APPENDIX 1: HYDROGEOLOGICAL SUMMARY OF THE GRUYERE GOLD PROJECT (PENNINGTON SCOTT 2016)

Gold Road Resources Limited

Hydrogeology Summary

Gruyere Project

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Gold Road Resources Limited

Hydrogeology Summary

Gruyere Project

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Rev 0	25 Feb 2016	Draft provided to Gold Road and MBS for review
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1. INTRODUCTION

Gold Road Resources Limited is seeking to develop the Gruyere gold project on the Yamarna Pastoral Station approximately 150 km ENE of Laverton in the Great Victoria Desert region of Western Australia (Figure 1-1). The project will include development of a 380m deep open pit, a 7.5 mtpa carbon in leach (CIL) plant, an integrated waste dump and tailings storage facility, an air strip and 400 person accommodation village. The project will be developed over a 15 year life, which includes a 2 year construction phase, followed by a 13 year operational phase.

This document provides a summary of the key water supply and hydrogeological issues associated with the project as supporting information for the EPA referral.

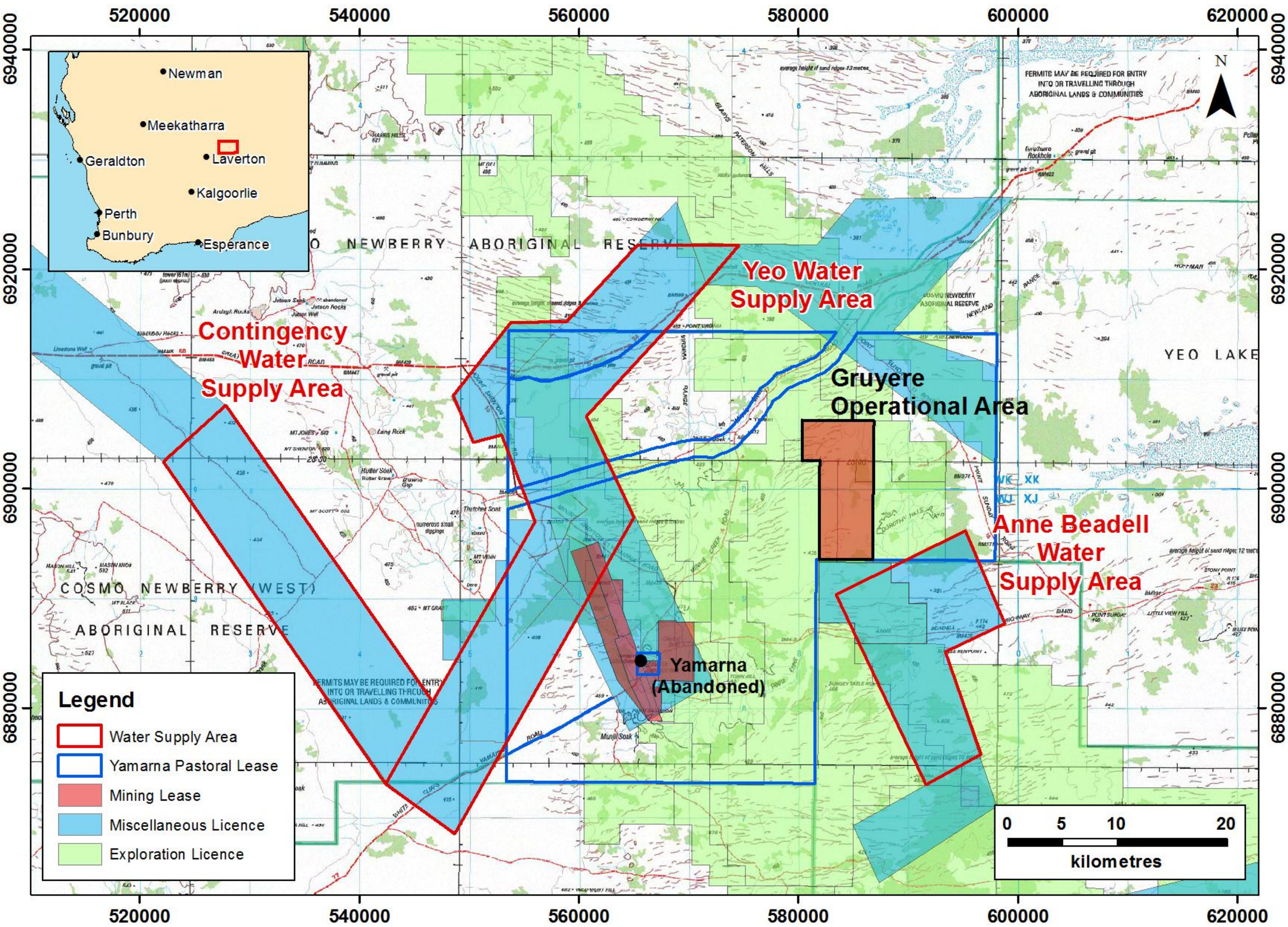

Figure 1-1 Location Plan

2. PROJECT WATER SUPPLY

2.1 Project Water Demands

The Project mining and processing activities will be conducted on the area covered by Mining Lease Application M38/1267 (Figure 1-1). The Project will require water resources during the development and operational phases. Table 2-1 summarises the anticipated water requirements for a number of different purposes over the life of Project.

Table 2-1: Summary of the Project's Water Requirements

Year	Phase	Water Use	Minimum Demand (kL/d)	Minimum Quantity (GL/yr)	Requirement
1 to 2	Construction	Soil compaction	1,200	0.4	Hypersaline
1 to 2	Construction	Concrete batching	400	0.1	Fresh
1 to 15	Construction & Mining	Dust suppression	1,200	0.4	Hypersaline
1 to 15	Construction & Mining	Administration and camp	120	0.2	Fresh
3 to 15	Mining only	Mineral processing	20,547	7.5	Hypersaline
3 to 15	Mining only	Elution circuit	400	0.1	Fresh

During the construction phase, the Project will require 120 kL/d of fresh water to support the village and administration offices, plus a further 400 kL/d for concrete batching in the Project area during the construction phase. A further 2,400 kL/d of hypersaline quality process water will be needed for soil compaction and dust suppression in the Project area and regionally on access roads, pipelines and at the airstrip. This water could be of any salinity up to and including being hypersaline quality.

The demand for fresh water will remain constant through into the operational phase as the water demand for concrete batching in the construction phase is replaced by a similar amount for use in the elution circuit at the CIL plant during the operational phase.

During the operational phase, the demand for hypersaline water will increase almost tenfold to an estimated total of 7,900,000 kL/yr, including 7,500,000 kL/yr for mineral processing and 400,000 kL/yr for dust suppression. The process water could be of any salinity up to and including hypersaline quality. However, the operational cost of reagents is optimised if the salinity is kept to less than 100,000 mg/L TDS. The Process water demand is expected to be highest at the beginning of the operational phase due to the following:

- Process plant throughput rates are expected to be highest during the processing of the oxide and transitional ore types;
- Processing of oxide and transitional ores will require highest water requirement due to lower slurry densities (45% and 47% respectively versus 50% solids (w/w) for the fresh ore) in the CIL circuit; and
- There will be no or very low decant return water from the TSF in the first 6 months of the operational phase.

The process water demand will progressively decrease by end of the second year to reach a steady state requirement of around 5.0 GL/yr. The reduction in water demand will be due to the recycling of process water from the tailings thickener overflow back to the plant process water dam and the consistent return of decant water from the TSF.

2.2 Project Water Resources

Table 2-2 summarises the potential water resources in the vicinity of the Project.

Table 2-2: Summary of the Project's Potential Available Water Resources

Year	Water Source	Water Demand	Water Quantity	Salinity	
		kL/d	GL/yr	Type	mg/L
1 to 2	Regional fractured rock bores	1,200+	0.3+	Brackish-saline	2,000 to 16,000
1 to 2	Anne Beadell Borefield	1,500	0.5	Brackish-saline	5,000 to 25,000
3 to 15	Yeo Borefield	20,500	7.5	Saline-Hypersaline	20,000 to 75,000
3 to 15	Anne Beadell Borefield	600	0.2	Brackish-saline	5,000 to 25,000
1 to 15	Gruyere mine dewatering	~2,200	~0.8	Brackish-saline	5,000 to 16,000
3 to 15	TSF Recovery bores	<1,500	<0.3	Hypersaline	20,000 to 100,000

There are no natural sources of fresh water within 50 km of the Project. All of the fresh water for the Project will therefore need to be produced through treatment of up to 600 kL/d of brackish water via a reverse osmosis (RO) water treatment plant. The brackish water will be sourced from the Anne Beadell borefield, located in a shallow palaeo-tributary channel 23 km south-east of the Project.

The bulk of the raw water supply for the Project will be sourced from a 65 km long borefield in the Yeo borefield, located in the Yeo palaeo-trunk drainage channel, 25 km west of the Project. The Yeo borefield, will not be ready until the completion of the construction phase of the Project. In the meantime, water for the construction phase would be sourced from advanced development of out-of-pit dewatering bores in the Project area, supplemented by an additional 900 kL/d of untreated makeup water supplied from the Anne Beadell borefield as required.

2.3 Project Water Licences

Gold Road currently has two 5C groundwater licences issued by the DoW in the Great Victoria Desert Sub-area of the Goldfields groundwater management area. GWL 176189 allows Gold Road to abstract 600,000 kL/year from the palaeochannel aquifer, while GWL 177087 allows abstraction of 600,000 kL/year from the fractured rock aquifer.

Gold Road has applied to the DoW to increase the allocation limit on 5C Licence GWL 176189 to abstract 7,800,000 kL/year from the Yeo and Anne Beadell borefields; and to increase the allocation on the fractured rock licence, GWL 177087, to 800,000 kL/year to cover the Project's mine dewatering and construction water supplies.

3. HYDROGEOLOGICAL SETTING

Geological units in the Gruyere Region are of Archean age with scattered Permian deposits and Cenozoic deposits within the Yeo palaeodrainage (Figure 3-1). Sediments filling the palaeovalleys principally comprise alluvial, colluvial and swamp/lacustrine Cenozoic deposits (65 Ma to 2.5 Ma). These consist of Eocene and Miocene formations where the Eocene sediments belong to the Werillup formation and Miocene sediments are of the Perkolilli shale. These are covered by Quaternary alluvial, lacustrine and aeolian clay, silt and sand, with gypsiferous and saline deposits associated with saline lakes.

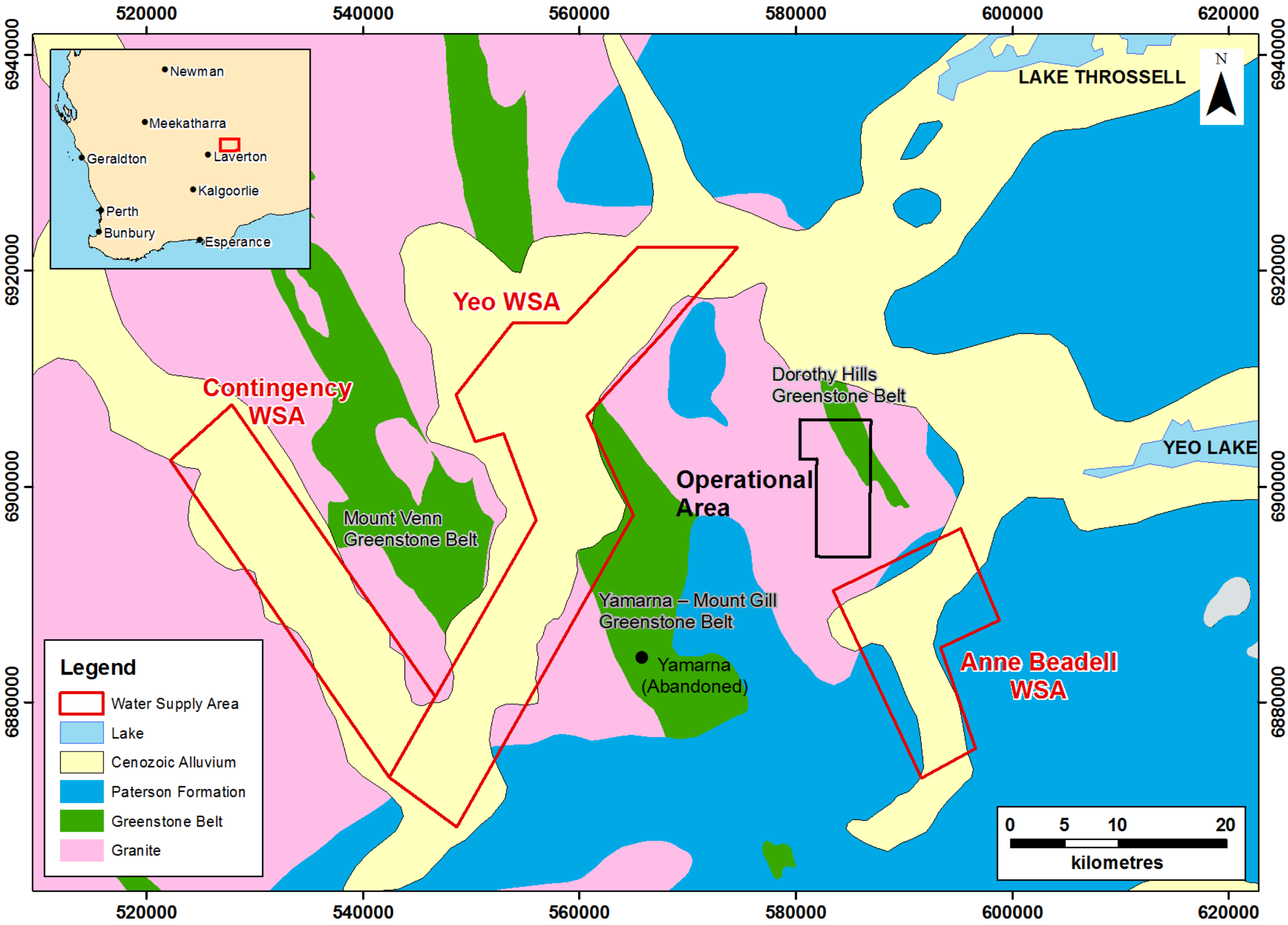

Figure 3-1 Pre-Quaternary geology in the Gruyere Project area

3.1 Groundwater Occurrence

The hydrogeological stratigraphy in the Yeo Palaeochannel is summarized in Table 3-1 and Figures 3-2 and 3.3. Groundwater occurs within the Quaternary calcrete aquifer and the thicker Werillup formation. The Perkolilli shale between the Quaternary and Werillup formation forms an aquitard between the two aquifers. Outside the palaeovalley, minor aquifers are generally present within the weathered saprolite and saprock profile.

The Permian Paterson formation contains aquifer units primarily in the fluvial sands of the formation. It forms an extensive but low permeability aquifer in the Minigwal trough on the western margin of the Officer basin east and south-east of the Project (Pennington Scott, 2011) and may also form a local aquifer where preserved in Permian palaeovalleys on the margin of the Yilgarn craton.

Table 3-1: Summary of Aquifer Types and Yields in the Gruyere Region

Aquifer	Geological unit	Max Saturated thickness (m)	Bore yield (kL/d)	Aquifer potential	Water quality
Palaeovalley					
Alluvial deposits and calcrete	**Quaternary**	14	0-500	Low - moderate	Brackish – saline
Perkolilli Shale	**Perkolilli Shale**	29	-	Aquitard	
Yeo palaeochannel aquifer	**Werillup Fm.**	+81	200-2000	High	Saline-hypersaline
Permian	**Paterson Fm.**	+100	-	Low – moderate	Brackish – hypersaline
Archean Basement	**Upper Saprolite**	~50	-	Low	Brackish – saline
	Lower Saprolite – Saprock (transition zone)	~100	0-1000	Low - moderate	Brackish – saline

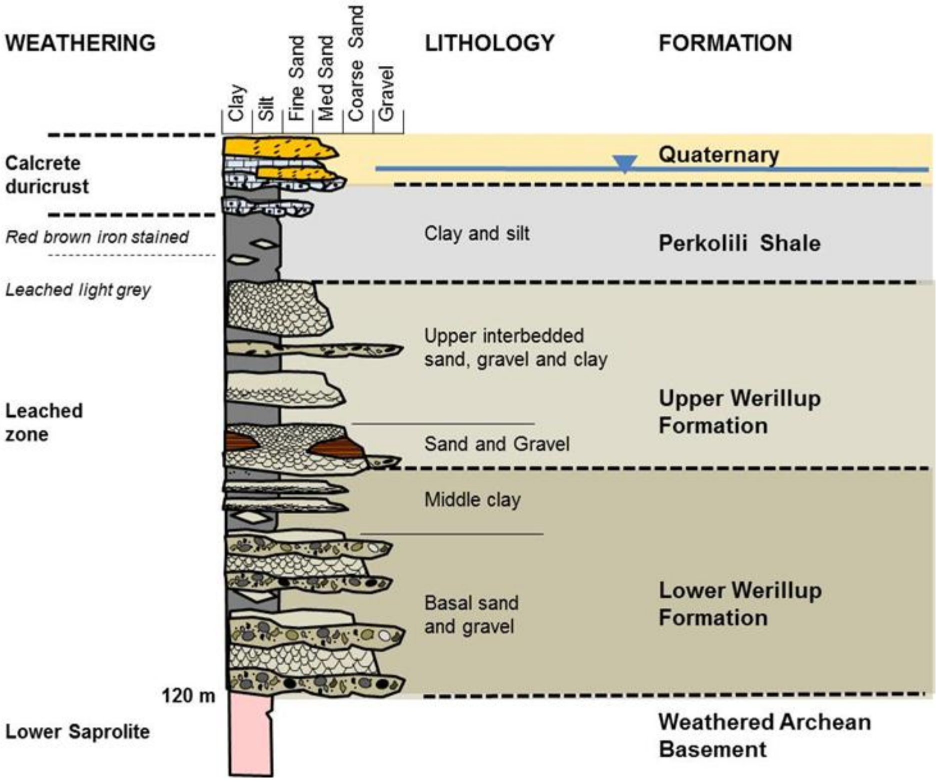

Figure 3-2: Representative Graphic Profile for the Yeo Borefield

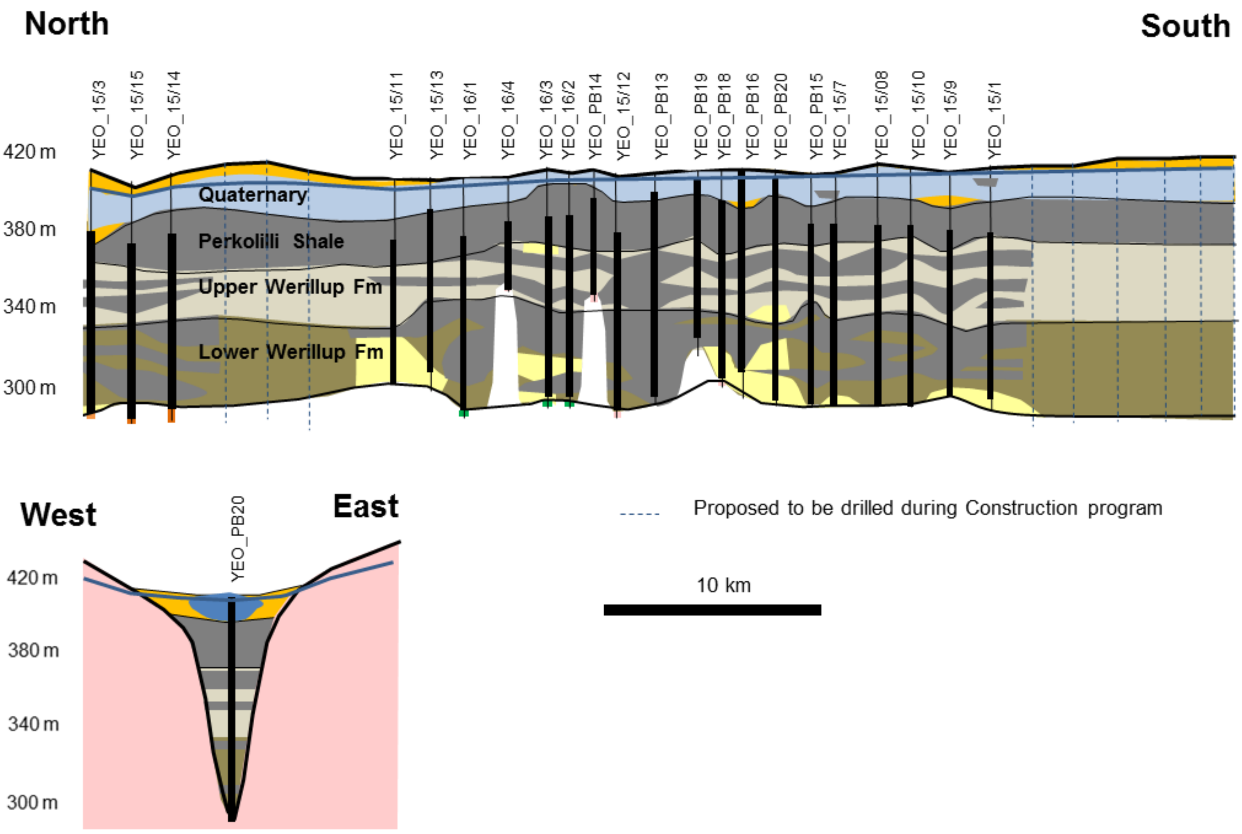

Figure 3-3: Geological long and cross sections through the Yeo Borefield

3.1.1 Alluvial and Calcrete Aquifer

An unconfined aquifer is present within the Yeo Palaeovalley, made up of Quaternary Deposits of alluvial gravel, sand, silt and clay, and calcrete deposits. Collectively these form the Alluvial and Calcrete aquifer.

Calcrete is present in the Yeo Palaeovalley extending almost continuously through the area of investigation, where it can be up to over 6 km wide (Figure 3-4). A series of investigation boreholes for the project intersected between 2 and 36 m of calcrete (Pennington Scott 2015).

The Alluvial and Calcrete aquifer present in the Yeo Palaeovalley comprises poorly sorted gravel and sand with variable portions of silt and clay, and is partially cemented in some portions. Calcrete is well developed in the central portion of the Palaeovalley, where it forms an unconfined aquifer. The thickest sections of calcrete appear to occur in about the middle of the floodplain, becoming thinner outward. Calcrete is generally very thin or absent within the Palaeovalley beyond the floodplain, and mostly unsaturated about the outer portion of the floodplain. Permeable aquifer zones may be present through the sand and gravel portions, and within calcrete where karstic solution cavities have developed significant secondary porosity and permeability.

Calcretes form an important water resource in the Goldfields region (Johnson et al, 1999) and are capable of producing significant bore yields of up to 2,000 kL/d where there is a sufficient thickness of karstic calcrete below the water table. Calcrete is also often associated with lower salinity water than other surrounding and deeper aquifers.

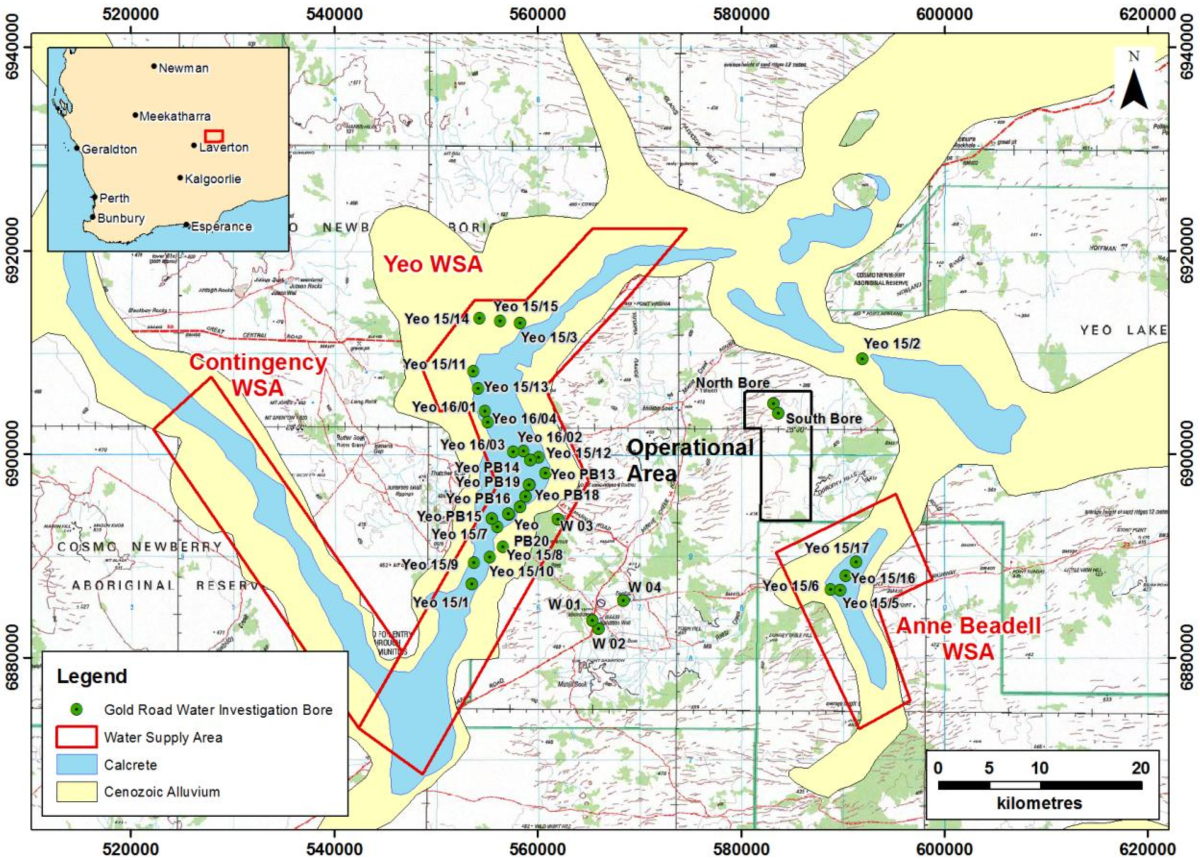

Figure 3-4 Approximate distribution of calcrete within the Yeo palaeodrainage.

3.1.2 Yeo Palaeochannel Aquifer (Werillup Formation)

The Werillup formation forms a productive palaeochannel aquifer present in the deepest parts of palaeovalleys upon the eastern Yilgarn craton. It is confined below the Perkolilli shale aquitard and bounded laterally and below by weathered to fresh bedrock. The aquifer comprises a basal coarse-grained sand and gravel with frequently clayey medium grained sand and interbedded clay in the upper portion. In the Yeo borefield, the palaeochannel aquifer is separated into upper and lower aquifer zones by the middle clay which forms at least a partial aquitard unit, although sand and gravel within the middle clay may facilitate some leakage across the unit. The upper aquifer zone consists of the sand and gravel unit together with the overlying unit of interbedded sand, gravel and clay, while the lower aquifer zone is within the Basal channel gravel and sands.

The potential of palaeochannels for significant groundwater resources was first recognised in 1969 during a water exploration program for the Windarra Nickel Mine and they have now become the main source of process water in the goldfields. During 2012 and 2015 twenty-three (23) investigation bores were drilled and tested for the project in the Yeo palaeochannel aquifer at rates of between 3 and

32 L/s (259 – 2,765 kL/d) with an average starting yield of 24 L/s (>2,000 kL/d) (Pennington Scott 2015). These tests showed that the main palaeochannel sands form a productive aquifer which appeared to be more productive than the palaeochannel aquifer in the Kalgoorlie area. This was due to the greater aquifer thickness present in the Yeo palaeochannel at the Project rather than aquifer permeability which is lower than values reported in the Kalgoorlie area.

The interpreted isopach for the Yeo palaeochannel around the Project is shown by Figure 3-5 which is based on Time Domain Electromagnetic geophysical survey and groundwater investigation drilling (Pennington Scott 2015). Deposits comprising the Yeo palaeochannel aquifer occupy the inset-valley which is about 600 m wide and mostly 90 – 120 m thick but thins rapidly up the flanks of the inset-valley. This is considerably thicker than Palaeochannel aquifers in the Kalgoorlie area (Johnson et al, 1999).

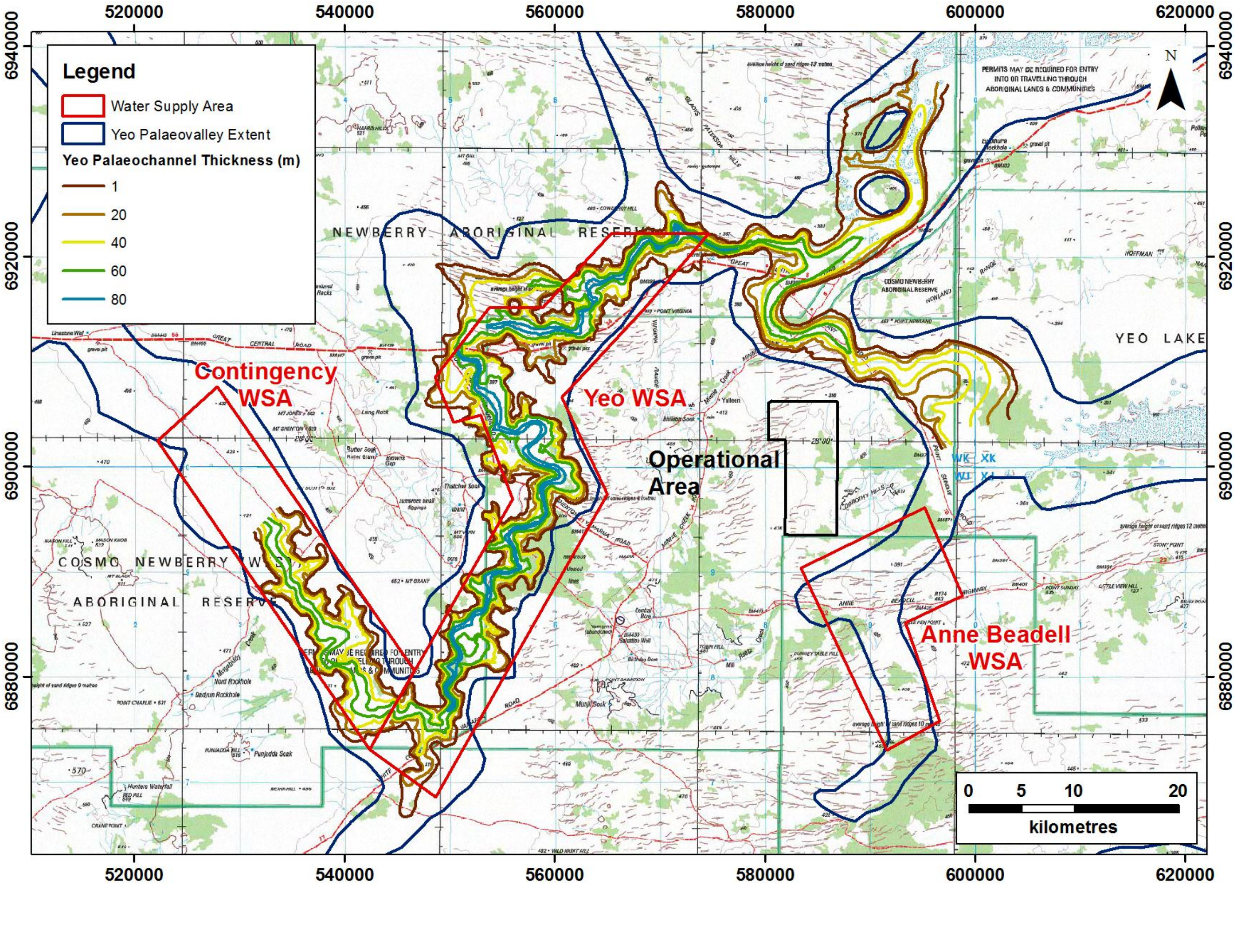

Figure 3-5: Isopach for the Yeo Palaeochannel Aquifer around the Project

3.1.3 Weathered Profile and Fractured Rock Aquifers

The weathered profile and underlying fractured bedrock can form moderately permeable aquifers, and locally may be highly productive. It is characterised by secondary porosity and permeability through the break-down of the primary rock material and fracturing that is typically more extensively developed about fault zones and about lithological contacts. A significant resource of groundwater is stored within the weathered profile, although the unit is not necessarily permeable. In contrast, a fractured rock aquifer contains a very small portion of groundwater relative to its volume, but can have zones of high permeability.

The weathered profile normally extends to depths of around 50 m below surface, but can be up to about 80 m thick in areas of shear zones, lithological contacts and areas of mineralisation. Low yields of groundwater are typically produced from bores constructed in the weathered profile, particularly profiles developed upon greenstone rocks which normally weather to very low yielding clay. Moderate yields of up to around 100 kL/day can be obtained from the base of the weathered profile in the transition zone with the underlying bedrock. This is mostly achieved over granitic rocks, and mafic and ultramafic greenstone rocks.

In a fractured rock aquifer, fractures developed within bedrock below the weathered profile can form permeable aquifer zones. Fracture development is enhanced by the oxidation and dissolution of minerals, but these tend to close with depth and are typically not significant below 120 m depth. The permeability of fractured rock aquifers is related to the degree of fracturing and how open (or clean) that the fractures are. Fracture zones in some rocks can be clogged by the presence of clay minerals. Fractured Rock aquifers tend to be better developed within greenstone rocks compared to granitoid rocks (Johnson et al, 1999). Large bore yields can be obtained from fault and shear zones through greenstone rocks, along lithological contacts, intrusive contacts, and mineralised zones. The alignment of fracture zones with tectonic elements such as shear zones and particular rock types tend to make the fractured rock aquifer highly anisotropic.

3.2 Groundwater Dynamics

3.2.1 Groundwater Recharge

Within the Yeo Palaeovalley, there are several mechanisms that groundwater can receive recharge. These include:

- Infiltration of rainfall through the surface soil and sediments, including ponding upon calcrete depressions and sink-holes;
- Infiltration of surface runoff from the surrounding valley flanks into alluvial fans and valley margins;
- Infiltration of flood water filling and flowing through braided swales upon the valley floodplain.

Groundwater recharge of calcrete within the Yeo Palaeovalley is likely to be through solution cavities at or near the valley surface (Johnson, 2004). Most recharge occurs from ponding of rainfall and runoff inundating calcrete, which can rapidly infiltrate sink holes and caverns in zones of indurated calcrete (Sanders, 1972). Development of gilgai (crabhole) terrain in the soil also facilitates the infiltration of water into the calcrete (Sanders, 1973). This is likely to occur from both direct rainfall and any surface inundation over the calcrete and along the streamlines. Recharge over the calcrete would be effectively instantaneous from these events. Areas of exposed calcrete are likely to receive greater rates of groundwater recharge from rainfall events due to local ponding and infiltration via preferred pathways (karstic solution channels and fractures) relative to more diffuse recharge through the adjacent alluvium.

Alluvial fans flanking the valley may be areas of enhanced groundwater recharge, where surface runoff from the fan catchment is carried upon the alluvial fan where it can infiltrate. This would occur during larger rainfall events resulting in surface runoff.

During exceptionally large rainfall events that result in broad-scale flooding, inundation of swales upon the floodplain and even stream flow will occur as surface runoff is directed into the valley. Infiltration of flood water into areas of permeable alluvial deposits will be rapid and result in significant groundwater recharge. This probably represents the largest recharge event which is capable of fully replenishing Groundwater levels and flow.

The approximate phreatic watertable depth and watertable elevation in the Gruyere Project Area is shown by Figure 4-3. A watertable depth of between about 1 and 8 m below ground level is found in the in the palaeovalley within bores drilled during 2012 and 2015. The watertable depth is largely governed by the surface topography in the palaeovalley, where the shallowest watertable is within the Central portion of the Yeo palaeovalley. A deeper watertable is normally present on the topographically higher ground beyond the palaeovalley, where the depth is likely to be highly variable depending on topography and the permeability of the weathered and fractured rock aquifers.

Within the Yeo palaeovalley the watertable declines down the course of the valley toward the eastern margin of the Yilgarn Craton. Locally, groundwater sinks in water levels are probably developed about salt lakes. Water levels are higher in the weathered profile and fractured bedrock areas adjacent to the palaeovalley. Groundwater beneath the palaeovalley flows toward the Eucla Basin following the valley north and eastward. About the flanks of the palaeovalley groundwater flow in the weathered profile and fractured bedrock (and possibly Permian palaeochannels) is toward the Yeo palaeovalley.

3.2.2 Groundwater Discharge

Groundwater is lost from the watertable by a combination of evaporation and evapotranspiration. Evaporation from areas of salt lake is probably the dominant mechanism of groundwater discharge in the Gruyere Project area (refer to Figure 4-3). Evapotranspiration by salt tolerant vegetation in areas of shallow watertable will also be aerially significant.

Groundwater contained in the confined Palaeochannel aquifer may discharge by upward movement through the Perkolilli Shale aquitard in topographically low parts of the valley, which typically correspond to present day drainage systems and salt lakes. However, the rates of upward discharge from the confined aquifer will be very low. Potentially the Palaeochannel aquifer becomes unconfined further north-east along the Yeo palaeodrainage where the Quaternary deposits have fully incised through the Perkolilli Shale, facilitating groundwater discharge from the aquifer. This may be the situation beneath Yeo Lake to the east.

Ultimately, groundwater flow will discharge groundwater from the palaeovalley to sedimentary basins east of the Yilgarn.

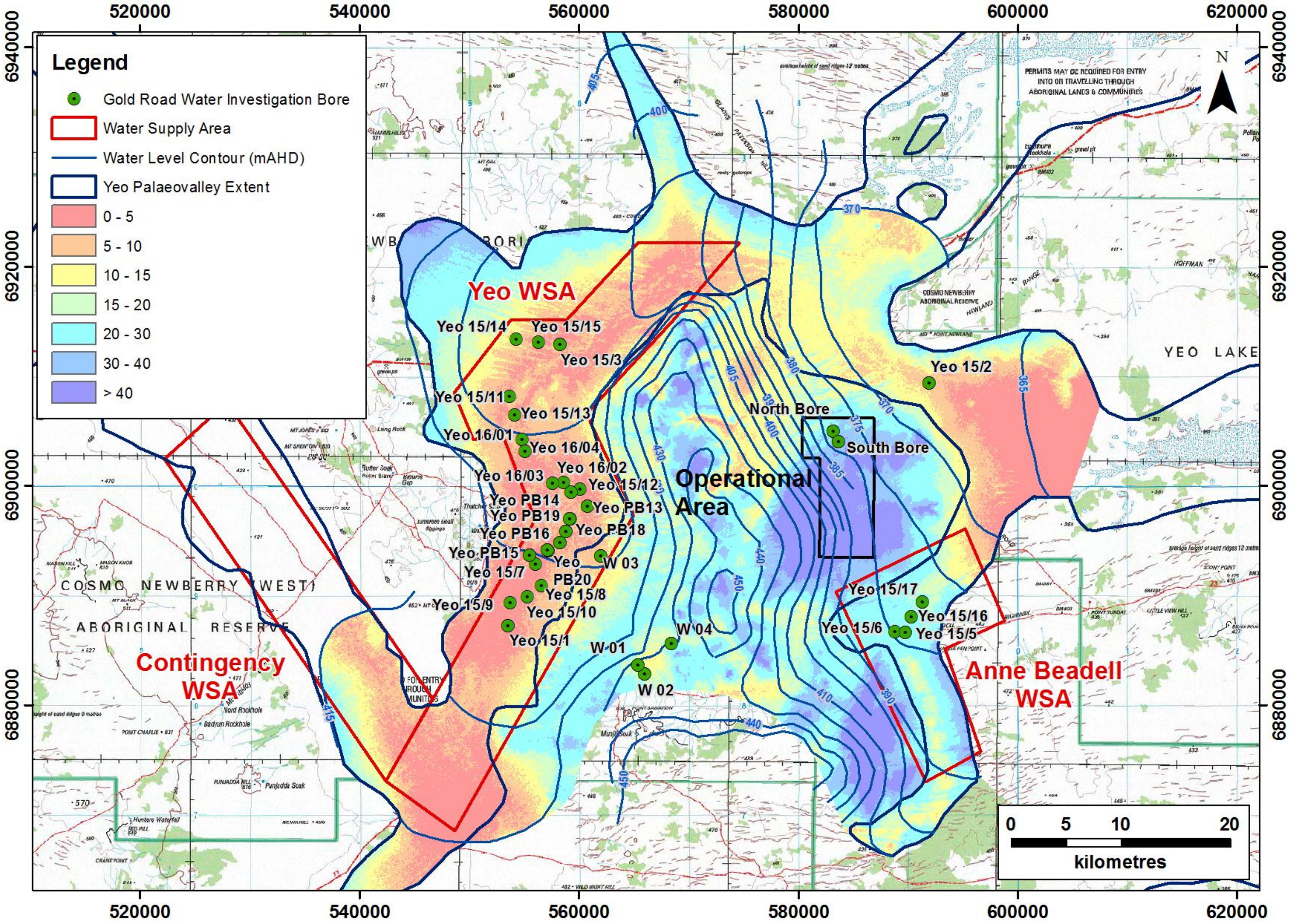

Figure 4-3 Depth to watertable and water level elevation contours for the Yeo palaeovalley.

3.3 Groundwater Quality

Groundwater salinity in the Yeo borefield appears to be stratified, with better quality brackish water overlying saline to hypersaline water at depth.

Groundwater in the shallow calcrete in the Anne Beadell drainage is often brackish, but is normally classified as ‘hard’ due to the high carbonate content. Previous investigations of the calcrete aquifer in the Yeo Water Supply Area (WSA) found groundwater salinities ranged between 7,200 mg/L and 9,500 mg/L (KH Morgan and Associates, 1996). Groundwater with a salinity of 5,910 mg/L was obtained from calcrete in the Anne Beadell Water Supply Area at one bore constructed for the project.

The pattern of groundwater salinity in the deeper palaeochannel sediments in the Yeo borefield is presented by Figure 3-6, which shows a pattern of increasing salinity down-gradient along the palaeochannel from saline to hypersaline, plus the deeper water tends to be more acidic.

Groundwater salinity from the exploratory water bores in the weathered profile and fractured rock for the project was notably better quality brackish, ranging between 1,240 mg/L and 16,000 mg/L TDS (Pennington Scott 2015).

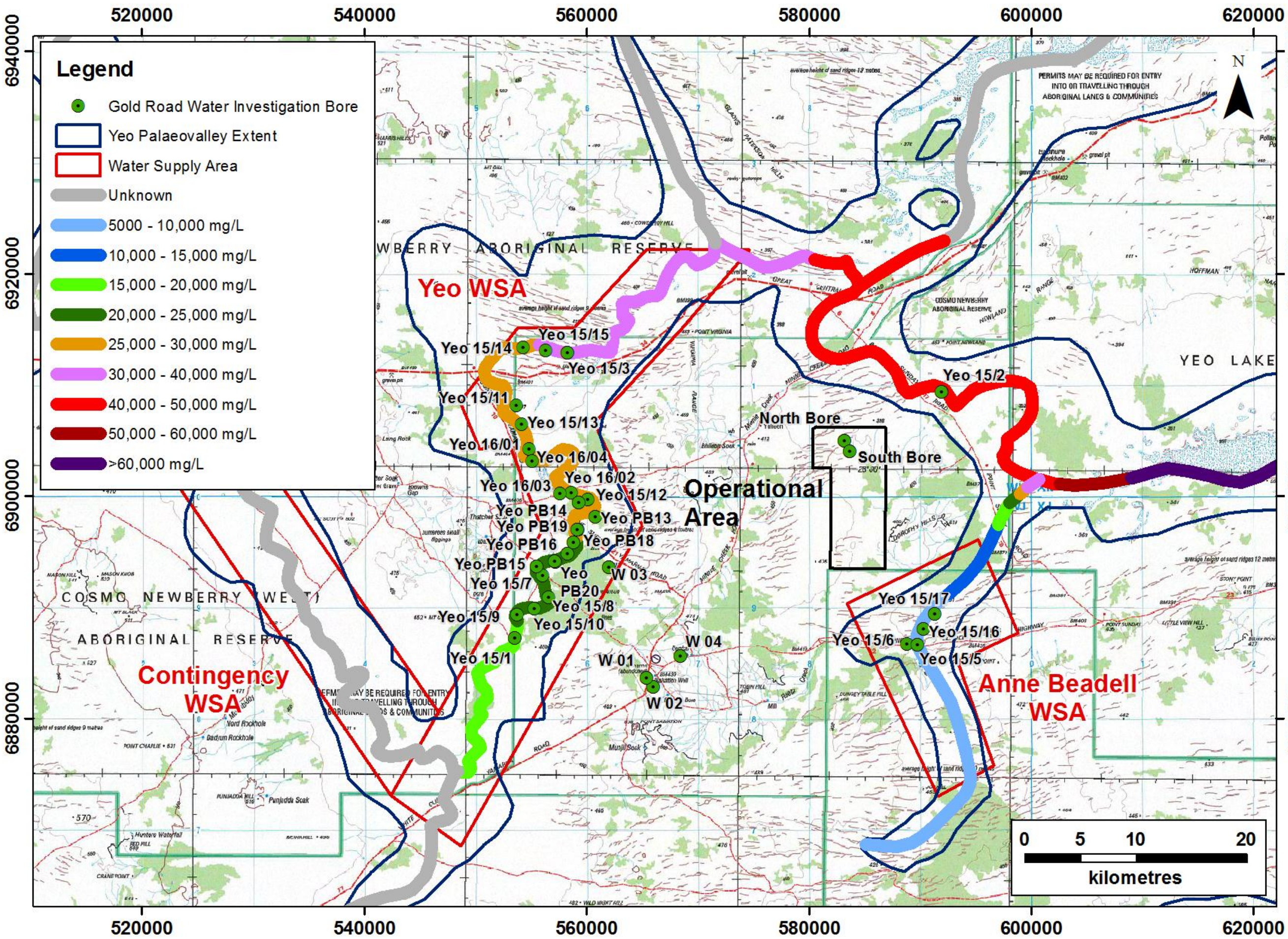

Figure 3-6: Groundwater Salinity (mg/L TDS) in the Gruyere Region

4. GROUNDWATER MANAGEMENT STRATEGY

4.1 Dewatering

The crystalline basement rocks at Gruyere offer low aquifer permeability and storage characteristics. Groundwater occurs mainly within the secondary porosity developed in the weathered lower saprolite horizon and structural defects such as faults, shears zones and fractures in the deeper saprock transition zone, particularly along the margin of a sub vertical monzonite through the centre of the pit. Depressurisation of the watertable around the Gruyere pit is necessary, not only to facilitate mining beneath the watertable, but also to increase the shear strength of upper saprolite rocks to increase pit wall stability.

Dewatering will be achieved over the 15 year life of mine (including advanced dewatering during the 2 year construction period) using a combination of in-pit sumps, out-of-pit dewatering bores, and horizontal seep wells. Figure 4-1 represents a schematic of pit dewatering operations.

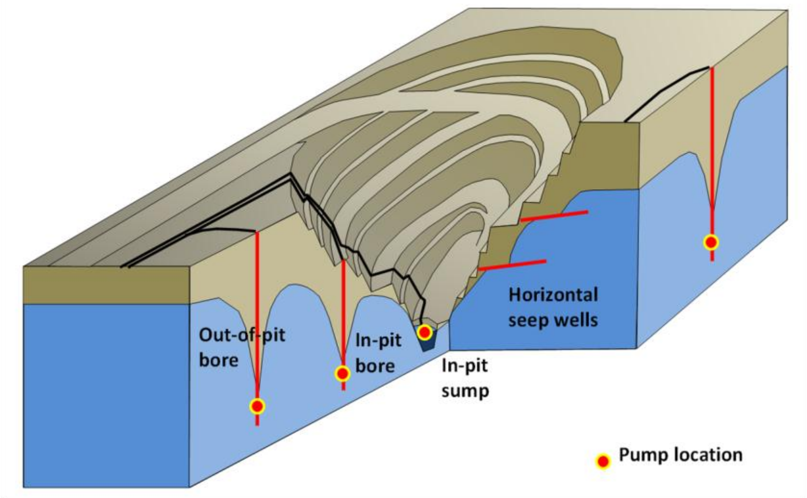

Figure 4-1: Schematic of dewatering operations

4.2 Water Supply Borefield Development

The bulk of the Project water supply will be developed from two borefields: the Yeo and Anne Beadell Borefields (Figure 4-2).

During the construction phase all construction water will be sourced from a combination of dewatering bores around the Gruyere pit, supplemented by up to 900 kL/day of makeup water from the Anne Beadell Borefield, located in a palaeotributary channel 23 km south of the Project. In addition, the Anne Beadell Borefield will be the primary water source of 600 kL/day needed to feed to the reverse osmosis water treatment plant, which in turn will supply all of the fresh water requirements for the temporary construction camp, accommodation village, administration offices and the elution circuit during both construction and operational phases.

The Anne Beadell Borefield has been designed to deliver peak demand of 1,500 kL/day (550,000 kL/year) during the construction phase (including 600 kL/day for the RO plant and up to a further 900 kL/day for construction). The borefield is anticipated to require a six (6) duty bores spaced nominally 1 km apart and delivering an average bore yield of 375 KL/day (4.2 L/s), sustainable over a period of 15 years.

The Yeo Borefield (which will not be operational until the start of the operational phase of the project) will supply the 20,550 kL/day (7,500,000 kL/year) for the project's process water demand at a salinity of less than 100,000 mg/L TDS, from the Yeo palaeo-trunk channel west of the Project Area. The Yeo Borefield is anticipated to require a minimum of twenty three (23) duty bores, plus nine (9) standby bores located nominally 2 km apart and delivering an average bore yield of 1,050 kL/day (12 L/s), sustainable over a period of 13 years. In addition to the Yeo Borefield, an additional section of palaeochannel has been identified as a contingency water supply area immediately upstream of the Yeo Borefield for future borefield expansion should it be required.

Twenty-three (23) of the planned thirty two (32) production bores in the Yeo Borefield, and three (3) of the planned six (6) bores in the Anne Beadell borefield have been constructed as part of the project investigations (Pennington Scott 2015). The remaining thirteen (13) palaeochannel production bores will be constructed during the construction phase.

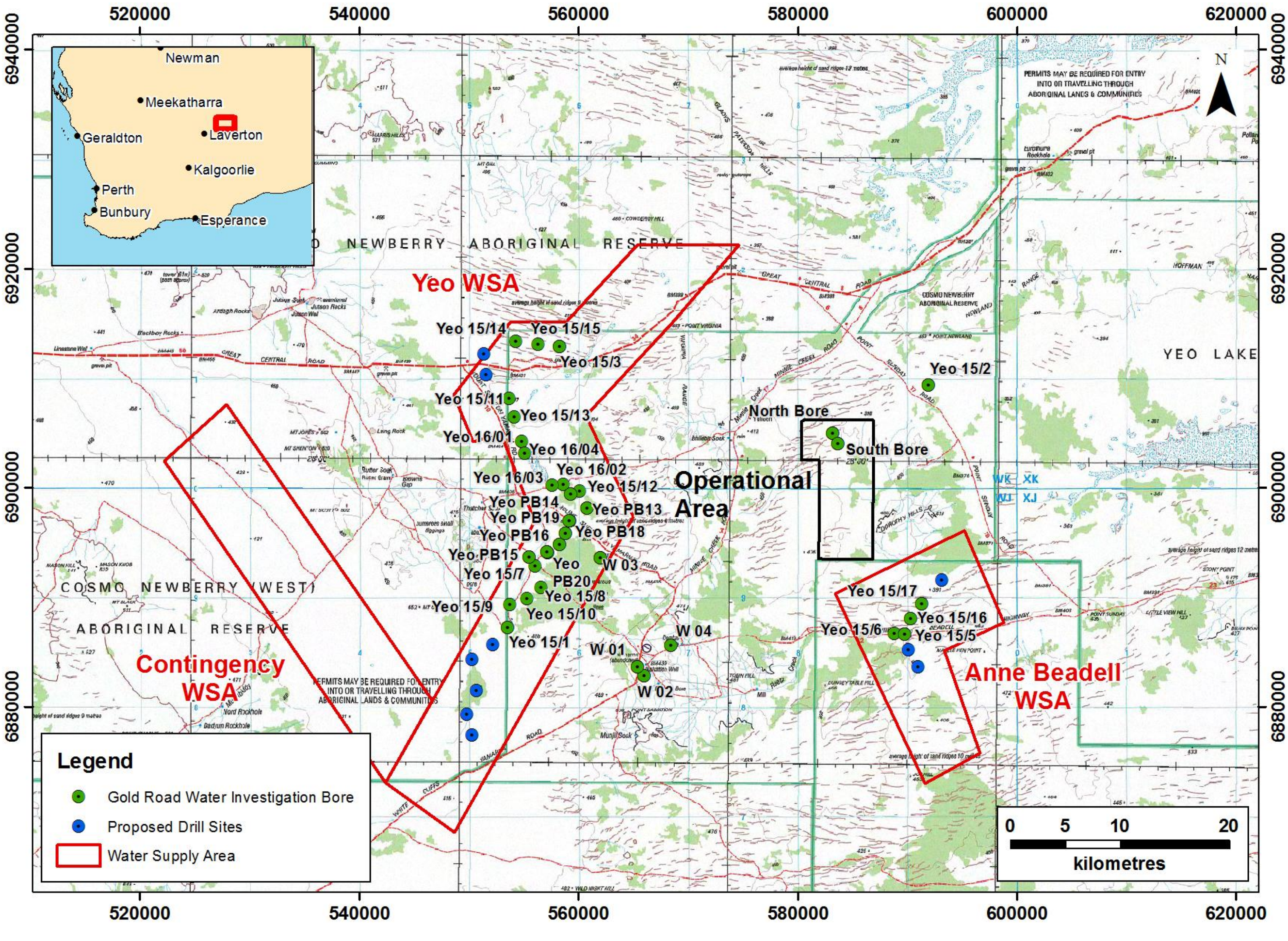

Figure 4-2: Proposed production bore sites

4.3 Borefield Operational Strategy

The borefield operational strategy will be developed as part of the project's feasibility investigations, to meet the key objectives of:

- Ensuring reliability and continuity of the project water supply; and
- Protecting key environmental and heritage values.

Ecological and heritage surveys and investigations are currently being undertaken to define key environmental and heritage values to be protected. Based on these surveys, monitor bores will be sited in the calcrete aquifer and water level and water quality trigger levels will be defined for potential mitigation measures (see below).

A calibrated numerical groundwater model of the Yeo Palaeochannel system has been developed for the project by Advisian (2015). The model has been calibrated to regional water levels and the results of aquifer tests, and incorporates surface water modelling of inundation events in the Yeo valley to simulate episodic recharge in the Alluvial and Calcrete Aquifer.

The model will be used to assess groundwater level drawdowns associated with the borefield and optimise abstraction volumes, location and timing. Figure 4-3 shows a 'base case' scenario based on the most efficient borefield operating strategy with abstraction spread evenly among the production bores.

4.3.1 Contingency Borefield Measures

Preliminary results from ongoing stygofauna and ecological surveys suggest that there is a possibility of higher stygofauna habitat values toward the centre of the Yeo Borefield, and lower stygofauna habitat values in the Anne Beadell borefield and the north and south of the Yeo borefield. Pre-empting the possibility that water level management strategy may be required, potential design and borefield operating mitigation measures that may be applied separately or collectively include, but are not limited to:

- Redistribution of borefield abstraction;
- Extending the borefield further to the north and/or south; and
- Adaptive aquifer reinjection into the deep aquifer adjacent to the area of interest.

Figure 4-3 to Figure 4-5 show that maximum drawdown in the shallow Alluvial and Calcrete Aquifer over the 15 year mine life could be managed using either of the borefield mitigation strategies above if necessary, albeit that these measures would add to the borefield operating costs and reduce the efficiency of the borefield.

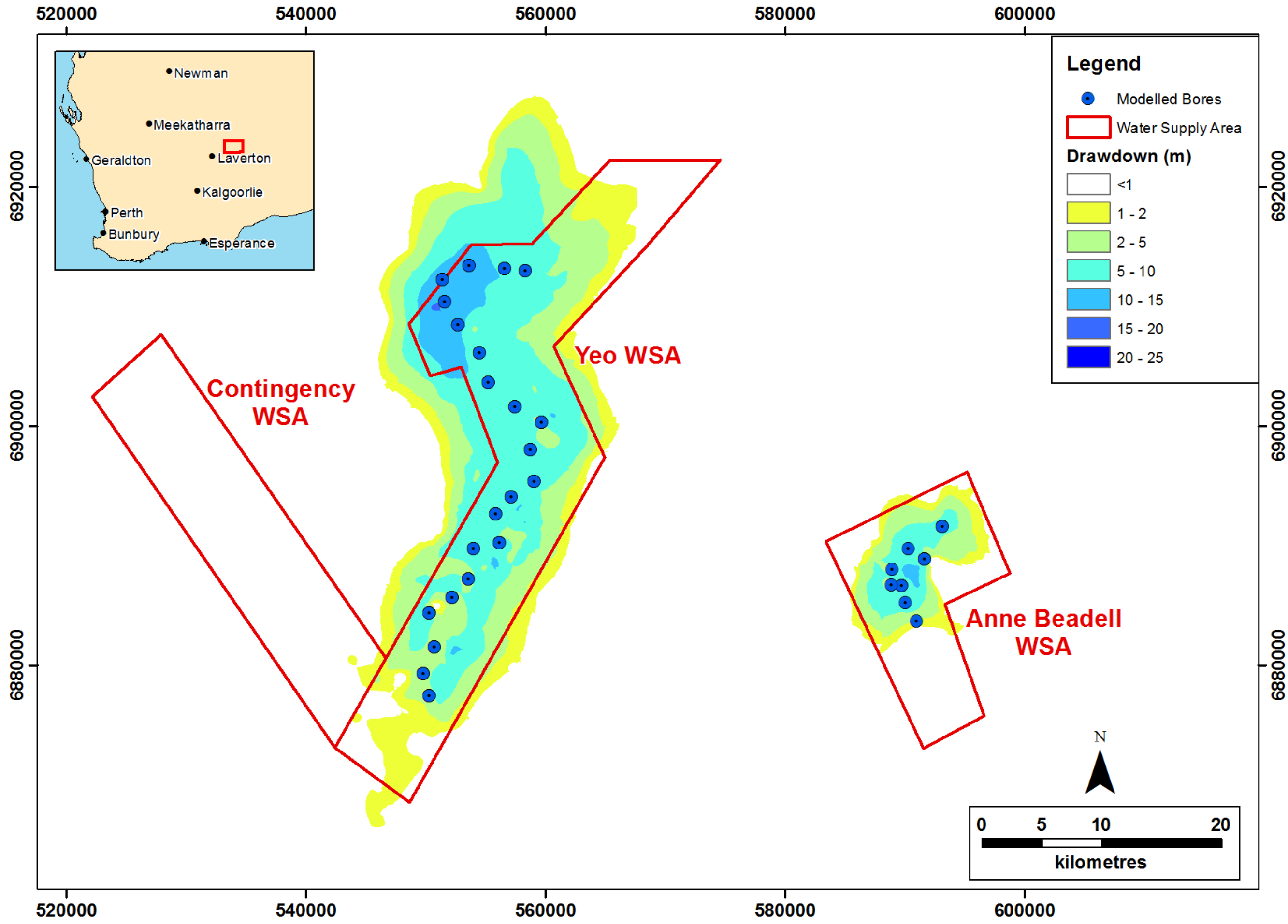

Figure 4-3 Modelled drawdowns in the Alluvial and Calcrete Aquifer from the Yeo palaeochannel borefield at year 15 - base case: even abstraction distribution

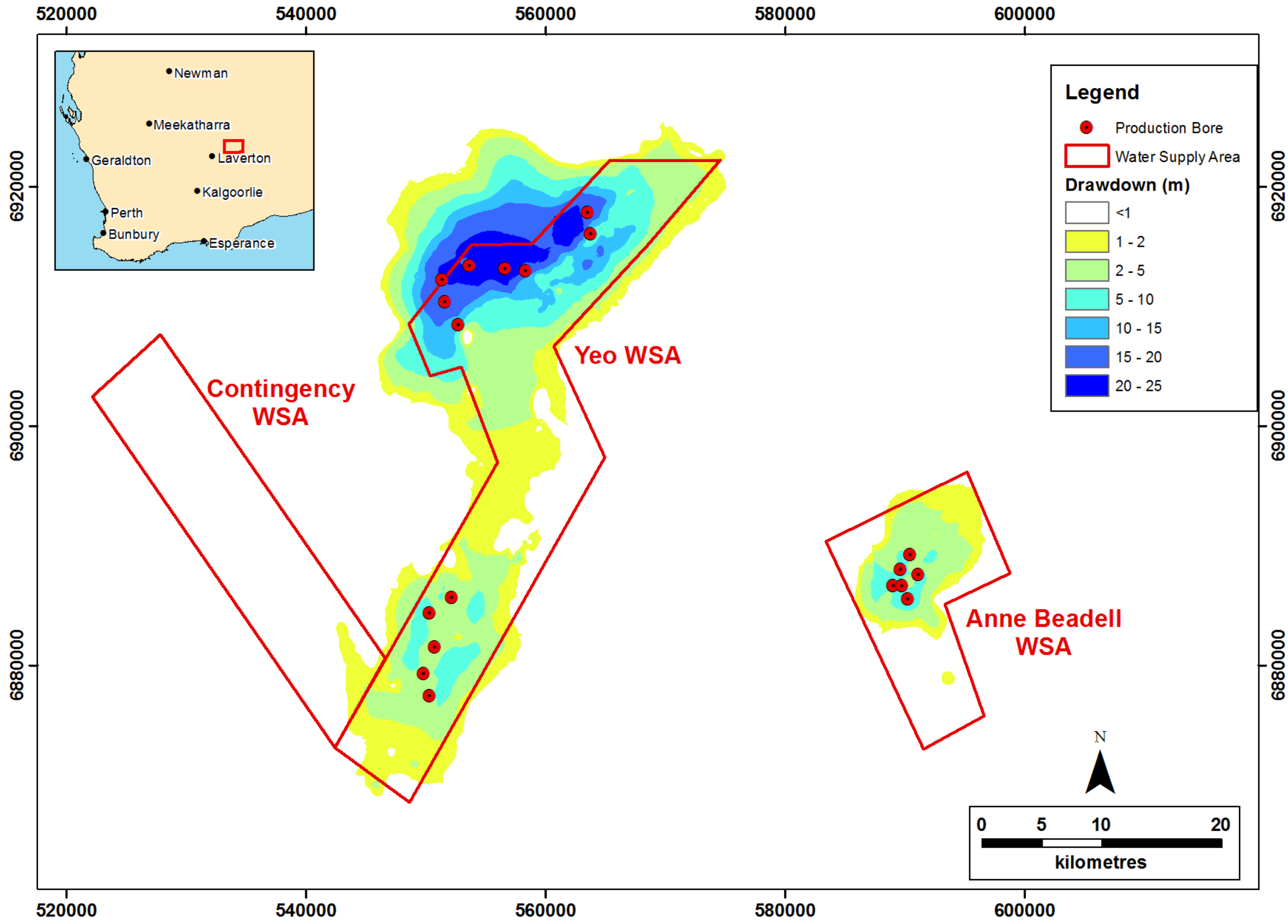

Figure 4-4 Modelled drawdowns in the Alluvial and Calcrete Aquifer from the Yeo palaeochannel borefield at year 15 – first alternative scenario: moving abstraction to the northern and southern extremities of the water supply area

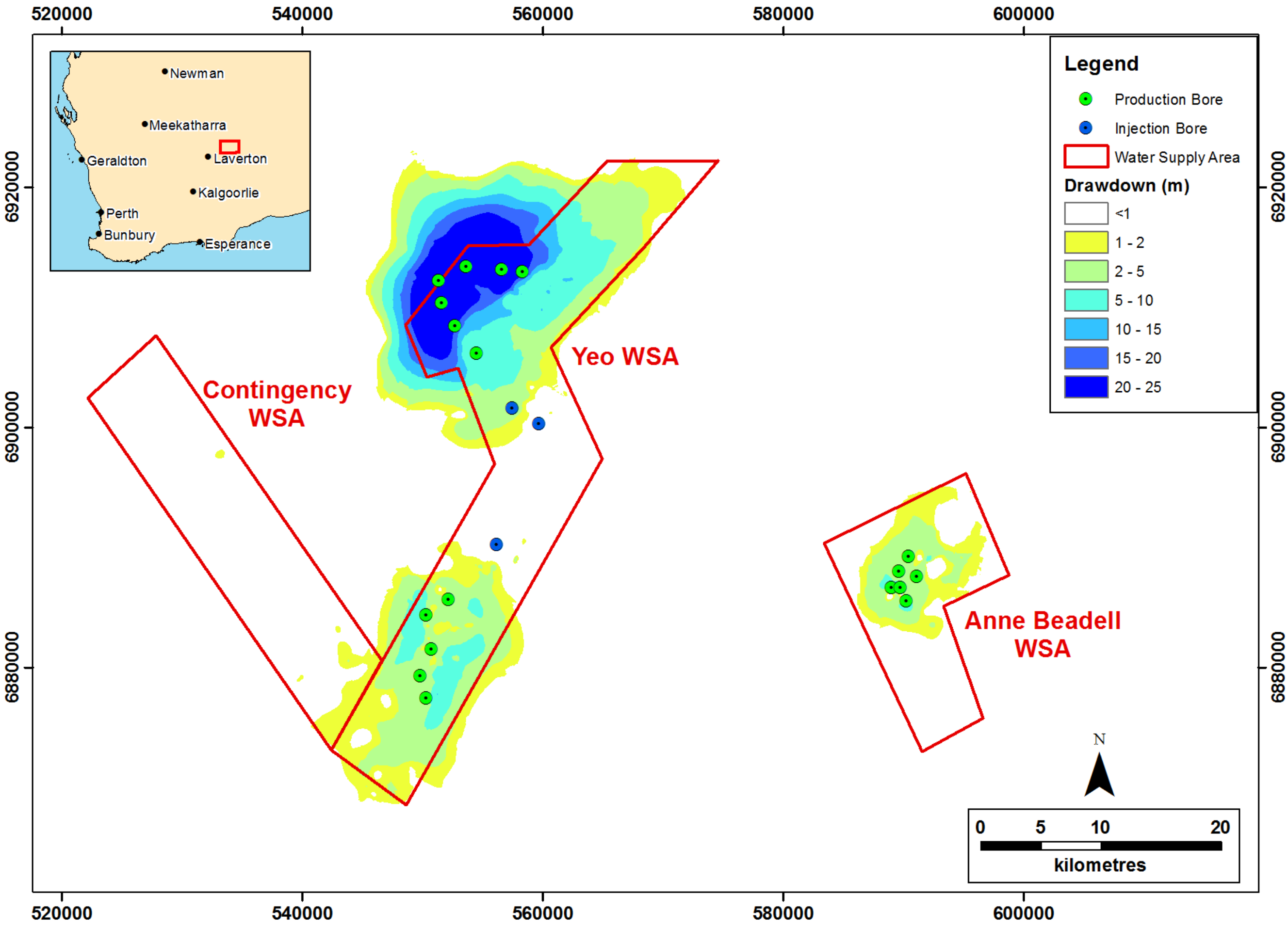

Figure 4-5 Modelled drawdowns in the Alluvial and Calcrete Aquifer from the Yeo palaeochannel borefield at year 15 – second alternative: incorporating reinjection to the deep aquifer in the central borefield

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