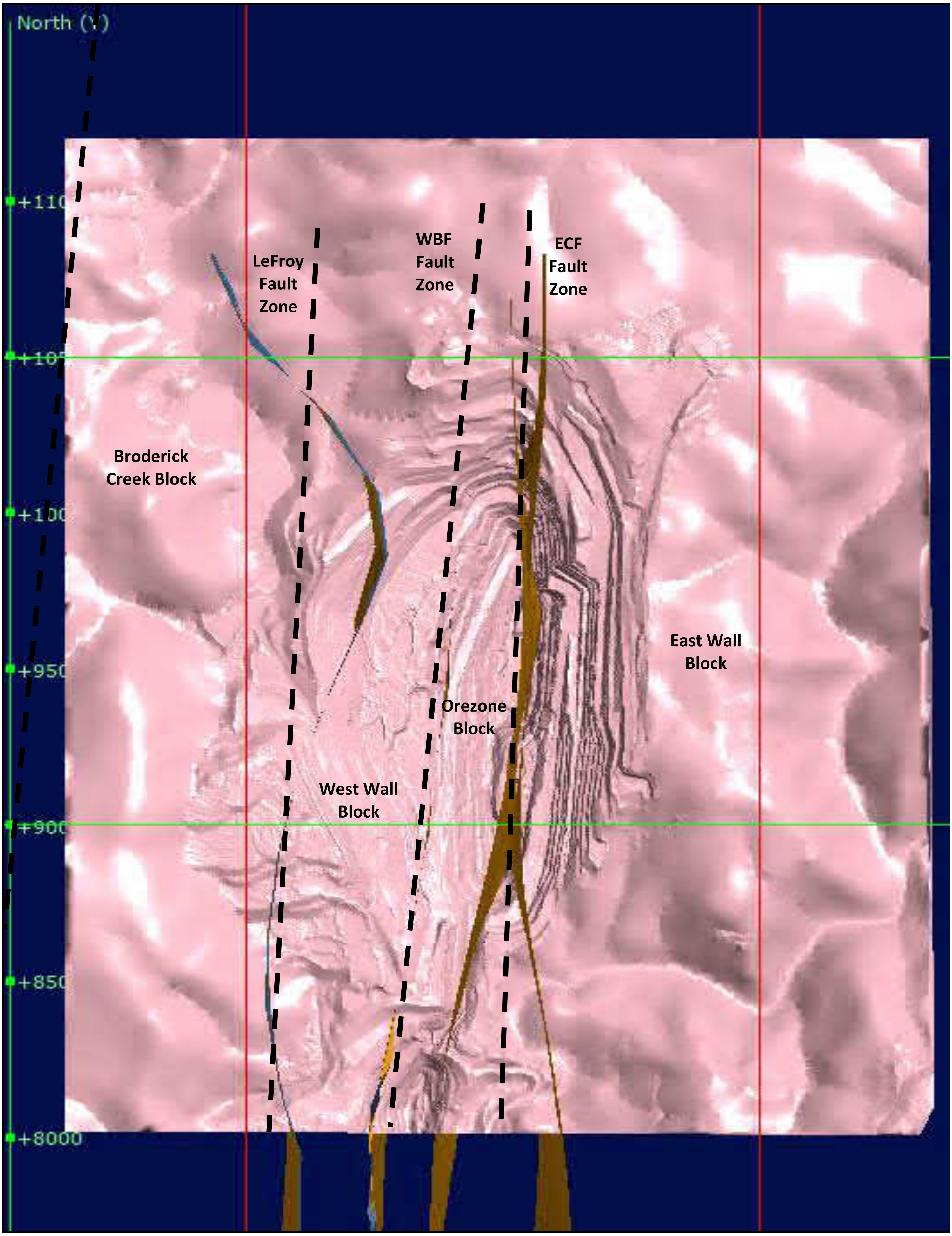
AUTHOR: JH

DRAWN: LC

DATE: 31/07/2019

REPORT NO: 020

JOB NO: 209



AQ2

Hydrogeological Block Model Main Aquifer Units - Plan FIGURE 2

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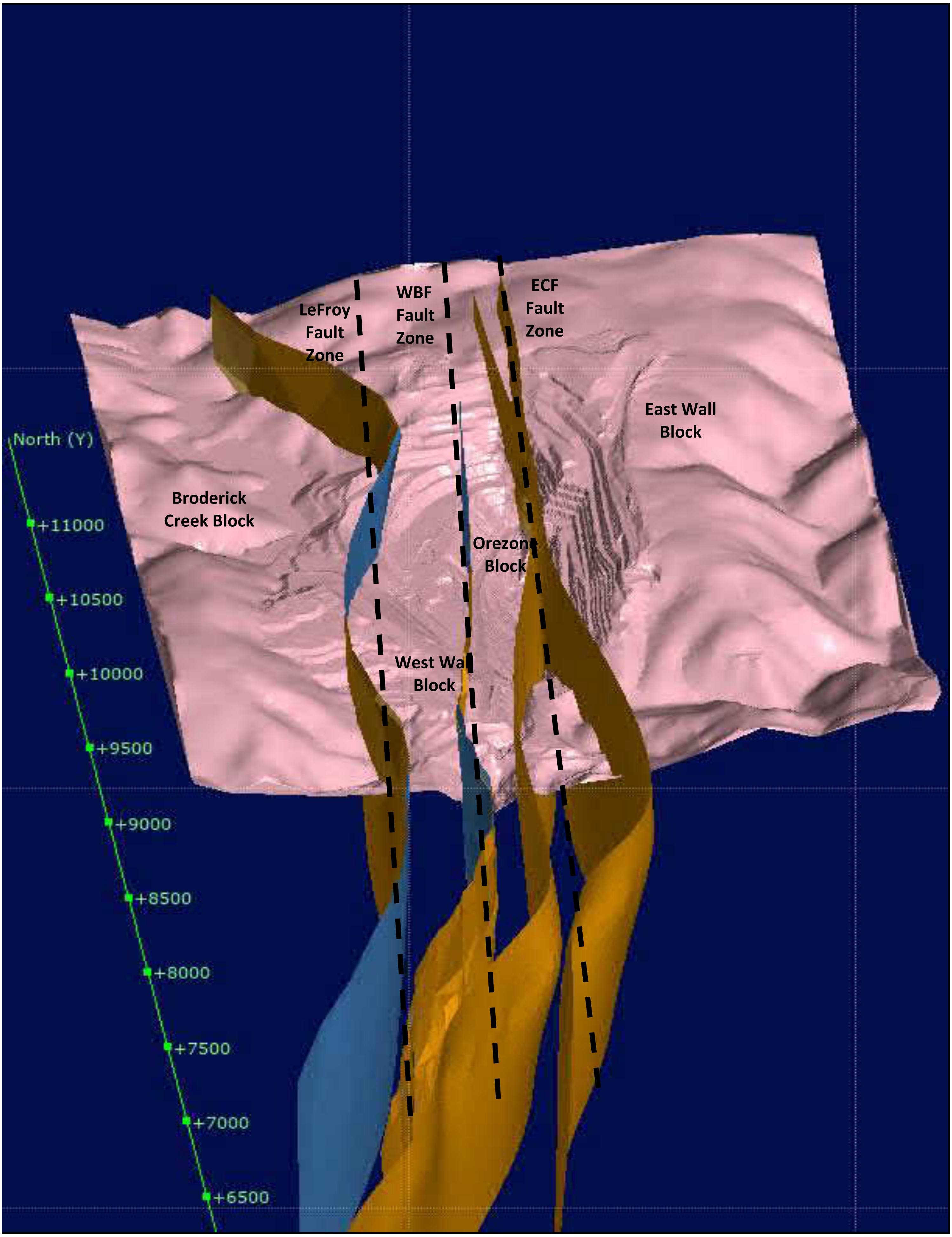

Hydrogeological Block Model Main Aquifer Units - Oblique View FIGURE 3

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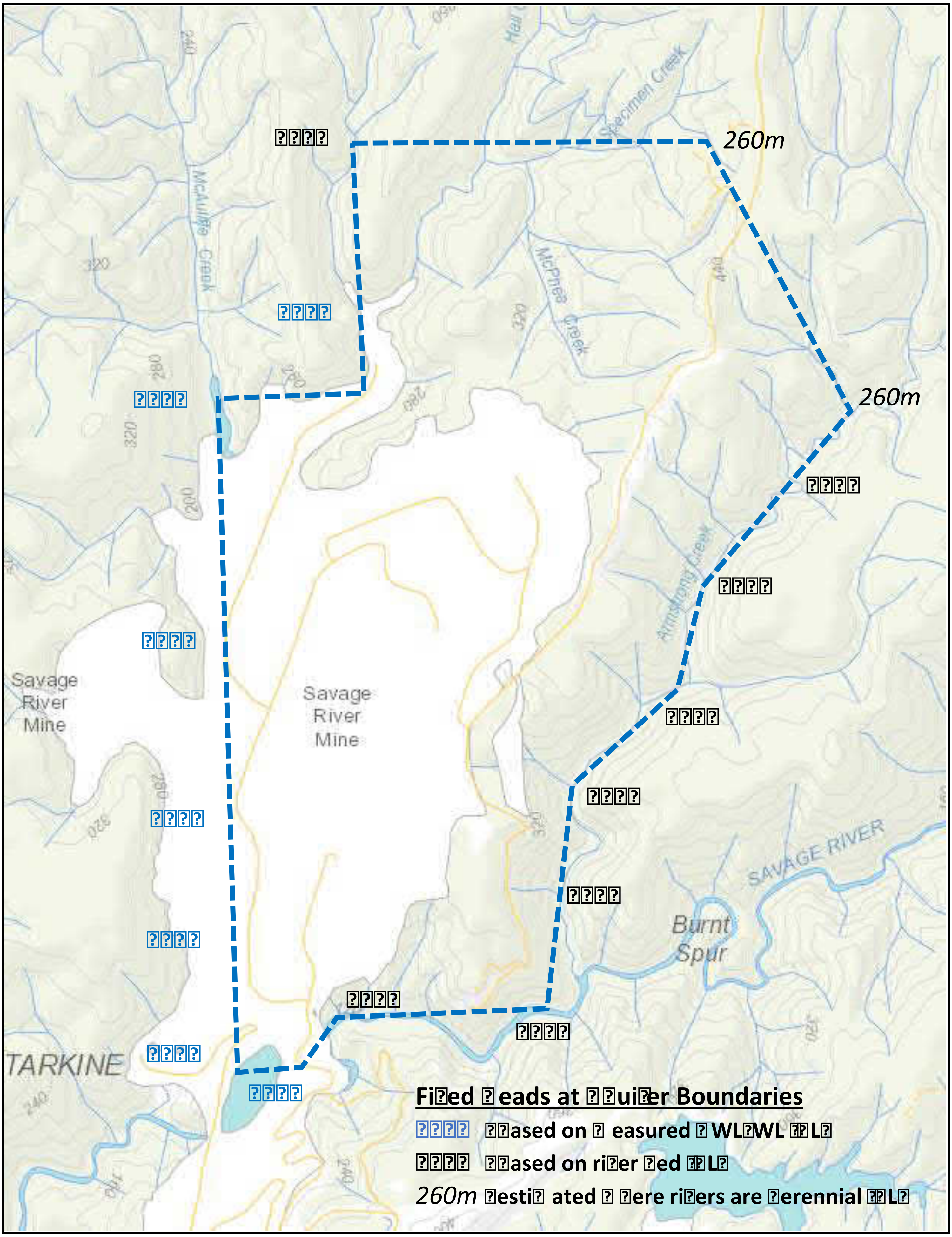

Aquifer Boundaries for Inflow Predictions FIGURE 4

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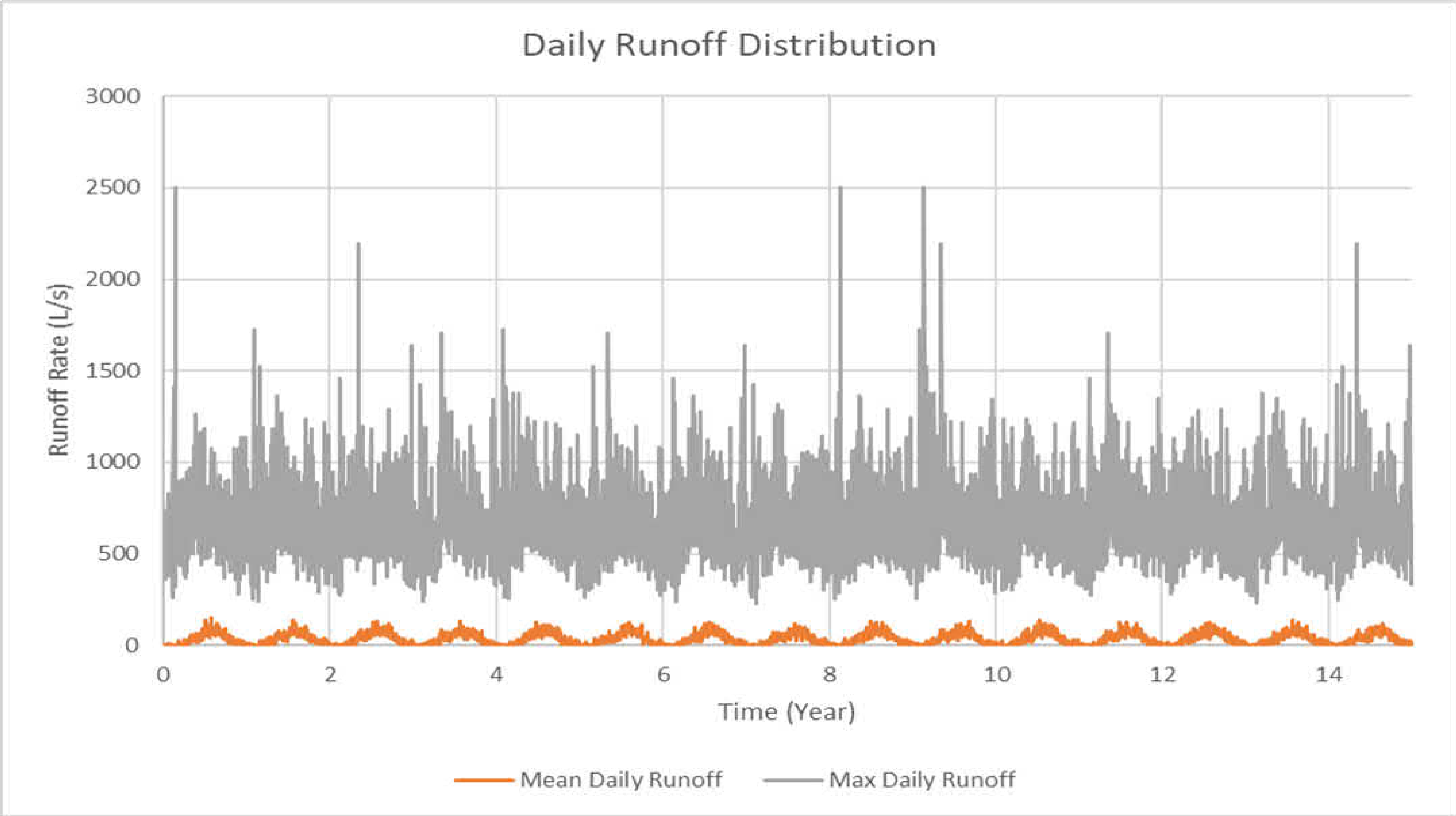

Predicted Rainfall Runoff to NPUG FIGURE 5

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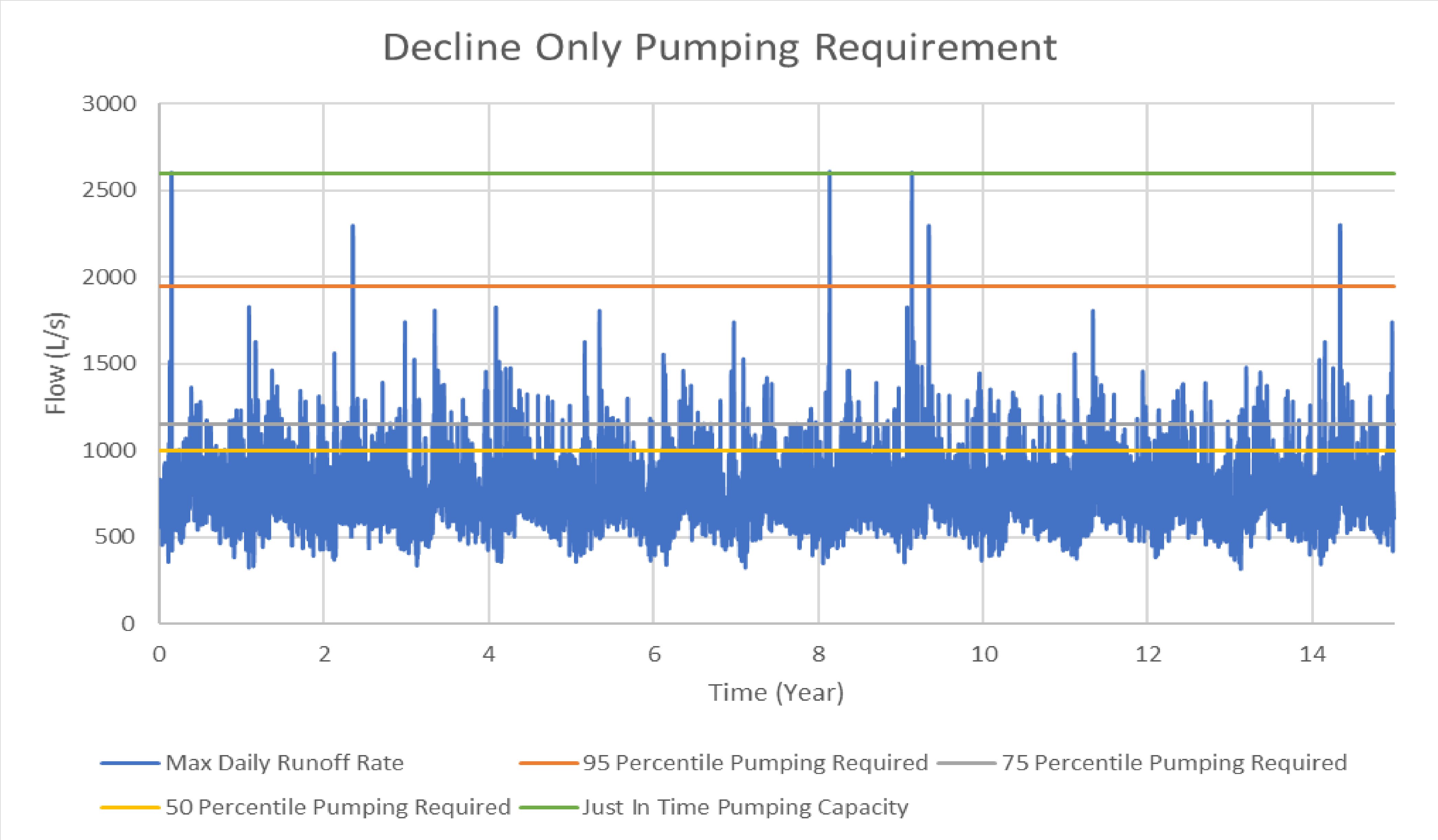
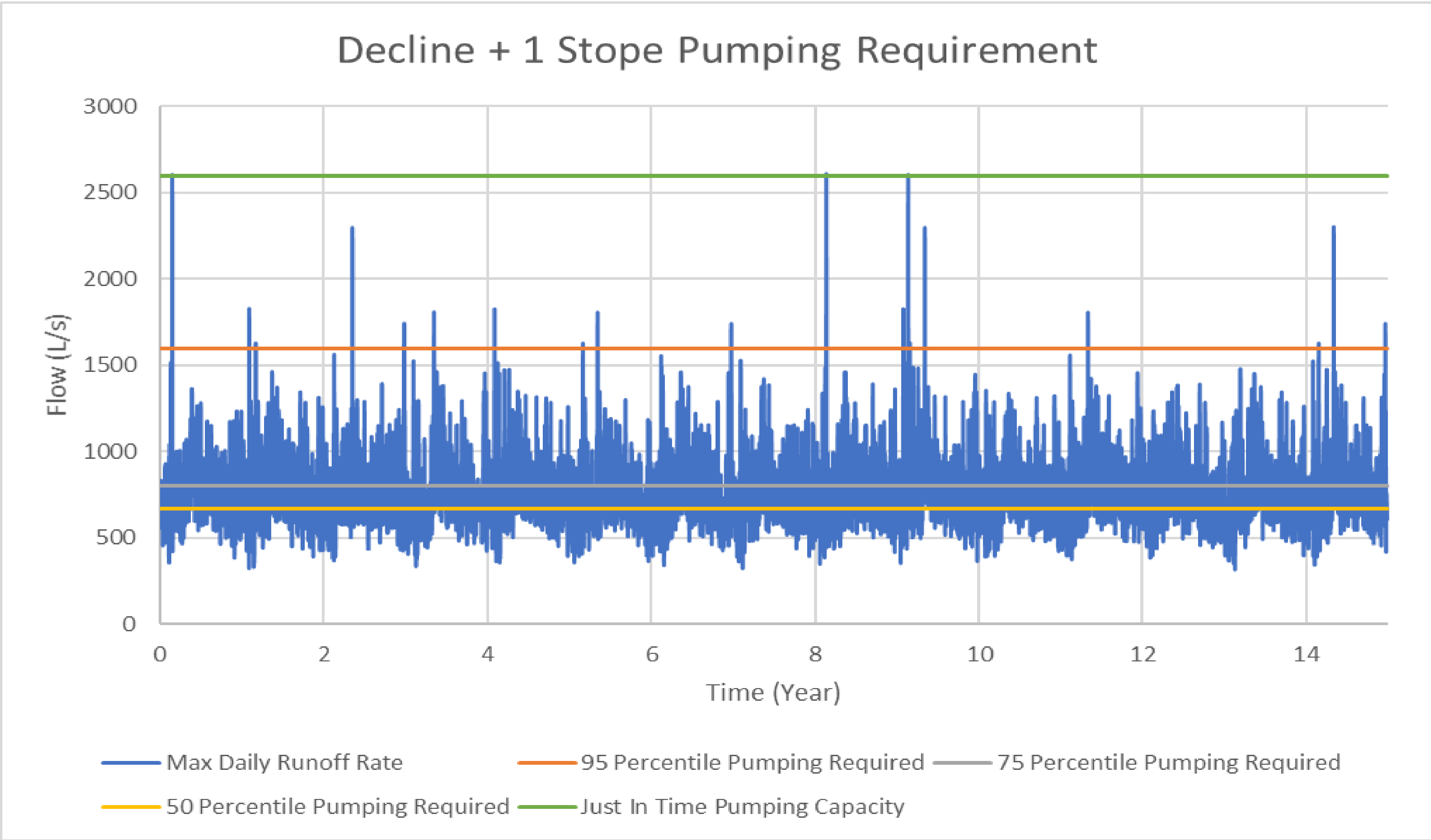


Water Balance Results: Decline Only FIGURE 6



Water Balance Results: Decline + 1 Stope FIGURE 7

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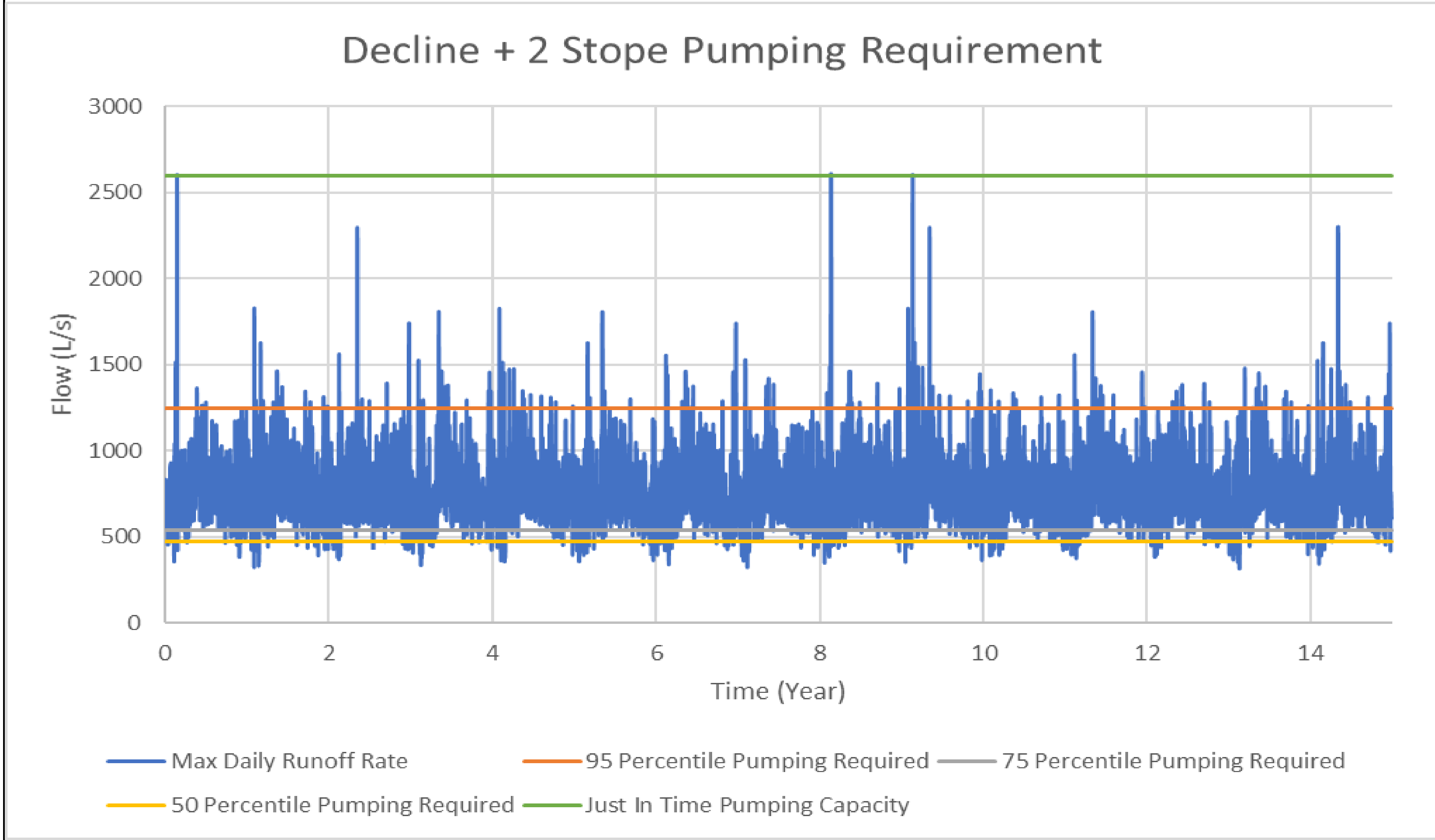

Water Balance Results: Decline + 2 Stope FIGURE 8

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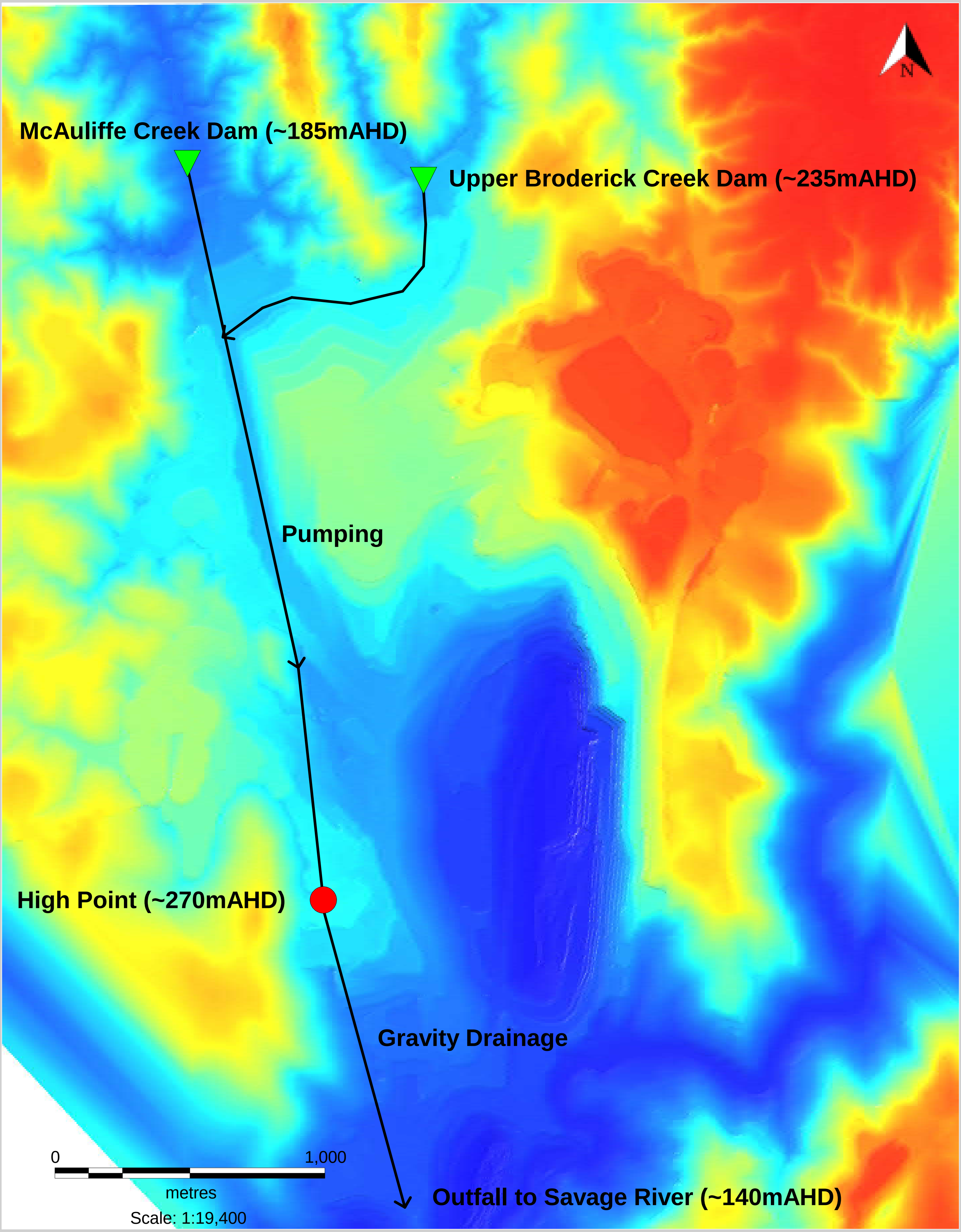


KEY

Elevation (mAHD)

382	342	294	232
370	333	279	195
360	319	267	150
351	307	250	-12

Upstream BCFT Dam & Pump

Transfer Tank

HDPE_Pipe

AUTHOR: JH DRAWN: LC DATE: 31/07/2019	REPORT NO: 020 JOB NO: 209	FIGURE 9	**BRODERICK CREEK DIVERSION - OPTION 2 (SCHEMATIC)**

AQ2

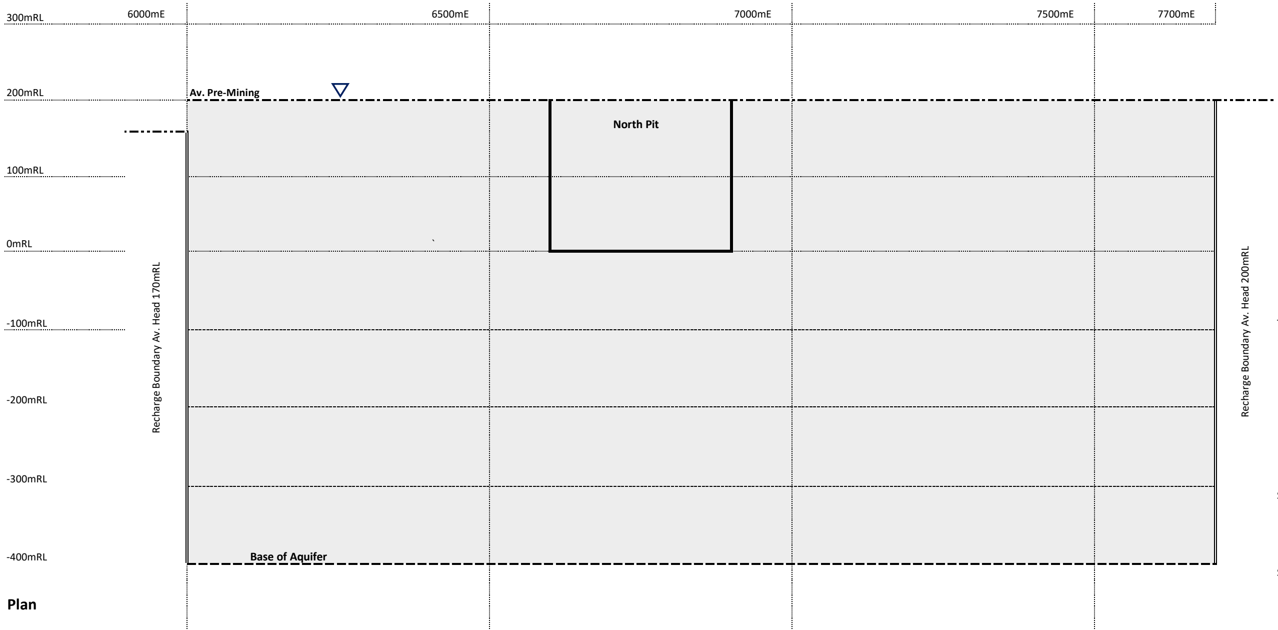
APPENDIX A

Groundwater Inflow Calibration Model

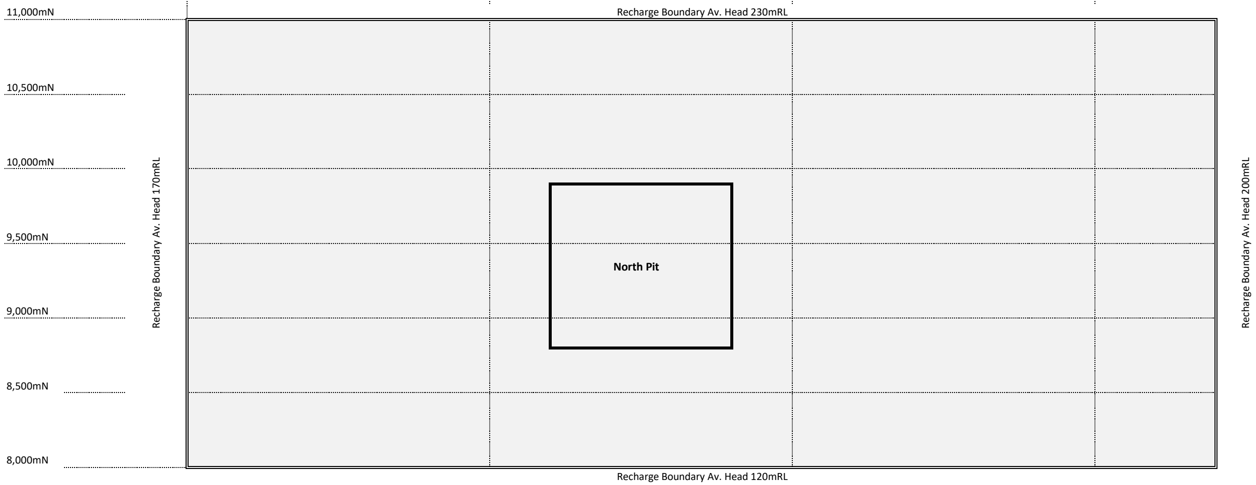
Conceptual Hydro Model and Calibration Model (Pit Inflows)

Conceptual Model

Section



Plan



Q=pi.k.(ho^2-hw^2)/ln(ro/rw)

Q=inflow or outflow from large diameter well or pit (kL/d)
k=hydraulic conductivity (m/d)
ho=height of SWL above base of aquifer (m)
hw=height of depressed water level in bore or pit (m)
rw=radius of well or equivalent radius of pit (m)
ro=radius of max extent of cone of drawdown (m)=SQRT(2.25.k.ho.t/Sy)
t=time since pumping or inflow started (days)
Sy=specific yield

SWL (mRL)	200	
Base Pit (mRL)	0	
Base of Aquifer (mRL)	-100	
Observed inflows (L/s)	20	"high" estimate only
Base area of effective pit (m2)	330,000	Pit is 300m (W) by 1,100m (L)

Bulk Aquifer Model

Basement Inflow Calcs - Bulk aquifer

Transient Model	k (m/d) =	0.0035		Calibrated
	ho (m) =	600		
	hw (m) =	400		
	rw (m) =	324		
	t (days) =	3650	(yrs)	10
	Sy=	0.005		Adopted
	ro (m) =	1857		Calculated
	Q (kL/d) =	**1260**		
	Q (L/s) =	**14.6**		

Anisotropic Aquifer Model

Steady State Model (N-S)	k (m/d)	0.0055	Calibrated K
	ro (m) =	1500	Fixed - based on avereage distance to north-south recharge boundaries
	Q (kL/d) =	**1128**	50% flow from N and S boundaries
	Q (L/s) =	**13**	
Steady State Model (E-W)	**k (m/d)**	0.00055	0.1 x k (N-S)
	ro (m) =	850	Fixed - based on avereage distance to east-west recharge boundaries
	Q (kL/d) =	**179**	50% flow from E and W boundaries
	Q (L/s) =	**2**	Also assumes K (east-west) = 0.1 K(north-south)
Steady State Model (Total Inflow)			
	Q (kL/d) =	1307	
	Q (L/s) =	**15**	Estimated Flow - currently around 15L/s

Notes

Needs k (N-S) of 0.14 to predict 15L/s

Needs k (bulk) of 0.15 to predict 20L/s

Needs k (N-S) of 0.18 to predict 15L/s

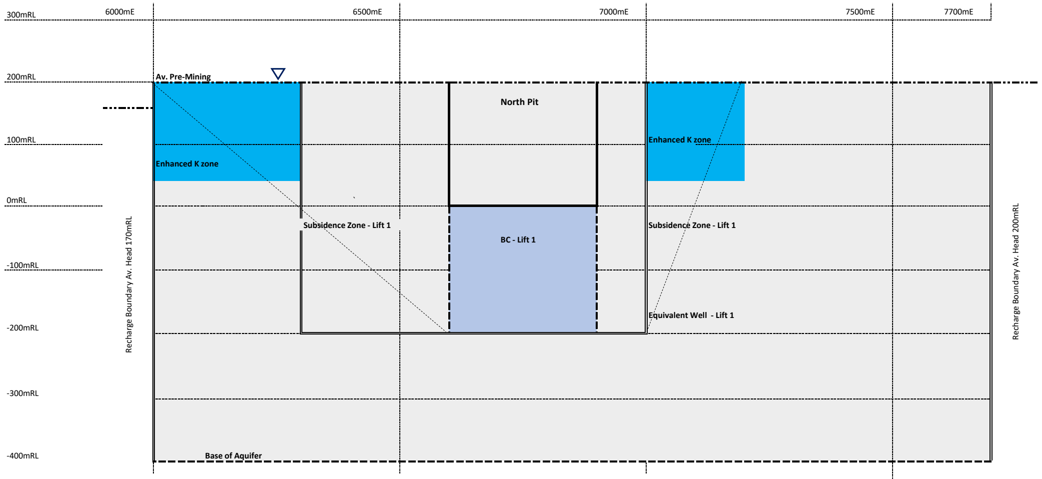
APPENDIX B

Groundwater Inflow Prediction Model
(Block Cave)

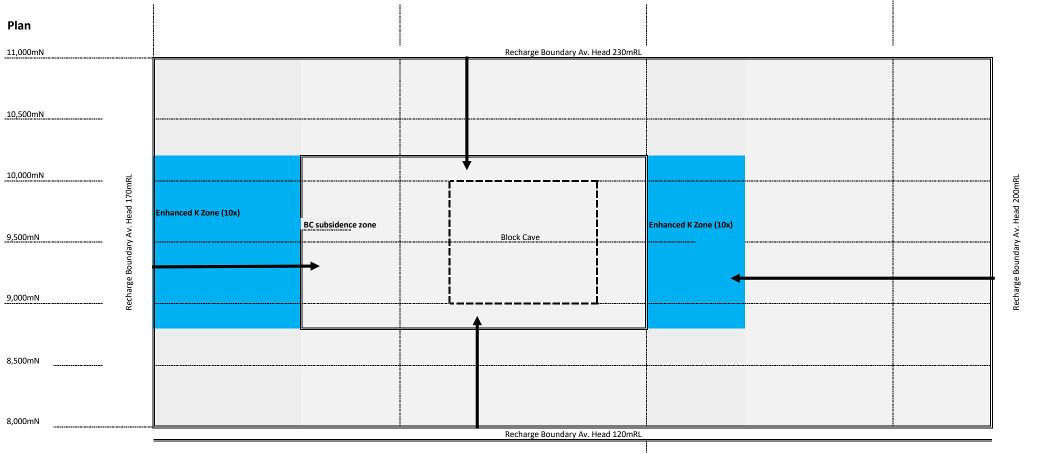
Conceptual Hydro Model and Prediction Model (Block Cave - Lift 1)

Conceptual Model

Section



Plan



Q=pi.k.(ho^2-hw^2)/ln(ro/rw)

Q=inflow or outflow from large diameter well or pit (kL/d)
k=hydraulic conductivity (m/d)
ho=height of SWL above base of aquifer (m)
hw=height of depressed water level in bore or pit (m)
rw=radius of well or equivalent radius of pit (m)
ro=radius of max extent of cone of drawdown (m)=SQRT(2.25.k.ho.t/Sy)
t=time since pumping or inflow started (days)
Sy=specific yield

SWL (mRL)	200	
Base Block Cave (mRL)	-100	Set at base of aquifer
Base of Aquifer (mRL)	-100	
Base area of effective well (BC + Enhanced	1,680,000	BC Well is is 1200m (W) by 1,400m (L)

Bulk Aquifer Model - well radius increased to cover enhanced K zone, and assume enhanced K is infinite.

Basement Inflow Calcs for Lift 1 - Bulk aquifer

	k (m/d) =	0.0035			Calibrated value	
	ho (m) =	600				
	hw (m) =	200				
	rw (m) =	731				Increased to simulate enhanced K zone
	t (days) =	5110	(yrs)	14		Assume BC Lift 1 from 2020 to 2024
	Sy=	0.005			Adopted	
	ro (m)=	2197			Calculated	That is, no recharge boundary
	Q (kL/d) =	3198				
Transient Model	**Q (L/s) =**	**37**			Does not account for flow from any recharge boundary	

Anisotropic Aquifer Model - modified to simulate flow from each side

Steady State Model (N-S)	K (m/d)	0.0055	Calibrated value
	ro (m) =	1500	Fixed - based on avereage distance to north-south recharge boundaries
	Q (kL/d) =	**3848**	50% of caslculated radial flow
	Q (L/s) =	**45**	Flow through calibrated K aquifer
Steady State Model (flow from W)	ro (m) =	850	Fixed - based on distance to west recharge boundary
	Q (kL/d) =	2296	25% of calculated radial flow
	Q (L/s) =	**27**	Assumes natural K (east-west) = 0.1 K(north-south) but enhanced (x10) over top 25% of aquifer (av enhancment is x 2.5)
Steady State Model (flow from E)	ro (m) =	850	Fixed - based on to east-west recharge boundary
	Q (kL/d) =	919	25% of calculated radial flow
	Q (L/s) =	**11**	Also assumes effective K (east-west) = 0.1 K(north-south)
Total	Q (kL/d) =	7063	
Steady State Model (Total Inflow)	**Q (L/s) =**	**82**	

Notice of Intent - Savage River Mine: North Pit Underground Operations

Pitt & Sherry (Operations) Pty Ltd
ABN 67 140 184 309

Phone 1300 748 874
info@pittsh.com.au
pittsh.com.au

Located nationally —
Melbourne
Sydney
Brisbane
Hobart
Launceston
Newcastle
Devonport
Wagga Wagga

Contact

David Lenel
03 6210 1485
dlenel@pittsh.com.au