HASTINGS
Technology Metals Limited

APPENDIX 4-1

Conceptual Hydrogeological Assessment

Global Groundwater

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Yangibana Rare Earth Project

Conceptual Hydrogeological Appraisal

for

Hastings Technology Metals Limited

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Global Groundwater

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1 INTRODUCTION

Hastings Technology Metals Limited (Hastings) is conducting a detailed feasibility study (DFS) for development of the Yangibana Rare Earths Project (Yangibana Project) located in the Fraser Creek area of the upper Gascoyne region of Western Australia (Figure 1). Stygofauna and troglofauna species have been discovered within the mining footprint. The area has been delineated by the Department of Parks and Wildlife as containing the Gifford Creek Priority Ecological Community (PEC) in a network of shallow calcrete aquifers. The project intersects the northern portion of the Gifford Creek PEC area. However, no calcrete aquifers occur where subterranean fauna species were found (Ecoscape, 2016a).

The conceptual hydrogeology of the broader mining area has not been documented previously but is required to understand any habitat relationships between the Project areas further and the PEC calcretes, inform the regional stygofauna and troglofauna sampling, project planning, approvals and subsequent development. Hastings engaged Global Groundwater to provide a desktop hydrogeological appraisal setting out the conceptual hydrogeology of the area. This report sets out the data acquired and its interpretation to present the conceptual hydrogeology (aquifer characterisation, waterlevels, groundwater flow and salinity).

1.1 LOCATION

The Yangibana Project will consist of several pits with associated mining and processing facilities located within mining leases and general and miscellaneous tenements within a larger area of mining tenements operated by Hastings, which cover about 645 km^2 overlying the Wanna and Edmund station pastoral leases (Figure 1). It occurs in the centre south of the Edmund 1:250 000 and 1:100 000 scale map-sheet areas and incorporates the Yangibana, Bald Hill, and Fraser's deposits.

2 PROGRAM DESCRIPTION

Searches were conducted of government agencies to obtain available data and reports. A study area covering approximately 6000 km^2 (600,000 ha) was established to extend some distance from the Yangibana tenement area.

Published geological maps at 1:250 000 and 1:100 000 scale were obtained from the Geological Survey of Western Australia (GSWA) within the Department of Mines and Petroleum (DMP). The GSWA's various databases were also searched for published and unpublished geological and hydrogeological reports, and for reporting associated with minerals exploration licenses (WAMEX) that may have detailed exploration drilling in the area, sometimes with results of water bore drilling.

The Department of Water (DoW) Water Information System (WIN) was interrogated for bore data and the DoW library system was interrogated for hydrogeological reports and consultants 'Accession' reports setting out details of groundwater drilling in the study area. The DoW licensing database was also interrogated for licensing associated with the area.

Groundwater, environmental and drilling data were requested from the Hastings project team.

The acquired data and reports were reviewed and consolidated to provide the background hydrogeology and a platform for ongoing groundwater work to support development of the project.

3 PREVIOUS WORK AND AVAILABLE DATA

3.1 GEOLOGICAL APPRAISALS

The 1:250 000 scale mapping of the Edmund sheet area (Daniels, 1967) and the accompanying explanatory notes (Daniels, 1969) was the first systematic geological mapping in the area. Daniels (1969) also provided a brief history of earlier geological investigations, which included mostly minerals investigations or regional geological data gathering exercises from 1890 onward.

Little published work appears to have been undertaken in the area after Daniels (1967, 1969) work until 1985, for revision of the Bangemall Basin Supergroup stratigraphy, for work on the Gascoyne Complex in 1986 and detailed work on the alkaline dykes in the southern and central part of the Edmund 1:250 000 sheet in 1996. These previous works were summarised by Martin et al. (2005) when the Edmund 1:250 000 sheet area was geologically mapped at 1:100 000 scale. Pirajno and González-Álvarez (2013) furthered the work on the alkaline intrusives of the area.

In excess of 150 WAMEX reports were recovered and briefly appraised. Most WAMEX reports covered smaller programs not inclusive of drilling and where drilling was undertaken and reported it is often difficult to identify drill-hole locations from the earlier reports. The published geological appraisals often draw on the WAMEX data.

Hastings has undertaken extensive mineral exploration activities focussed in the Fraser, Gifford and Yangibana areas. These have been summarised in the context of the broader geological setting and detail has been provided on each prospect (Whittock, 2016).

3.2 HYDROGEOLOGICAL APPRAISALS

Detailed hydrogeological appraisals of the area have not been undertaken and correspondingly there is a paucity of groundwater data for the area. Daniels (1969) noted from geological mapping of the 1:250 000 Edmund sheet area that most of the water for pastoral stations in the area was obtained from shallow bores and wells sunk in alluvium, colluvium and calcrete. He also identified that water quality was best in higher catchment areas and deteriorated down catchment.

Smaller scale hydrogeological appraisals for stock supplies were undertaken by the hydrogeology section of the GSWA for pastoralists on the Wanna pastoral lease area (Davidson, 1973; Thorpe, 1990). Davidson (1973) selected sites for drilling around Suspense Bore located about 33 km east of Yangibana tenement area. The appraisal indicated limited potential in shallow superficial strata but greater potential in underlying basement rocks where structure was favourable for formation of fractures.

Thorpe (1990) undertook a desk top study and reconnaissance site visit to appraise sites for groundwater drilling following failure of a number of stock bores and wells on the same lease. The program provided limited background details on a number of the existing bores and wells and focussed on calcrete as the primary target. It is not known if new groundwater bores were drilled and constructed at the selected sites. It was identified that calcrete may extend over large areas beneath alluvial deposits, and that large calcrete deposits up to 30 m in thickness occur within the Edmund and Lyons River valleys. Thorpe (1990) concluded that calcrete deposits in the area could be up to 50 m thick.

Whittock (2016) noted hydrogeological studies have been undertaken that indicated aquifer transmissivity of 43 m^2/day and 173 m^2/day for Yangibana North and Bald Hill South prospects respectively, but no formal reporting to provide perspective to these values was provided for this report. It was also reported that water quality samples obtained showed groundwater to be within acceptable National Environmental Protection Measures (NEPM) for inorganic analytes, and for most organic analytes.

3.3 GROUNDWATER DATA

Available groundwater data are limited and mostly from bores and wells established for stock supplies, as obtainable from the WIN system of the DoW (Figure 2). Stock bores and wells do not require licensing and as such there was little imperative for data to be recorded at the time of drilling or for data to be forwarded to government. Apart from occasional data captured by early government workers or perhaps provided by pastoral lease holders, most of the data contained on the WIN system for the area were probably captured when the bores and wells were visited during regional mapping of the Edmund sheet by the GSWA (Daniels, 1967). Many of the available records show dates of 1965 but go back to as early as 1927. Some are from the 1970's and 1990's and many have no known date of capture.

Limited data are available from Hastings sources either as set out in a report on stygofauna and troglofauna (Ecoscape, 2016a) or as informal spread sheets made available for this report. Whittock (2016) provides some description on porosity and data on groundwater levels associated with structure and weathering at the various Yangibana prospects.

Limited test pumping data were provided in spread sheets for a PVC cased bore named YGBWB1 (L. Jefferson, pers. comm., September 2016). A drill hole YGBWB1 is not listed in the Hastings drill hole database provided and it may be that the bore is YGWB001, which is listed in the database as a water bore. The test was conducted at a flow rate of 22 m^3/day for about 15 minutes during which drawdown of 0.7 m was recorded. Hydraulic conductivity of 7.6 m/day and transmissivity of 38 m^2/day were included in the spread sheet results.

4 WATER LICENSING

The DoW Water Register shows the Yangibana tenement area located within the Gascoyne Groundwater area, Bangemall/Capricorn Groundwater subarea for the purposes of groundwater licensing, which will be required for dewatering and groundwater supplies for the Project. The register shows the Yangibana tenement area overlying groundwater resources of the Fractured Rock West aquifer (Alluvium, Calcrete, Palaeochannel and

Fractured Rock aquifers), with water currently available from each. Existing licenced drawpoints are shown on Figure 1.

The DoW register lists Hastings current groundwater licence 183285 associated with mining lease M09/157 with an annual allocation of 500 kL from the Fractured Rock West - Fractured Rock aquifer. The next closest licenced drawpoint is about 20 km southeast of Fraser's deposit. It is included on groundwater licence 46673 with a postal address of Cobra Station for an annual allocation of 10,000 kL. The register shows the underlying resource as the Combined - Fractured Rock West - Alluvium aquifer but lists the licence as drawing from the Carnarvon - Superficial aquifer. No other groundwater licences were identified close to the Yangibana tenement area.

Surface water licence 174568 to the Shire of Upper Gascoyne for 6000 kL/annum from the Gascoyne River and Tributaries resource is linked to an area that extends over much of Yangibana tenement area and further west. Although the annual allocation is small, the potential for the broad licence area to impact the Yangibana planned development should be investigated.

5 SETTING

5.1 CLIMATE

The climate of the area is set out by Ecoscape (2016a). In summary, the area is arid to semi-arid with cool daytime temperatures in the winter months and warm to hot daytime temperatures in the summer months. A number of climatic influences impact the area causing bi-modal average rainfall with an average annual total of about 220 mm.

During the warmer season, generally from December to April, rainfall results from occasional thunderstorm activity associated with development of west coast troughs, movement of tropical cloud banks southeast from the Indian Ocean over the area and from the passage of tropical cyclones. This warmer season rainfall is mostly intense; generally isolated in thunderstorms and more widespread from tropical cloud banks and cyclones. Cooler season rainfall, generally from May to August results from the passage of winter cold fronts from the southwest. These may bring less intense, more widespread rain for extended periods of up to a week. The months from September to November are normally the driest months.

5.2 GEOMORPHOLOGY

The geomorphology of the study area is described in broad terms by Daniels (1969) in his description of the Edmund 1:250,000 scale sheet area. The bulk of the tenement area is underlain by granitic rocks (Figure 3) characterised by subdued topography with some broad open flats and occasional rounded granitic hills with elevations to about 350 m AHD (Australian Height Datum). Older metamorphic rocks that have been intruded by the granitic rocks can have slightly higher elevations of up to 400 m AHD.

The far northeast of the Yangibana tenement area comprises rocks of the Bangemall Group which cross the area from the northwest to southeast. This area is relatively high at up to about 500 m AHD and relatively strongly dissected with some long, northwesterly trending strike ridges, steep sided valleys and gorges.

The drainages in the area of the granitic rocks form a dendritic pattern and are located within generally broader more gently sloping areas of alluvial deposition (Figure 4). The drainages in the area of the Bangemall Group rocks are transitional between a dendritic and trellis pattern and generally occupy narrower drainage lines with steeper sides, particularly where they cross cut strike ridges. The largest drainages are the Lyons and Edmund Rivers crossing the southern and western margins of the study area, respectively (Figure 1). Yangibana and Fraser's Creeks, tributaries of the Lyons River rise in the area of granitic rocks and drain the tenement area. Pimbyana Creek, also a tributary of the Lyons River drains the eastern parts of Yangibana tenement area and then rises in the area of Bangemall Group rocks in the northeast. Rockhole Creek and Dingo Creek drain the northwest part of the Yangibana tenement area and extend across the north of the area to rise in the area of Bangemall Group rocks in the northeast.

5.3 VEGETATION

Vegetation of the broader area is set out by Martin et al. (2005) drawing on the published regional vegetation mapping from 1975, 1981 and 1990. The area occurs south of a major biogeographical boundary, the Acacia-Triodia line and as such is characterised by woody-Acacia dominated vegetation occurring as scrub on the hills and low woodland on the plains. Tall trees, comprising mainly species of Eucalyptus and Melaleuca, are confined to rivers and major creeks. More detailed delineation of land systems and associated vegetation within the Yangibana tenements, drawn from Department of Agriculture and Food, WA (DAFWA) is provided by Ecoscape (2016b).

5.4 GROUNDWATER DEPENDANT ECOSYSTEMS

Baseline detailed biological surveys comprehensively defining groundwater dependant ecosystems (GDE) are defined in a flora and vegetation survey report (Ecoscape, 2016b) across a biological assessment study area within the Yangibana tenement area. Regionally, surface GDE associated with phreatophytic vegetation can establish at sites of shallow groundwater and at points of groundwater discharge (springs, soaks, groundwater supported river pools etc.). Subsurface GDE occur below the watertable where water quality and porosity is sufficient to support stygofauna. Troglofauna occur as GDE in geological layers that provide air filled pockets and cavities where the presence of permanent groundwater ensures that humidity levels are high enough to ensure their survival (Ecoscape, 2016a).

Surface GDE

Springs and soaks are not known to occur within the study area on the basis of available data but the Geoscience Australia topographic data set shows a number of perennial pools along the Lyons River, southwest of the proposed development, Rockhole Creek, northwest of the proposed development and Pimbyana Creek, southeast of the proposed development (Figure 1). Pools along Pimbyana Creek occur approximately 4 km southeast of the Fraser's deposit. Pools along Dingo Creek and Rock Hole Creek occur within about 3 and 7 km, respectively of Yangibana North deposit and pools along the Lyons River are a minimum of about 5 km from the Tongue prospect.

Data are not adequate to allow depth to groundwater to be accurately contoured in order to delineate areas with shallow groundwater and therefore broader areas in which phreatophytic vegetation would more likely occur. However, available waterlevel data (Figure 5) suggests that groundwater levels are shallowest adjacent to/along drainage lines and it would be these areas in which significant surface GDE are most likely to occur.

A vegetation type dominated by *Eucalyptus camaldulensis* was identified as a GDE by Ecoscape (2016b). It largely corresponds with the Lyons and Edmund Rivers and major tributaries of these, which are typically areas that contain large permanent pools. This vegetation type occupies 447.6 ha (0.84%) of the biological assessment study area, but was not mapped within the proposed development footprint.

Additional vegetation types characterised by *Eucalyptus victrix* that may represent GDE were also identified by Ecoscape (2016b). In the biological assessment study area, these correspond with drainage lines and outwash from these lines and with a large clay swamp near the southern boundary. These vegetation types occupy 4283.3 ha (8%) of the biological assessment study area of which 60.9 ha was mapped within the proposed development footprint.

Stygofauna

Stygofauna sampling undertaken on behalf of Hastings was conducted by Ecoscape (2016a). The sampling was undertaken over two phases at a total of 23 sites in exploratory drill holes and at Andy's Bore. All sites were located within the Yangibana tenement area (Figure 2). Ten (10) species were recorded from eight of the sample sites and of these, three taxa were considered likely to be of conservation concern (Ecoscape, 2016a). Ecoscape concluded that the diversity of stygofauna is unlikely to be impacted by the Yangibana Project due to the extent of the mining pits and associated drawdown but data on predicted drawdown were not provided. Nonetheless, Hastings are currently conducting further sampling at greater distance from the proposed development to establish with more certainty the occurrence and nature of the stygofauna over a broader area.

It is assumed that stygofauna will be most abundant where porosity is highest below the watertable. Within the study area this will likely be where secondary porosity has developed through fracturing of basement rocks and through the development of solution channels and cavities within both ironstone veins and calcrete. The mapped extent of the ironstone and calcrete units is given in Figures 4 and 6, respectively.

Troglofauna

Troglofauna sampling for Hastings was carried out by Ecoscape (2016a). The sampling was undertaken in two phases at a total of 34 drill holes by trapping and at 32 drill holes by troglofauna scraping. All sites were located within the Yangibana tenement area. Eleven (11) troglofauna specimens representing at least five species were recorded from five of the sample sites. Of these, four species were considered likely to be of conservation concern with the fifth having an unknown status due to the poor condition of the specimen (Ecoscape, 2016a).

Ecoscape (2016a) concluded that impacts of the Yangibana Project on troglofauna would be mostly direct as their habitat is typically only removed through mine pit excavation. Indirect impacts including vibration from blasting and stockpiles could also occur and although likely to reduce population density, they are not likely to impact troglofauna species as a whole.

It is assumed that troglofauna will be most abundant where porosity is just above the watertable. Within the study area this will likely be where secondary porosity has developed through the development of solution channels and cavities within both ironstone veins and calcrete. However, Ecoscape (2016a) found that troglofauna were found in several different rock types, not restricted to ironstone and did not find any associated with calcrete. Further sampling currently being undertaken at greater distance from the proposed development will help to establish with more certainty the occurrence and nature of the troglofauna over a broader area.

6 GEOLOGY

The area is located within the Gascoyne Province of the Capricorn Orogen, between the Archaean Yilgarn Craton to the south, the Archaean Pilbara Craton to the north and Phanerozoic Carnarvon Basin sediments to the west. The following is taken mostly from the work of Martin et al. (2005), Pirajno and González-Álvarez (2013) and the reporting of Whittock (2016). The geology of the area is shown in Figures 3 and 4.

6.1 BASEMENT ROCKS

The study area is underlain mostly by Proterozoic metasedimentary basement rocks of the Pooranoo Metamorphics, which consist of metamorphosed feldspathic sandstone and psammitic schist and calc-silicate rocks. These have been intruded by Proterozoic granitic rocks (specifically the Pimbyana and Yangibana Granites), which underlie the bulk of Yangibana tenement area. The granitic rocks are fresh to weathered.

A sequence of rocks belonging to the Edmund Group of the Bangemall Supergroup overlie the Pooranoo Metamorphics and the granites in large parts of the northeast and to a lesser extent the region southwest to southeast of the Yangibana tenement area. These rocks consist of variable lithologies including dolostone, dolomitic siltstone, massive and laminated chert, mudstone, sandstone and conglomerate. Later dolerite and gabbro sills were subsequently emplaced in the Edmund Group succession to the northeast of Yangibana tenement area.

The earlier basement rocks have been intruded by later dolerite sills and dykes as well as veins of ferrocarbonatite, ironstone and quartz of the Gifford Creek Ferrocarbonatite Complex (GFC) as described by Pirajno and González-Álvarez (2013). The ironstone veins have shallow (c. 10°) to steep (c. 65°) dips, consist of magnetite, hematite, and supergene goethite and are locally weakly radioactive. Lenses and pods up to 10 m wide of massive to vuggy iron oxide are contained within the veins. These are considered to have resulted from later alteration of intruded ferrocarbonatites by hydrothermal iron oxides followed by supergene alteration closer to the surface to produce massive goethite and gossanous outcrop (Pirajno and González-Álvarez, 2013). They host the rare earth element (REE) mineralisation of the proposed Project, and occur as sinuous pods and veins that are traceable for up to 25 km (Whittock, 2016).

Basement Rock Structure

The basement rocks were subject to several phases of deformation causing shearing, faulting and folding. Regional structural deformation of the area is extensive and is set out by Johnson (2013). The Lyons Fault is the main structural feature throughout the area and intrusion of the GFC veins is thought to be associated with this zone. Many other interpreted faults are noted from the 1:100,000 scale geological mapping by GSWA (Figure 3) and at a local scale within the Yangibana tenement area by Whittock (2016).

6.2 SUPERFICIAL STRATA

Cenozoic superficial strata covers much of the basement rocks in the study area. Martin et al. (2005) subdivided the superficial strata into an extensive set of superficial units linked to the physiographic division in which they occurred and their provenance. For the purposes of this report, the set within the study area has been simplified into: calcrete, colluvium and other transported and older residual units (excluding calcrete and saprolite), eluvium (saprolite), more recent alluvium and lake deposits.

Calcrete

Dissected calcrete units occur scattered along the major drainage lines. The calcrete units are characterised by a hard surface layer of brecciated and partly silicified calcrete underlain by softer more friable material. These units consist mostly of vuggy calcrete with irregular, lenticular, bedding parallel cavities. Veins and cavities can be filled by quartz cement, especially in upper parts of the calcrete profile. The calcrete can be 30 m thick and possibly up to 50 m thick (Thorpe, 1990), and is commonly partly eroded and degraded.

Colluvium and Other Transported and Residual Units

Colluvial units consist of locally derived quartz and rock fragments in a clay, silt and sand matrix and form restricted aprons around rock outcrops. Colluvial material derived from dolerite is often ferruginous and rich in swelling clay minerals and rock fragments. Colluvium from Pooranoo Metamorphics can also be clayey. Siliciclastic material with calcrete cutans and carbonate cement is derived from calcrete, and quartz-rich material associated with quartz veins also occurs.

Partially and fully cemented and ferruginsed older alluvial units occur along flood plains adjacent to the more recent alluvium in the upper reaches of drainages where they can form partially dissected terraces above active channels. They can also occur as ferruginous, cemented sheet-like deposits of older alluvium that blanket older rocks. They are incorporated with the colluvial units in Figure 4.

Sheetwash deposits are best developed on gentle distal slopes adjacent to major drainages. Quartzofeldspathic sand and silt wash is derived from granitic rocks. The upper surface of some sheetwash units may be marked by a deflation lag of vein quartz and rock fragments. Sheetwash deposits are less developed in areas of steeper slopes associated with the main strike ridges.

Ferruginous duricrust ranges from thin cappings of bedded or vuggy ironstone with disseminated quartz veins, to pisolitic laterite deposits up to 10 m thick. It is best developed over Edmund Group rocks and dolerite sills in the northeast with small, scattered occurrences developed over the metasedimentary rocks of the Pooranoo Metamorphics, granitic rocks and over siliciclastic and carbonate rocks of the Edmund Group where they occur as outliers over the granitic rocks.

Dolomitic units within the Edmund Group are characterised by extensive development of silcrete and brecciated siliceous caprock and silicified sandstone and conglomerate. Scattered occurrences of ferruginous silcrete also occur.

Recent Alluvium

Extensive alluvial units composed of silt, sand, and gravel are present along the main drainage lines. They can be clay-rich where derived from dolerite outcrops. The thickness is as yet not documented in the area.

Eluvium

Outcrops of the granitic rocks can be covered in places with a veneer of locally derived, weathered quartzofeldspathic rock in a sand and sandy clay matrix. At Fraser's deposit Whittock (2016) noted deeper intensely weathered saprolitic granite and clays in flatter, outcrop-deficient areas but only shallow weathering profiles in areas of outcropping granite and ironstone. At the Bald Hill deposit, significant depths of intense weathering were observed in the hanging wall mineralisation. Intense weathering of granite to dominantly clay and remnant quartz was observed to depths up to 50 m.

Lake Deposits

Fine-grained, unconsolidated lacustrine deposits occur in isolated claypans, perennial lakes, and swamps; and low-lying areas with internal drainage. They are most abundant in the southwest part of the province and along the line of the Edmund River and are usually thickly vegetated. They commonly overlie older alluvium or sheetwash.

7 CONCEPTUAL HYDROGEOLOGY

Due to a paucity of groundwater data the hydrogeology of the study area is poorly defined, although general characterisation is possible using the limited data and information available from government records of stock bores and wells, geology, minerals exploration and the very limited groundwater specific data and information.

The study area is not characterised by regional aquifers, rather aquifers are likely to be present in superficial strata, where sufficiently thick and saturated and in basement rocks, where fractured or weathered but in general, these will be isolated and effectively disconnected from each other over much of the study area. Some degree of hydraulic connection will occur locally depending on geological structure, weathering, landscape position and aquifer geometry. Figure 7 schematically sets out the general conceptual hydrogeology.

7.1 AQUIFERS

Most superficial units within the study area will be low permeability and/or unsaturated. In general, only alluvium and/or calcrete in proximity to recharge along the main drainages are aquifers with potential to supply useable, sustainable quantities of groundwater. Both units would essentially act as one aquifer of variable extent, occasionally layered, and with highly variable permeability; highest where solution channels and cavities are present in calcrete and lowest where the strata is clayey.

Basement rocks in the study area will, in the main be very low permeability and could be regarded as effectively impermeable throughout much of the area, although some zones of very high permeability will occur. Permeability in basement rocks will be very high in the vicinity of bedding plane partings and fractures from faulting, folding, intrusives and where solution cavities and channels (vugs) have developed in ironstone veins. Large cavities were identified as a significant feature of the mineralised zone at depth at the Fraser's deposit (Whittock, 2016). Permeability may also be relatively high where quartzose saprolite has developed at the base of the weathered sections of granitic rocks above fresh granitic basement. However, these zones of high permeability will likely account for only a comparatively small part of the area.

Groundwater in superficial aquifers is likely to be generally unconfined but confined groundwater will be present locally where the aquifer is overlain by low permeability units such as clayey sections of calcrete or alluvium.

Groundwater in fractured rock aquifers is often unconfined but a degree of confinement can occur where clayey weathered basement rock overlies either more sandy weathered strata above the fresh basement rocks or fractures within the basement rocks. This can often be the case in granitic basement rocks. Weathering in granites is noted as occurring in the Yangibana tenement area but does not appear ubiquitous. Correspondingly, it is concluded that that across the study area the aquifers will be mostly unconfined with confined conditions occurring locally. A broader set of information across the Yangibana tenements will assist this characterisation.

7.2 GROUNDWATER LEVELS

Available waterlevels from the study area are given in Figure 5. These are non-synoptic having been obtained over an extended period of years and it is very difficult to make a reliable assessment. However, while variations do occur there is a trend of shallowest waterlevels (generally 10 m depth or less) closest to the drainage lines with waterlevel depths increasing with distance from the drainage lines and up catchment where levels are often 15 to 23 m depth.

In the terrain of granitic rocks intruded by veins and dykes within the Yangibana tenement area, a watertable should be evident in all drill holes that penetrate to sufficient depths, irrespective of drill hole location, although the time for recovery of the watertable in holes drilled into low permeability strata will be extensive.

Ecoscape (2016a) recorded waterlevels in open and often angled drill holes of between about 6 and 35 m depth during stygofauna sampling within the Yangibana mining leases.

Little seasonal variation in waterlevels was also observed during the sampling programs, although with the nature of rainfall and recharge events, it is possible there may well be significant natural variation in groundwater levels from season to season depending on those factors.

Whittock (2016) observed waterlevels between 10 and 30 m depth at Yangibana West and a correlation between zones of more intense weathering and a relatively shallow watertable. This was also observed at Bald Hill South, with the suggestion this was related to the increased porosity and permeability associated with weathering. This may be a function of higher rates of recharge locally through these more permeable zones.

Whittock (2016) observed the watertable at Bald Hill to be strongly structurally controlled and associated with a highly porous ironstone unit. The watertable was deeper in topographically higher areas and also down dip of mineralisation in the southern portion of Bald Hill South, where the ironstone unit dips more steeply. The watertable at Fraser's deposit was found to be between 30 to 40 m depth and also subject to structural control.

7.3 RECHARGE, FLOW AND DISCHARGE

The nature of rainfall in the region produces periods of high runoff to creeks and rivers. This in turn produces sporadic recharge to permeable units; for example permeable alluvium and calcrete along the drainages or where fractured basement rocks contact surface drainage lines, in areas where the runoff is concentrated (Thorpe, 1990). Groundwater recharge by direct infiltration of rainfall over the superficial units or fractured outcropping rocks will likely be minor.

Estimates of groundwater recharge are not available for the study area but Skidmore (1996) provided estimates of recharge to broad aquifer types throughout the Pilbara region including for rocks on the Edmund 1:250,000 map sheet within the Ashburton River catchment, north of the Yangibana tenement area. Correspondingly, aspects of that assessment are likely relevant to this work as first pass estimates.

The significant geological units within the Yangibana tenement area could be broadly regarded as granitic basement rocks (inclusive of Pooranoo Metamorphics), and alluvium/calcrete around the margins of those basement rocks. Recharge from infiltration of rainfall to granitic basement rocks in the Ashburton River catchment was estimated at 2% of annual rainfall over outcrop (Skidmore, 1996). Assuming annual rainfall of 220 mm, then recharge of about 1 GL/annum (equivalent to approximately 2800 m^3/day) is estimated for approximately 230 km^2 of outcropping granitic rocks in the Yangibana tenement area.

As alluvium/calcrete aquifers along the surface drainages are recharged principally by infiltration of accumulated runoff, recharge estimates were made on the basis of volumes per kilometre of drainage line in contact with the unit (Skidmore, 1996). A recharge value of 90,000 m^3/km/year was applied to a similar aquifer unit in the Ashburton catchment. Using that value over the approximately 70 km of surface drainage associated with significant sections of calcrete/alluvium within the Yangibana tenement area, recharge to the unit would total about 6 GL/annum. This indicates recharge to the alluvium/calcrete by accumulated runoff is the dominant mechanism across the study area.

Groundwater will flow from recharge areas, down hydraulic gradients, most likely in the direction of surface water flow. Regional flow systems are not likely to be generated, rather local flow systems will have established in response to aquifer distribution and geometry, which is highly variable. Correspondingly, while the available data are as yet inadequate to enable delineation of the watertable over a large area from which to map groundwater flow, it is likely that the irregular geological structure and distribution of permeability would cause both preferential groundwater flow paths and barriers to flow such that the watertable configuration would be difficult to accurately construct and would appear irregular.

Groundwater discharge will occur via:

- groundwater flow down hydraulic gradient and out of the area,
- evaporation,
- transpiration from phreatophytes,
- groundwater pumping for water supplies, and
- discharge at springs, soaks and river pools depending on local geological structure, topography, aquifer geometry and waterlevels.

7.4 STORAGE

Estimates of aquifer storage are not available for the area. However, storage coefficients assumed for rocks on the Edmund 1:250,000 map sheet area within the Ashburton River catchment (Skidmore, 1996) have been applied to the current Project for derivation of first pass estimates.

In terms of volume, the significant geological units in the vicinity of the Yangibana prospects are granitic basement rocks (inclusive of Pooranoo Metamorphics) and alluvium/calcrete around the margins of those basement rocks. Granitic rocks were assigned a storage coefficient of 0.05 and groundwater storage of 0.38 GL/km^2 was estimated for the rocks in the Ashburton catchment (Skidmore, 1996). Applying these values to the Yangibana tenement area of approximately 645 km^2 suggests storage in the basement rocks of about 245 GL. This would likely be the upper value and it is thought unlikely that this storage would be accessible in a practicable way due to generally very low bore yields, apart from discrete zones of higher permeability and limited connectivity between these zones.

The alluvium/calcrete aquifers along the surface drainages in the Ashburton River catchment were assigned a storage coefficient of 0.1 and average groundwater storage of 3 GL/km^2 (Skidmore, 1996). Applying these values to the area of calcrete (85 km^2 outcrop and subcrop) within the Yangibana tenement area suggests storage in calcrete of about 255 GL. This may also be the upper value as some of the calcrete occurs in the upper catchment areas, which may impact saturated thickness. Nonetheless, the estimates indicate the likely proportional dominance (in terms of surface area) of storage in the superficial strata as compared to that in the basement rocks.

7.5 GROUNDWATER SALINITY

Lowest salinity groundwater will occur closest to areas of higher volumes of recharge. This is likely to occur mostly through infiltration of accumulated runoff along drainage lines. Groundwater salinity will increase with time after recharge events and with distance from recharge areas.

Available WIN data are non-synoptic having been obtained over an extended period of many years and quite likely of limited reliability. Many of the earlier readings would likely have been obtained using early model electrical conductivity bridges known to have limited accuracy. Nonetheless, the available data indicate wide variability in groundwater salinity across the broader area ranging from 130 mg/L TDS in Alma Well along the Alma River, west of the Yangibana tenement area to 12,590 mg/L TDS in Newell Well south of the Lyons River about 35 km southwest of the tenement area (Figure 8). The median salinity value from available data is 1390 mg/L. Groundwater salinity within the Yangibana tenement area ranges from 1350 to 4000 mg/L, which is relatively high and if representative, reflects limited aquifer recharge.

7.6 BORE CAPACITIES

Bore capacities from the study area are effectively unknown but it is likely that high bore yields in basement rocks will be encountered in discrete, narrow zones of very high permeability. These are associated with fractures around bedding plane partings, faulting, folding, intrusives, where solution cavities and channels have developed in ironstone veins and where quartzose saprolite is developed over fresh granitic rocks. It is likely that initial high discharge rates encountered by drilling will diminish relatively quickly with longer term pumping as permeability (and correspondingly storage) outside the discrete high permeability zones will be very low.

High bore yields will also likely be encountered in thick sections of alluvium/calcrete where solution channels and cavities are encountered in the vicinity of drainage lines. Initially high yields in these aquifers are likely to be sustainable for longer periods (depending on actual aquifer extent and geometry) due to the much larger storage associated with these superficial aquifers compared to the basement rock aquifers. However, the unit is also closer to GDE associated with the surface drainage lines and shallower groundwater and potentially to stygofauna and troglofauna with implications for management of abstraction should successful water bores be located within it.

Discharge rates within the WIN data are listed for eleven (11) bores and wells over the study area. These range from 2 to 109 m^3/day and average 37 m^3/day. However, these values were not likely derived from analysis of controlled test pumping and most likely reflect pump capacity rather than bore capacity. This probably skews the values lower as many of the bores would be equipped with windmills or small capacity solar pumps.

Within the Yangibana Project area, several dedicated water bores are listed in the drill hole database (BHWB001A, FRWB001, YGWB001 and YGWB002). There is effectively no capacity data that can confidently be attributed to these bores but limited database annotations and anecdotal advice from Hastings is that the bores are of either low or unknown capacity. Other database notes suggest that at least two mineral exploration drill holes associated with large water intersections in ironstone veins have potential for higher capacity (BRC082 and FRCC009). The ironstone veins at Bald Hill deposit were observed to be commonly vuggy and friable and the mineralised zone at depth at Fraser’s deposit was described as extremely vuggy, with drilling identifying large cavities associated with large volumes of water (Whittock, 2016). High bore yields could be expected where such vuggy zones are intersected below the watertable.

Data are available for a brief period of test pumping at low yields carried out on a PVC cased bore named YGBWB1 (L. Jefferson, pers. comm., September 2016). Drill hole YGBWB1 is not listed in the drill hole database provided and it may be that the bore is YGWB001, which is listed in the database as a water bore. The test was conducted at a flow rate of 22 m^3/day for about 15 minutes during which 0.7 m drawdown occurred. The analyses was not set out in a formal report but working sheets provided predicted that 24-hour drawdown at a discharge rate of about 1000 m^3/day might be 22 m. The prediction is based on a two order of magnitude increase of the test discharge rate and from only 15 minutes of pumping so cannot be regarded with anything other than caution but nonetheless, the predicted 24-hour drawdown is significant.

Additional information on ATC Williams Figure YB1 (L. Jefferson, pers. comm., September 2016) shows the location of mineral exploration holes at Yangibana deposit where ‘water strikes’ were recorded. The figure shows about 7 of 135 drill holes have ‘water strikes’ but the nature or details of the ‘water strike’ are not provided and the implications of that in terms of bore capacities are not clear. Of note is hole YWRC003, listed on Figure YB1 as encountering a ‘water strike’, there is no such information in the drill hole database provided indicating that another source of information on ‘water-strikes’ exists within the Hastings data sets. This may be drillers day sheets, geologists notes etc. This type of information has potential to focus groundwater exploration efforts around and within the proposed pits saving significant funds. This information should be systematically evaluated to assist targeting of exploratory groundwater drilling for test production bores prior to expending resources on groundwater exploration drilling for dewatering or water supply.

8 IMPLICATIONS FOR THE YANGIBANA RARE EARTHS PROJECT

The Yangibana Project incorporates mining below the watertable in several open cut pits requiring dewatering and provision of water supplies for processing, dust suppression, potable supplies and other site activities. Groundwater abstraction will cause drawdown that will impact areas surrounding pumping bores (for example stygofauna and troglofauna) but the extent and nature of the drawdown impact is not yet clear as very little groundwater work has been undertaken to date. Confidence on the conceptual hydrogeology is also limited by the lack of available data. Nonetheless, the conceptualisation has been made and the following are points that emerge for consideration;

- The ironstone veins hosting the ore body(s) are aquifers of local significance with high permeability where solution channels and cavities are developed within the ironstone. However, outside of these discrete zones, the ironstone is more massive and permeability will be generally very low.

- Large areas of calcrete occur along the surface drainage lines and with alluvium form a significant local aquifer. The calcrete may be as much as 30 to 50 m thick. Solution channels and cavities occur in the calcrete.

- Stygofauna and troglofauna have been recovered from Yangibana Project area exploratory drill holes that have intersected granite and ironstone and from Andy's Bore located in an area of calcrete between Kane's Gossan prospect and Bald Hill deposit. The chances are high that both stygofauna and troglofauna will occur in other sections of vuggy calcrete and ironstone and possibly in fractured basement rocks throughout the study area.

- The granite at the margins of the ironstone veins will be of very low relative permeability apart from discrete zones of secondary porosity developed due to fracturing from faults or intrusives or from weathering to form permeable saprolite, which may be relatively thick in places.

- Dewatering will likely be achievable through relatively simple design with interception bores at the ends of the pits intersecting inflows along ironstone veins. Depending on lead times, mine scheduling, actual aquifer parameters and structures/weathering in the ironstone veins and the adjoining granitic rocks, in-pit bores and/or sumps and other bordering bores could be utilised. Further work is required to assess this.

- Elliptical cones of depression are expected to develop during dewatering, and to extend rapidly over significant distance along the veins and relatively short distance in the bordering lower permeability granitic rocks. As such, while pumping from one section of ironstone may cause significant drawdown along strike, drawdown impacts across strike may not extend far, which has implications for the occurrence and continuance of stygofauna and troglofauna in unmined areas across strike. Further work is required to assess this.

- Yields of water bores drilled into ironstone will likely be low based on the available data with occasional high to very high initial bore yields where solution channels and cavities are intersected. However, the lack of groundwater drilling data and groundwater observations from mineral exploration drilling hampers the understanding and it is possible that the ironstone could be more prospective for higher initial bore yields over larger areas.

- The generally low storage in the ironstone veins and bordering granitic rocks will cause high bore yields to decline relatively quickly with extended pumping as storage depletes. Higher bore yields would be prolonged where the cone of depression intersects sufficient interconnected secondary porosity but the chances of this occurring often are considered low on the basis of the currently available information.

- At this stage, in generating Project water budgets it’s important not to overestimate the volumes of water available from dewatering due to the generally low aquifer storage in the ironstone veins and bordering granitic rocks.

9 CONCLUSIONS

The Hastings proposed Yangibana Project incorporates mining below the watertable of several ore bodies hosted in narrow, dipping ironstone veins that have been intruded through granitic country rock and can be traced over tens of kilometres. The ironstone veins and adjacent granitic rocks form basement rock aquifers. The ironstone veins are massive to vuggy with correspondingly variable permeability. The granitic country rock is also of variable permeability; mostly low through the bulk of the rock with discrete zones of high permeability where fractures occur or where weathering has produced zones of quartzose sand above the fresh granite. Groundwater storage will be low in these units due to limited porosity.

Alluvium and calcrete associated with main drainage lines will form shallow aquifers with overall comparatively higher permeability to that in the ironstone veins or granitic rocks. The highest permeability will be associated with solution channels and cavities in the calcrete. Groundwater storage will be higher in these units due to greater overall porosity.

Groundwater recharge to the aquifers from direct infiltration of rainfall will be low due to the low average rainfall and its sporadic nature. The rainfall is mostly high intensity and infiltration of accumulated runoff is correspondingly the greatest source of recharge. This will be enhanced where aquifer units contact drainage lines and higher volumes of recharge to the alluvial/calcrete aquifer units can be expected compared to the basement rock aquifers. Recharge to the basement rock aquifers will occur preferentially where permeable zones contact surface drainages or overlying shallow alluvial/calcrete aquifers.

Groundwater will move down hydraulic gradient from areas of recharge, nominally in the direction of surface water flow. A regional groundwater flow system is unlikely to be established with more local, structurally controlled systems probable. Correspondingly, while the available data are as yet inadequate to enable delineation of the watertable over a large area, it is likely that the watertable configuration would appear irregular due to irregular geological structure and highly variable permeability causing both preferential flow paths and barriers to flow.

Groundwater salinity is variable and values derived within Yangibana tenement area range from about 1350 to 4000 mg/L. This is relatively high and if representative, reflects limited aquifer recharge.

Bore yields are likely to be highly variable. They can be expected to be initially high to very high where higher permeability zones are intersected and very low elsewhere. As the bulk of the geology has low permeability, non-systematically targeted groundwater drilling will likely have low rates of success. Success rates for groundwater drilling will be highest where the focus is on systematic exploration for zones of higher permeability.

Initial discharge rates of bores in basement rock can be expected to decline relatively quickly with long-term pumping due to the low groundwater storage in these aquifers. Potentially higher sustainable average bore yields with less drawdown occur in the alluvial/calcrete aquifers associated with the surface drainages bordering the granitic rocks.

Dewatering of pits to mine ore bodies will likely be achievable through relatively simple design with interception bores at the ends of the pits intersecting inflows along ironstone veins possibly with in-pit bores and/or sumps and other bordering bores.

Elliptical cones of depression are expected to develop during dewatering, and to extend rapidly over significant distance along the veins and relatively short distance in the bordering lower permeability granitic rocks. As such, while pumping from one section of ironstone may cause significant drawdown along strike, drawdown impacts across strike may not extend far.

However, detailed hydrogeological investigation is required to establish actual dewatering requirements and predicted impacts. Continued geological work on structural features associated with the ore bodies, ground-based VLF electromagnetic geophysical surveying and comprehensive review of data accompanying minerals exploration drilling undertaken to date will be a major benefit in focussing the field groundwater exploration effort.

Stygofauna and troglofauna species have been recovered from mineral exploration holes intersecting the ore bodies. Further sampling is being undertaken over a wider area to better understand the stygofauna and troglofauna communities locally and regionally. Stygofauna and troglofauna habitat is known to occur within alluvial/calcrete aquifers and ironstone veins because of the presence of solution channels and cavities. Targets for sampling may therefore include existing stock bores and wells often in the vicinity of the alluvial/calcrete aquifers and mineral exploration holes that may have been drilled into ironstone veins across strike from those currently planned for mining.

10 RECOMMENDATIONS

1. Investigate potential for DoW surface water licence 174568 to impact the Project.

2. Detail the Project water requirements (processing, dust suppression, potable supply etc.) against which potential dewatering and water supply aspects can be assessed and a project water budget generated.

3. Undertake a systematic groundwater exploration program to establish site groundwater conditions and evaluate dewatering and water supply requirements.

    a. Complete a detailed evaluation of the full records of the exploratory minerals drilling undertaken on the prospects to date to enable delineation of zones of potentially high permeability both in and around each proposed pit.

    b. Evaluate the geological structure (faults, quartz veins, dykes etc.) in and around each pit as interpreted by Hastings geologists.

    c. Undertake rapid terrain coverage, ground-based VLF electromagnetic geophysical surveying across the delineated features to assess dip direction of targets for exploratory groundwater and drilling rig placement.

d. Generate a set of nominal exploratory groundwater drilling sites throughout the project area and obtain DoW 26D licence(s) to allow exploratory groundwater drilling and testing to be undertaken.

e. Complete test production bores at sites indicating sufficient potential for relatively high yields of groundwater.

f. Complete monitoring bores at sites that do not indicate sufficient potential for high yields and around sites of successful test production bores.

g. Undertake test pumping of successful bores, monitoring both the production bores as well as dedicated monitoring bores to enable delineation of pumping cones of depression for assessment of impacts.

h. Use data acquired to generate numerical groundwater models to enable pumping scenarios with predictions of drawdown impacts and for subsequent applications to the DoW for 5C licence(s) for groundwater allocations.

11 REFERENCES

Daniels, J. L., 1967, Edmund, W.A. (1st edition) Sheet SF 50-14: Western Australia Geological Survey, 1:250 000 Geological Series.

Daniels, J. L., 1969, Edmund, W.A.: Western Australia Geological Survey, 1:250 000 Geological Series Explanatory Notes, 20p.

Davidson, W. A., 1973, Report on groundwater prospects, Wanna Station – via Carnarvon: Western Australia Geological Survey, Hydrogeology Report 1142 (unpublished).

Ecoscape, 2016a, Yangibana Project biological assessment: Subterranean fauna: for Hastings Rare Metals, Ecoscape (Australia) Pty Ltd, Draft Report 10108-3397-15R (unpublished).

Ecoscape, 2016b, Yangibana Project biological assessment: Flora and vegetation: for Hastings Rare Metals Ltd, Ecoscape (Australia) Pty Ltd, Draft Report 10079-3397-15R (unpublished).

Johnson, S. P., 2013, The birth of supercontinents and the Proterozoic assembly of Western Australia: Geological Survey of Western Australia, 78p.

Martin, D. McB., Sheppard, S., and Thorne, A. M., 2005, Geology of the Maroonah, Ullawarra, Capricorn, Mangaroon, Edmund, and Elliott Creek 1:100 000 sheets: Western Australia Geological Survey, 1:100 000 Geological Series Explanatory Notes.

Pirajno, F. and González-Álvarez, I., 2013, The ironstone veins of the Gifford Creek ferrocarbonatite complex, Gascoyne Province: Geological Survey of Western Australia, Record 2013/12, 19p.

Skidmore, D. J. P., 1996, Groundwater resources of major catchments in the Pilbara Region, Western Australia: Water and Rivers Commission, WA, Hydrogeology Report 35 (unpublished).

Thorpe, P. M., 1990, Groundwater prospects - Wanna: Western Australia Geological Survey, Hydrogeology Report 1990/R3 (unpublished).

Whittock, K., 2016, Combined group report C265/2008 for the period 1st December 2014 to the 30th November 2015, Yangibana Project, Upper Gascoyne Region, Western Australia: Hastings Technology Metals LTD, Report, C265/2008 (unpublished).

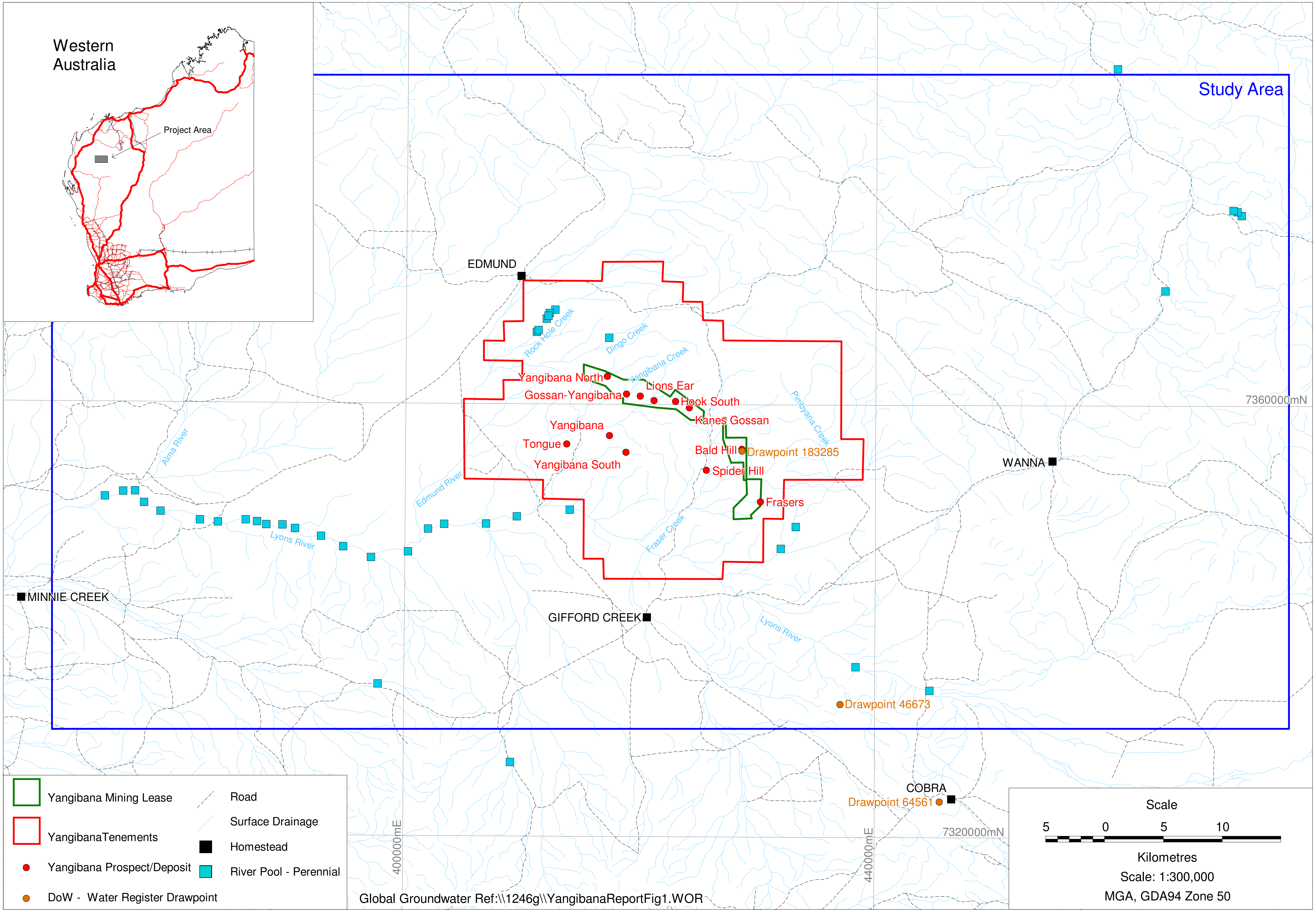


Figure 1. Location

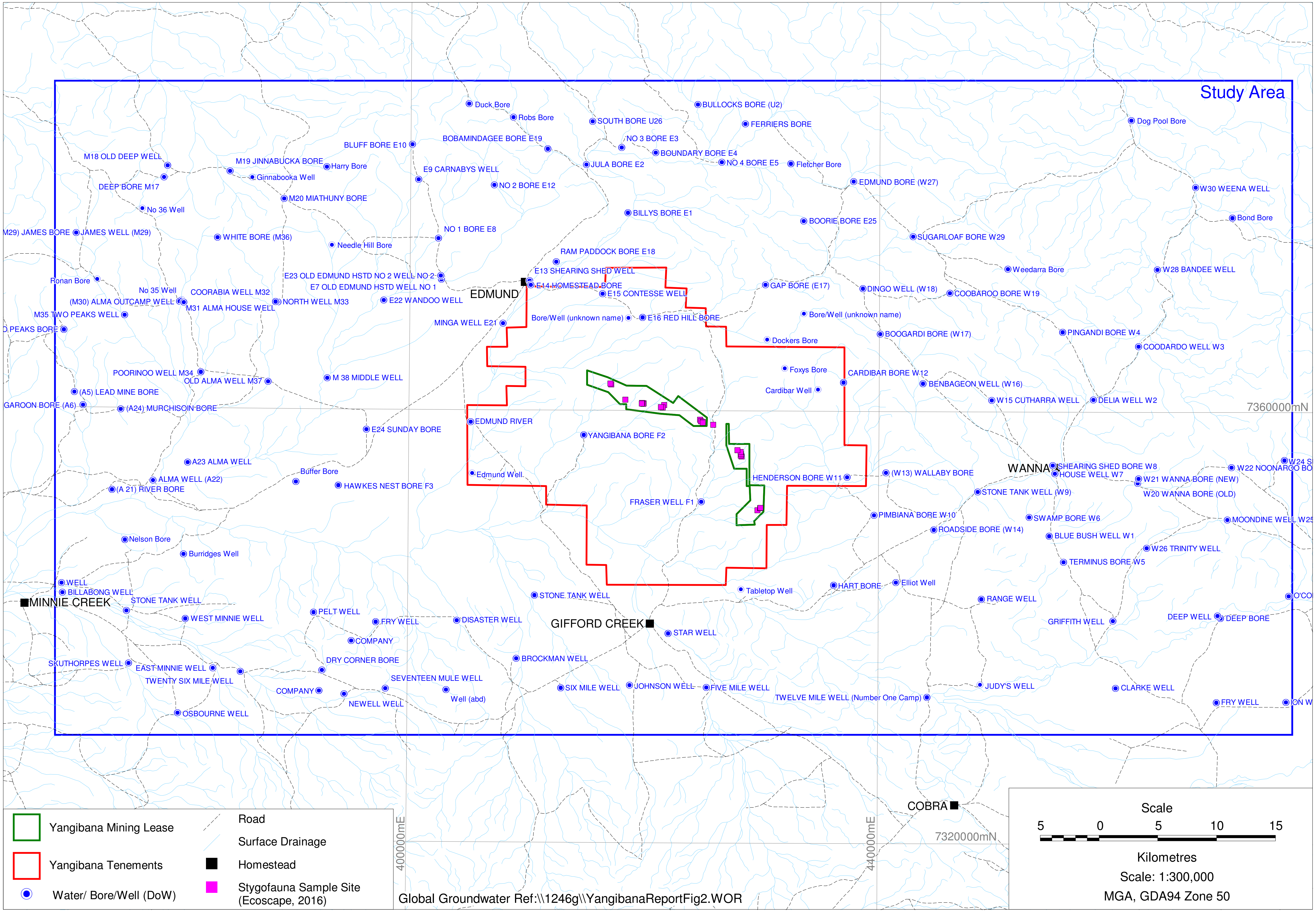


Figure 2. Bore/Well Locations

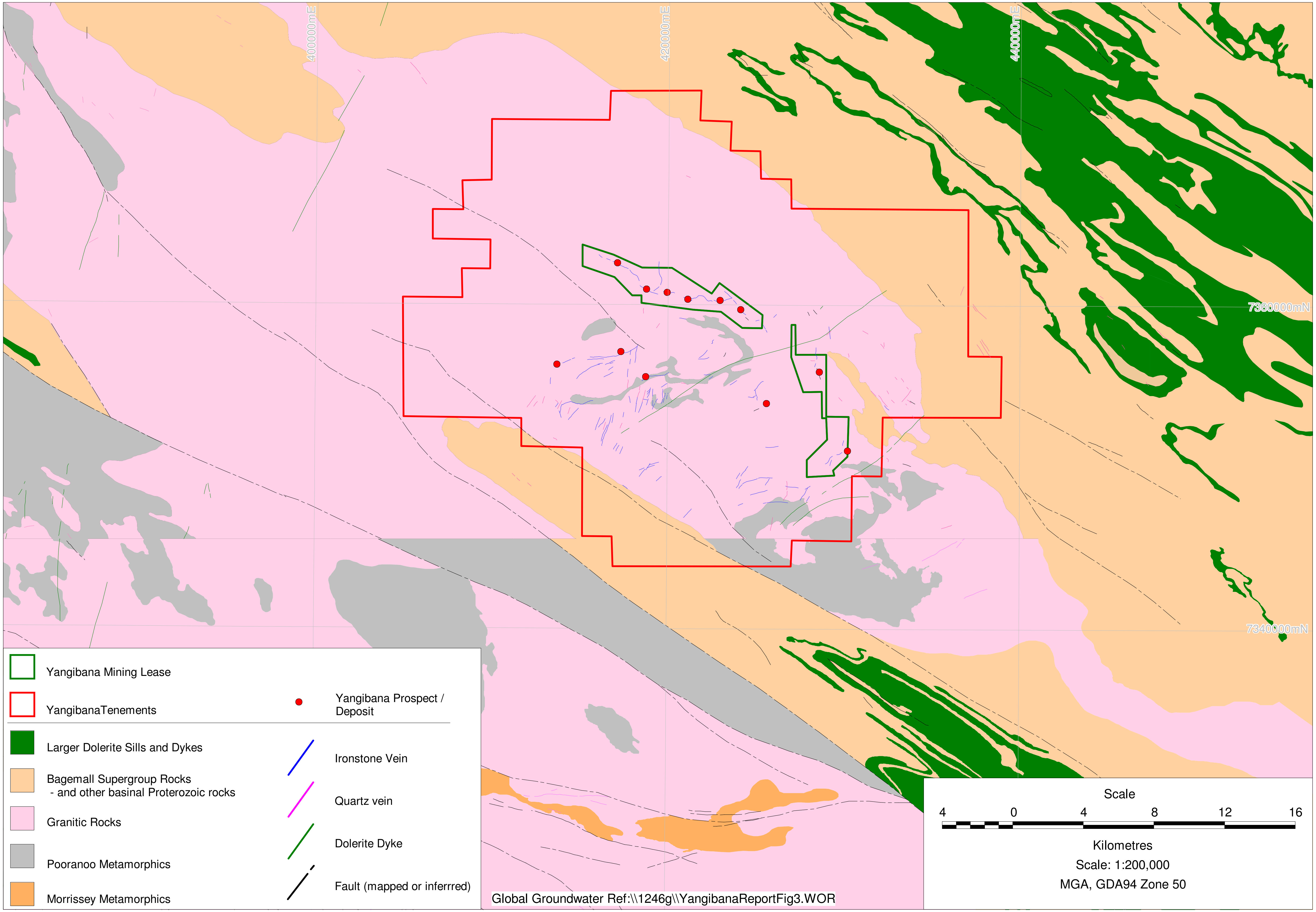


Figure 3. Simple Geology

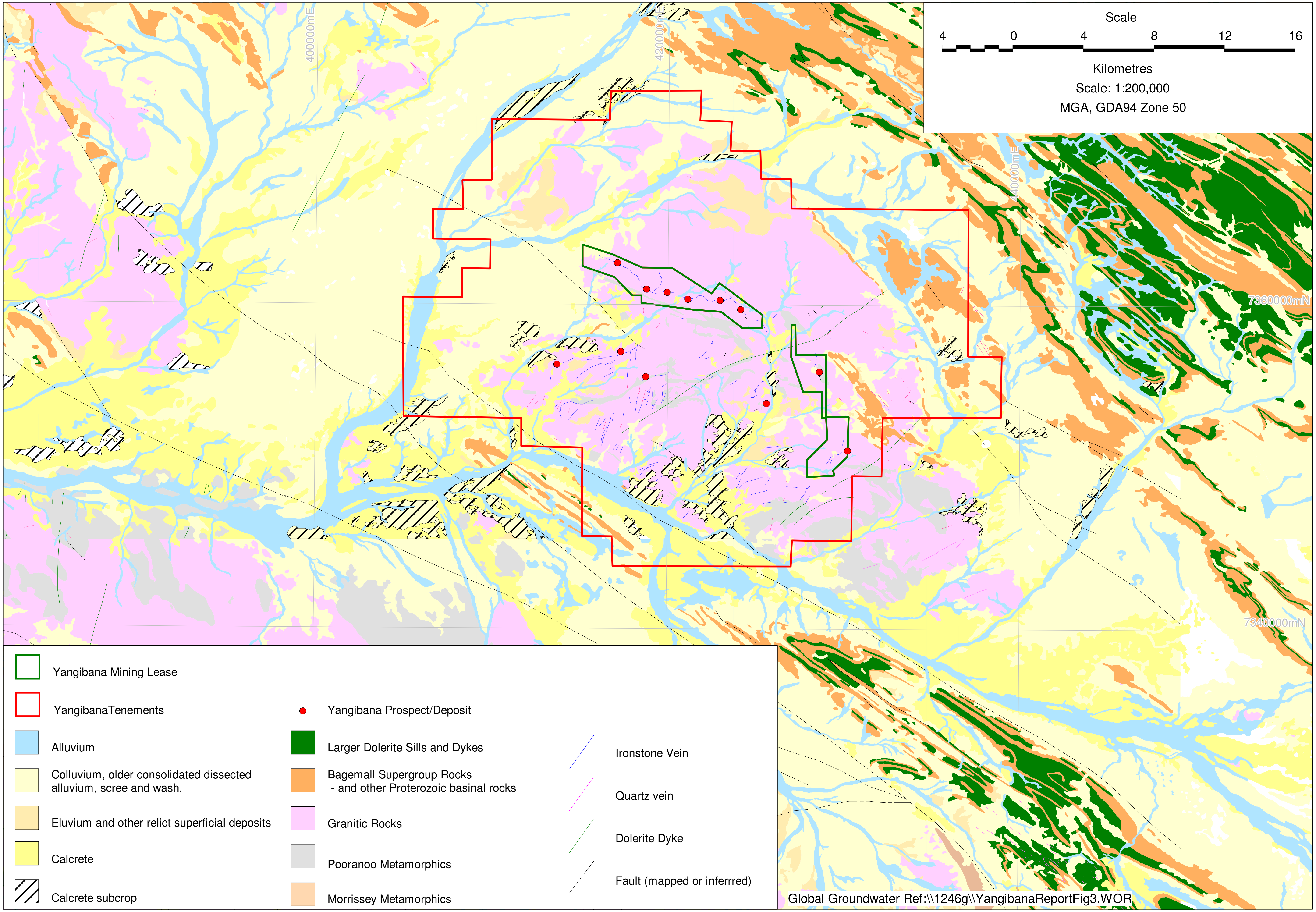


Figure 4. Surface Geology

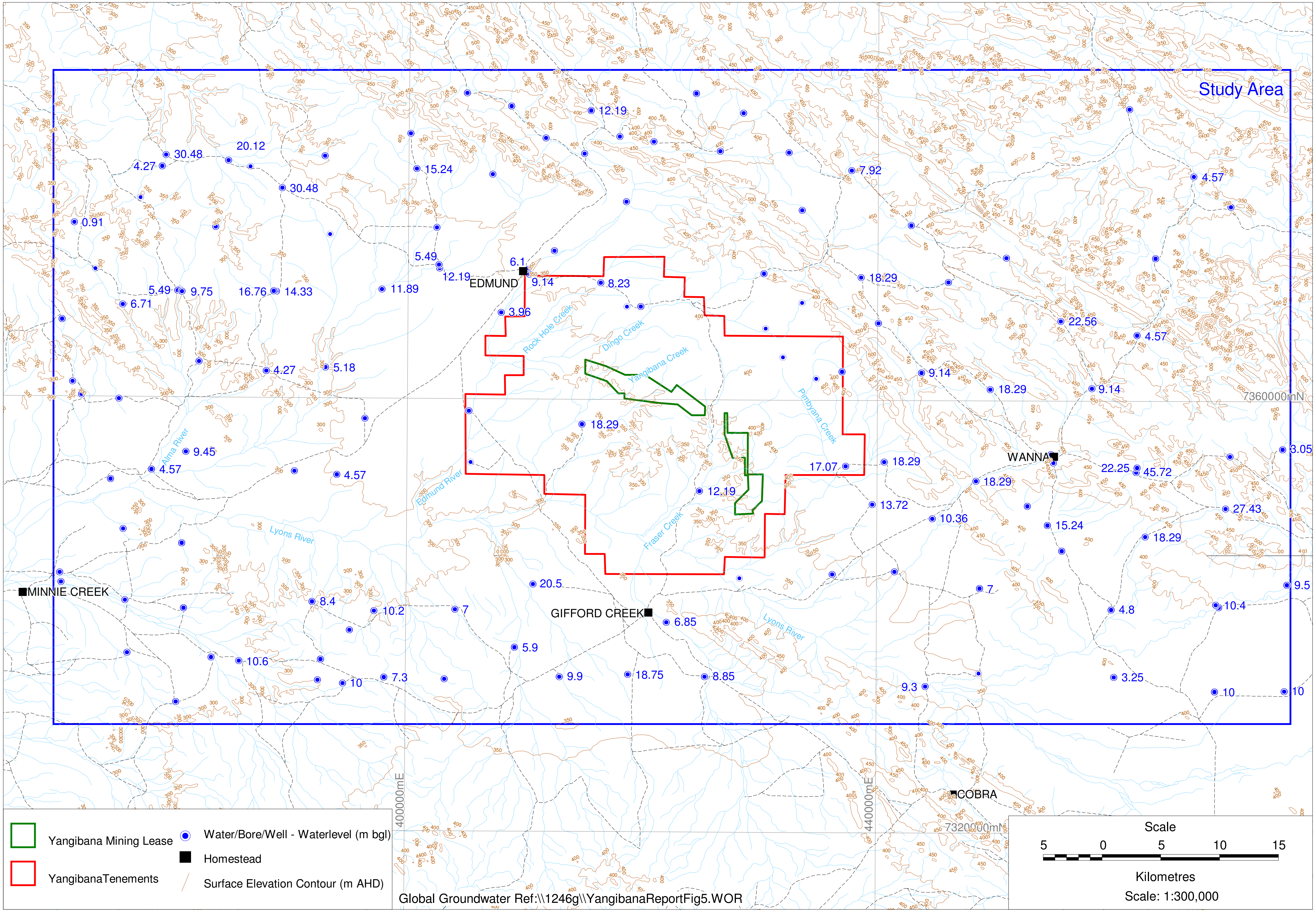


Figure 5. Groundwater Levels

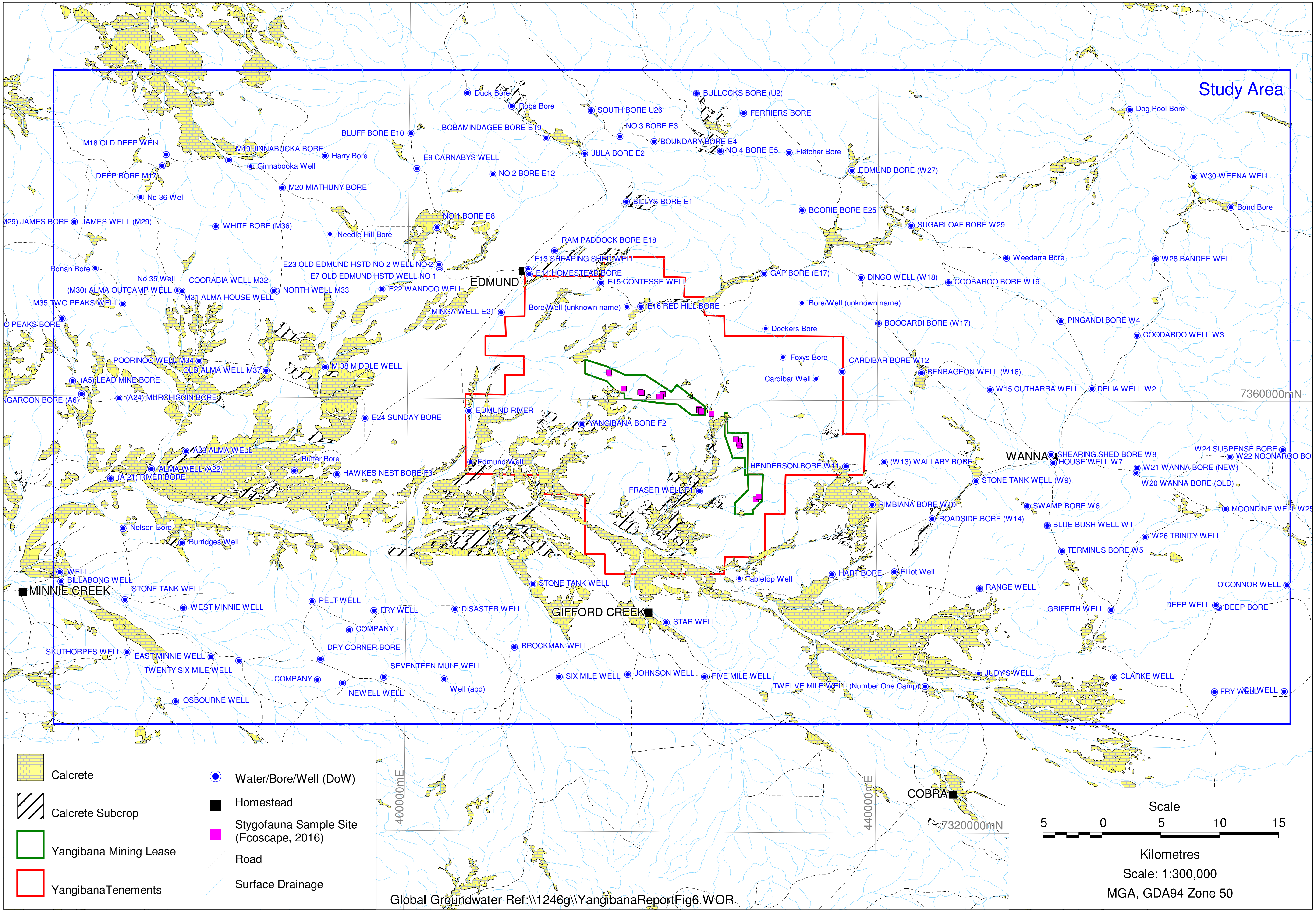
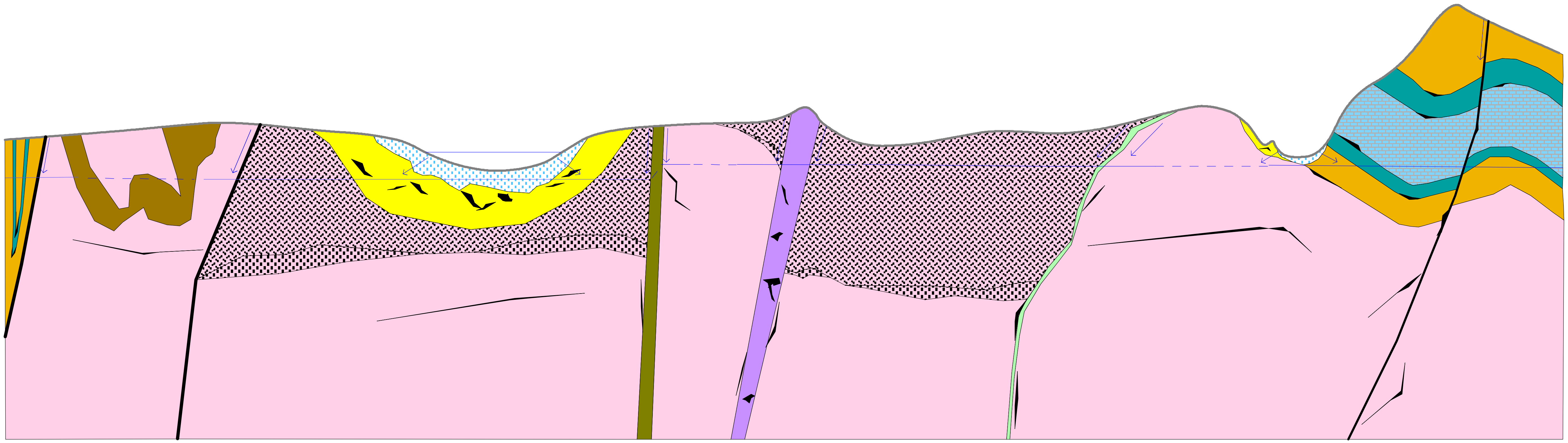


Figure 6. Calcrete Extent

Conceptual Hydrogeology Yangibana Area - Schematic Section



Broad Units

- Alluvium
- Calcrete
- Quartz Veins
- Ironstone Veins
- Dolerite Dykes
- Dolerite - Gabbro Sills
- Bangemall Supergroup Rocks
- Pimbyana and Yangibana Granites
- Pooranoo Metamorphics

Secondary Porosity Freatures

- Weathered - Low permeability eluvium
- Weathered - Higher permeability saprolite
- Faults
- Fractures - Solution Channels and Cavities

Watertable

- Mapable
- Difficult to immediately establish

Main Hydrogeological Characteristics

A series of generally discontinuous aquifers, often disconnected and of mostly limited extent. Psuedo discontinuous watertable.

Main Aquifers

Alluvium and calcrete along the larger drainages, ironstone veins where secondary porosity developed, saprolite where developed above fresh granites and ocassional fractures in basement rocks.

- Alluvium holds groundwater in primary porosity but has generally limited extent and is thin with little saturated thickness.
- Calcrete holds groundwater in secondary porosity of solution channels and cavities but can be clayey.
- Ironstone veins hold groundwater in secondary porosity of soultion channels and cavities but are of limited extent.
- Saprolite developed over fresh granitic basement rocks will hold water in secondary porosity but its extent is unknown.
- Fractures in basement rocks will hold water in secondary posrosity but will be almost impermeable where fresh and unfractured.

Recharge

Occurs mostly where accumulated runoff coincides with alluvium-calcrete and structure with less direct infiltration of rainfall over outcrop.

Hydraulic Characteristics

Permeability will be extremely high where solution channels and cavities or open fractures are developed and may be high in saprolite but will be very low elsewhere.

Storage very low overall. Greatest storage will occur in saturated alluvium and calcrete as well as saprolite and lower permeability eluvium over saprolite.

Yangibana Project Implications

Mostly low bore yields. May be very high in ironstone veins and calcrete where solution channels and cavities intersected and in fractures.

Mostly low storage causing initially high yields to decline relatively quickly with extended pumping.

Steep cones of depression extending rapidly over significant distance along structure/ironstone veins, extending relatively short distance in lower permeability units.

Relatively simple dewatering design likely.

Opportunities for occurence of stygofauna highest in secondary porosity of ironstone veins and calcrete.

Global Groundwater Ref:\\1246g\\Schematic\YangibanaReportFig7.WOR

Figure 7. Conceptual Hydrogeology - Schematic Section

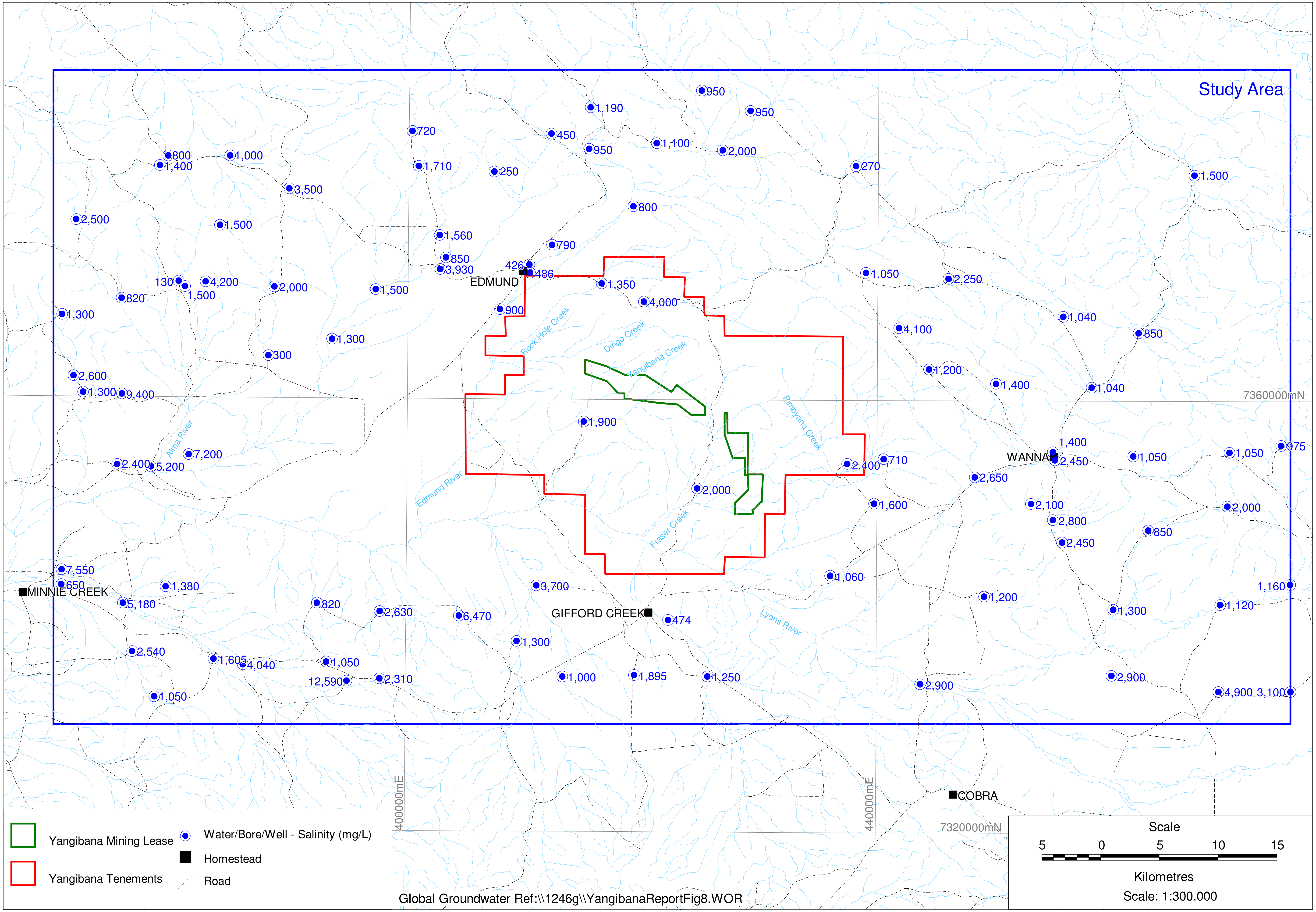


Figure 8. Groundwater Salinity