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FLINDERS MINES LIMITED

Pilbara Iron Ore Project

Groundwater Impact Assessment Report

201012-00322

9-Mar-12

Level 7, QV1 Building
250 St Georges Terrace
Perth WA 6000 Australia
Tel: +61 8 9278 8111
Fax: +61 8 9278 8110
www.worleyparsons.com
WorleyParsons Services Pty Ltd
ABN 61 001 279 812

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FLINDERS MINES LIMITED
PILBARA IRON ORE PROJECT
GROUNDWATER IMPACT ASSESSMENT REPORT

PROJECT 201012-00322 - PILBARA IRON ORE PROJECT

REV	DESCRIPTION	ORIG	REVIEW	WORLEY-PARSONS APPROVAL	DATE	CLIENT APPROVAL	DATE
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0	Issued for Use	L.Siraz	D Cravens	S. Atkinson	09-Mar-12		9-Mar-12

EXECUTIVE SUMMARY

WorleyParsons were commissioned by Flinders Mines Limited (FMS) to undertake hydrogeological assessments to assess the potential groundwater impacts associated with the Pilbara Iron Ore Project (PIOP). The PIOP comprises five main project areas in the mining lease E47/882 of which Delta, Champion and Eagle were of main interest to the current study.

The PIOP is situated within the Millstream Catchment Area, in a Priority 2 Public Drinking Water Source Area (PDSWA). This report presents the work undertaken to develop an understanding of the hydrogeology within the project area, and the results of groundwater modelling used to quantify the potential impact the PIOP may have on local and regional groundwater resources, with particular reference to the Millstream Water Resource. The PIOP was referred for an API level of assessment and accepted by the EPA (Category A). Referral guidelines and a request for additional information have been received by FMS. This report will accompany FMS's response to the EPA referral guidelines and contains relevant information requested by the EPA.

It is currently planned to pump approximately 1.33 GL/a from the Champion, Eagle and Delta deposits to make up the 4 GL/a needed to meet the project water demand over the life of mine (4GL/a over 15 years). This groundwater is to be sourced from mine dewatering systems, with any excess mine dewater returned to the aquifer off tenement to minimise drawdown impacts. Groundwater modelling was used to assess the net impact the abstraction of 4GL/a has on groundwater resources and whether mine dewatering can be used to meet the projects water demands for life of mine.

Detailed mine dewatering and aquifer reinjection systems have not been included in model simulations. Only the net impact of abstracting 4GL/a has been assessed. However sensitivity analysis was performed to assess the need for reinjection systems.

The results suggest that it may be possible to meet the projects water demands for life of mine (4GL/a over 15 years) by extracting 1.33GL/a from the Delta, Eagle and Champion deposits. The results also suggest that mine dewatering volumes may exceed the mine water demand, and therefore excess mine dewater may need to be returned to the aquifer via reinjection off tenement to minimise drawdown impacts.

Recharge calculations and groundwater modelling suggest that the majority of groundwater recharge at the Champion, Eagle, Delta deposits will be intercepted and removed by dewatering systems. The combined average annual recharge at these deposits is estimated at approximately 1.8 GL/a by assuming 5% of average annual rainfall. Therefore an additional 2.2 GL/a of mine dewater may need to be drawn in from off tenement areas to meet the project water demands (4GL/a).

The depths to total head[1] predicted by groundwater models at Serenity and north of Champion after 15 years of pumping 1.33 GL/a from the Champion, Eagle and Delta deposits (4 GL/a in total), vary between 30m bgl and 75m bgl within the model areas in the areas where GDEs have been identified. The actual depths to groundwater at Serenity are likely to be even greater in areas where there is an extensive clay layer overlying the CID/BID aquifer (semi confining conditions).

The results of groundwater modelling and impact assessments suggest that the PIOP may have the following impacts on groundwater resources during mining:

- Modelling suggests that mine dewatering will reduce water levels (total head) within aquifers located at the Champion, Eagle, Delta, Blackjack and Ajax deposits and also within hydraulically connected off tenement aquifers. The maximum predicted reduction in total head off tenement at Serenity and Champion are expected to be in the order of 9.5m and 40m respectively;

- It is anticipated that the deposits will be mined from surface down to the BIF bedrock. Therefore the CID/BID aquifers and the water contained within will be removed via dewatering systems. Modelling suggests that mine dewatering may also draw some groundwater from off tenement areas;

- Mine dewatering may have the potential to impact approximately 38% of the estimated total local on and off tenement aquifer ***area*** considered by the groundwater models[2], by reducing the saturated aquifer thickness. This impact reduces to approximately 10% when the entire potential aquifer extent, inferred from available data within the Caliwigina Creek and Weelumurra Creek catchments is considered;

- Mine dewatering may have the potential to impact approximately 17% of the estimated total local on and off tenement aquifer ***volume*** considered by the groundwater models[2], by reducing the saturated aquifer thickness. Although there is insufficient data to assess regional impacts on aquifer volumes, comparison of aquifer volumes and areas suggests that the impact would reduce to less than 10% when the entire potential aquifer extent, inferred from available data within the Caliwigina Creek and Weelumurra Creek catchments is considered; and

- It is anticipated that mining will intercept and remove groundwater recharge at each of the deposits. Average annual recharge from the combined on tenement areas normally accounts for approximately 1.4% or between 0.25 to 0.39GL of the total average annual recharge to the

[1] Total head = sum of the elevation head and the pressure head (Freeze and Cherry, 1979)
[2] The groundwater models cover a limited area and do not account for the full extent of the interconnected regional aquifer system

Millstream aquifer. Therefore the intercepted volume is small when compared with the total annual recharge.

The mine pits are to be backfilled with material that are expected to have similar or higher permeabilities than the existing geological units. This is expected to promote higher recharge rates during rainfall events and result in unconfined aquifer conditions.

The pits will be backfilled to ensure that the finished surface is at a higher elevation than the predicted post development groundwater levels, to prevent the formation of pit lakes. This will prevent salt accumulation which could impact on groundwater quality. The groundwater chemistry within the aquifer systems within the on tenement areas post closure will be a function of the geochemical composition of the backfilling material, which is discussed in detail in the report by Graeme Campbell and Associates (2011).

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1. INTRODUCTION

1.1 Background

WorleyParsons were commissioned by Flinders Mines Limited (FMS) to undertake a hydrogeological investigation to assess the potential groundwater impacts associated with the Pilbara Iron Ore Project (PIOP). The project is a large scale, high quality iron ore mine situated in the Pilbara region of Western Australia (Figure 1-1). The PIOP site (the Site) comprises five deposits within the Blacksmith tenement (E47/882) of which the Delta, Champion and Eagle deposits were the main focus of this study. The Blackjack and Ajax deposits have also been investigated but in less detail.

The PIOP is situated within the Millstream Catchment Area, in a Priority 2 Public Drinking Water Source Area (PDSWA). This report presents the work undertaken to develop an understanding of the hydrogeology within the project area, as well as results of groundwater modelling used to quantify the potential impact the PIOP may have on local and regional groundwater resources, with particular reference to the Millstream Water Resource.

The PIOP was referred for an API level of assessment and accepted by the EPA (Category A). Referral guidelines and a request for additional information have been received by FMS. This report will accompany FMS's response to the EPA referral guidelines and contains relevant information requested by the EPA.

Groundwater dependant ecosystems (GDEs), stygofauna and troglofauna surveys have been undertaken by Consultants Bennelongia and Ecoscape. The results presented in this report will be used by these consultants to assess the potential impact the PIOP may have on GDEs, stygofauna and troglofauna communities. This report does not present the results of the GDE, stygofauna and troglofauna impact assessments.

1.2 Consultation with the Department of Water (DoW)

WorleyParsons and FMS have met with the DoW on the following occasions to present the methodology adopted for the hydrogeological investigations presented in this report:

- Karratha Meeting 17th March 2011;
- Karratha Meeting 15th Dec 2011;
- Perth Meeting 20th Dec 2011; and
- Perth Meeting 30th Jan 2012.

The following areas of interest relevant to this investigation were highlighted by the DoW at these meetings:

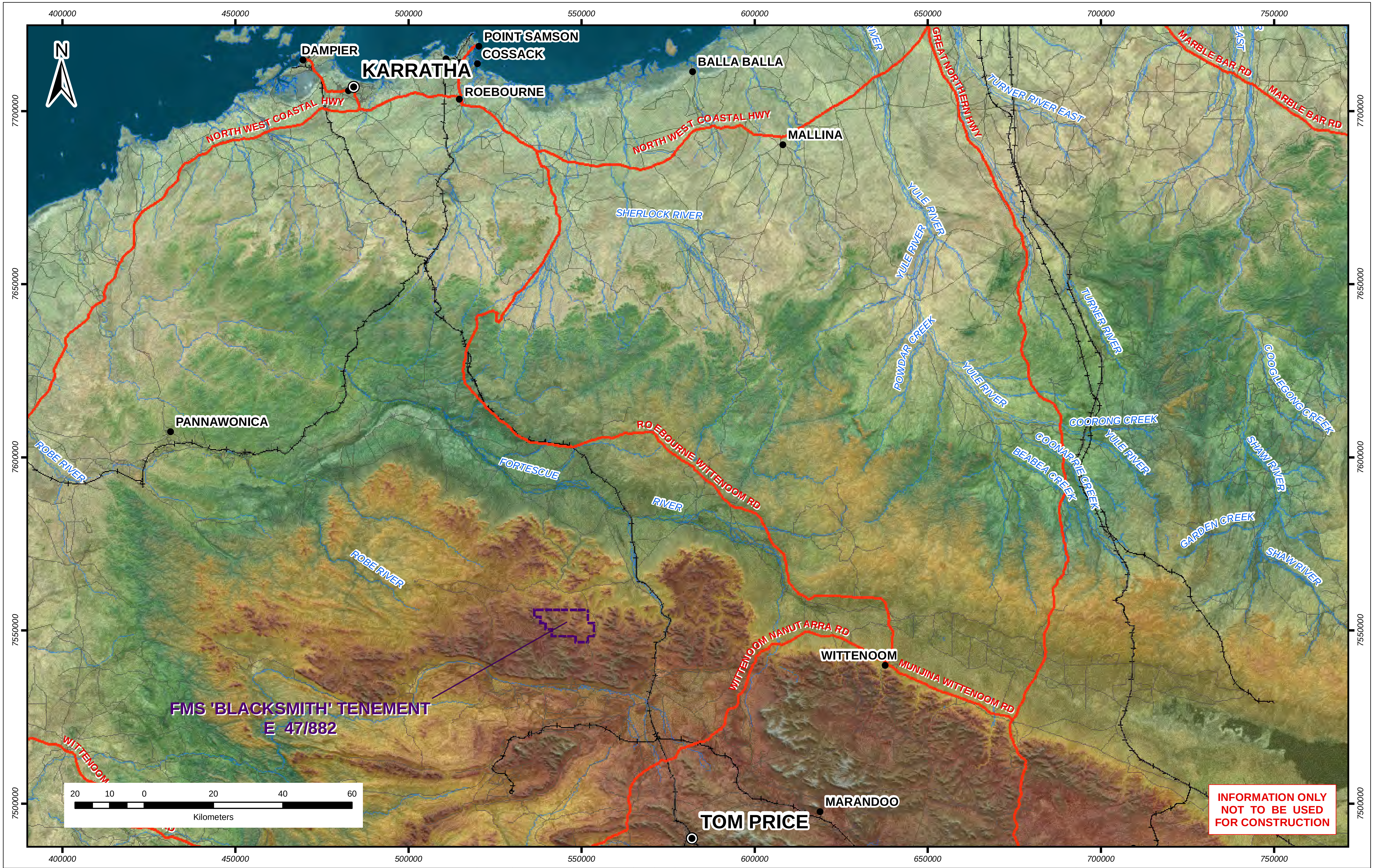
- Impacts of the PIOP on the Millstream Water Resource (quantity and quality);
- Local and regional drawdown impacts associated with the PIOP; and
- Impacts of the PIOP on GDEs: stygofauna. and troglofauna communities.

1.3 Scope of Work

The scope of work for this investigation includes:

- Reporting on the desktop hydrogeological and surface water studies and field investigations completed to date;
- Development of conceptual hydrogeological models for Champion, Eagle, Delta, Blackjack and Ajax Deposits (on tenement) as well as adjacent off tenement areas;
- Development of groundwater models to quantify the potential off-tenement groundwater impacts associated with the PIOP;
- Preparation of drawdown contours based on indicative modelling outside the PIOP tenements; and
- Impact assessments with particular reference to the Millstream Water Resource and other groundwater users.
- The scope of work for this investigation does not include:
- Reporting the results of GDE, stygofauna and troglofauna impact assessments with respect to groundwater;
- Reporting the results of geochemical testing; and
- Reporting the mine closure plans developed to protect and preserve the quality of surface and groundwater within the local catchment and the wider Millstream catchment area (methodologies developed for backfilling of mine pits and management of acid mine drainage).

These scope items will be addressed in separate reports that will also accompany FMS's response to the EPA referral guidelines.



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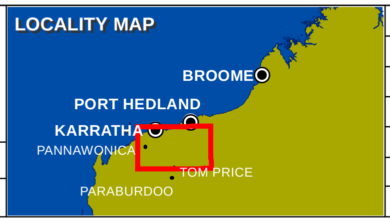
LOCALITY MAP



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0	ISSUED TO CLIENT	MR	LS	29-02-2012
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NOTES
1) Aerial Imagery from Microsoft Virtual Earth.
1) Terrain data - SRTM

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FIGURE 1-1 - SITE LOCATION MAP

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2. PROJECT DESCRIPTION

2.1 Mine Plan and Mine Schedule

Geological modelling and mineral resource estimates have been undertaken and preliminary life of mine schedules and summaries developed. The life of mine plan forecasts production of 15 Million tonne per annum (Mtpa) of total product for 15 years from year 1 onwards.

2.2 Projected Water Requirements

As part of the Preliminary and Definitive Feasibility Studies (PFS and DFS), FMS has recognised a need to identify a reliable water source or sources for its future operation and understand the dewatering requirements during open pit mining. WorleyParsons undertook preliminary estimations of water requirements to support the mining and processing operation. The estimated raw water demand is approximately 4GL/a for the 15 Mtpa base case scenario over 15 years.

It is currently planned to pump approximately 1.33 GL/a from the Champion, Eagle and Delta deposits to make up the 4 GL/a needed to meet the project water demand over the life of mine. This groundwater is to be sourced from mine dewatering systems, with any excess mine dewater returned to the aquifer off tenement to minimise drawdown impacts.

Further investigations will be undertaken during the DFS to confirm the PIOP water demand and dewatering requirements.

3. PROJECT SETTING

3.1 Location

The PIOP Project site (the Site) is located approximately 70 km northwest of Tom Price, in the Pilbara Region of Western Australia. The study area is situated within the Hamersley Range, to the north and west of FMG's Serenity deposit and 175 km south of Dampier, in the Central Hamersley Channel Iron Deposit (CID) Province. Access to the tenement is via Rio Tinto's Pilbara Iron railway access road, which follows the railway north from Tom Price and then via well-graded pastoral and power line access tracks (Mt Brockman Road).

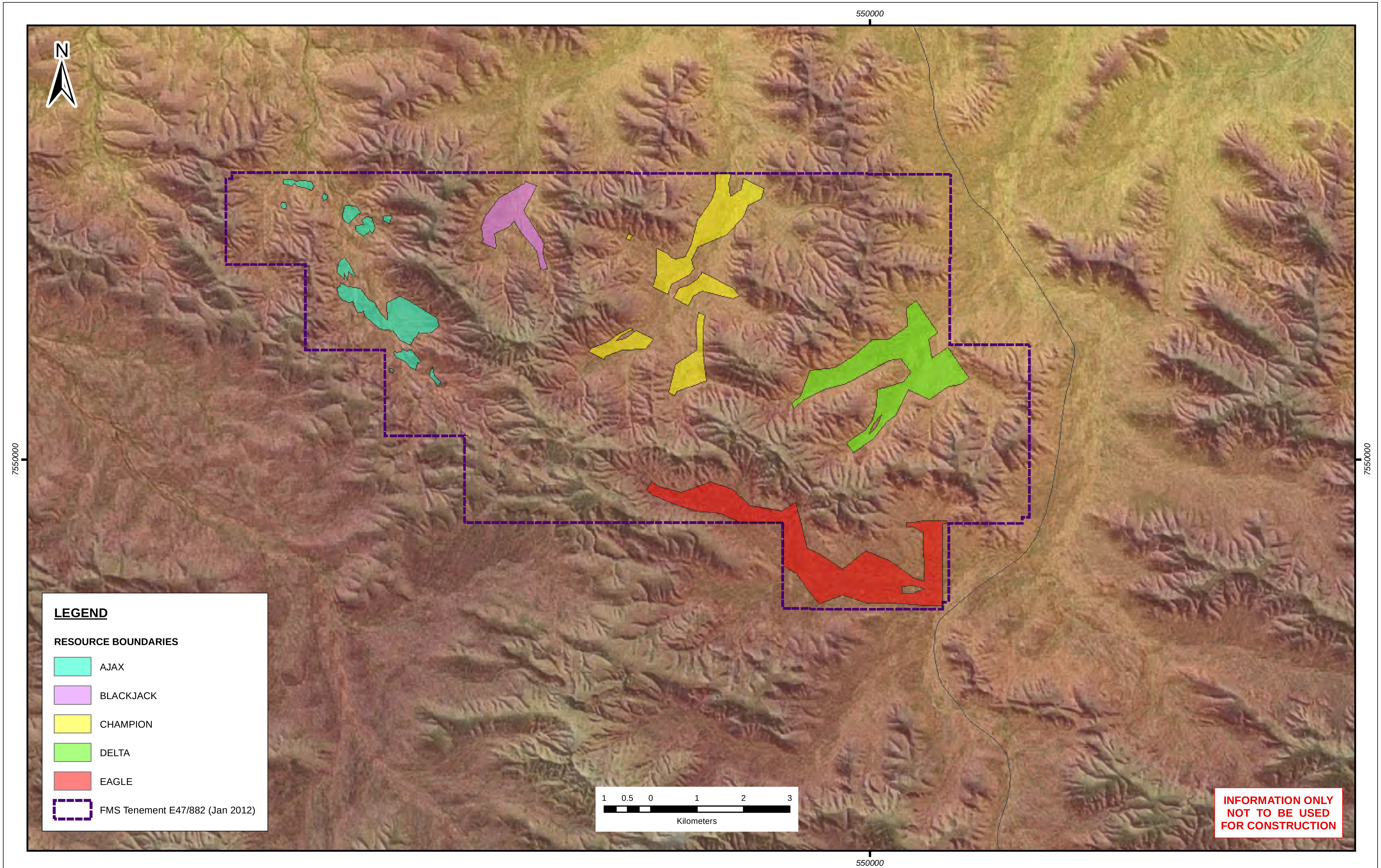
The PIOP comprises the Ajax, Blackjack, Champion, Delta and Eagle deposits located within the Blacksmith tenement area (E47/882) and shown in Figure 3-1. The main ore types of economic interest in the tenement are Detrital Iron Deposits (DID), Channel Iron Deposits (CID), and Bedded Iron Deposits (BID). Other iron ore mining tenements in the Central Pilbara in the vicinity of the Site are shown in Figure 3-2.

3.2 Climate

The Pilbara region has hot summers and mild winters. Rainfall is highly variable and largely falls in the wet summer months between December and April. Most significant rainfall events have high rainfall intensities and are associated with cyclonic events. There is a flash flooding potential associated with such events; dependent on the track, speed and spatial extent of the tropical low. It is reported that rainfall above 100 mm is common with cyclonic systems that move slowly over land over many days. It is not uncommon for there to be little or no rainfall over the dry season (June to November).

Monthly climatic data recorded at Wittenoom (BoM #5026) has been plotted in Figure 3-3. This weather station is approximately 90km east of the site and is considered representative of site conditions. The maximum temperatures presented in Figure 3-3 vary between 24.2 to 39.6℃ and minimum temperatures between 11.5 and 26.1℃. The maximum average monthly rainfall recorded at Wittenoom is 112.2mm in February and has a minimum of 3.3mm in September. The average annual rainfall recorded at Wittenoom between 1950 and 2011 is 457mm (BoM #5026) while the average annual evaporation exceeds 3000 mm (BoM).

A pluviometer recording rainfall at 5 minute intervals was installed at the exploration camp located in the Eagle catchment area, and has recorded rainfall data from 16/11/2011 to 30/01/2012. Daily rainfall measured by the rain gauge over this period is presented in Figure 3-4.



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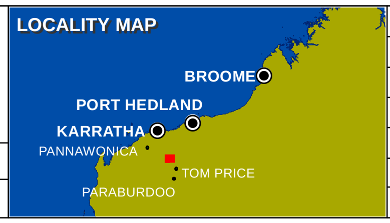

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NOTES
1) Aerial Imagery from Microsoft Virtual Earth.

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FIGURE 3-1 - RESOURCE AREAS
WITHIN FMS POIP LEASE OUTLINE

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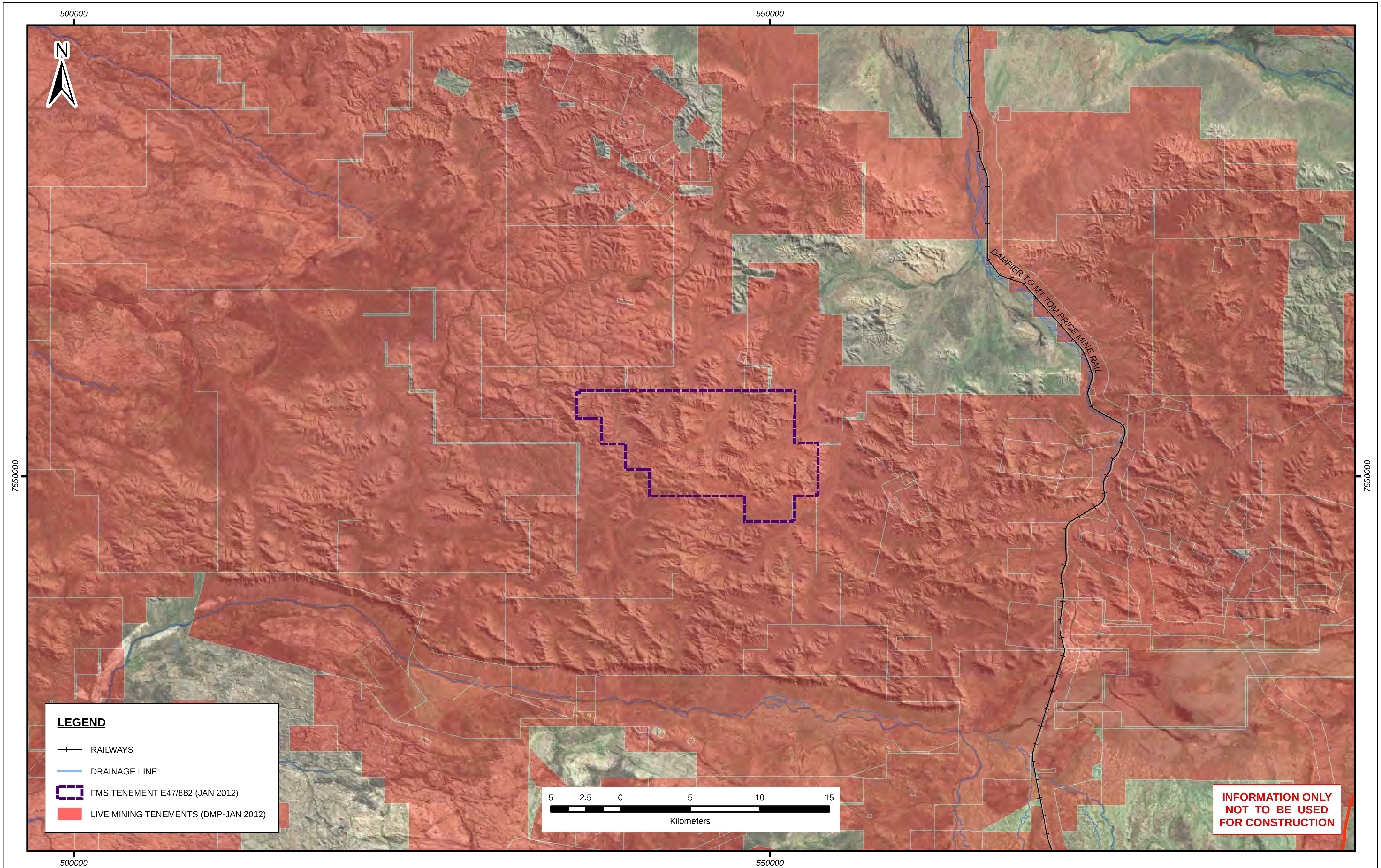

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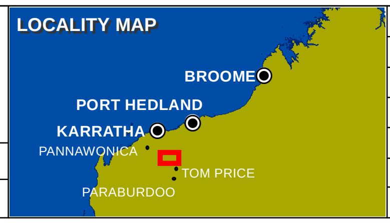

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1) Aerial Imagery from Microsoft Virtual Earth.

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FIGURE 3-2 - TENEMENTS WITHIN CENTRAL PILBARA

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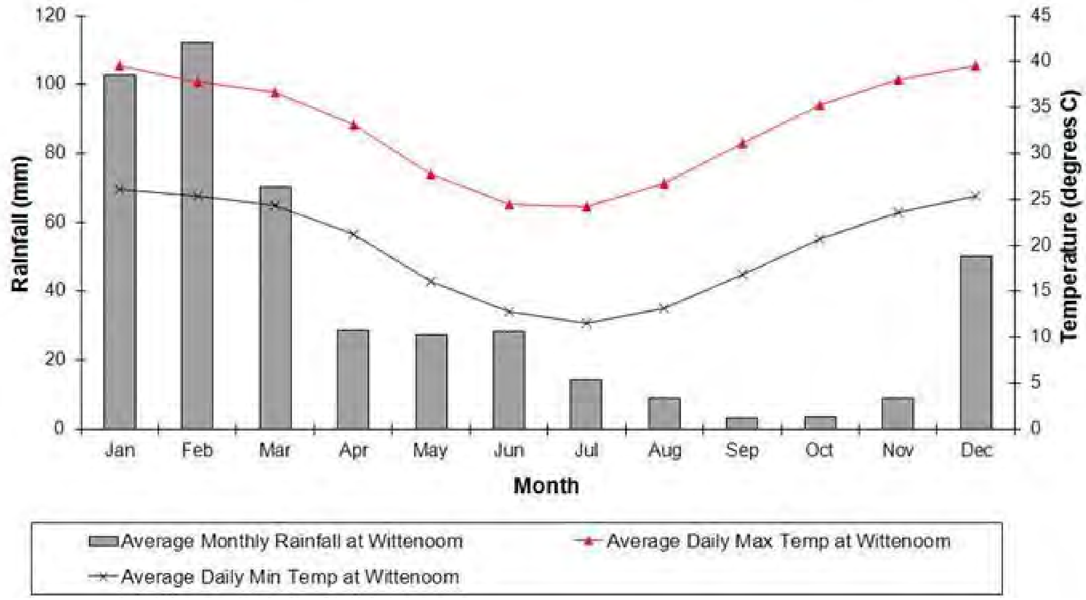


Figure 3-3: Average Monthly Climate Data Wittenoom, 1950 to 2011 (BoM #5026)

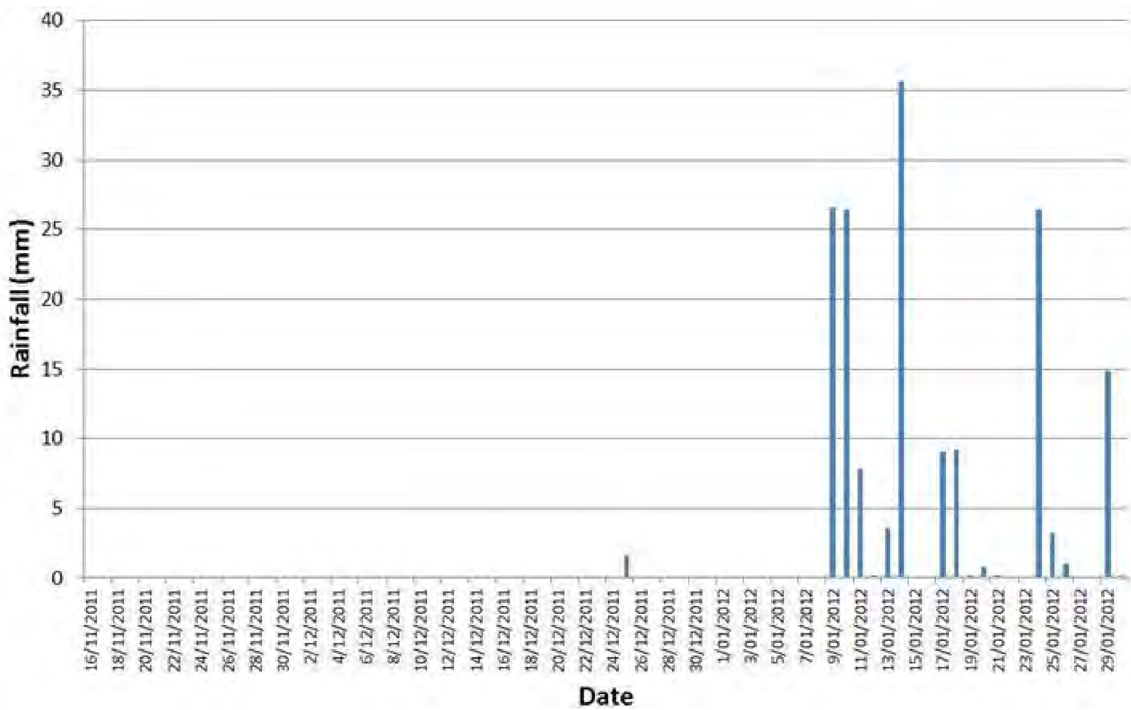


Figure 3-4: Daily rainfall data recorded at Eagle between 16/11/2011 and 30/01/2012

3.3 Topography

The Central Pilbara region is characterised by a series of narrow connected valleys formed within steep hills of the bedrock of the Hamersley Ranges. Hamersley Basin rocks give rise to a varied topography of high, rounded hills, plateaus, and strike ridges. The most extensive upland areas are associated with the iron formations of the Hamersley Group, especially the Brockman Iron Formation. Regionally, the Fortescue River valley, which runs to the south east of the study area, separates Hamersley Basin rocks in the Chichester Range from those in the Hamersley Range.

The iron ore resources generally lie within major drainages and the associated minor tributary valleys. There are broad, flat valleys constrained by bedrock hills within the three deposits of interest. The Site elevations range between 500m and 900metres above Australian Height datum (mAHD).

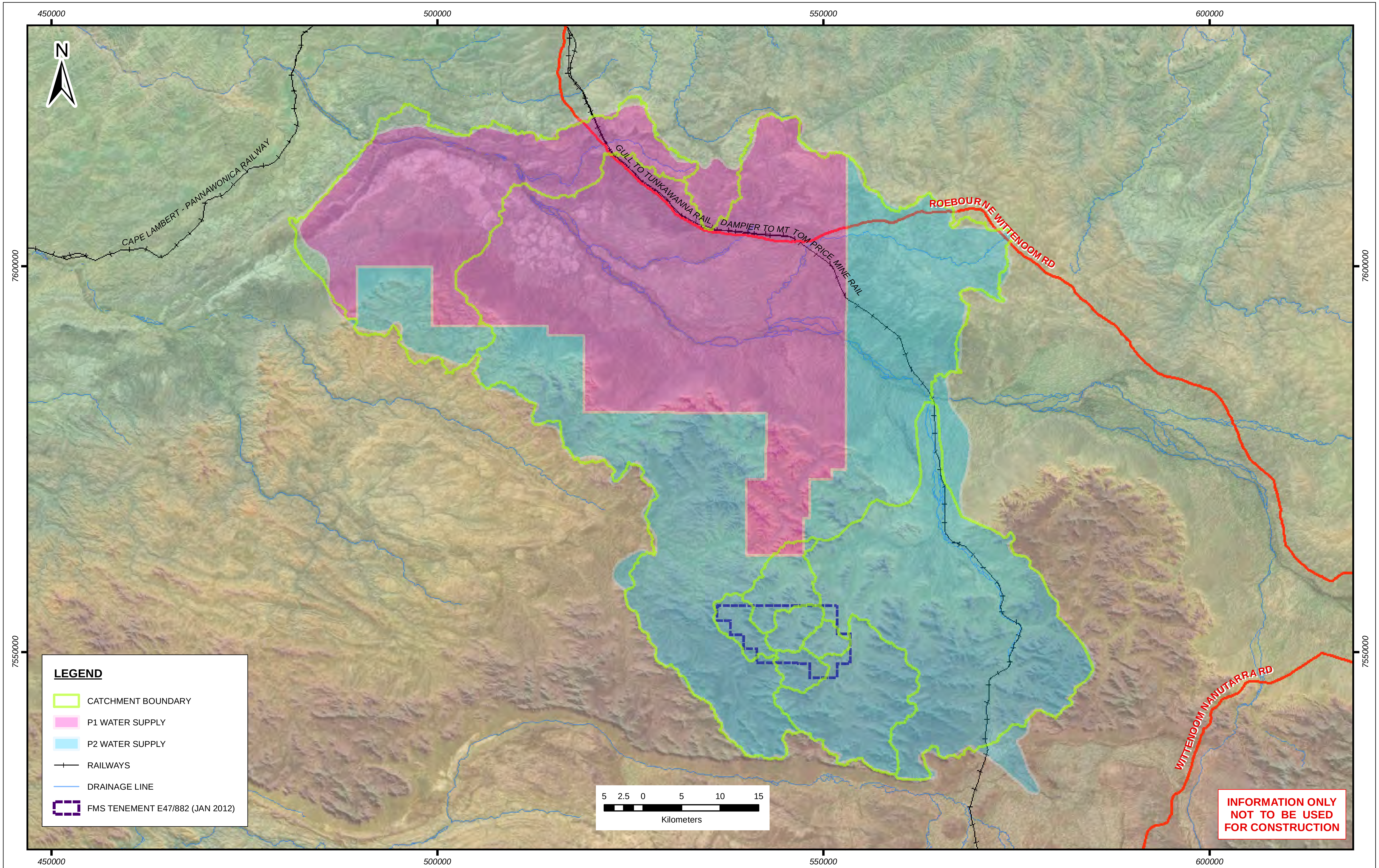
3.4 Hydrology

3.4.1 Catchments

The FMS Blacksmith tenement area (E47/882) is located on a catchment divide running north east through the tenement area (Figure 3-5). The Eagle and Delta catchments drain east into the Serenity area before flowing north into Weelumurra Creek and then into the Fortescue River. The Champion, Blackjack and Ajax catchments drain north into Caliwingina Creek before discharging to the Fortescue River at Millstream approximately 350km north of the study area. Therefore the entire Blacksmith tenement area is located within the Fortescue River Catchment and also within the Millstream Priority 2 Public Drinking Water Source Area (PDSWA).

Table 3-1 presents the estimated surface water catchment areas for the Eagle, Delta, Champion, Blackjack and Ajax deposits within the Blacksmith tenement area. It also presents the Millstream catchment area estimated at approximately 5,480km^2 by Barnett and Commander (1985). The catchment area for Millstream excludes the upper Fortescue River catchment area, which dissipates into the Fortescue Marsh and is not considered to contribute recharge to Millstream. Catchments were delineated using topographic contours generated using LIDAR survey data and 90m SRTM data. Catchment areas are also expressed as a percentage of the Millstream catchment area in Table 3-1.

Table 3-1 suggests that the total area of the Blacksmith tenement (111km^2) accounts for only 2.0% of the total Millstream catchment area (5,480km^2), and therefore provides a minor contribution of surface water runoff and recharge to Millstream.



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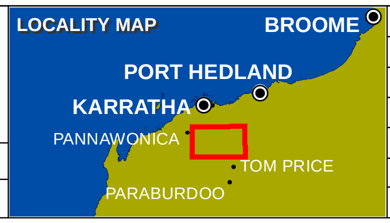

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NOTES
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2) Contours and terrain shading derived from SRTM90 data (NASA).

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FIGURE 3-5 - TOPOGRAPHY, REGIONAL DRAINAGE AND MILLSTREAM P1/P2 AREAS

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Table 3-1: Delineated catchment areas

Catchment Name	Catchment Area (km^2)	% of Millstream Catchment Area
Millstream	5,480	100%
Blacksmith tenement	111	2.0%
Ajax	36	0.7%
Blackjack	11	0.2%
Champion	31	0.6%
Delta	19	0.3%
Eagle	27	0.5%

3.4.2 Watercourses

The major watercourses within the Fortescue River catchment area are ephemeral, have low hydraulic gradients and are located in wide valleys bounded by moderate to steep rocky terrain. The watercourses generally comprise wide braided channels bounded by floodplains which are seasonally inundated during cyclonic flood events. The main channels and floodplains are populated with riverine vegetation.

As a large proportion of the catchments contain steep and rocky terrain, surface water runoff during rainfall events is expected to be rapid in response to rainfall resulting in flash floods during extreme events. Floodwater can persist in the receiving floodplains due to low hydraulic gradients. This can cause long term surface water inundation lasting several weeks.

The hydrology within the Blacksmith tenement area is relatively similar in most areas. The main watercourses within the Champion, Eagle, Delta and Blackjack catchments are located in wide valleys bounded by moderate to steep rocky terrain. The main channels of these watercourses are normally dry during the dry season (June to November) and no permanent pools or significant GDEs have been identified. The Ajax catchment is elongated and the main watercourse flows through deeply incised valleys bounded by steep rocky terrain. The main channel at Ajax is narrower and contains some permanent pools and GDEs. Plates 1 and 2 show photographs taken at typical watercourses within the FMS tenement area. A more detailed description of the hydrology and hydrogeology at Ajax is provided in Appendix 1.

3.4.3 Streamflow Data

A shallow standpipe piezometer has been installed along a creek line at the Delta deposit and fitted with an automatic water level recorder to act as a stream gauge. This stream gauge was installed to allow for comparison of surface and groundwater response to rainfall, which could then be used to confirm the conceptual model adopted for recharge.

Cross sectional survey data has been collected at the stream gauge location as well as at upstream and downstream locations. The data collected at this location will be used to generate a stage-discharge relationship so water levels recorded during flood events can be converted easily to flows. The data collected during the most recent rainfall event is plotted in . This figure shows a very rapid runoff response to rainfall. This data will be converted to flows once the hydraulic modelling has been completed and validated.

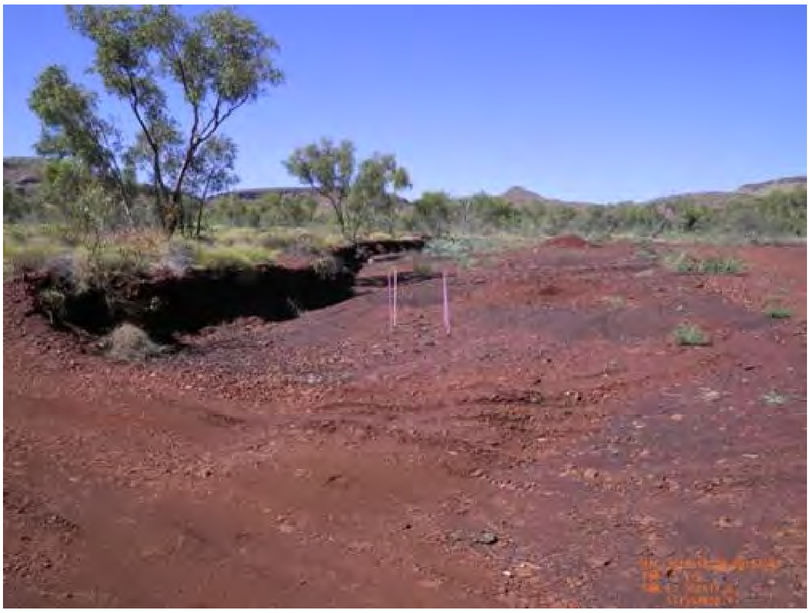


Plate 1: A Typical Ephemeral Creek at Delta, Eagle, Champion and Blackjack

Plate 2: A Permanent Pool at Ajax

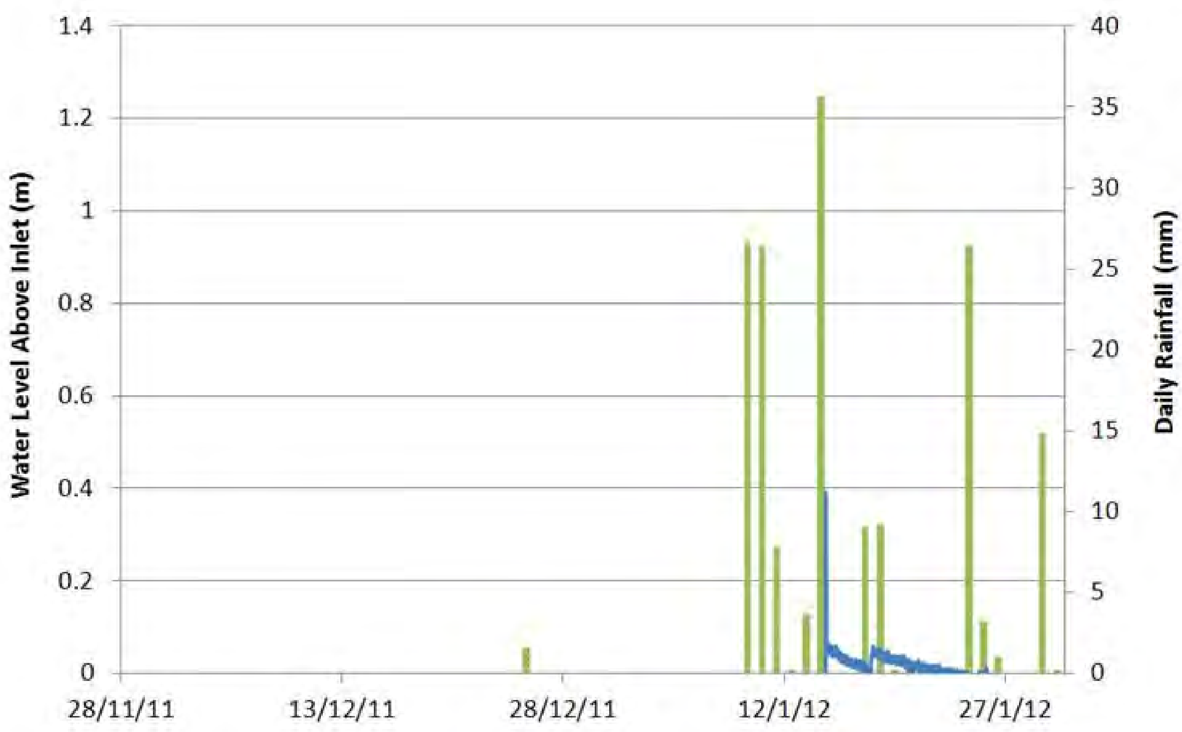


Figure 3-6: Water levels recorded at the stream gauge at Delta compared with Eagle between 28/11/2011 and 30/01/2012

4. REGIONAL HYDROGEOLOGICAL SETTING

4.1 Regional Geology

The regional geology of the area is described in the 1:250,000 Mt. Bruce map sheet (SF 50-11) and associated explanatory notes as first and second editions (de la Hunty, 1965; Thorn et al (GSWA), 1997). In general, the Blacksmith tenement lies within the ancient Hamersley Basin. This depositional Basin consists of Archaen to Lower Proterozoic (2765-2470 Ma) sedimentary rocks, and overlies the older Archaen granites and greenstones of the Archaean Pilbara Block (Trendall, 1990). These formations are classified as the Mount Bruce Supergroup and are sub-divided into the following three Groups:

- **The Fortescue Group** - the oldest, rests unconformably over the basement granites and greenstones and comprises interlayered sedimentary sequences of volcanic and volcaniclastic rocks intruded by doleritic dykes and sills.
- **The Hamersley Group** - characterises the geology of the Hamersley Iron province, isa late Archaean and early Proterozoic rock formation conformably overlying the Fortescue Group; and
- **The Turee Creek Group** - consists of sequences of siltstone, greywacke, sandstones and quartzites.

The Hamersley Group hosts the tenements described in the report, and in general, is formed by chemical precipitation and depositional sedimentation of minerals in a marine environment. It contains metasedimentary rocks termed Banded Iron Formations (BIF) interbedded with felsic volcanics and intrusions of dolerite dykes. The BIF contains bands of iron minerals (magnetite and hematite) and gangue minerals (mostly carbonates, silicates and chert). Within the BIF of the Hamersley Group are the following three major formations:

- **The basal Marra Mamba Formation** - consisting of carbonates, shales and minor cherts;
- **The Brockman Iron Formation** - which formed during long periods of fairly stable and calmer depositional environments, and consists of thin sands and shales; and
- **The Weeli Wolli Iron Formation** - which was accompanied by intense 2,450 Ma bimodal volcanism and mafic sills, overlain by a suite of felsic volcanic rocks.

The Brockman Iron Formation lies within the Blacksmith tenement. Geomorphological events during the last 100-20 Ma (and even more recently), have resulted in a secondary reconcentration of economically viable iron deposits.

In the case of the Champion, Delta, and Eagle deposits, the ore bodies can be described as aquifers as well as the host rock. The main rock rocks units which are the Detrital Iron deposits (DID), Channel

Iron Deposits (CID) and Bedded Iron Deposits (BID) are tertiary age channel and detrital sediments, and will be the primary consideration of this report. In order to understand the hydrogeological characterisation of the channels and detritals, it is important to recognise the various depositional environments associated within the tenements, which control the ore deposit as well as the aquifer hydrogeological parameters. On-site hydrostratigraphical units and their depositional environments are discussed in Section 6.

4.2 Regional Hydrogeology

4.2.1 Groundwater Occurrence

The study area is located within the upper reaches of the Caliwigina Creek and Weelumurra Creek catchments. The majority of groundwater within the upper reaches of these catchments, including the study area is located within the more permeable CID and BID units. Localised groundwater may also be found in some areas within shallow alluvial deposits associated with watercourses, and perched above clay layers. There is insufficient regional data to confirm the extent of these perched aquifers and the degree of connectivity between shallow and deeper CID/BID aquifers.

A review of the regional groundwater data and a search of the DoW WIN database for groundwater information around a 25 km search around the Delta deposit was undertaken by Golder Associates in 2010 (Golder, March 2010) and has not been repeated here. Complete lithological logs and yield information is not available for most bores. The shallower bores (<30 m) reported a yield between 0.05 to 0.8 L/s. A Hamersley bore to the south east of the site records 2.5 L/s at a drilled depth of 47 m and a bore is most likely screened in the Quaternary alluvial to the northeast records a yield of 2.3 L/s. Production bores drilled as part of the current groundwater investigation yielded quantities as much as 30 L/s in each of Champion, 25 L/s in Delta and 30 L/s in Eagle pit areas.

4.2.2 Aquifer Recharge

The Caliwigina Creek and Weelumurra Creek catchments have been estimated to supply 7.7 GL/a and 16 GL/a respectively to the Millstream aquifer located approximately 350km north of the study area (Barnett and Commander, 1985). This contributes approximately 85% of the total recharge to the Millstream aquifer, which is estimated by Barnett and Commander (1985) to be in the order of 27.7GL/a. Recharge to the CID and BID aquifers within the upper reaches of these catchments can be via the following three mechanisms:

- River recharge;
- Recharge from mid-slopes or the valley flanks; and
- Rainfall recharge.

The contribution from each recharge mechanism is not well defined for areas outside of FMS Blacksmith tenement area, due to a lack of published data. It is possible that the contributions may vary depending on relative positions within the catchment. Detailed investigations are being undertaken within the FMS Blacksmith tenement to better understand and quantify recharge and the recharge mechanisms. This approach is discussed in more detail in Section 6.

4.2.3 Groundwater Allocations

Groundwater allocation data for tenements in the vicinity of the Site was obtained from the DoW database. There are ten existing licences, including the FMS licences, within a 10 km distance from the project area and 63 licences within a distance of 20 km. The allocated volumes within a 10km radial distance range between 1500 and 45,000 kilolitres/annum (KL/a or m3/a). The volumes of allocation may indicate that these are short term supply bores supplying nominal volume of water from exploration and or recreational purposes.

4.2.4 FMS Water Supply Bores

There are two existing water supply bores within the tenement. The Camp bore within Eagle deposit, and the Delta Bore at Delta deposit (HPRC2076). The Camp bore is used as a water supply source for the Camp located at Eagle whereas the Delta bore supplies water for drilling and exploration. Both bores are screened within the upper CID unit.

5. HYDROGEOLOGICAL INVESTIGATIONS

5.1 On-Site Hydrogeological Drilling Programme

The on-tenement drilling programme was carried out from August to October 2011 and focused on three main deposits within the Flinders tenement; Eagle, Delta and Champion. These three deposits are the largest deposits holding approximately 85% of the mineral inventory on tenement. No on site hydrogeological investigations have been undertaken at Ajax and Blackjack, however a separate desk top investigation study was undertaken for Ajax to assess the associated surface and groundwater characteristics (Appendix 1).

A previous desktop study was performed by WorleyParsons on behalf of FMS to hydrogeologically characterise the aquifers, establish baseline groundwater conditions, and to determine the most ideal location for production and monitoring bores.

An airborne geophysical survey was also conducted using electromagnetic conductivity via fly overs and the results used to identify areas with greatest saturated thickness. These areas were selected as target areas for drilling because of their inferred high potential to yield groundwater. The results of the geophysical surveys are presented in Appendix 2.

WorleyParsons then designed a drilling and bore installation program for Champion, Delta and Eagle and developed a scope of work for drilling contractors. Austral Drilling Services Pty Ltd was engaged by FMS to undertake the drilling and bore construction program using their Schramm T64 drill rig. Hydrogeological supervision was carried out by WorleyParsons hydrogeologists.

One production bore was drilled in each of Delta, Champion and Eagle deposits. Three explorations holes were initially drilled at each of the deposit and airlifted. The production bores were then drilled and completed adjacent to the exploration holes that yielded the highest volumes of groundwater while air lifting. The following section provides a general summary of the work carried out within each deposit:

- Drilling of three 5.5 inch exploration holes using a combination of air-core and reverse-circulation percussion (RC) techniques:- Once drilled, the holes were completed as monitoring bores by installing a 50mm PVC standpipe screened from the static water level to the base of the aquifer. The bores were completed with 50mm class 12 uPVC casing and 1mm machine slotted 50mm class 12 uPVC screens. Bores were backfilled with graded 8/16 gravel pack to 2 metres above the slotted interval followed by a 2 meter bentonite plug and backfilled to the surface with gravel. Bores were completed with a 1x1 m cement pad and lockable standpipe;
- Drilling and construction of one test production bore within each deposit at the most productive exploration site: - Sites were chosen based on airlift yields, aquifer material, and aquifer thickness encountered during the exploration drilling. Production bores were drilled with a

12.25 inch tricone bit using mud rotary techniques and completed with 8 inch class 12 uPVC casing and 1mm machine slotted class 12 uPVC screens. Bores were backfilled with graded 8/16 gravel pack to 2 metres above the slotted interval followed by a 2 meter bentonite plug and backfilled to the surface with gravel. Bores were completed with a 1x1 m cement pad and lockable standpipe. Production bores were sited 15m from the completed exploration/monitoring bores;

- Drilling and construction of one nested monitoring location with screens set at varying depths within a single 8.5inch drill hole. The hole was drilled using an 8.5inch tricone bit with mud rotary techniques. Individual bores were completed with 50mm class 12 uPVC casing with 1mm aperture 50m class 12 uPVC screens. Screens were set against selected aquifer zones with the aim of determining aquifer parameters on selected aquifer units. Up to three screens were set within a single borehole. Bores were completed with graded 8/16 gravel pack and bentonite to isolate individual screens. The bores were completed with a 1x1 m cement pad and lockable standpipe;
- Conversion of 43 existing RC holes to monitoring bores in selected areas: - Flinders Mines have completed an extensive network of resource drilling predominately using RC drilling methods. Selected RC holes were identified and converted to monitoring bores using 50mm class 12 uPVC casing with 1mm aperture 50mm class 12 uPVC screens. Bores were completed with graded 8/16 gravel pack and bentonite to isolate the aquifer of interest. The bores were completed with a 1x1 m cement pad and lockable standpipe;
- An abundance of exposed BID has been identified in some of the upper reaches/flanks of all three deposits. Some of this BID is intersected by large watercourses in areas where the watercourse is constricted on either side by outcropping bedrock. There is high potential for groundwater recharge in these areas. Several open exploration holes were converted and constructed as monitoring bores in the vicinity of these recharge areas to monitor groundwater response to rainfall; and
- Automatic water level loggers were installed in 32 of the monitoring bores.

5.1.1 Drilling and Bore Construction Results

EAGLE

The following key observations were made during the drilling programme and during site walkover surveys at the Eagle deposit:

Exploration Holes:

- The major geological units intersected during the exploration drilling programme from top to bottom include the Recent Sediments (alluvium and colluvium), DID, CID, BID and BIF;

- The upper CID unit was found to have relatively lower permeability and yielded lower volume of water. The vugs and cavities in the lower CID unit were found to hold a larger supply of water and acted as the major groundwater supply zone;
- The DID was generally found to be dry during drilling with no significant groundwater flows/yields encountered. The potentiometric head rose after drilling through an intercalated clay and sand unit, and rests within the DID suggesting that the DID with intercalations of clay within and also a basal unit of clay at places acts as a confining to semi-confining layer;
- Of the three exploration holes drilled, Eagle-obs-02 was chosen as the preferred production bore location as it had the highest recorded yields during drilling and the largest saturated aquifer thickness.

Production Bore:

- The production bore was screened against the Upper and Lower CID from 57 to 114.3 metres below ground level. An airlift yield of 15L/s was recorded.

Nested Bore:

- The nested monitoring bore was constructed to determine vertical gradients under natural conditions and during pump testing. Three 50mm PVC standpipes were installed:
  - the first screened against the Upper CID;
  - the second against the lower CID; and
  - the third against the Lower CID conglomerate/BID unit.

RC Holes Converted to Monitoring Bores at Eagle:

A total of 14 existing holes drilled as part of the FMS exploration works using RC methods, were converted into monitoring bores as part of the Phase 3 drilling works (Table 5-1). These bores were selected to provide long-term information on groundwater levels and assist with recharge estimation.

The DID was found to be dry during drilling. To assess whether there is any recharge to the DID system and any potential gradients between the DID unit and the underlying aquifers, two adjacent exploration holes were converted to monitoring bores at two locations within the tenement, with one screened solely against the DID, with the other screened below this unit. Automatic groundwater loggers were then installed to monitor groundwater response to rainfall.

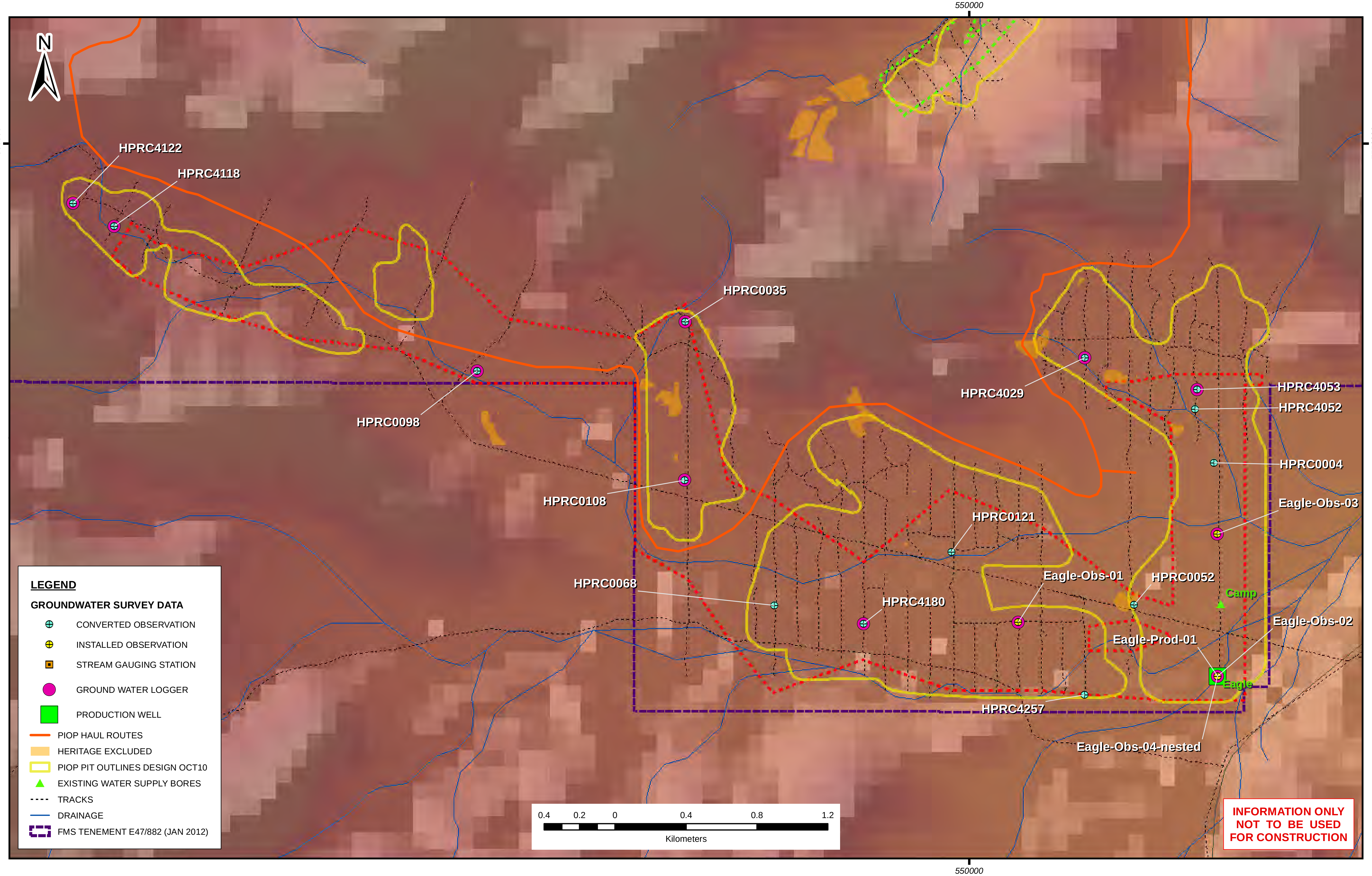
Monitoring bores located within the central part of the catchment, in low lying areas, were screened approximately 2-5 m above the static water level to the base of the aquifer, with the remaining bores located around the flanks of the catchment screened from approximately 2 m below ground level (bgl) to the base of the aquifer.

A summary of the construction details for each of the bores installed in the Eagle deposit is provided in Table 5-1. The locations of the exploration holes, production bores and monitoring bores are provided in Figure 5-1 to Figure 5-3. Bore logs with detailed geological and construction information are provided in Appendix 3.

Table 5-1: Summary of Drilling and Construction Details for Exploration Holes, Production Bores and Monitoring Bores at Eagle

Bore ID	Easting	Northing	Screen (m bgl)	Geology Screened	Standing Water Level (SWL) (m bgl)
Production Bore Pad					
Eagle-Prod-1	551396	7547002	57-114	CID	43.28
Eagle-Obs-4-Shallow	551407	7547011	56-65	Upper CID	43.30
Eagle-Obs-4-Medium	551407	7547011	70-82	Lower CID	43.27
Eagle-Obs-4-Deep	551407	7547011	88.5-114	Lower CID/BID	43.25
Eagle-Obs-1	550278	7547284	41.5-113.15	DID/CID/BID	53.69
Channels and floodplain					
Eagle-Obs-3	551373	7547810	40-82	DID/CID	43.78
Eagle-Obs-2	551404	7546985	41.15-113.15	CID	43.03
HPRC0098	547225	7548718	53-71.4	BID	61.6
HPRC0108	548395	7548102	48.5-60.5	DID/BID	54.5
HPRC0068	548901	7547396	59-83	CID/BID/BIF	61.2
HPRC4180	549404	7547292	55.74-73.83	BID/BIF	59.8
HPRC0121	549900	7547696	52-70	BID/BIF	-
HPRC4257	550650	7546890	48.5-93.5	CID/BID	49.85
HPRC0052	550929	7547398	43.85-74	DID/BID/BIF	48.4
HPRC0004	551380	7548198	35.88-60	ALL/CID	38.3
Recharge bore pairs					
HPRC4122	544946	7549663	1-37	DID/BID/BIF	34.3
HPRC4118	545177	7549533	3-25.5	DID/BID	Dry
HPRC4053	551285	7548613	25.56-43.65	BID/SHL	32.6
HPRC4052	551272	7547398	11.5-43.5	DID	Dry
Flanks					
HPRC4029	550653	7548792	2-62.5	CID/DID/BIF/CHT	49.8
HPRC0035	548399	7548996	2-51.5	DID/BID/CHT	-

ALL = Alluvium COL = Colluvium DID = Detrital Iron Deposit CID = Channel Iron Deposit
BID = Bedded Iron Deposit BIF = Banded Iron Formation CHT = Chert SHL = Shale



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LOCALITY MAP: BROOME, PORT HEDLAND, KARRATHA, PANNAWONICA, TOM PRICE, PARABURDOO

REV	REVISION DESCRIPTION	DRN	CHK	DATE
0	ISSUED TO CLIENT	MR	RB	29-02-2012
B	FOR INFORMATION ONLY	MR	RB	03-02-2012
A	FOR INFORMATION ONLY	MR	RB	23-11-2011

NOTES

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FIGURE 5-1 - BORE LOCATIONS - EAGLE

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DATUM: GDA 1994 MGA Z50S

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CHAMPION

The following key observations were made during the drilling programme and during site walkover surveys at the Champion deposit:

Exploration Holes:

- The major geological units intersected during the exploration drilling programme from top to bottom include the Recent Sediments including (alluvium and colluvium), DID, CID, BID, some weathered BIF and BIF;
- The upper CID unit was found to have relatively lower permeability whereas the vugs and cavities in the lower CID unit where found to hold a larger supply of water and act as the major groundwater supply zone;
- The DID was generally found to be dry during drilling with no significant groundwater flows/yields encountered;
- During exploration hole air core drilling, it was determined that groundwater at the production bore was located in a weathered BIF zone, as well as the CID/BID unit. After the CID unit was drilled through, the static water level rose up slightly; and
- Of the three exploration holes drilled, Champion obs-02 was chosen as the preferred production site as it had the highest recorded yields during drilling and the largest saturated aquifer thickness.

Production Bore:

- The production bore was screened against the CID, BID and weathered BIF from 59.19 to 99.9 metres below ground level. An airlift yield of 22.5L/s was recorded.

Nested Bore:

- The nested monitoring bore was constructed approximately 15m from the production bore to determine the presence of vertical gradients under natural conditions and during pump testing. Three PVC standpipes were installed:
  - the first screened against the CID;
  - the second against the BID; and
  - the third against the weathered BIF.

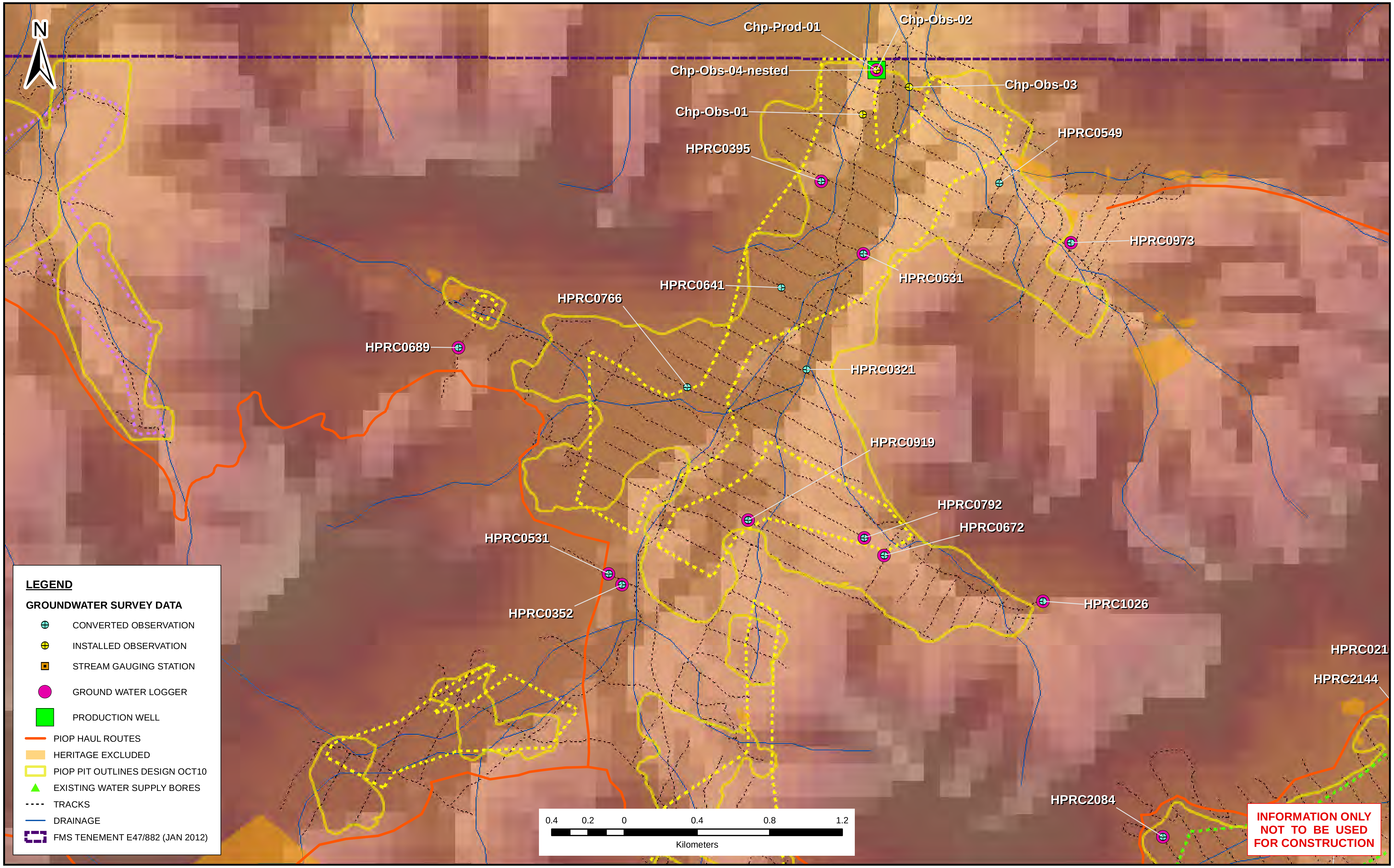
RC Holes Converted to Monitoring Bores:

A total of 14 existing holes drilled as part of the FMS exploration works were converted to monitoring bores as part of the Phase 3 drilling works. These holes were selected in order to provide long-term information on groundwater trends and assist with recharge estimates. Holes located within the central part of the catchment, in low lying areas, were screened approximately 2-5 m above the static water level to the base of the aquifer, with the remaining holes located around the flanks of the catchment screened from approximately 2 m below ground level (bgl) to the base of the aquifer. A further two RC holes were screened against the unsaturated DID to provide information on recharge mechanisms. The location of the exploration holes, production bores and monitoring bores are provided in Figure 5-2, with a summary of the bore data outlined in Table 5-2.

Table 5-2: Summary of Drilling and Construction Details for Exploration Holes, Production Bores and Monitoring Bores at Champion

Bore ID	Easting	Northing	Screen (m bgl)	Geology Screened	Standing Water Level (SWL)(m bgl)
Production Bore Pad					
Champ-Prod-01	546977	7556128	59.19-99.9	CID/BID/BIF	33.155
Champ-Obs--4-Shallow	546970	7556140	59-69	CID	33.98
Champ-Obs--4-Medium	546970	7556140	73-80	BID	33.98
Champ-Obs-4-Deep	546970	7556140	91-100	BIF	33.98
Champ-Obs--2	546966	7556118	30-96	DID/CID/BID	33.35
Channels and floodplain					
Champ-Obs--1	546891	7555872	30-90	DID/CID/BID	36.77
Champ-Obs--3	547146	7556023	56.5-84.5	CID/BIF	29.00
HPRC0549	547642	7555493	24.5-59.5	DID/BID/BIF	30.46
HPRC0395	546661	7555504	39.2-51.2	BID/BIF	39.80
HPRC0631	546894	7555105	30.1-48.1	BIF/CHT	35.54
HPRC0641	546442	7554919	40-70	DID/BID/BIF	49.63
HPRC0321	546581	7554468	22-34	DID/BIF	30.98
HPRC0766	545924	7554370	32-56	BID/BIF	39.87
HPRC0919	546260	7553640	42-59	CID/CHT/BIF	38.13
HPRC0973	548036	7555165	16-52	DID/SHL	22.93
Recharge bore pairs					
HPRC0792	546899	7553541	11-38	DID	Dry
HPRC0672	547008	7553444	32-56	DID/BIF/CHT	47.17
HPRC0352	545565	7553283	15-30	DID	Dry
HPRC0531	545490	7553342	18-42	COL/DID/BID/CHT	36.14
Flanks					
HPRC1026	547883	7553187	2-22	ALL/SHL	16.46
HPRC0689	544663	7554588	2-29	BID/BIF	25.39

ALL = Alluvium COL = Colluvium DID = Detrital Iron Deposit CID = Channel Iron Deposit
BID = Bedded Iron Deposit BIF = Banded Iron Formation CHT = Chert SHL = Shale



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LOCALITY MAP

BROOME
PORT HEDLAND
KARRATHA
PANNAWONICA
TOM PRICE
PARABURDOO

REV	REVISION DESCRIPTION	DRN	CHK	DATE
0	ISSUED TO CLIENT	MR	RB	29-02-2012
B	FOR INFORMATION ONLY	MR	RB	03-02-2012
A	FOR INFORMATION ONLY	MR	RB	23-11-2011

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FIGURE 5-2 - BORE LOCATIONS - CHAMPION

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DELTA

The following key observations were made during the drilling programme and during site walkover surveys at the Delta deposit:

Exploration Holes:

- The major geological units intersected during the exploration drilling programme from top to bottom include the Recent Sediments (alluvium and colluvium), DID, CID, BID and BIF;
- The upper CID unit was found to have relatively lower permeability whereas the vugs and cavities in the lower CID unit where found to hold a larger supply of water and act as the major groundwater supply zone;
- There are two distinct clay units mapped at Delta, an upper clay unit and a lower clay unit which extends eastwards;
- The DID was generally found to be dry during drilling with no significant groundwater flows/yields encountered. The static water level in the CID rose up significantly after drilling through a semi-cofining thin clay unit, and upon rising, the potentiometric head rested within the DID suggesting that the basal clays beneath DID and the interlayered clay units within the CID act as a confining to semi-confining layer; and
- Of the three exploration holes drilled, the one with the highest recorded yields during drilling and the largest saturated aquifer thickness was selected as the preferred production site.

Production Bore:

- The production bore was screened against the CID from 68 to 104 metres below ground level. An airlift yield of 13L/s was recorded.

Nested Bore:

- The nested monitoring bore was constructed approximately 15m from the production bore to determine the presence of vertical gradients under natural conditions and during pump testing. Two bores were set, the first against the upper clay rich CID, and a second deep bore screened against the lower mineralised CID.

RC Holes Converted to Monitoring Bores:

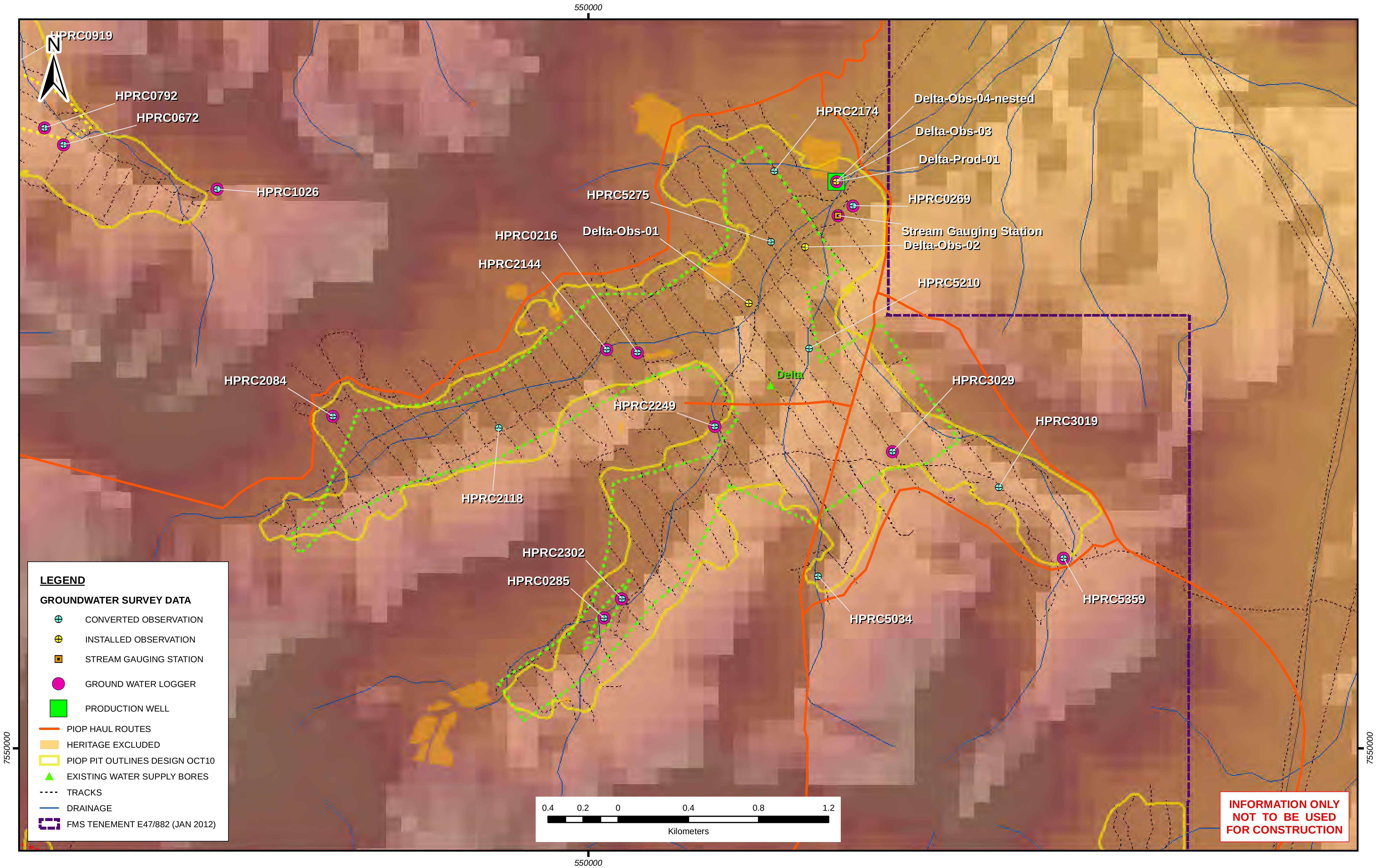
A total of 15 existing holes drilled as part of the exploration works using RC methods, were converted into monitoring bores as part of the works. These bores were selected to provide long-term information on groundwater levels and assist with recharge estimation. At two locations within the tenement, two existing bores were converted in close proximity to one another, one screened solely against the DID (Table 5-3 and Figure 5-3), with the other screened below this unit.

Bores located in the central part of the catchment, in low lying areas, were screened approximately 2-5 m above the static water level to the base, with the remaining bores located around the flanks of the catchment screened from approximately 2m below ground level (bgl) to the base.

Table 5-3: Summary of Drilling and Construction Details for Exploration Holes, Production Bores and Monitoring Bores at Delta

Bore ID	Easting	Northing	Screen (m bgl)	Geology Screened	SWL (m bgl)
Production Bore Pad					
Delta-Prod-1	551425	7553228	68-106	CID	38.56
Delta-Obs-4-Shallow	551418	7553214	68.33-77.41	Upper CID	38.79
Delta-Obs-4-Deep	551418	7553214	84.42-98.55	Lower CID	38.80
Delta-Obs-3	551412	7553239	40-106	DID/CID	38.85
Channels and floodplain					
Delta-Obs-1	550923	7552537	44-95	DID/CID	45.27
Delta-Obs-2	551237	7552862	41-101	DID/CID	40.61
HPRC2174	551059	7553294	41.5-85.5	DID/BID/CHT	47.12
HPRC5210	551257	7552282	40-52	DID/SHL	45.37
HPRC5275	551040	7552891	39.5-63.5	DID/BID	43.74
HPRC2249	550720	7551836	35.5-53.5	BIF	43.61
HPRC2118	549487	7551828	46-64	DID/BID/CHT	51.18
HPRC3029	551731	7551694	46-76	SHL/BIF	51.99
HPRC3019	552340	7551490	41-77	SHL/BID/CHT/SHL	58.08
Recharge bore pairs					
HPRC0216	550278	7552258	19-31	DID	29.7
HPRC2144	550103	7552277	52-69	BIF	46.82
HPRC2302	550190	7550852	9-33	DID	23.46
HPRC0285	550089	7550744	27-51	BID/B IF/SHL/CHT/BIF	40.22
Flanks					
HPRC5359	552705	7551089	2.3-28.3		23.03
HPRC5034	551308	7550982	2-21.5	DID/BID/BIF	18.68
HPRC2084	548542	7551894	2-76	DID/BID/BIF/SHL	64.79
Stream flow gauge bore					
HPRC0269	551508	7553096	24-27.5		Dry

ALL = Alluvium COL = Colluvium DID = Detrital Iron Deposit CID = Channel Iron Deposit
BID = Bedded Iron Deposit BIF = Banded Iron Formation CHT = Chert SHL = Shale



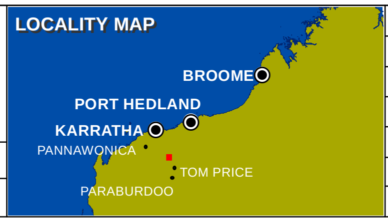


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FIGURE 5-3 - BORE LOCATIONS - DELTA

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5.2 Aquifer Testing Programme

5.2.1 Pump Test Setup

A pump testing programme was undertaken between the 15th of November 2011 and the 3rd of December 2011 to assess the hydraulic properties of the screened aquifer units. The pump testing was performed by Boretec Test Pumping Pty Ltd and supervised by WorleyParsons Hydrogeologists.

Pump testing was performed at each of the production bores installed in Eagle, Delta and Champion deposits. Testing of each bore included a step drawdown test and constant rate discharge test with recovery.

A Grundfos SP95-9/45 electric submersible pump on a Wellmaster rising main was used for testing. Discharge was controlled using a manual gate valve, and the rate measured using an Emflux EM2020 electromagnetic flow metre.

Prior to the commencement of the pumping tests, the following activities were conducted:

- Installation of InSitu RuggedTROLL 100 groundwater loggers to measure water levels – all loggers were set to measure water depths at 1 minute intervals for the duration of the pump testing programme;
- Installation of a single BaroTROLL to measure barometric pressure, used for correction of the RuggedTROLL data;
- Setup and lowering of the pump and riser main into the production bore. A direct read InSitu Vented LevelTROLL 500 was attached to the riser main above the pump assembly, in order to provide both real-time monitoring and recorded logging of water depths in the production bore. The LevelTROLL was set to log water depths at an interval of 30 seconds; and
- A discharge hose was set up to carry pumped water to an existing dry creek over 200m away from the site.

The transducers were installed approximately 24 hours prior to the start of the pumping testing in order to monitor background natural groundwater level variations. No significant rainfall was recorded during the pump tests.

5.2.2 Testing Details

Details of the pump testing program including pumping rates and durations, monitored observation bores and drawdown at selected time intervals are summarised below in Table 5-4 for Eagle, Delta and Champion deposits.

Table 5-4: Pump Testing Data for Eagle, Delta and Champion

Pumping Bore	Observation Bores	Distance from Pumping Bore (m)	Drawdown (m)			Test Period	Test Information		
			t = 540min	t = 1440min	t = 2880min		Step Rate	Constant Rate	Recovery
Eagle Production	Eag-O1	1152.8	0.011	0.037	0.083	25-28NOV2011	5 steps 60min duration; Q increasing 6, 12, 18, 24, 30L/s	2880min duration; Q = 30L/s	1500min
	Eag-O2	18.3	0.547	0.634	0.701				
	Eag-O3	807.9	0.004	0.040	0.033				
	Eag-O4 Shallow	13.9	0.646	0.769	0.834				
	Eag-O4 Middle		0.512	0.600	0.657				
	Eag-O4 Deep		0.388	0.467	0.545				
Delta Production	Dlt-O3	16.7	0.598	0.638	0.66	21-23NOV2011	4 steps 60min, 5th 40min duration; Q increasing 5, 10, 15, 20, 25L/s	2880min duration; Q = 20L/s	650min
	Dlt-O4 Shallow	15.5	0.808	0.848	0.869				
	Dlt-O4 Deep		0.855	0.887	0.912				
Champion Production	Chp-O1	265.9	0.058	0.109	0.156	29NOV-02DEC2011	4 steps 60min duration; Q increasing 15, 20, 25, 30L/s	2880min duration; Q = 28L/s	2000min
	Chp-O2	15.7	1.681	1.706	1.728				
	Chp-O3	198.3	1.682	1.788	1.850				
	Chp-O4 Shallow	14.0	1.698	1.767	1.809				
	Chp-O4 Middle		2.005	2.059	2.090				
	Chp-O4 Deep		4.318	4.397	4.468				

5.2.3 Data Correction

Analysis of the continuous water level data from the in-situ data logger's and the atmospheric pressure readings recorded by a BaroTROLL installed at the site, indicated a strong influence of atmospheric pressure changes. When the atmospheric pressure decreases, the water levels rise in compensation, and vice versa. By comparing the atmospheric changes, expressed in metres of water, with the actual changes in water levels, the barometric efficiency (BE) of the aquifer can be calculated. The BE is defined as the ratio of change in water level in the bore to the corresponding change in atmospheric pressure. BE usually range from 0.2 to 0.75. The pre-test data was used to calculate the BE for Eagle, Delta and Champion and are presented in Table 5-5. The results were then used to correct the water level data recorded.

A graph of corrected versus uncorrected drawdown data for the constant rate and recovery test for Delta is presented in Figure 5-4 to Figure 5-6.

Table 5-5: Calculated Barometric Efficiency Values

Deposit	Calculated BE Ratio
Eagle	0.90
Delta	0.80
Champion	0.38

5.2.4 Step Testing

The data recorded during the step drawdown tests at Champion, Eagle and Delta are presented in Figures 5-7 to 5-9 and Tables 5-6 to 5-8.

Analysis of the step drawdown test provides an indication of the sustainable pumping rate for the constant rate test, as well as providing information on the bore efficiency.

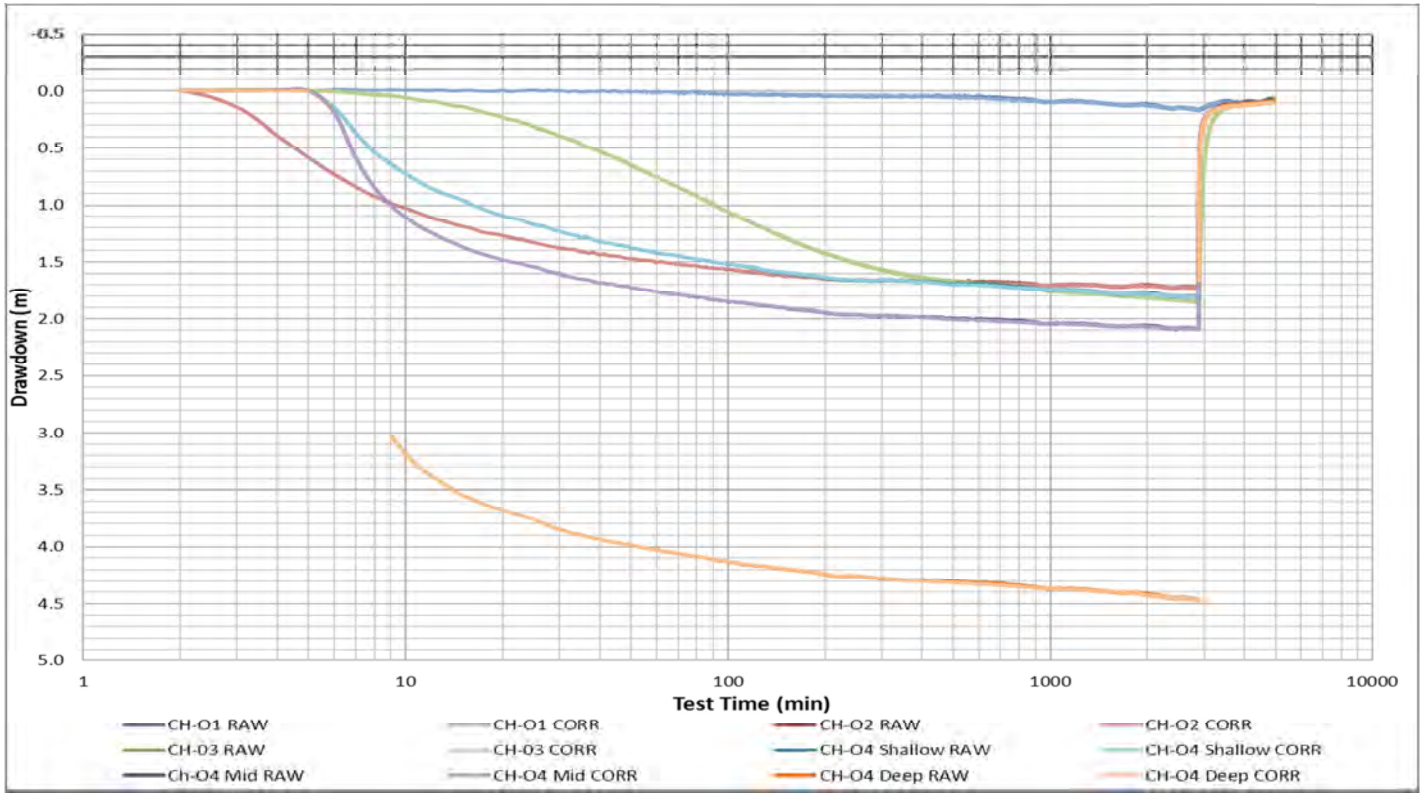

Figure 5-4: Champion Corrected and Uncorrected Drawdown Data

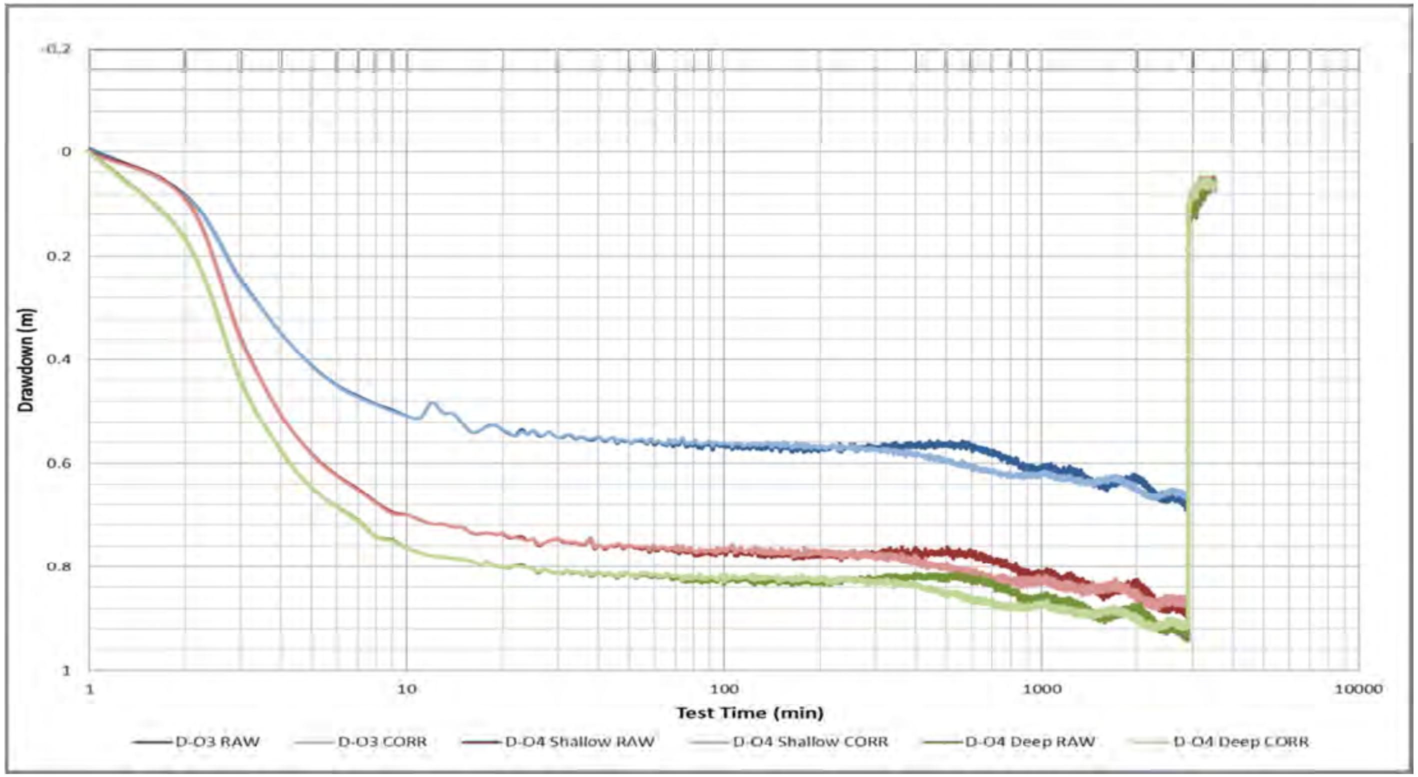

Figure 5-5: Delta Corrected and Uncorrected Drawdown Data

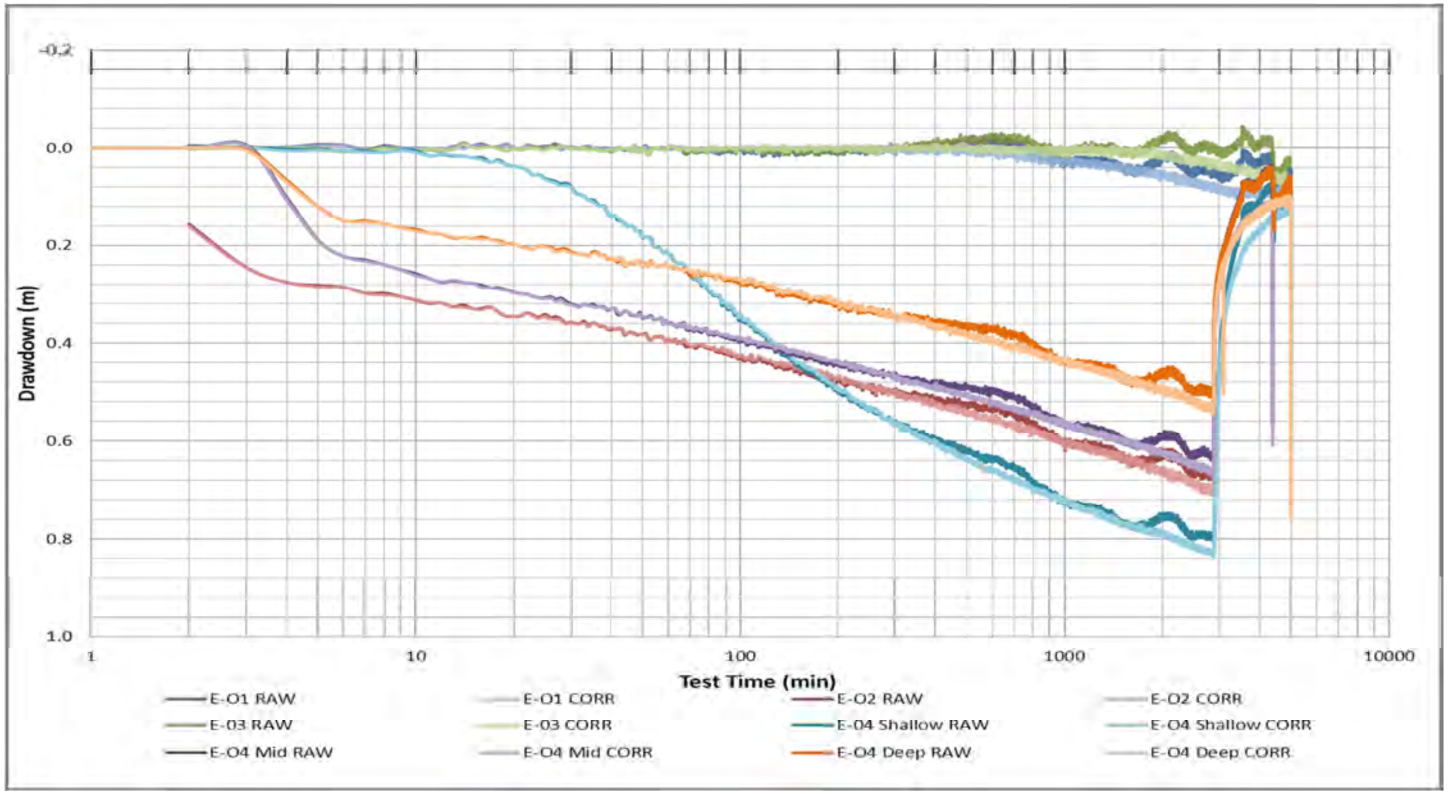

Figure 5-6: Eagle Corrected and Uncorrected Drawdown Data

Table 5-6: Delta Step-Test Pumping Rates and Durations

Step Number	Step Duration (min)	Pumping Rate (L/s)	Maximum Drawdown (m)
1	60	5	5.50
2	60	10	13.30
3	60	15	22.94
4	60	20	35.25
5	40	25	51.22

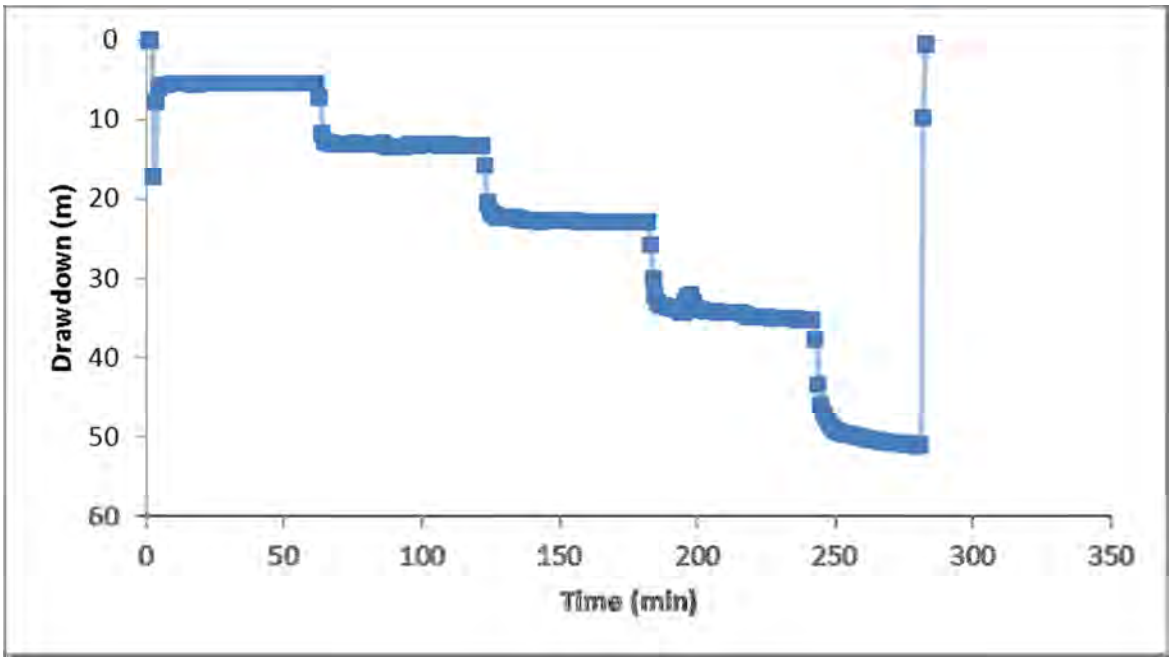

Figure 5-7: Drawdown and Recovery at Delta Production Bore During Step-Discharge Test

Table 5-7: Eagle Step-Test Pumping Rates and Durations

Step Number	Step Duration (min)	Pumping Rate (L/s)	Maximum Drawdown (m)
1	60	6	1.16
2	60	12	2.55
3	60	18	4.27
4	60	24	6.34
5	60	30	9.30

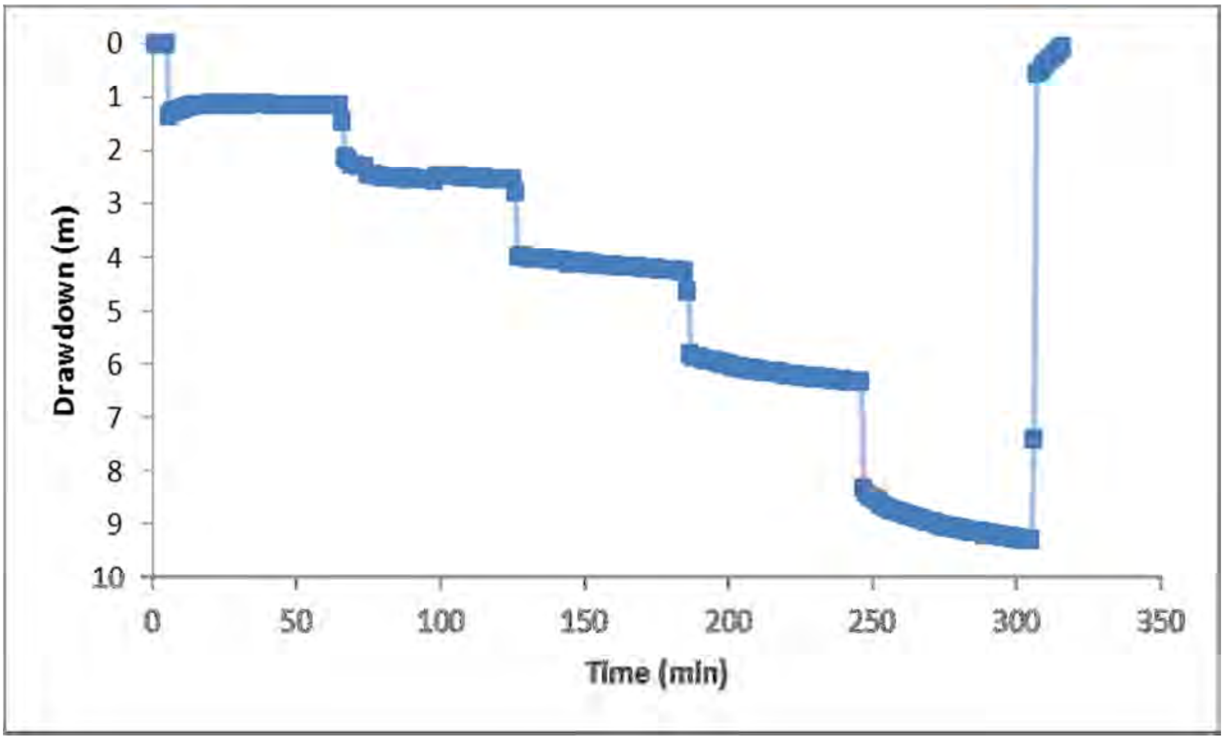

Figure 5-8: Drawdown and Recovery at Eagle Production Bore During Step-Discharge Test

Table 5-8: Champion Step-Test Pumping Rates and Durations

Step Number	Step Duration (min)	Pumping Rate (L/s)	Maximum Drawdown (m)
1	60	6	1.16
2	60	12	2.55
3	60	18	4.27
4	60	24	6.34
5	60	30	9.30

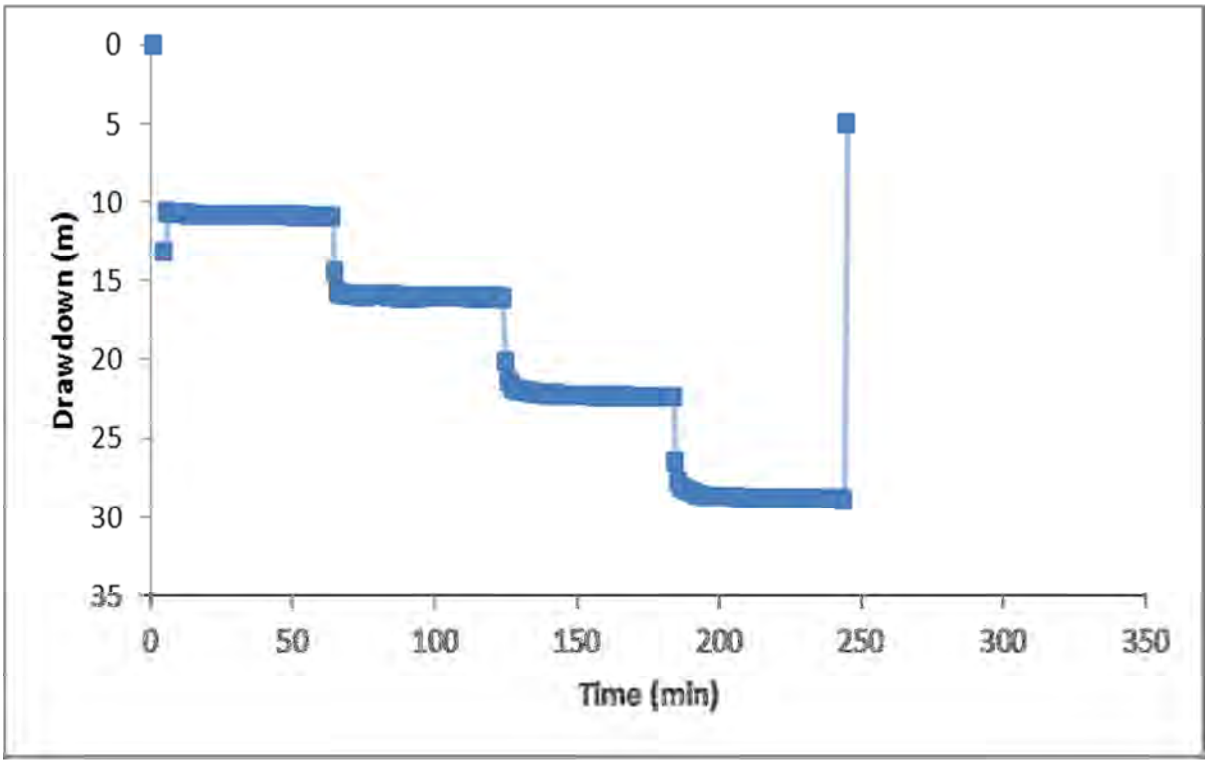

Figure 5-9: Drawdown and Recovery at Champion Production Bore during Step-Discharge Test

5.2.5 Constant Rate Tests

Diagnostic plots have been used to determine the appropriate analytical solution to analyse the hydraulic data. Geological and hydraulic data obtained during the drilling program has also been used to develop a conceptual model of the groundwater system at each pump testing site.

The following observations are consistent for all testing sites.

- Groundwater levels throughout Delta showed a strong correlation between atmospheric pressure and groundwater levels which is typical of either confined or leaky aquifer systems;
- Drilling indicated that the DID unit which has a clay matrix, within and below acts as a partially confining layer to the CID aquifer unit;
- No significant yields (all recorded yields less than 0.1L/s) were intersected when drilling through the DID suggesting that it largely an unsaturated unit; and
- The fact that the slope at late time does not reach zero indicates that for the duration of the test, the bore's area of influence did not intersect a recharge boundary.

Based on the observations the aquifer test data has been analysed assuming both confined and leaky aquifer systems. The Theis (1935)/Hantush (1961) which analyses both drawdown and recovery and Theis (1935) residual drawdown method which analysing recovery alone have been used to analyse the constant rate data.

5.2.6 Summary of Aquifer Test Results

Aquifer properties based on pump test results are summarised in Table 5-9 to able 5-11. Detailed analytical solutions and plots are presented in Appendix 4.

Results suggest that the hydraulic parameters in the three deposits are similar. Hydraulic conductivities and storativities of the two CID units and BID are very similar although a clear change in air lift yields was noted between the upper and lower CID units during drilling.

5.2.7 Water Level Monitoring

Groundwater levels were monitored using a dip meter after the bores were drilled and aquifer stabilised. Thirty two (32) of the monitoring bores installed across Champion, Eagle and Delta have been equipped with automatic water level loggers (InSitu Rugged TROLL's). Results of water level monitoring data for selected open exploration holes, all constructed bores and groundwater hydrographs collected using the InSitu Rugged TROLL's analyses are presented in Appendix 5 and interpreted and discussed in Section 6.

Table 5-9: Delta Pump Test Results

Pumping Bore	Monitoring Bore	Units Screened	Aquifer Model	Analytical Method	Transmissivity (m2/d)	Hydraulic Conductivity (m/d)	Storativity	S/S'	Summary of Analysis
Delta Production Bore	Dlt-04s	Upper CID	Confined	Theis (1935)/Hantush (1961)	4358.8	109.0	1.00E-10		
				Theis (1935) Residual drawdown/recovery	4801.6	120.0		1.165	Av. T = 4779m2/d
			Leaky	Hantush (1960) w/aquitard storage	2562.8	64.1	3.33E-07		Av. S = 6.31 x 10-9
	Dlt-04d	Lower CID	Confined	Theis (1935)/Hantush (1961)	4123.4	103.1	1.00E-10		Av. K = 119.5m/d
				Theis (1935) Residual drawdown/recovery	4984.9	124.6		1.019	b = 40m
			Leaky	Hantush (1960) w/aquitard storage	2628.6	65.7	8.91E-08		
	Dlt-03	DID/CID	Confined	Theis (1935)/Hantush (1961)	4579.5	114.5	2.36E-08		

Pumping Bore	Monitoring Bore	Units Screened	Aquifer Model	Analytical Method	Transmissivity (m2/d)	Hydraulic Conductivity (m/d)	Storativity	S/S'	Summary of Analysis
				Theis (1935) Residual drawdown/recovery	5824.8	145.6		0.5857	
			Leaky	Hantush (1960) w/aquitard storage	2504.2	62.6	1.13E-05		
	All Bores		Confined	Theis (1935)/Hantush (1961)	4176.5	104.4	1.40E-09		
				Theis (1935) Residual drawdown/recovery	5167.6	129.2		0.9077	
			Leaky	Hantush (1960) w/aquitard storage	1927.5	48.2	2.58E-09		

Table 5-10: Eagle Pump Test Results

Pumping Bore	Monitoring Bore	Units Screened	Aquifer Model	Analytical Method	Transmissivity (m^2/d)	Hydraulic Conductivity (m/d)	Storativity	S/S'	Summary of Analysis
Eagle Production Bore	Eag-04s	Upper CID	Confined	Theis (1935)/Hantush (1961)	1472.9	25.4	7.74E-02	1.113	Av. T = 2299m^2/d Av. S = 3.91 x 10^{-2} Av. K = 39.6m/d b = 58m * fails to converge
				Theis (1935) Residual drawdown/recovery	1411.3	24.3			
				Cooper-Jacob (1946)	1495.8	25.8	7.22E-02		
			Leaky	Hantush (1960) w/aquitard storage	948.3	16.4	1.04E-01		
	Eag-04m	Lower CID	Confined	Theis (1935)/Hantush (1961)	2424.3	41.8	2.43E-02	0.580	
				Theis (1935) Residual drawdown/recovery	2924.5	50.4			
			Leaky	Hantush (1960) w/aquitard storage	1120.4	19.3	2.57E-05		
	Eag-04d	Lower CID/BID	Confined	Theis (1935)/Hantush (1961)	2349.8	40.5	1.26E-01	0.467	
				Theis (1935) Residual drawdown/recovery	3153.7	54.4			
				Cooper-Jacob (1946)	2803.0	48.3	5.54E-02		
			Leaky	Hantush (1960) w/aquitard storage	2369.2	40.8	1.22E-01		
	Eag-01	CID/BID	Confined	Theis (1935)/Hantush (1961)	1500.9	25.9	4.08E-03		
				Theis (1935) Residual drawdown/recovery	30160.0	520.0		1.0E-05	* residual showed poor

Pumping Bore	Monitoring Bore	Units Screened	Aquifer Model	Analytical Method	Transmissivity (m^2/d)	Hydraulic Conductivity (m/d)	Storativity	S/S'	Summary of Analysis
									curve fit
			Leaky	Hantush (1960) w/aquitard storage	1500.7	25.9	4.08E-03		
	Eag-02	CID	Confined	Theis (1935)/Hantush (1961)	2395.4	41.3	9.84E-03	0.555	
				Theis (1935) Residual drawdown/recovery	2935.4	50.6			
			Leaky	Hantush (1960) w/aquitard storage	1117.0	19.3	1.89E-05		
	Eag-03	CID	Confined	Theis (1935)/Hantush (1961)	1015.3	17.5	1.46E-02	1.0E-05	
				Theis (1935) Residual drawdown/recovery	53200.0	917.2			* residual showed poor curve fit
			Leaky	Hantush (1960) w/aquitard storage	1015.7	17.5	1.46E-02		
	All Bores		Confined	Theis (1935)/Hantush (1961)	2412.0	41.6	1.77E-02	0.466	
				Theis (1935) Residual drawdown/recovery	3593.1	62.0			
			Leaky	Hantush (1960) w/aquitard storage	2508.9	43.3	1.41E-02		* fails to converge

Table 5-11: Champion Pump Test Results

Pumping Bore	Monitoring Bore	Units Screened	Aquifer Model	Analytical Method	Transmissivity (m^2/d)	Hydraulic Conductivity (m/d)	Storativity	S/S'	Summary of Analysis
Champion Production Bore	Chp-04s	CID	Confined	Theis (1935)/Hantush (1961)	2221.7	42.7	3.66E-08	1.295	Av. T = 1717m^2/d
				Theis (1935) Residual drawdown/recovery	1818.9	35.0			
			Leaky	Hantush (1960) w/aquitard storage	1000.4	19.2	3.66E-08		Av. S = 2.63×10^{-8}
	Chp-04m	BID	Confined	Theis (1935)/Hantush (1961)	2125.5	40.9	3.32E-09	1.323	Av. K = 33.0m/d
				Theis (1935) Residual drawdown/recovery	1858.0	35.7			b = 52m
			Leaky	Hantush (1960) w/aquitard storage	1449.9	27.9	3.66E-08		* fails to converge
	Chp-04d	BIF	Confined	Theis (1935)/Hantush (1961)	1267.6	24.4	3.66E-12	1.534	
				Theis (1935) Residual drawdown/recovery	1514.8	29.1			
			Leaky	Hantush (1960) w/aquitard storage	647.6	12.5	3.66E-08		* fails to converge
	Chp-01	DID/CID/BID	Confined	Theis (1935)/Hantush (1961)	28990.0	557.5	3.66E-08	0.010	* Removed due to poor curve fit
				Theis (1935) Residual drawdown/recovery	11350.0	218.3			
			Leaky	Hantush (1960) w/aquitard storage	2477.3	47.6	0.02166		* Manual fit
	Chp-02	DID/CID/BID	Confined	Theis (1935)/Hantush (1961)	2271.1	43.7	3.42E-08		
				Theis (1935) Residual	1967.5	37.8		1.14	

Pumping Bore	Monitoring Bore	Units Screened	Aquifer Model	Analytical Method	Transmissivity (m^2/d)	Hydraulic Conductivity (m/d)	Storativity	S/S'	Summary of Analysis
				drawdown/recovery				7	
			Leaky	Hantush (1960) w/aquitard storage	2098.9	40.4	4.87E-08		
	Chp-03	CID/BIF	Confined	Theis (1935)/Hantush (1961)	1605.5	30.9	3.66E-08	2.466	
				Theis (1935) Residual drawdown/recovery	679.4	13.1			
			Leaky	Hantush (1960) w/aquitard storage	535.8	10.3	3.66E-08		
	All Bores		Confined	Theis (1935)/Hantush (1961)	1707.8	32.8	3.66E-08	1.517	
				Theis (1935) Residual drawdown/recovery	1568.1	30.2			
			Leaky	Hantush (1960) w/aquitard storage	674.3	13.0	6.26E-10		

5.3 Groundwater Chemistry

Groundwater samples were taken at the end of pump testing for laboratory analysis. Major Ions and physical parameters were assessed. The results are summarised below in Table 5-12. All samples are below the aesthetic guidelines for drinking water in relation to total dissolved solids.

In Summary:

- Groundwater is fresh ranging from 187 to 269 mg/L of Total Dissolved Solids (TDS);
- Calcium, magnesium and sodium are the most dominant cations;
- Chloride and bicarbonate are the dominant anions;
- pH varied between 7.03 and 7.26; and
- Results indicate that the groundwater on site is of potable and fresh quality.

Broad hydrochemical relationships between the samples have been investigated by plotting the groundwater analysis on a Piper diagram in Figure 5-10.

Table 5-12: Groundwater Chemistry Data

Analyte	Units	Bore ID			NHMRC Drinking Water Guidelines[1]	
		DLT-PROD-01	EAGLE-PROD-01	CHAMPION-PROD-01	Health	Aesthetic
pH		7.26	7.03	7.18	-	6.5-8.5
Electrical Conductivity @25°C	µS/cm	352	248	315	-	-
Total Dissolved Solids @180°C	mg/L TDS	241	187	269	-	500
Suspended Solids	mg/L SS	<5	<5	10	-	-
Hydroxide Alkalinity	mg/L $CaCO_3$	<1	<1	<1	-	-
Carbonate Alkalinity	mg/L $CaCO_3$	<1	<1	<1	-	-
Bicarbonate Alkalinity	mg/L $CaCO_3$	113	82	99	-	-
Total Alkalinity	mg/L $CaCO_3$	113	82	99	-	-
Sulfate	mg/L SO_4	12	8	5	500	250
Chloride	mg/L Cl	38	32	43	-	250
Calcium	mg/L Ca	18	12	13	-	-
Magnesium	mg/L Mg	18	13	15	-	-
Sodium	mg/L Na	27	24	27	-	180
Potassium	mg/L K	9	6	6	-	-

Analyte	Units	Bore ID			NHMRC Drinking Water Guidelines[1]	
		DLT-PROD-01	EAGLE-PROD-01	CHAMPION-PROD-01	Health	Aesthetic
Total Anions	meq/L	3.58	2.71	3.3	-	-
Total Cations	meq/L	3.78	2.87	3.21	-	-
Ionic Balance	%	2.77	N/A	1.3	-	-

1. Australian Drinking Water Guidelines 6, NHMRC 2011; Endorsed by NHMRC August 2010; Full document: [http://www.nhmrc.gov.au/_files_nhmrc/publications/attachments/eh52_aust_drinking_water_guidelines_111130.pdf]

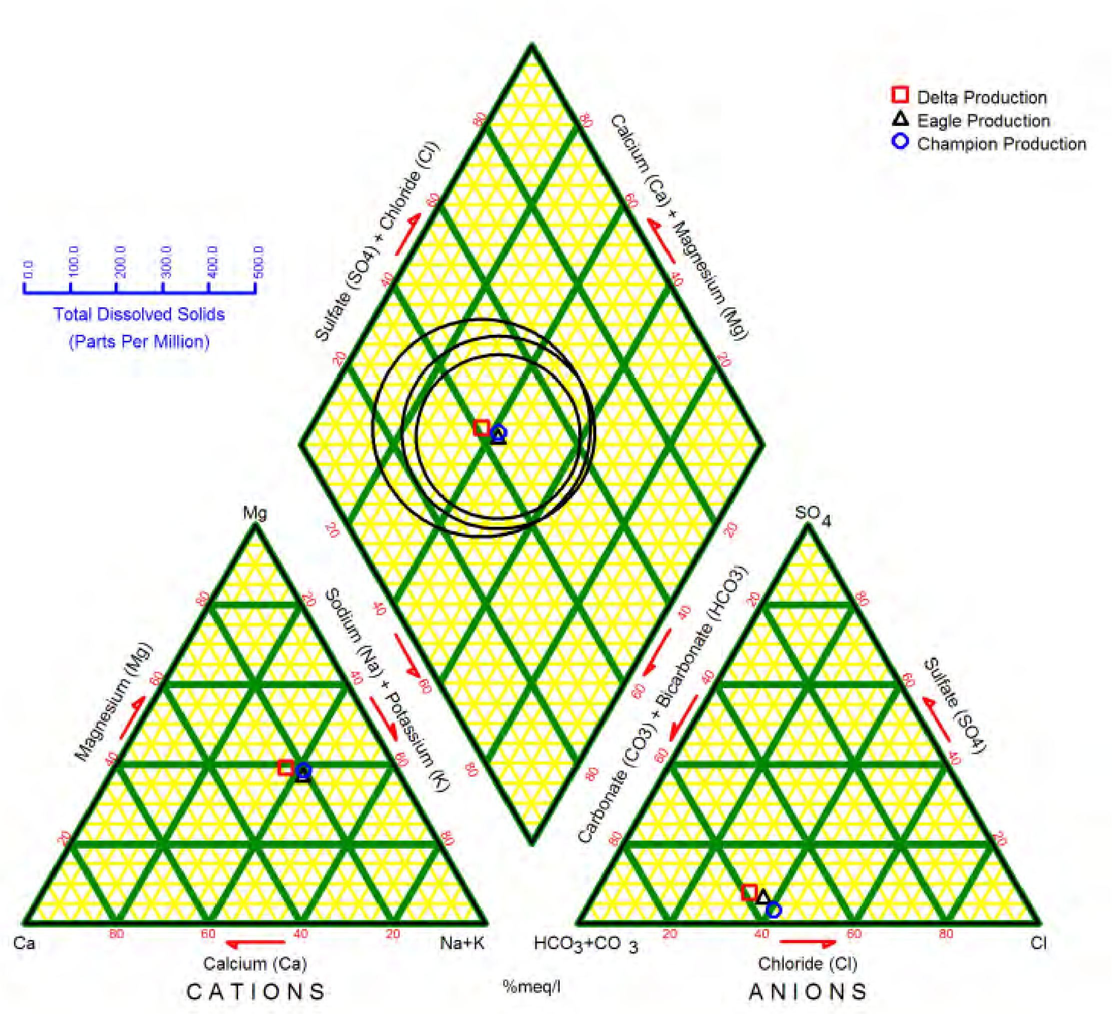

Figure 5-10: Piper Diagram for Production Bore Groundwater

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6. HYDROGEOLOGICAL CONCEPTUALISATION

6.1 Sources of Information

Conceptual hydrogeological models for on and off tenement areas, have been developed using the following sources of information:

- Geological logs from exploration drilling on tenement and supplied by FMS;
- Groundwater levels recorded in open exploration holes and provided by FMS;
- Groundwater levels recorded by automatic loggers installed in monitoring bores at Champion, Eagle and Delta;
- Geological cross sections derived from the FMS resource model for all on tenement areas;
- Data and information collected during the field investigations undertaken by WorleyParsons, and described in Section 5;
- Existing published reports for the Millstream catchment area (Barnett and Commander; 1985, SKM, 1982; PWD WA,1982; Water Authority of WA, 1992; DoW, 2009;)
- DoW WinSite database data.

The hydrogeological conceptualisation presented in this section of the report has formed the basis for the groundwater modelling described in Section 7.

6.2 Geological Units

6.2.1 Classification of Units

Exploration drilling has been undertaken by FMS within the Blacksmith tenement area (E47/882), and was used to develop a detailed resource model. WorleyParsons reviewed the data from the resource model as well as exploration borehole data provided by FMS which includes information for 1,904 exploration holes (RC and or Diamond), and lithological logs for 1,926 exploration holes. The exploration data has focused on the main channel systems for CID mineralisation and the BID, both beneath and on the margins of the channels.

The geological units mapped by FMS using this resource model are shown in Table 6-1. A set of simplified geological units have been developed for the conceptual hydrogeological models by grouping units with similar hydrogeological properties derived from field investigations described in Section 5. The resulting set of simplified geological units is presented in Table 6-1, and discussed in more detail.

Table 6-1: Mapped Lithological Units and Simplified Geological Units Adopted for the Conceptual Model

Code	Unit Description	Simplified Unit Description
All	Recent Alluvium	Recent (Colluvium/Alluvium)
COL	Recent Colluvium	
DIDh	Detrital Iron Deposit - hematite dominant	DID
DIDg	Detrital Iron Deposit - goethite dominant	
CIDh	Chanel Iron Deposit - hematite dominant	CID
CIDg	Chanel Iron Deposit - goethite dominant	
CLY	Clay	Clay
BIDg	Bedded Iron Deposit - goethite dominant	BID
BIDh	Bedded Iron Deposit - goethite with hematite	
BIF	Banded Iron Formation	BIF
SHL	Shale	
CHT	Chert	
CAV	Cavity	
DOL	Dolerite	
QTZ	Quartz Vein	

6.2.2 Stratigraphy and Depositional Environments

It is important to recognise the depositional environments of stratigraphical units within the Blacksmith tenement, before interpreting the various formations encountered while drilling. In general, the Brockman Iron Formation (BIF) has been relatively stable since its formation as part of the Pilbara Craton. The BIF consists mainly of thin laminae of ironiferous silts and shales. Oxidation of the iron rich zones in the BIF is also possible, as shown in Plate 6-1.

During Permian age, glacial environments covered the area, resulting in series of valleys carved into the weaker and more fractured zones of the BIF. Due to the resistant weathering of the BIF, channel geomorphology was a relatively slow process. Climatic environments were much more tropical and wetter from 100 million years (my) to 20my resulting in lagoonal environments, clays, mudflows, and shallower gradient channel related sedimentation. The secondary iron enrichment and formation of the, Detrital Iron Deposits (DID) and Channel Iron Deposits (CID) in the Blacksmith tenement, is related to the depositional environments which occurred during the end of the Cretaceous and into the early Tertiary (FMS, 2010; de la Hunty, 1965; Thorn et al; GSWA, 1997). The Bedded Iron Deposits (BID) were a tertiary concentration of iron deposits, and are a geochemical result of the leaching of fresh meteoric groundwater through any of the existing BIFs, CIDs, and DIDs. Plate 6-2 shows and example of the Bedded Iron Deposit juxtaposed against an adjacent large clast associated with the Detrital Iron Deposit. Plate 6-3 shows a close up of the same picture.

Plate 6-1: BIF Showing Thin Sedimentary Laminae.

Plate 6-2: Geochemically Altered BID Adjacent to Large Clastic Debris Associated with Fluvial DID

Plate 6-3: Tertiary Geochemical Alteration of DID to BID

Due to the various geomorphological events which have existed over the last 20my, the resulting sub surface environments in the Delta, Eagle, and Champion drainages, consists of a series of inter fingered and lateral deposition of the DIDs, CIDs, tertiary mineralisation (BIDs from DID and CID), and secondarily mineralisation (BID from BIF), along with various stages of goethite and hematite mineralisation within the units. Weathering events capable of producing massive cross cutting through the deposition of the pre-existing DIDs and CIDs must have occurred to create the channel cutting, geomorphological channel configuration and deposition of the CID observed. The result has been continuous channels filled with CID, at the more distal locations of the catchments, as they enter larger drainage channels down gradient. Also sometime immediately after the major CID channel environment and resultant CID deposition, a separate thicker clayey layer more than likely in a lower energy lagoonal depositional environment associated with the Serenity drainage, has also developed.

DETRITAL IRON DEPOSITS (DID)

Detrital Iron Deposits (DIDs) are formed as a result of ancient weathering which eroded existing BIFs, BIDs and CIDs, re-depositing detrital sediments originating from ore fragments, into natural topographic lows, such as drainage channels and/or river valleys. The DIDs exhibit a characteristic of mudflow or debris flow type sedimentation, in that the detritus consists of mixed large pebble to boulder size angular and sub rounded clasts in a finer grained clay matrix. The textural variation could also be attributed to change in flow energy and differential deposition during a high velocity flood events.

Channel Iron Deposits (CID)

The Channel Iron Deposits (CIDs) characterised by their pisolitic appearance, were formed during hematite-rich fragment accumulation in soils, that were derived from an iron-rich lateritic surface. The lateritic surface previously developed on underlying iron-rich rocks. The warm-to-tropical climate favoured the precipitation of further goethite resulting in pisolitic concentric layers around the hematite cores, as well as around fragments of woody material (later replaced by goethite).

Further geomorphological and weathering processes resulted in the deposition of the iron-rich pisolitic material into the beds of incised meandering low-energy and shallow gradient streams. As CID was further oxidised and altered to goethite, the cementation of the fragments resulted in a combination of CID and more clay rich pisolitic/goethitic texture. This resulted in a greater degree of secondary permeability in the highly weathered deposits. Plate 6-4 shows an outcrop from the upper reaches of the Eagle tenement, and the degree of goethitic alteration possible, adjacent to non-goethitic alteration (note the subtle disconformity between the two units). The exposed units are not likely to be CID units associated with drilling in the deeper channels, but show the stark contrast in weathering and rock types resulting in goethitic alteration.

Bedded Iron Deposits (BID)

Numerous examples of commercially important iron ore deposits in the Pilbara are thought to be formed by natural enrichment of BIF eventually into BID (e.g. the Brockman and Marra Mamba Iron Formations). Hypogene and supergene enrichment caused by the continuous iron enrichment within the ancient groundwater system, resulting in high concentrations of iron mineralisation occur. The non-iron minerals were largely replaced by hydrous iron oxides (goethite), partly dissolved out, while the magnetite in the BIF oxidised to hematite.

In the case of BID deposition associated with the Blacksmith tenement, it is probable that a fairly recent geochemical tertiary BID transition from iron rich rocks could be a result of continual flushing of fresh groundwater across iron mineralised rocks (BIFs, DIDs, or CIDs). The diagenesis of detrital mudflows and debris flows would need to be post deposition of the detrital sediments as is shown in Plates 6-2 and 6-3. If the process was only restricted to ancient BID diagenesis, then more recent depositional environments such as DID, could not host BID (as seen in Plate 6-3).

Plate 6-4: Outcrop in upper reaches of Eagle tenement, showing goethitic alteration adjacent to minimal or non-goethitic alteration.

6.3 Aquifer Characteristics

Interpretation of drilling and pump test results in Section 5 suggests that the CID and BID units have very similar hydrogeological properties and contain the bulk of groundwater (Section 5). Therefore the BID and CID units have been combined, defined as the main aquifer, and assigned the same hydrogeological properties for the purpose of groundwater modelling for off tenement areas.

The extent of the aquifers was inferred using on tenement data and extrapolated to off tenement areas. Aeromagnetic conductivity data flown across the Delta, Champion and Eagle tenements, and also the adjacent off tenement areas was also used to extrapolate the channel geomorphological geometry. The local extent of inferred aquifers for on off tenement areas is presented in Figure 6-1.

The regional extent of the CID unit has also been mapped in Figure 6-2 using data presented by FMG 13th International River Symposium (2011) to assess the degree of interconnectivity between aquifer systems throughout the Caliwigina Creek and Weelumurra Creek catchments. The CID units mapped by FMG are associated with drainage patterns and appear to have been mapped using drainage, geology and topography as a guide. Additional CID units have also been mapped in Figure 6-2 using this methodology as well as available geological data from the Blacksmith tenement to provide more detail on the potential aquifer extents within the study area. The CID extents presented in this figure suggest there is potential for aquifer interconnectivity between and across catchment areas via the CID units.

During drilling, it became apparent that the presence of clay units above the CID was responsible for the semi confined conditions. Of primary interest, was the degree of confinement, as well as lateral and spatial variations associated with the clay units.

Drilling data collected at Delta, Eagle and Champion reveals the following:

- **Delta:** There is a CID unit draining north east towards Serenity that is locally confined by a clay unit extending out into Serenity;
- **Eagle:** There is CID unit that consists of a non-continuous lower clay unit separating an upper and lower CID unit, as well as an upper clay unit, behaving as a semi-confining laterally continuous unit, above the CID; and
- **Champion:** There is a continuous CID unit that contains the majority of the groundwater, and drains to the north. The clay encountered is scattered and not continuous within and beneath the DID and hence the CID unit is considered as an unconfined aquifer.

Figure 6-3 shows the subsurface mapped units of CID and clay encountered at Eagle and Delta.

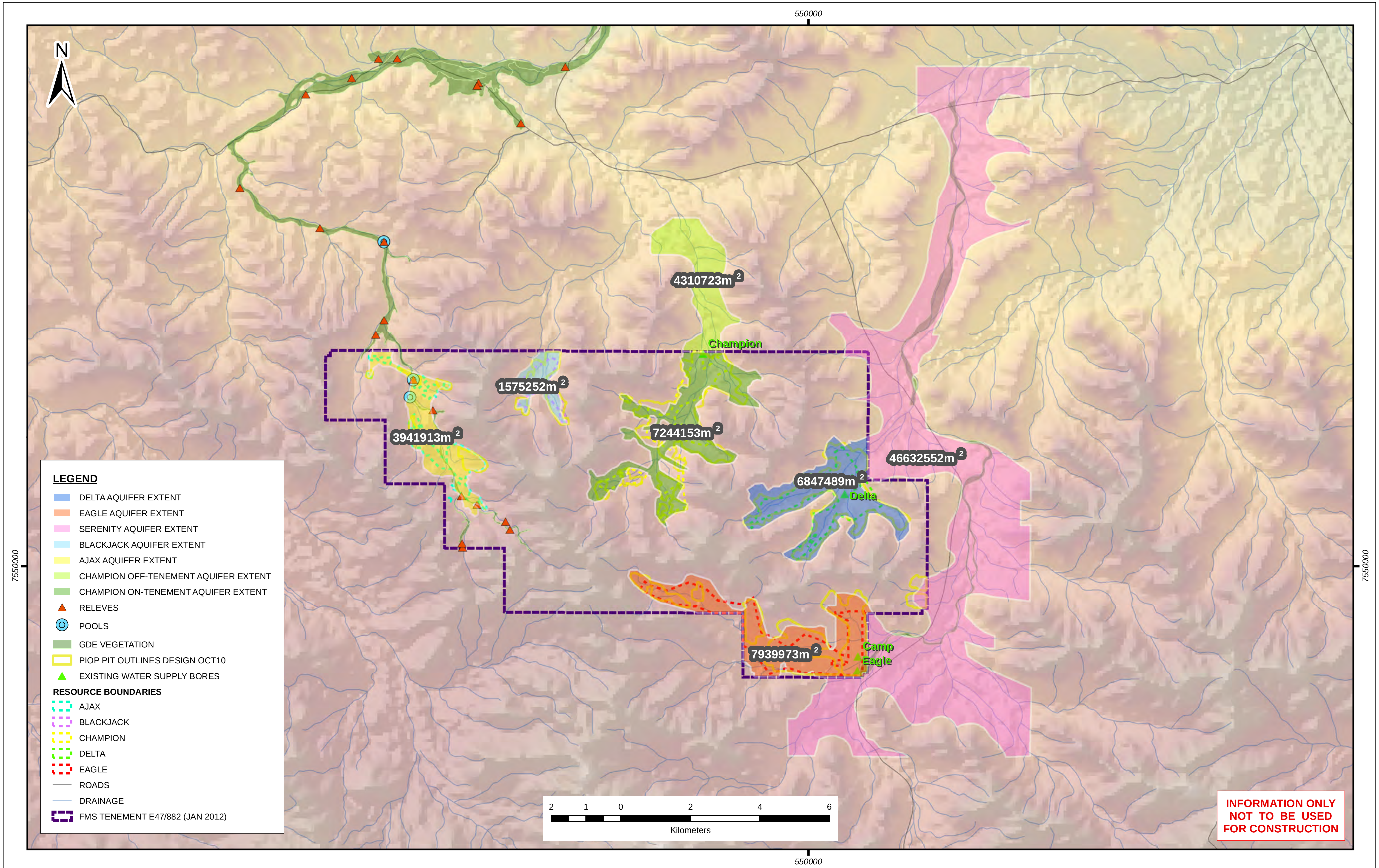
6.4 Groundwater Levels and Recharge

WorleyParsons installed a series of 52 monitoring bores at selected locations at discretely screened intervals within all tenements. A groundwater level contour map (Figure 6-4) has been developed using dipped water level readings from constructed bores. The contours show the direction of groundwater flow from the high to low elevations within the catchments, consistent with the topography. The Ajax characterising report provided in Appendix 1 provides some groundwater level data, derived from limited data, which was used to develop contours. These contours show the direction of groundwater flow to the north, consistent with topography. There was insufficient data for Blackjack to develop groundwater contours, however the direct of groundwater flow is expected to be to the north and following topography.

There is no recorded (publically available) groundwater level data available for Serenity or north of Champion, so it has been assumed that the direction of groundwater flow follows topography and that the hydraulic gradients can be extrapolated to off tenement areas using on tenement groundwater levels and topographic gradients.

6.4.1 Water Level Data Assessment

Field observations and exploration borehole log assessments have identified the presence of sediment layering and inter bedding within the Champion, Delta, and Eagle tenements. For the most part, DID and CID are inter layered throughout. Exposed BID also occurs along the flanks as well as at depth. BID was also identified to be one of the main receptors of surface to groundwater recharge.



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LOCALITY MAP
BROOME
PORT HEDLAND
KARRATHA
PANNAWONICA
TOM PRICE
PARABURDOO

WORLEYPARSONS PROJECT	SCALE					
201012-00322	1:100,000 @ A3					
	DATUM					
	GDA 1994 MGA Z50S					

REV	REVISION DESCRIPTION	DRN	CHK	DATE
0	ISSUED TO CLIENT	MR	SA	29-02-2012
A	FOR INFORMATION ONLY	MR	SA	25-02-2012

NOTES

CLIENT
Flinders MINES

TITLE
PILBARA IRON ORE PROJECT
GROUNDWATER IMPACT ASSESSMENT REPORT
FIGURE 6-1 - INTERPRETED EXTENT OF INTERCONNECTED AQUIFERS

DRG NO 201012-00322-GIS-DSK-099
REV 0

Produced by Worley Parsons, Geomatics WA

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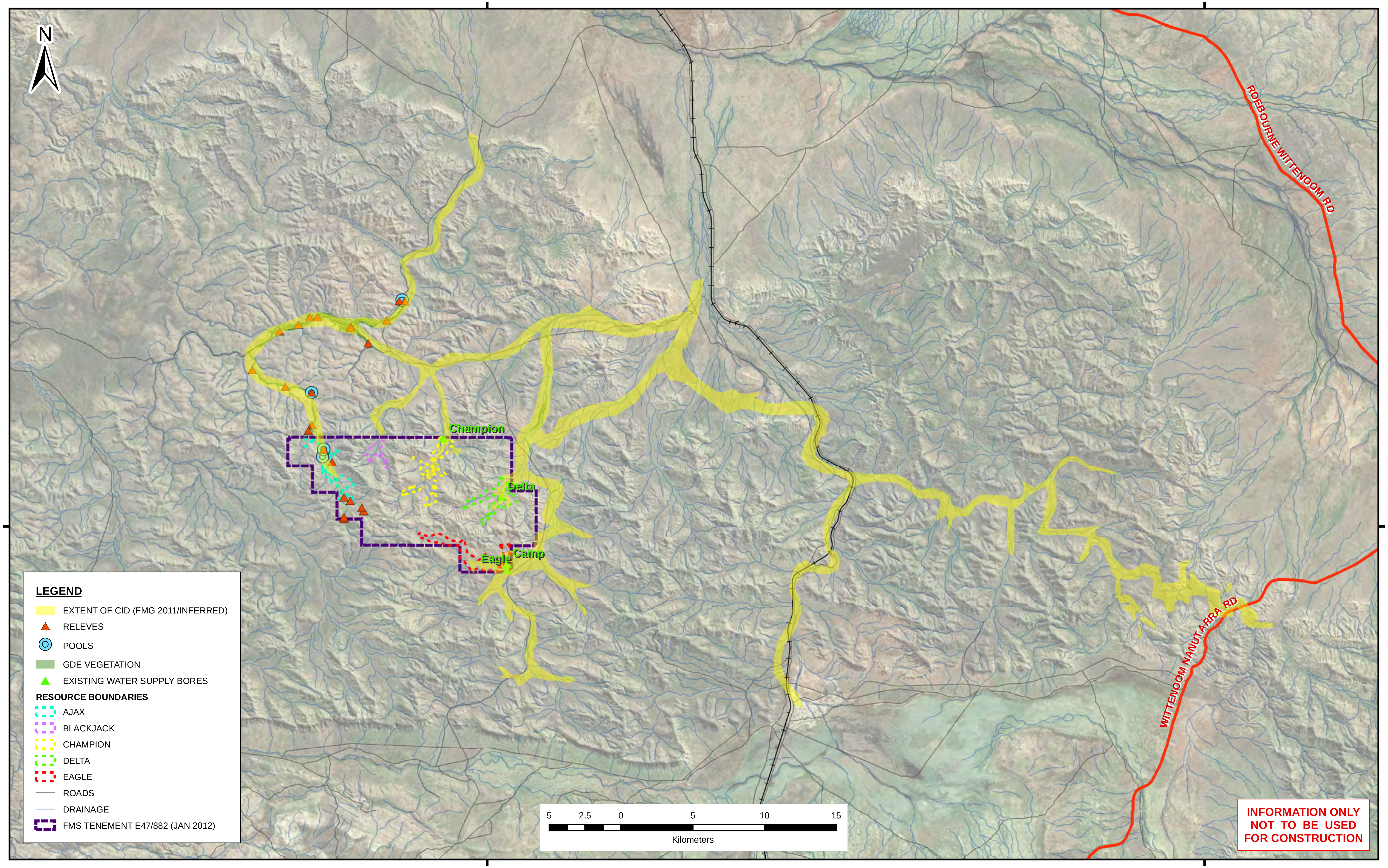

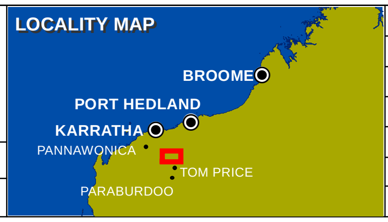

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WORLEYPARSONS PROJECT	SCALE	DATUM
201012-00322	1:250,000 @ A3	GDA 1994 MGA Z50S

REV	REVISION DESCRIPTION	DRN	CHK	DATE
0	ISSUED TO CLIENT	MR	LS	29-02-2012
A	FOR INFORMATION ONLY	MR	LS	28-02-2012

NOTES

1) Extent of CID inferred by FMG (Ref: Water Management for the Solomon Project, Ron Coleman, Fortescue Metals Group, 13th International River Symposium, 11-14th October, Perth WA)

CLIENT

Flinders Mines

TITLE

PILBARA IRON ORE PROJECT
GROUNDWATER IMPACT ASSESSMENT REPORT
FIGURE 6-2 - INFERRED REGIONAL EXTENT OF CID

DRG NO 201012-00322-GIS-DSK-108

REV 0

Produced by Worley Parsons, Geomatics WA

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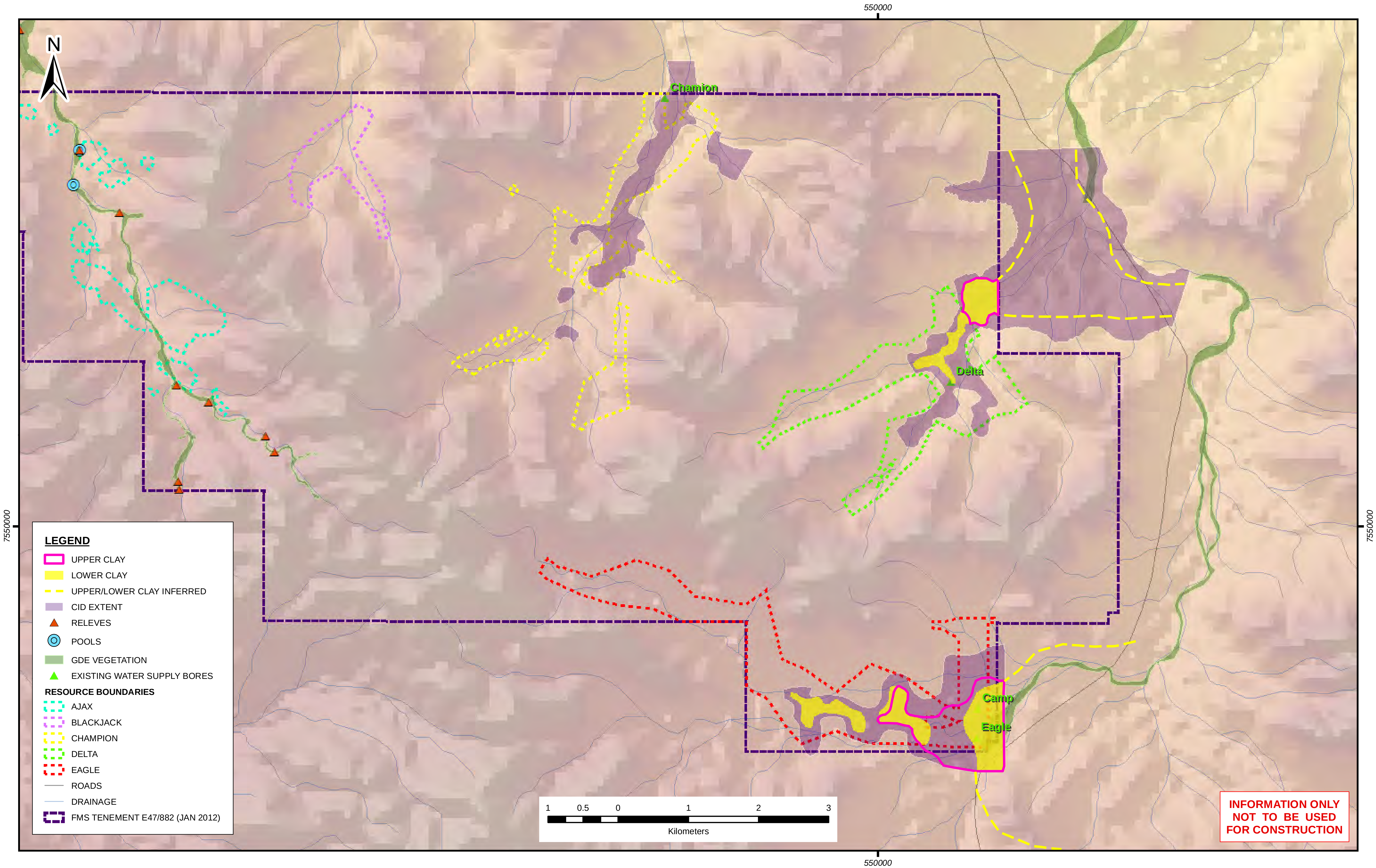

WorleyParsons
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OneWay to zero harm

LOCALITY MAP
BROOME
PORT HEDLAND
KARRATHA
PANNAWONICA
TOM PRICE
PARABURDOO

WORLEYPARSONS PROJECT 201012-00322	SCALE 1:50,000 @ A3	REV	REVISION DESCRIPTION	DRN	CHK	DATE	NOTES	CLIENT Flinders Mines
	DATUM GDA 1994 MGA Z50S	0	ISSUED TO CLIENT	MR	LS	29-02-2012		
		A	FOR INFORMATION ONLY	MR	LS	27-02-2012		

TITLE
PILBARA IRON ORE PROJECT
GROUNDWATER IMPACT ASSESSMENT REPORT
FIGURE 6-3 - EXTENT OF CID AND CLAY

DRG NO 201012-00322-GIS-DSK-101 REV 0

Produced by Worley Parsons, Geomatics WA

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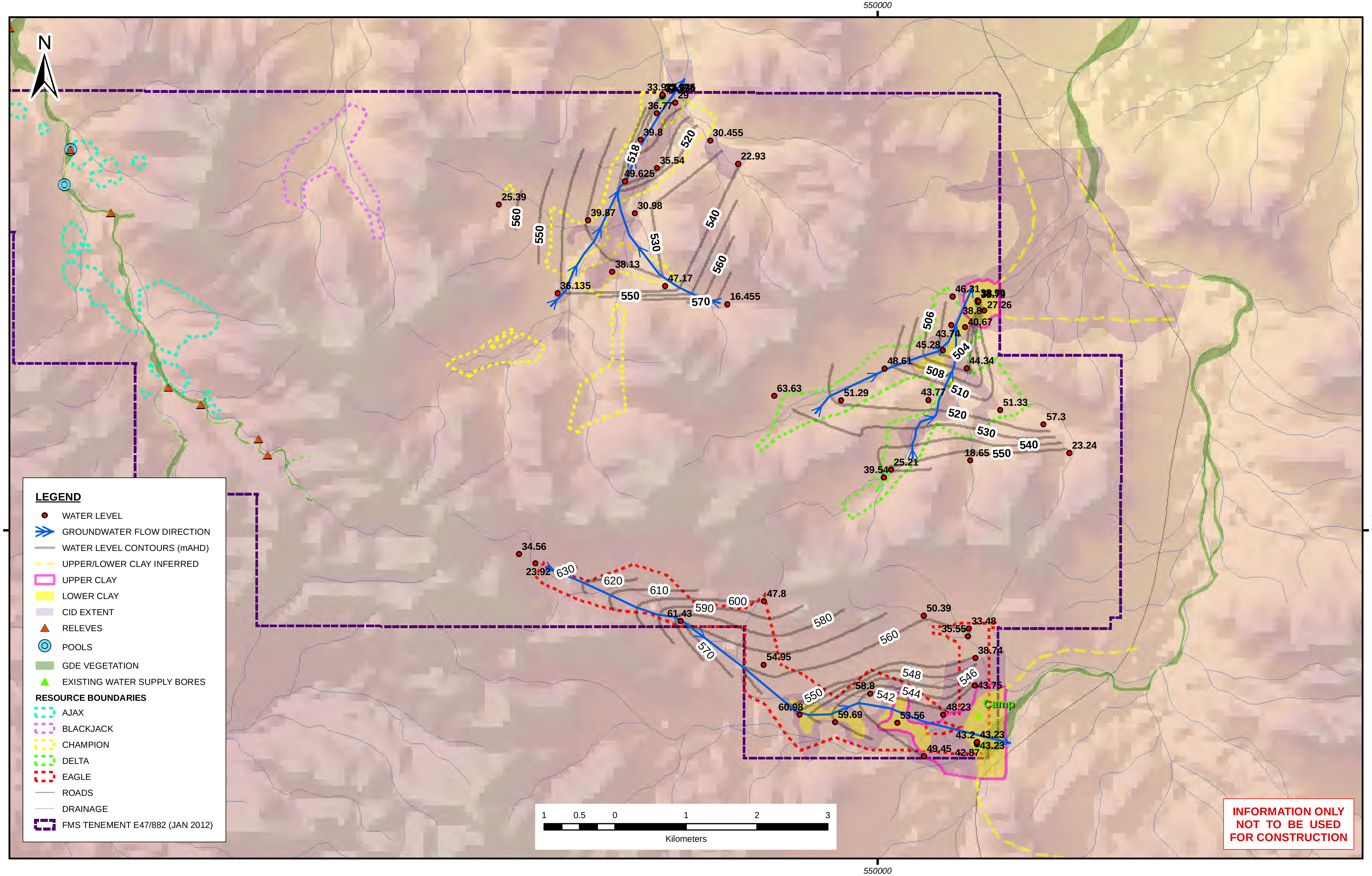

WorleyParsons resources & energy	OneWay to zero harm	LOCALITY MAP: BROOME, PORT HEDLAND, KARRATHA, PANNAWONICA, TOM PRICE, PARABURDOO

REV	REVISION DESCRIPTION	DRN	CHK	DATE
0	ISSUED TO CLIENT	MR	LS	29-02-2012
A	FOR INFORMATION ONLY	MR	LS	25-02-2012

WORLEYPARSONS PROJECT: 201012-00322
SCALE: 1:50,000 @ A3
DATUM: GDA 1994 MGA Z50S

NOTES

CLIENT: Flinders Mines

TITLE:
PILBARA IRON ORE PROJECT
GROUNDWATER IMPACT ASSESSMENT REPORT
FIGURE 6-4 - GROUNDWATER CONTOURS

DRG NO: 201012-00322-GIS-DSK-103
REV: 0

Produced by Worley Parsons, Geomatics WA

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Discretely intervals were screened in the monitoring bores within all tenements, to help quantify the relationship between surface water runoff, groundwater recharge to shallow sediments and groundwater recharge to the main CID aquifer at depth. Thirty two (32) of these monitoring bores were equipped with automatic water level recorders (InSitu RuggedTROLL's) and water level data recorded since November 2011. The location of these water level recorders are shown in Figure 6-5 (Champion), Figure 6-6 (Delta), and Figure 6-7 (Eagle).

The CID unit contains the largest volume of groundwater storage throughout the majority of all three tenements. As previously discussed, parts of the CID unit can be altered to BID, depending upon continual movement of fresher meteroric groundwater through the system. This is consistent with the results of pump test analysis, which suggests that the BID and CID units have very similar hydraulic properties.

The mechanism for groundwater recharge can be recognised as a series of catchments directing rainfall runoff to watercourses that flow across (intersect) areas where there is exposed BID, which is highly permeable and allows for significant groundwater recharge. This groundwater recharge may flow through the BID and into the CID/BID units at depth where there is hydraulic connectivity.

The bulk of groundwater storage is held in CID/BID units that range from unconfined to confined, depending upon the location of the CID/BID zone with respect to above confining clay layers. After careful review and evaluation of the data, it is recognised that five distinct surface and/or groundwater flow regimes exist. These are,

- **Upper tenement recharge zones -** zones within the upper reaches of the fluvial channels, which may or may not be recharging the main storage within the CID aquifer. Recharge in these areas mostly occurs in areas where watercourses intersect areas of exposed BID. These zones transmit groundwater but the aquifers are understood to be potentially thin and have hydraulic gradients that prevent large volumes of groundwater from being stored;
- **Mid tenement groundwater zones -** zones in the mid fluvial channel, which transmit water to the lower gradients, and stores moderate volumes of groundwater;
- **Lower tenement groundwater zones -** zones in the lower fluvial channel which have the greatest storage capacity within the groundwater aquifer, and are in a partially confined state;
- **Surface water zones -** zones which transmit surface water flow rapidly via watercourses through the system, and therefore potentially do not allow for significant recharge to the subsurface groundwater system; and
- **Groundwater above BIF -** zones which are structurally, stratigraphical, and hydraulically isolated from the main CID/BID groundwater flow within the system.

6.4.2 Surface-Groundwater Water Interaction

The water level data recorded by the 32 automatic loggers installed in monitoring bores across Champion, Eagle and Delta has been analysed to gain a better understanding of the surface-groundwater interactions and confirm the dominant mechanisms and flow pathways for groundwater recharge following rainfall events.

Groundwater hydrographs recorded at monitoring bores at Champion, Delta, and Eagle are provided in Figures 6-5, 6-6, and 6-7. Monitoring bore construction details, water level data and interpreted trends observed in groundwater hydrographs are also summarised for each of the monitoring bores in Tables 6-2, 6-3, and 6-4. Consistent ID numbers are provided to allow for comparison between figures and tables.

Analysis of the groundwater data suggests that recharge to the groundwater system primarily occurs along the flanks of the valleys, at the contact zone between the steeply dipping exposed BIF, and areas with exposed and highly permeable BID. Coincidentally, the BID is formed from the meteoric surface waters interacting with the exposed BIF, or DID, and geochemically altering to BID, which increases the permeability and promotes groundwater recharge.

Monitoring bore HPRC4122, is located in the upper reaches of the Eagle catchment and in an area where exposed BID is intersected by a watercourse draining a significant catchment area. The monitoring bore is screened within the BID unit. The groundwater hydrograph for this monitoring location shows an instantaneous one day response to rainfall, as a result of direct recharge to the BID. Comparison with rainfall records also indicates that two smaller rainfall events were needed to saturate the catchment enough to allow for significant volumes of runoff to be generated and for recharge to occur in the areas where the watercourses intersect highly permeable outcrops of BID.

The data recorded by the surface stream gaging station installed at Delta HPRC0269, shows an instantaneous response to rainfall. The water level data recorded in monitoring bores HPRC0269 and Delta-04-Nested, screened within the DID and CID units respectively and located adjacent to the stream gauge, shows that there was no response in the DID and a delayed/dampened response to rainfall and recharge. This suggests that surface water recharge is not transmitted to the groundwater aquifer uniformly throughout the tenement, and that the most of the surface water runs off the exposed colluvium or DID as sheet flow and surface water runoff with little or no vertical infiltration. Analysis of the geology on tenement suggests that surface infiltration is limited by:

- The inherent clay matrix which is part of the original depositional environment of the DID mud flow/debris flow unit; and
- Recent fluvial colluvium processes that are responsible for clay layers formed by the settling of fine sediments following runoff events.

Nearly all of the exploration holes drilled throughout all tenements were dry from the surface to about 40 meters depth, at which point damp conditions were encountered. Larger volumes of water were typically not encountered until the CID unit was intersected.

There is potential for shallow groundwater to be present in stream beds, perched in places by the presence of intermittent clay horizons below the more permeable outwash cutbanks of the surface fluvial systems. These perched zones may not be extensive, and probably random throughout the valleys. This perched groundwater can be as much as 40 meters above the actual groundwater aquifer in the CID unit.

Monitoring data recorded at Delta HPRC2144, shows a constant reduction in groundwater levels which suggests that the groundwater aquifer at this location is part of a constantly discharging system. The majority of monitoring bores located in the upper reaches of the catchments at Champion, Delta and Eagle show the same trend, which suggests that the aquifer systems are constantly discharging to the off tenement areas where the aquifers and storage capacities are much larger.

The monitoring bores located in the lowest areas of the catchment and screened within the CID showed delayed response to rainfall (approximately 9 to 10 days). The delay is most likely a result of the time groundwater recharge takes to flow from the outer flanks of the catchment where there are areas of exposed BID, then down through the CID/BID aquifer, and into the deepest section of the CID aquifer. The response is potentially dampened by the significant storage capacity of the aquifer at this location, associated with a larger and more extensive aquifer. The dampened response is more evident at Delta and Eagle, where semi confining conditions have been observed.

Monitoring location Delta HPRC3029 is located and screened just outside of the CID aquifer. The monitoring data collected shows minimal change in levels, which could be due to the presence of a structural high (elevated BIF bedrock) located down gradient of the monitoring bore, which may be inhibiting subsurface flow.

6.4.3 Potential Subsurface Inflows

The production bores at Delta and Eagle, were screened in semi-confined aquifers and Figure 6-6 (Delta Nested (11), and Eagle Nested (8)) shows a delayed response to rainfall and recharge. The monitoring data shows groundwater levels remaining fairly stable prior to the rainfall event, and remains that way until 9 to 10 days after the event occurs. The CID/BID units which comprise the bulk of storage within all groundwater aquifer systems are in a semi-confined state in Delta and Eagle, while unconfined at Champion. Delta and Eagle which are both fairly identical in their hydrogeological characterisation and properties, are semi-confined by the laterally continuous clay unit and eventually discharge into Serenity (Figure 6-3). As the CID aquifer at Serenity is also saturated with groundwater, discharge from the Delta and Eagle tenements into Serenity is relatively slow, as is evident by the groundwater monitoring bore behaviour.

The production bore at Champion drains into an unconfined groundwater system, which does not have a continuous clay cap over the CID unit (Figure 6-5). According to the drilling log, at the Champion production bore, Champion has a greater degree of weathering on top of the lower BIF unit, which provides some storage and saturation not recognised in the BIF at Delta or Eagle. Groundwater levels recorded in monitoring bores installed across the catchment at Champion show a more noticeable decline in water levels in time, which suggests that the system is draining, albeit at a slow rate.

Table 6-2: Summary of monitoring bore details, water level data and interpreted trends observed in groundwater hydrographs at Champion

Monitoring ID	Screened Interval (mbgl)	Water Level 28/1/2012 (mAHD)*	Geology of screened interval	Hydrogeological Characteristics	Summary of Discharge and 14/1/2012 Recharge Event Behaviour
HPRC0395	39.2 – 51.20	515	BID & BIF	Hydraulic gradient = 1:2300 Aquifer screened = Edge of Confined Saturated thickness of aquifer = 11.8m	Very low hydraulic gradient Continuous saturated discharge (minor) No response to event Larger groundwater system
HPRC0689	2.0 – 29.0	566.4	BID & BIF	Hydraulic gradient = 1:45 Aquifer screened = Unconfined Saturated thickness of aquifer = 3.0m	Steep hydraulic gradient Continuous saturated discharge (major) Minimal response to event ~ 2 days Directly influenced by recharge, edge of aquifer response after saturation
HPRC0919	42.0 – 59.0	530.4	CID & BIF	Hydraulic gradient = 1:120 Aquifer screened = Unconfined Saturated thickness of aquifer = 20.7m	Low hydraulic gradient Continuous saturated discharge (minor) Minimal response to event Edge of aquifer, response after saturation
HPRC0531	18.0 – 42.0	541	DID, CID & BIF	Hydraulic gradient = 1:65 Aquifer screened = Unconfined	Moderate hydraulic gradient Negligible discharge No response to event

Monitoring ID	Screened Interval (mbgl)	Water Level 28/1/2012 (mAHD)*	Geology of screened interval	Hydrogeological Characteristics	Summary of Discharge and 14/1/2012 Recharge Event Behaviour
				Saturated thickness of aquifer = 12.5m	Water on BIF, not major part of aquifer
HPRC0352	15.0 – 30.0	DRY	DID	Hydraulic gradient = N/A Aquifer screened = DRY Saturated thickness = N/A	Dry Bore No response to event Not part of groundwater aquifer
HPRC0792	11.0 – 38.0	DRY	DID	Hydraulic gradient = N/A Aquifer screened= DRY Saturated thickness of aquifer = N/A	Dry Bore No response to event Not part of aquifer
HPRC1026	2.0 – 22.0	579.1	BID & BIF	Hydraulic gradient = 1:25 Aquifer screened = Unconfined Saturated thickness of aquifer = 5.9m	Steep hydraulic gradient Continuous saturated discharge (minor) Minor response to event ~ 2 days Delayed resposne after saturation
HPRC0631	30.2 – 48.20	517.1	CID & BIF	Confined behaviour through CID Hydraulic gradient = 1:190 Aquifer screened = Confined Saturated thickness of aquifer = 12.5m	Low hydraulic gradient Continuous saturated discharge (minor) No response to event Delayed response, edge of larger groundwater aquifer
HPRC0973	16.0 – 52.0	535.8	DID, BID & BIF		Moderate hydraulic gradient

Monitoring ID	Screened Interval (mbgl)	Water Level 28/1/2012 (mAHD)*	Geology of screened interval	Hydrogeological Characteristics	Summary of Discharge and 14/1/2012 Recharge Event Behaviour
				Hydraulic gradient = 1:60 Aquifer screened = Edge of Confined Saturated thickness of aquifer = 25.0m	Continuous saturated discharge (minor) Major response to event ~ 2-3 days Directly influenced by recharge
Champion- 04-Nested	59.0 – 69.0 (s) 91.0 – 100.0 (d)	514.7 (s) 514.7 (d)	CID (s) BIF (d)	Hydraulic gradient = N/A Aquifer screened = Confined Saturated thickness of aquifer = 66.4m	Continuous saturated discharge (minor) No response to event Larger groundwater aquifer

Table 6-3: Summary of monitoring bore details, water level data and interpreted trends observed in groundwater hydrographs at Delta

Monitoring ID	Screened Interval (mbgl)	Water Level 26/1/2012 (mAHD)*	Geology of screened interval	Hydrogeological Characteristics	Summary of Discharge and 14/1/2012 Recharge Event Behaviour
HPRC0216	19.0 – 31.0	DRY	DID	Hydraulic gradient = N/A	Dry bore; saturated recharge from mounding in BID.
				Aquifer screened = Dry Saturated thickness of aquifer = N/A	No response to event
HPRC2144	52.0 – 69.0	510.8	BIF	Hydraulic gradient = 1:155 Aquifer screened = Edge of Confined Saturated thickness of aquifer = 20.9m	Low hydraulic gradient Continuous saturated discharge (major) Minor response to event ~3 days Edge of groundwater aquifer
HPRC2084	2.0 – 76.0	528.1	DID, BID & BIF	Hydraulic gradient = 1:75 Aquifer screened = Unconfined Saturated thickness = 12.9m	Moderate hydraulic gradient Continuous saturated discharge (minor) Negligible response to event
HPRC2249	35.5 – 53.5	514.3	BIF	Hydraulic gradient = 1:130 Aquifer screened= Unconfined Saturated thickness of aquifer = 10.2m	Low hydraulic gradient Continuous saturated discharge (minor) No response to event

Monitoring ID	Screened Interval (mbgl)	Water Level 26/1/2012 (mAHD)*	Geology of screened interval	Hydrogeological Characteristics	Summary of Discharge and 14/1/2012 Recharge Event Behaviour
HPRC2302	9.0 – 33.0	552.2	DID	Hydraulic gradient = 1:30 Aquifer screened = Unconfined Saturated thickness of aquifer = 10.3m	Steep hydraulic gradient Continuous saturated discharge (minor) Minor delayed response to event ~5 days
HPRC0285	27.0 – 51.0	540.3	BID & BIF	Hydraulic gradient = 1:13 Aquifer screened = Unconfined Saturated thickness of aquifer = 11.9m	Steep hydraulic gradient Continuous saturated discharge (minor) Major response to event ~instantaneous-1 day
HPRC5359	2.3 – 28.3	557.5	BID & BIF	Hydraulic gradient = 1:25 Aquifer screened = Unconfined Saturated thickness of aquifer = 5.6m	Steep hydraulic gradient Continuous saturated discharge (minor) Minor recharge response to event ~2 days Not in recharge catchment zone
HPRC3029	46.0 – 76.0	510.2	BIF	Hydraulic gradient = 1:190 Aquifer screened = Edge of Confined	Low hydraulic gradient Negligible discharge Minor recharge response to event 1-2 days

Monitoring ID	Screened Interval (mbgl)	Water Level 26/1/2012 (mAHD)*	Geology of screened interval	Hydrogeological Characteristics	Summary of Discharge and 14/1/2012 Recharge Event Behaviour
				Saturated thickness of aquifer = 0.8m	Minor water BIF
Stream Gauge	Screened in shallow alluvium to base of channel	-	Surface stream gauge.	Hydraulic gradient = N/A Aquifer screened = N/A Saturated thickness of aquifer = N/A	Very minor response to event ~instantaneous, dissipates rapidly. Overland Flow.
HPRC0269	24.0 – 27.5	512.26	DID	Hydraulic gradient = N/A Aquifer screened = Unconfined Saturated thickness of aquifer = 12.4m	Dry bore No response to event
Delta- 04-Nested	68.3 – 77.4 (s) 84.4 – 98.6 (d)	501.86 (s) 501.85 (d)	uCID (s) lCID (d)	Hydraulic gradient = N/A Aquifer screened = Confined Saturated thickness of aquifer = 59.8m	No deep discharge; semi-confined system Minor recharge response to event ~9 days through entire CID layer Part of Major groundwater aquifer

Table 6-4: Summary of monitoring bore details, water level data and interpreted trends observed in groundwater hydrographs at Eagle

Monitoring ID	Screened Interval (mbgl)	Water Level 27/1/2012 (mAHD)*	Geology of screened interval	Hydrogeological Characteristics	Summary of Discharge and 14/1/2012 Recharge Event Behaviour
HPRC0035	2.0 – 51.5	599.1	DID & BIF	Hydraulic gradient = 1:25 Aquifer screened = Unconfined Saturated thickness of aquifer = 3.7m	Steep hydraulic gradient Continuous saturated discharge (major) No response to event
HPRC0098	53.0 – 71.4	569.4	BID & BIF	Hydraulic gradient = 1:340 Aquifer screened = Unconfined Saturated thickness of aquifer = 10.0m	Low hydraulic gradient Negligible discharge No response to event
HPRC4122	1.0 – 37.0	639.1	BID & BIF	Hydraulic gradient = 1:95 Aquifer screened = Unconfined Saturated thickness = 2.4m	Moderate hydraulic gradient Continuous saturated discharge (minor) Major pulse response to event ~1day Catchment recharge to directly discharging aquifer
HPRC4118	3.0 – 25.5	637	DID & CID	Hydraulic gradient = 1:32 Aquifer screened = Unconfined Saturated thickness of aquifer = 1.6m	Steep hydraulic gradient Negligible discharge No response to event Early response questionable, possibly slipping

Monitoring ID	Screened Interval (mbgl)	Water Level 27/1/2012 (mAHD)*	Geology of screened interval	Hydrogeological Characteristics	Summary of Discharge and 14/1/2012 Recharge Event Behaviour
HPRC0108	48.5 – 60.5	565	DID	Hydraulic gradient = 1:60 Aquifer screened = Unconfined Saturated thickness of aquifer = 5.6m	Moderate hydraulic gradient Continuous saturated discharge (minor) Minor recharge response to event ~ 2 days
HPRC4180	55.7 – 73.8	543.3	DID & BIF	Hydraulic gradient = 1:430 Aquifer screened = Edge of Confined Saturated thickness of aquifer = 14.7m	Low hydraulic gradient Negligible discharge Minor recharge response to event ~ 2 days Saturation resting on BIF
Eagle-Obs-01	41.5 – 113.2	541.2	CID & BIF	Hydraulic gradient = 1:6000 Aquifer screened = Confined Saturated thickness of aquifer = 59.6m	Very low hydraulic gradient Negligible discharge Minor response to event ~3 days Confined aquifer
Eagle-04 -Nested	56.0 – 65.0 (s) 88.5 – 114.0 (d)	540.9 (s) 540.9 (d)	DID (s) CID & BIF (d)	Hydraulic gradient = N/A Aquifer screened = Confined Saturated thickness of aquifer = 70.8m	Negligible discharge Minor response to event ~ 5 days Confined aquifer
Eagle-Obs-03	40.0 – 82.0	541	CID & BIF	Hydraulic gradient = 1:8000	Very low hydraulic gradient Negligible discharge

Monitoring ID	Screened Interval (mbgl)	Water Level 27/1/2012 (mAHD)*	Geology of screened interval	Hydrogeological Characteristics	Summary of Discharge and 14/1/2012 Recharge Event Behaviour
				Aquifer screened = Confined Saturated thickness of aquifer = 38.3m	Minor response to event ~ 2-3 days Confined aquifer
HPRC4053	25.6 – 43.7	560.9	DID	Hydraulic gradient = 1:40 Aquifer screened = Unconfined Saturated thickness of aquifer = 11.3m	Steep hydraulic gradient Continuous saturated discharge (major) Minor recharge response to event ~ 1 day
HPRC4029	2.0 – 62.5	560.6	DID & BIF	Hydraulic gradient = 1:65 Aquifer screened = Unconfined Saturated thickness of aquifer = 12.1m	Moderate hydraulic gradient Continuous saturated discharge (moderate) No response to event

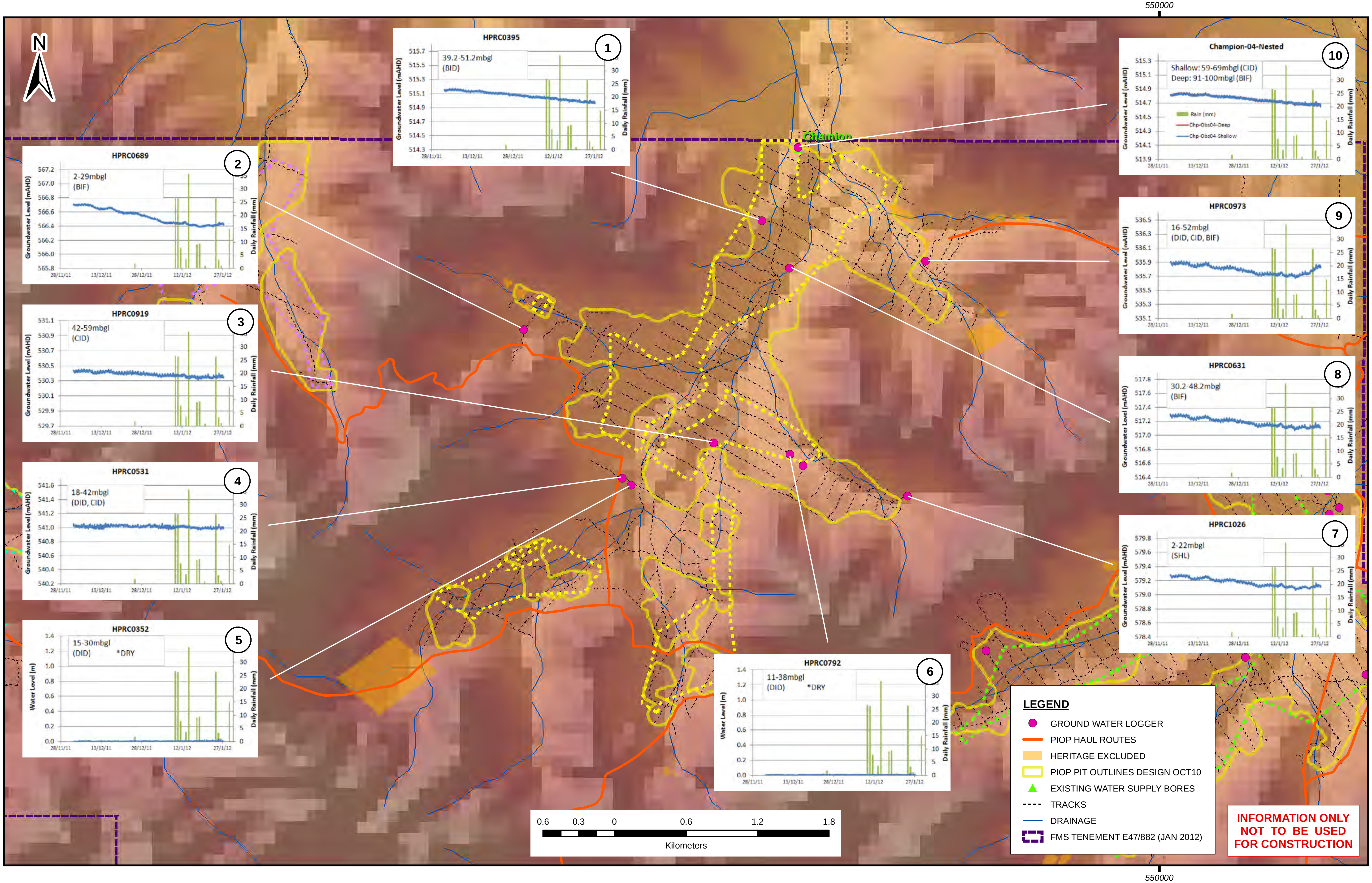

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FIGURE 6-5 - HYDROGRAPHS (CHAMPION)

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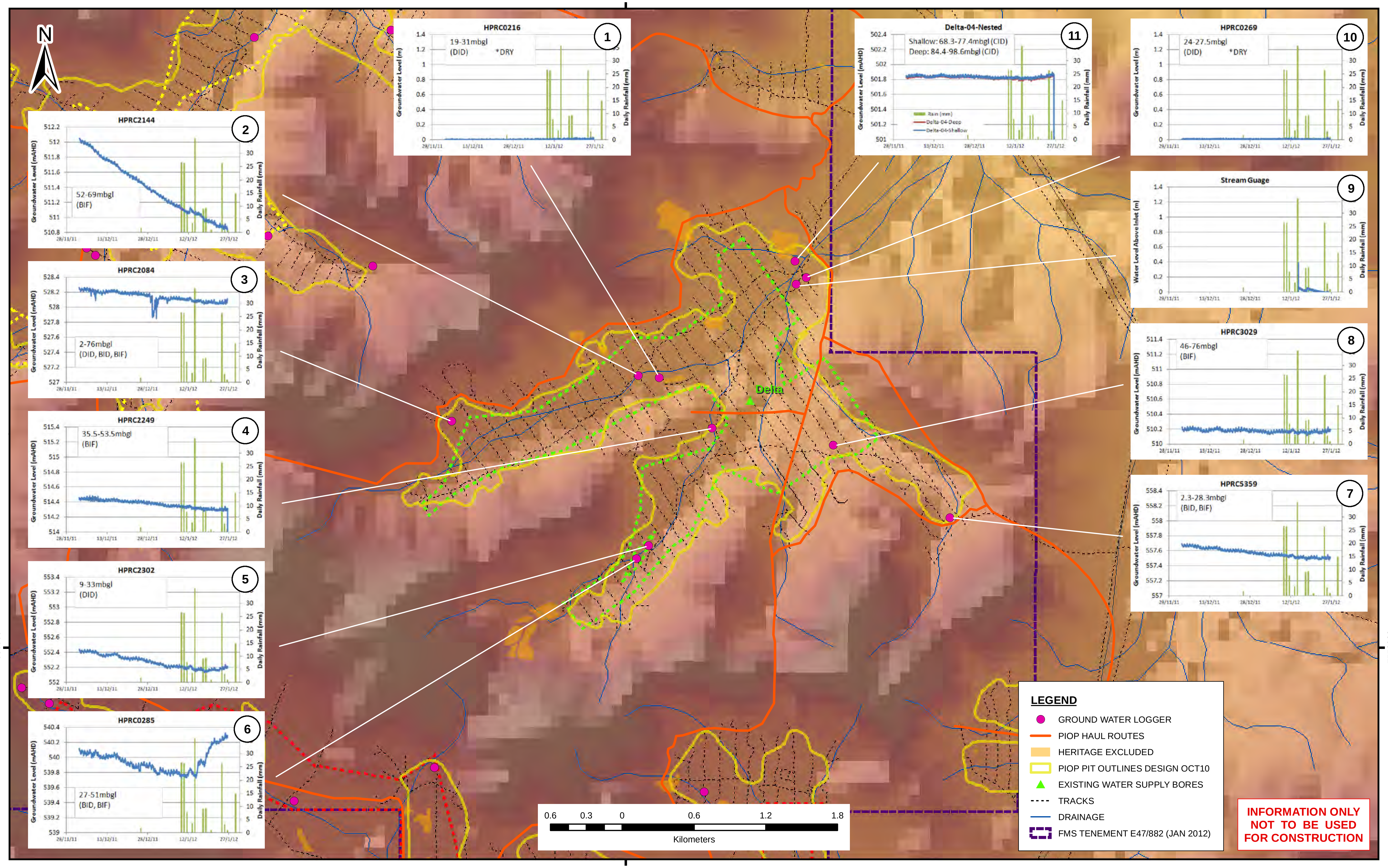

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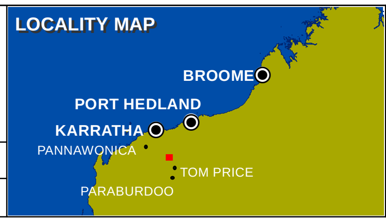

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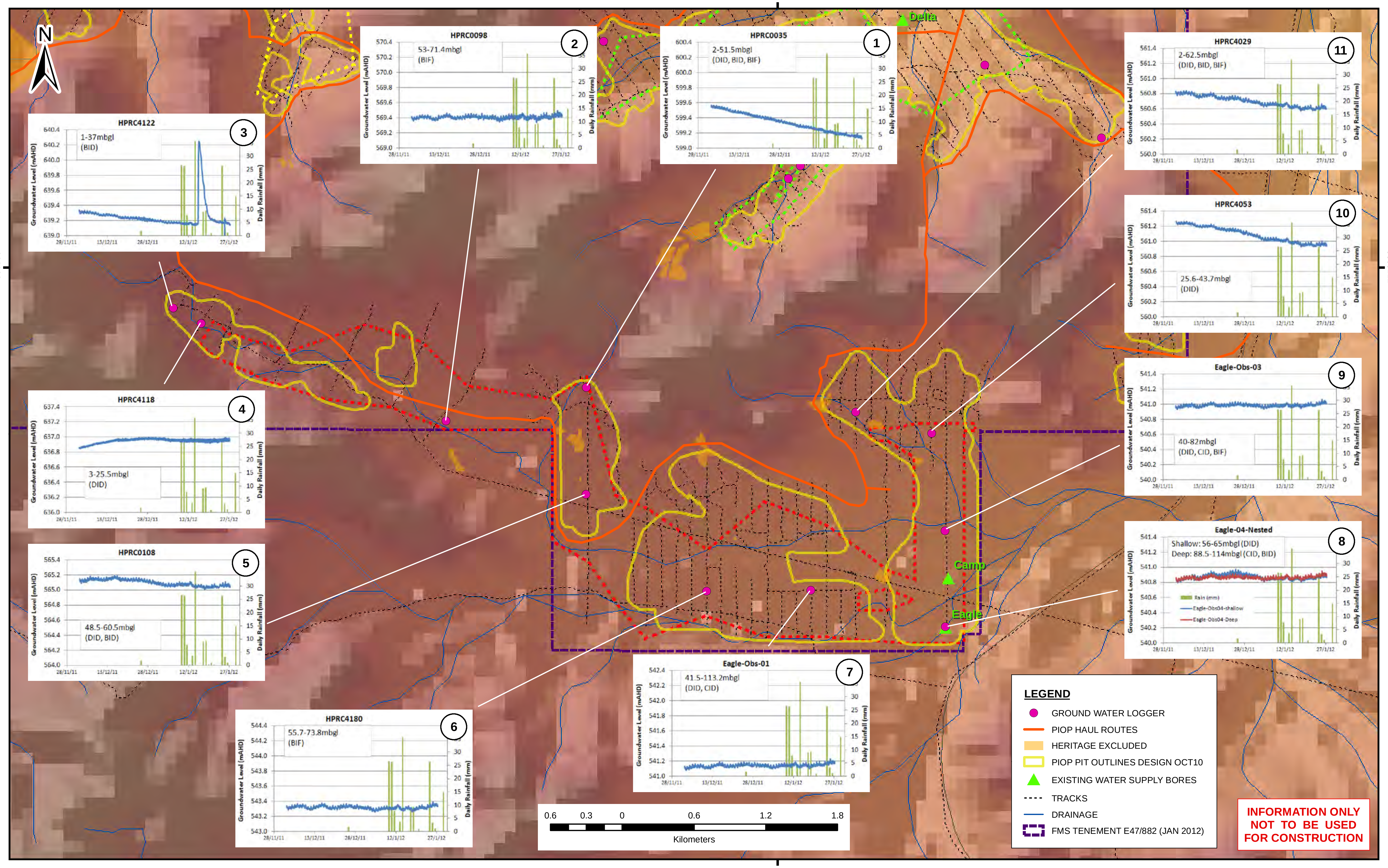

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FIGURE 6-7 - HYDROGRAPHS (EAGLE)

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6.5 Conceptual Hydrogeology – Summary

6.5.1 Conceptual Models

Groundwater recharge to the aquifers is a direct result of the stratigraphy and geology associated with the surface water drainage within each catchment. Groundwater recharge is a result of surface water infiltration into surface sediments. If the surface sediments are relatively impermeable, then the majority of surface water will run off. More permeable surface rocks such as BID that are exposed and intersected by watercourses tend to offer a higher degree of infiltration when compared with clay rich surface colluvium and clay rich surface DID.

Upon infiltration, groundwater moves down gradient, ultimately intercepted by deeper channels which are often filled with more permeable CID and BID deposits. These CID and BID filled channels offer a greater degree of permeability as well as storage, compared to other sedimentary units in the drainages. They are typically located at deeper elevations within the valleys themselves. These deeper units can often be hydrogeologically separated from upper recent fluvial/alluvial deposits associated with ephemeral creeks, by low permeability units/layers. These recent deposits often contain shallow groundwater perched above clay layers formed/deposited by the inherent fluvial channel geomorphology. The groundwater is generally localised and is not found everywhere within the catchment. There is currently insufficient data to confirm the presence, depth and extent of this perched groundwater however it is likely to be present in the areas where GDEs have been identified.

Based on review of FMS's exploration database, lithologs and the hydrogeological field investigations undertaken by WorleyParsons, the on-site hydrogeology is summarised as follows:

- The aquifer in the Delta, Eagle and Champion deposits is predominantly CID;
- The CID and BID units have very similar hydrogeological properties and contain the bulk of the groundwater in the Delta, Eagle and Champion deposits. Therefore the aquifer is defined as the combined CID/BID units for the purpose of groundwater modelling (Section 7);
- The aquifer is interconnected and extends into off tenement areas as far as Millstream (based on the inferred CID extents shown in Figure 6-2);
- Groundwater recharge is mainly through rainfall runoff during significant rainfall events and often associated with cyclonic activity;
- The mechanism for groundwater recharge can be recognised as a series of catchments directing rainfall runoff to watercourses that flow across (intersect) areas where there is exposed BID, which is highly permeable and allows for significant groundwater recharge. This groundwater recharge may flow through the BID and into the CID/BID units at depth where there is hydraulic connectivity;
- Depth to groundwater follows surface topography in the unconfined portions of each aquifer/drainage;
- The CID is semi-confined in the Delta and Eagle tenements, and unconfined in the Champion tenement;

- Semi-confined CID conditions in the Eagle and Delta aquifers resulted in rising heads/ groundwater levels after drilling, through the upper clay units; and
- The groundwater system is semi confined to partially confined where a significant thickness and fairly continuous clay layer is present in the Delta and Eagle tenements.

Cross sections showing the conceptual hydrogeology, simplified geological units and inferred groundwater levels (total heads[3]) estimated using groundwater levels provided by FMS and recorded by automatic water level recorders are presented for Delta, Champion and Eagle in Appendix 6. As there is no available geological or hydrogeological data for the off tenement areas, the generalised cross section presented in Figure 6-8 has been adopted as the conceptual model for the off tenement areas at Serenity. This cross section is also presented in Appendix 4. The conceptual model for the off tenement area immediately north of Champion is represented by the cross sections for Champion provided in Appendix 6. These conceptual models have been used as the basis for groundwater modelling presented in Section 7.

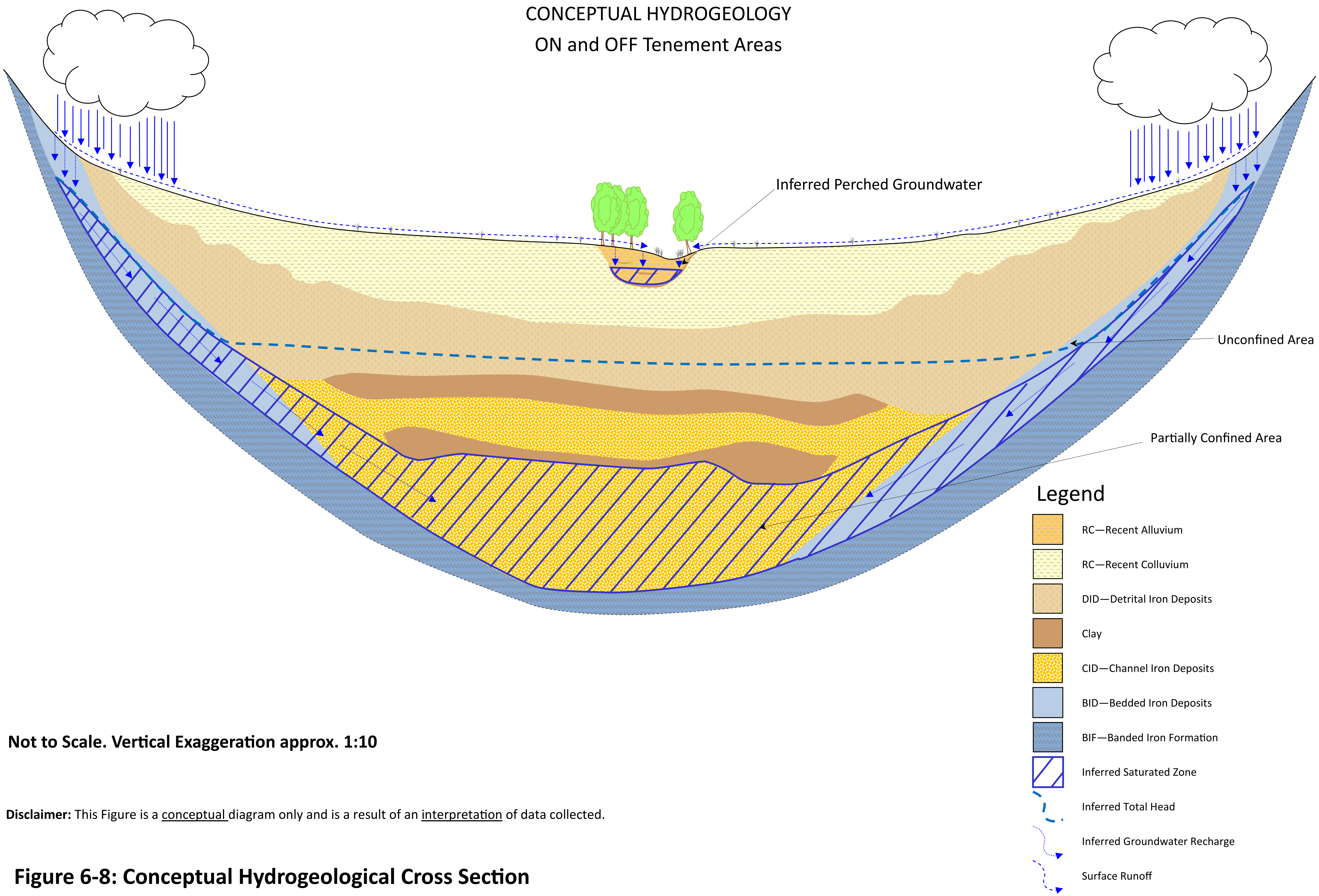
6.5.2 Environmental and Social Considerations

Groundwater and streamflow monitoring at Delta suggests that there is negligible river recharge from the creeks to the deeper CID/BID aquifer at the northern end of the catchment adjacent to the Serenity catchment (see Section 6.4.2). The majority of recharge to the CID/BID aquifers is via recharge from the valley flanks. Although there is likely to be shallow groundwater perched in alluvial sediments associated with creeks and major watercourses, it is expected to contribute minimal recharge the aquifer on tenement and the majority of this water is expected to flow through the surface water systems, evaporate or be removed via evapotranspiration. This perched water may be available to support any GDEs or pools with social or cultural significance.

This conceptual understanding has been extrapolated to the off tenement areas, and is considered representative for the purposes of this investigation. The groundwater models presented in this report have been developed only to predict drawdown within the deeper CID/BID aquifer as a result of mine dewatering because:

- The shallow perched aquifer was not encountered while drilling on tenement;
- The shallow perched aquifer was does not appear to be in hydraulic connection with the deeper CID/BID aquifer, based on Groundwater and streamflow monitoring at Delta (see Section 6.4.2); and
- There is insufficient data to confirm the presence and extent of shallow perched groundwater.

[3] Total head = sum of the elevation head and the pressure head (Freeze and Cherry, 1979)



Not to Scale. Vertical Exaggeration approx. 1:10

Disclaimer: This Figure is a conceptual diagram only and is a result of an interpretation of data collected.

Figure 6-8: Conceptual Hydrogeological Cross Section

7. GROUNDWATER MODELLING OF OFF-TENEMENT IMPACTS

7.1 Serenity System

7.1.1 Model Set Up and Geometry

The off-tenement numerical groundwater model for the Serenity system was developed using Schlumberger Water Services' Visual Modflow Pro software (Schlumberger Water Services 2011). The software is essentially a user interface based around the original MODFLOW finite difference code (Harbaugh et al. 2000).

MODEL MESH

The finite difference grid covers a model domain of 20km by 7km shown in Figure 7-1. This domain incorporates the areas adjacent to FMS's Eagle and Delta deposits in its southern half as well as the area north of Delta. The origin of the model domain is located in the south-western corner, at 549,380mE and 7,544,500mN. Grid cell size is 100m x 100m, with a total of 70 rows and 200 columns.

MODEL LAYERS

The Serenity model grid was divided into the following three layers, representing a simplified version of the conceptual geological models developed for the on-tenement areas and described in Section 6:

- Layer 1 – incorporating the Recent Colluvium and DID geological units;
- Layer 2 – the Clay layer; and
- Layer 3 – incorporating the CID and BID units (the aquifer);

The bottom of Layer 3 defines the no-flow boundary which provides an acceptable (and conservative) representation of the basement formation (BIF).

Aerial LIDAR survey data, where available, was interpolated to the model grid to approximate the existing ground level and used to define the top elevations for Layer 1. A small portion of the model domain used NASA SRTM data for ground levels, as LIDAR was not available in this area.

Layer elevations were input into the model using grid surfaces created in Golden Software's Surfer v9. These surfaces utilised some drill data from on-tenement bores at Eagle and Delta, however this data covered only a very small percentage of the model area. Due to the absence of off-tenement drilling data, layer elevations in the off-tenement area were extrapolated from the Eagle and Delta data using the conceptual models presented in Section 6 as a guide. Dummy points were created throughout the Serenity channel area, each with notional elevation data for each of the three model layers. Surfer was then used to interpolate surfaces for each layer elevation based on these data points. Table 7-1 presents the model layers and their approximate depths below ground level. The layers and geological unit delineations used in the model are also graphically represented in Figure 7-2.

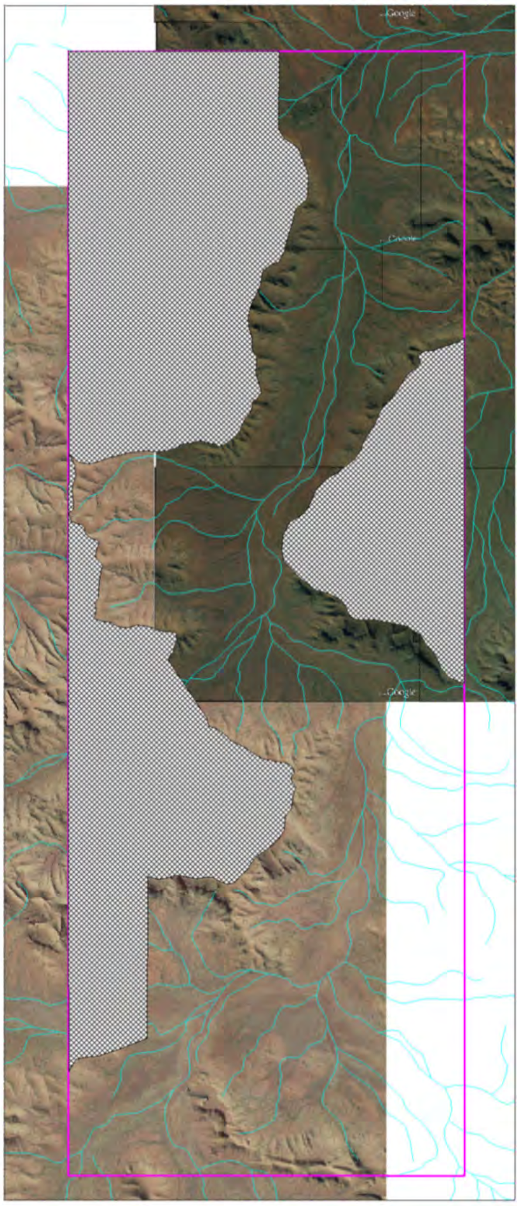
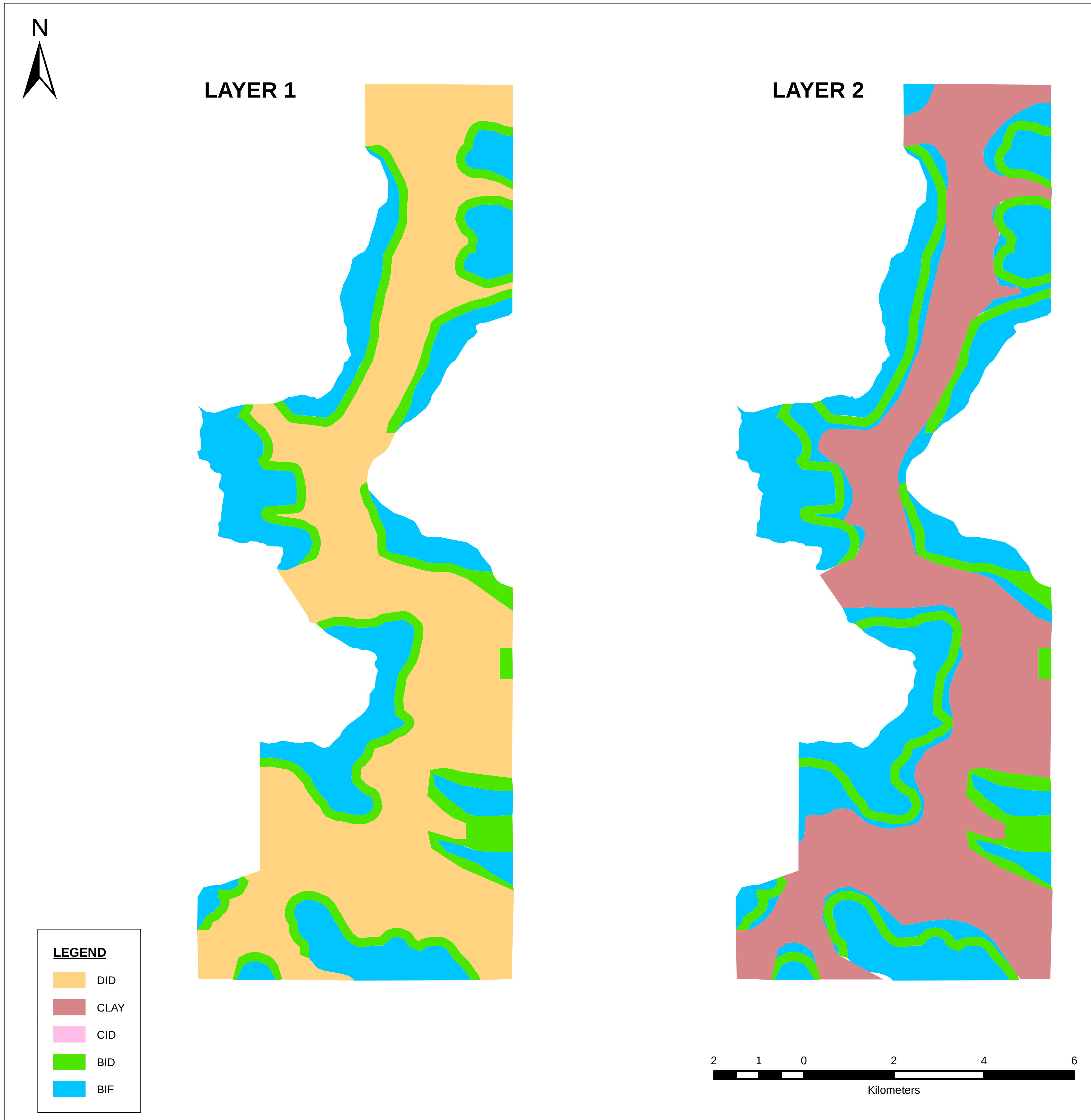


Figure 7-1: Groundwater model domain for the Serenity System

Table 7-1: Serenity Model Layer Setup

Layer	Geological Units	Aquifer Type	Top of layer (approx. metres below ground)	Bottom of layer (approx. metres below ground)	Thickness (m)
1	Recent Colluvium (RC) / Detrital Iron Deposits (DID)	Confined / Unconfined	Ground surface	~50	~50
2	Clay	Confined / Unconfined	~50	~58	8
3	Channel Iron Deposits (CID) / Bedded Iron Deposits (BID)	Confined / Unconfined	~58	~120	~62

The Serenity area was modelled as a semi-confined system. A confining layer of clay (Layer 2) was modelled above the CID layer throughout the main channel area. However, along the flanks of the channel, this clay layer, along with the DID layer above it, were interrupted with higher conductivity zones to represent areas where BID surface outcroppings were inferred to yield relatively high rates of recharge to the aquifer below.



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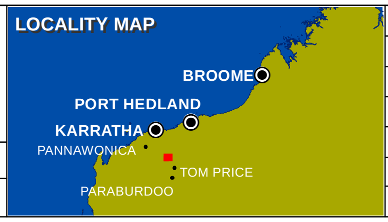

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FIGURE 7-2 - SERENITY GROUNDWATER MODEL
GEOLOGICAL UNITS

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7.1.2 Model Stresses

Boundary Conditions

The model required boundary conditions to represent the groundwater through flow processes assumed to be occurring in off tenement areas. The upstream boundary conditions, located at the southern end of the model, consisted of three recharge boundaries, which were applied to the three main aquifer channels entering the model domain from the south near the Eagle deposit. A conservative estimate for the average annual recharge entering the system through the southern boundaries was calculated by multiplying the contributing catchment area by 5% of the average annual rainfall. The catchment area considered did not include the catchment area north of Delta which is outside of FMGs Serenity tenement area. The total annual groundwater through flow calculated for the Serenity main channel was 4.6GL/yr (Appendix 7). This calculated recharge total was apportioned between the three main aquifer channels.

In addition to the northern boundary conditions, groundwater recharge was also added to the central section of the model at the Eagle and Delta deposits. The recharge at Eagle and Delta were initially set to 0.6GL/a and 0.4GL/a respectively based on catchment area (Appendix 7). These recharge estimates were then increased to 1.0GL/a each to account for recharge from other contributing catchment areas north of the deposits.

The outflow of groundwater at the downstream (northern) boundary of the model was simulated using a constant head boundary. This boundary was set at a level of 430.0mAHD (35m bgl). This corresponded to the extrapolated initial head estimated at the northern end of the domain.

Initial Groundwater Levels

Initial groundwater levels in the model were set up using a similar technique to the layer elevation setup. A single surface representing the initial water level was created using Surfer v9. Where available, groundwater level measurements recorded on-tenement at Eagle and Delta were used. In the off-tenement area, the same dummy points used to create the layer elevation surfaces were assigned estimated water levels based on measurements taken in the on-tenement bores at Eagle and Delta, and the levels were then interpolated into an initial head surface using topography.

Rainfall Recharge

Two types of rainfall recharge were applied in the Serenity model. The first simulated standard rainfall recharge was applied across the model domain and calculated by multiplying the monthly long-term average rainfall data from the Wittenoom BoM station (5026) by a factor of 3%.

The second form of rainfall recharge was applied only to certain zones in the model, located on the higher-relief zones flanking the main Serenity channel. This was intended to simulate BID outcrops similar to those observed on-tenement, where recharge rates were inferred to be extremely high relative to the rest of the model area. The recharge in these areas was estimated by multiplying the monthly long-term average rainfall data from the Wittenoom BoM station (5026) by a factor of 3%. The recharge data adopted for preliminary model runs are presented in Table 7-2.

The Serenity model start time was set as the beginning of July, so that the model would start and end during the dry season.

Table 7-2: Serenity Model Rainfall Recharge Rates

Month	Average rainfall (mm)	Standard recharge rate in mm/yr (3%)	High recharge rate in flank zones in mm/yr (40%)
January	102.7	36.3	483.7
February	112.2	43.9	585.0
March	70.4	24.9	331.6
April	28.7	10.5	139.7
May	27.4	9.7	129.0
June	28.3	10.3	137.7
July	14.3	5.1	67.3
August	8.8	3.1	41.4
September	3.3	1.2	16.1
October	3.7	1.3	17.4
November	8.9	3.2	43.3
December	50.2	17.7	236.4

EVAPOTRANSPIRATION

Evapotranspiration was not included in the Serenity MODFLOW model. This was because the depth to groundwater in the main CID/BID aquifer is more than 35m so evapotranspiration effects are expected to be negligible.

DEWATERING BORES

Dewatering bores were inserted into the model at the Eagle and Delta tenement boundaries to simulate the potential impacts associated with mine dewatering. It is currently planned to pump approximately 1.33 GL/a from the Champion, Eagle and Delta deposits to make up the 4 GL/a needed to meet the project water demand over the life of mine. This groundwater is to be sourced from mine dewatering systems, with any excess mine dewater returned to the aquifer off tenement to minimise drawdown impacts. Therefore single bores were inserted at the Delta and Eagle boundaries and each assigned pumping rates of 3,644m^3/d, or 1.33GL/a.

Detailed mine dewatering and aquifer reinjection systems have not been included in model simulations. Modelling only assesses the net impact of abstracting 2.66GL/a for the purpose of meeting the project water demand.

7.1.3 General Modelling Assumptions

- An aquifer reinjection system would be in place if the mine dewatering requirements exceed the 2.66GL/a needed to meet the projects water demand. Therefore only the net impact of abstracting 2.66GL/a has been modelled;
- The Delta and Eagle mines will be completely dewatered from the beginning of the mine life; this is conservative as this will be a stepped process as the mine is excavated and will take a significant time period;
- The CID and BID have been modelled as one unit. This is considered to be pragmatic as there is very limited data on the ground conditions in this area and results for the Delta and Eagle deposits indicate that the CID and BID in this area have similar properties;
- Recharge occurs across the whole model. This is considered to be a realistic assumption; and
- It has been assumed that the CID/BID deposits are continuous down the valley.

7.1.4 Initial Parameters

Hydrological parameters derived for the Eagle and Delta deposits using the results of pump test analysis were adopted for the off-tenement Serenity area. Table 7-3 describes the initial parameters used before model calibration took place.

Table 7-3: Initial Model Parameters (Pre-Calibration)

Geological Unit	Pre-Calibration Parameters				
	K_{xy} (m/d)	Ss (m^{-1})	Sy (1)	Eff. Porosity	Tot. Porosity
BIF	0.01	0.0001	0.0015	0.001	0.0015
DID	0.1	0.01	0.15	0.15	0.2
Clay	0.01	0.005	0.05	0.2	0.25
CID/BID	60	0.00001	0.2	0.1	0.15

7.1.5 Model Calibration

Calibration Procedure and Results

Due to a lack of available water level data in the Serenity off-tenement area, a true model calibration to real data located throughout the modelled area was not possible at the time of this study. However, a steady-state calibration to the observed water levels at the Eagle and Delta on-tenement bores was conducted, and inferred water levels at the dummy bores located within Serenity were also checked for consistency with the simulated water levels.

Conductivity and storage values were adjusted to assist with the calibration, and the final parameter values used were generally within the minimum and maximum bounds obtained from the on-tenement pump test data.

Recharge boundary condition values were also varied as part of the model calibration. The recharge boundary conditions at the southern end of the model remained at their initial values however the values at Eagle and Delta were increased approximately 30% in order to maintain a good fit to observed and inferred groundwater levels. The constant head boundary at the northern end of the model was also varied as part of the calibration process.

The final steady-state calibration results are presented in Table 7-4. Note that the Serenity South and North “observed” water levels are based on inferred water levels, and not on field measurements. The calibration errors were deemed to be within tolerances in the context of the current study, and given the lack of site data in the Serenity area. The mass balance calculated by MODFLOW for the steady state calibration run is also presented in Table 7-5.

Table 7-4: Steady-State Calibration Results

Location	Observed Water Level (mAHD)	Simulated Water Level (mAHD)	Difference (m)
Eagle Production Bore	540.8	539.8	1.0
Delta Production Bore	501.3	499.9	1.4
Serenity South	Varies*	Varies	Approx. 2.0 – 11.0
Serenity North	Varies*	Varies	Approx 0.2 – 7.0

* Inferred levels based on extrapolation of on tenement data

Table 7-5: Steady-State Calibration Mass Balance

Mass Balance Item	IN (GL/yr)	OUT (GL/yr)	TOTAL (GL/yr)
Storage	-	-	-
Eagle Recharge	0.99	0	0.99
Delta Recharge	1.00	0	1.00
Southern Recharge	4.11	0	4.11
Northern Head Boundary	0	7.56	-7.56
Rainfall Recharge	1.45	0	1.45
TOTAL MASS BALANCE (GL/yr)			**-0.01**

FINAL CALIBRATION PARAMETERS

Table 7-6 presents the final aquifer parameters adopted for the transient model runs, after steady-state calibration was completed.

Table 7-6: Final Model Parameters Adopted for Transient Simulations

Geological Unit	Post-calibration parameters				
	K_{xy} (m/d)	Ss (m^{-1})	Sy (1)	Eff. Porosity	Tot. Porosity
BIF	0.01	0.0001	0.0015	0.001	0.0015
DID	0.5	0.01	0.15	0.2	0.25
Clay	0.1	0.005	0.05	0.15	0.2
CID/BID	30	0.0001	0.2	0.1	0.15

7.1.6 Model Results

Once the steady-state calibration was completed, transient model scenarios were run. The results of these are described in the sections below.

PRE-DEVELOPMENT SCENARIO

The first transient run was a ‘Pre-Development’ scenario, which was run for the 15-year mine life, with all model stresses set to the same values as the steady state model. No mine dewatering was simulated in this scenario, to simulate the natural groundwater fluctuations over a 15-year period.

Water levels in simulated boreholes maintained near steady-state levels throughout the pre-development simulation, with water levels generally showing a slight rise of less than 2.0m over the 15-year period. This rise could be attributed to the constant recharge entering the model, without extended dry periods. This model yielded a set of water levels at the end of the 15-year period, from which drawdowns in the dewatering scenarios could be calculated.

Figure 7-3 shows the final groundwater levels of the Pre-Development scenario in metres AHD as well as the depth to water below ground level.

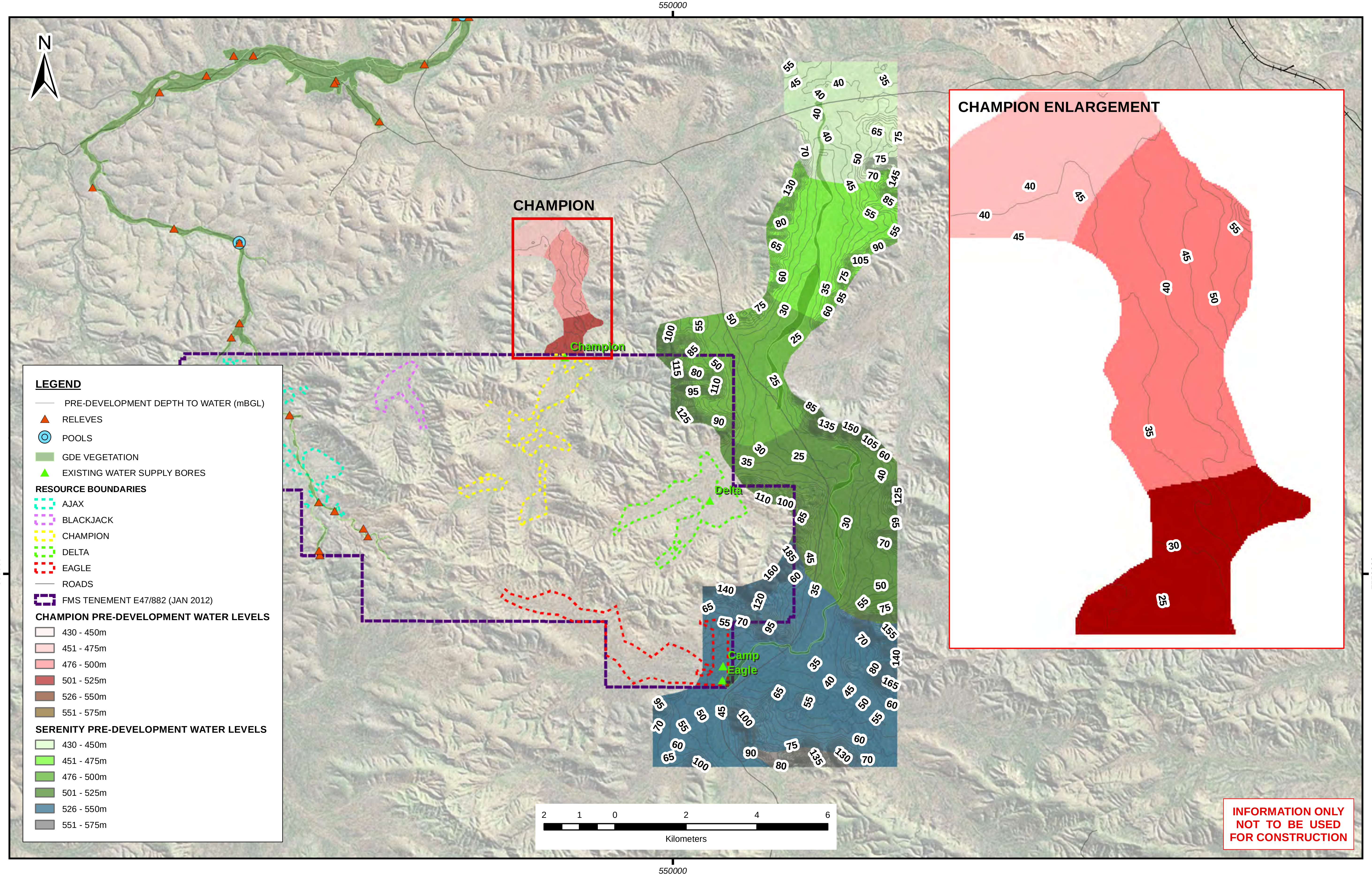

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FIGURE 7-3 - MODELLED GROUNDWATER LEVELS AND DEPTHS
NO DEWATERING - t = 15 YEARS

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Table 7-7 presents the cumulative mass balance at the end of the 15-year modelled time period, averaged into gigalitres per year for each parameter. The overall mass balance remained stable throughout the model run.

Table 7-7: Pre-Development Scenario Mass Balance

Mass Balance Item	IN (GL/yr)	OUT (GL/yr)	TOTAL (GL/yr)
Storage	0.55	1.79	-1.24
Constant Head	0.00	7.94	-7.94
Total Recharge	9.18	0.00	9.18
TOTAL MASS BALANCE (GL/yr)			**0.00**

DEWATERING – BASE CASE RAINFALL SCENARIO

The first dewatering scenario assumed that rainfall during the 15-year mine life would remain at long-term average levels.

Modelling showed groundwater levels throughout the Serenity area slowly declining over the 15 year model period. The resulting final groundwater and drawdown contours at the end of the simulation are shown in Figure 7-4 and Figure 7-5 respectively.

The predicted drawdown along the southern boundary of the model is considered conservative, due to boundary effects. There is a significant volume of groundwater storage south of the model boundary which is not accounted for in the model and is likely to reduce the actual drawdown from mine dewatering.

Table 7-8 presents the cumulative mass balance at the end of the 15-year modelled time period, averaged into gigalitres per year for each parameter. The overall mass balance remained stable throughout the model run.

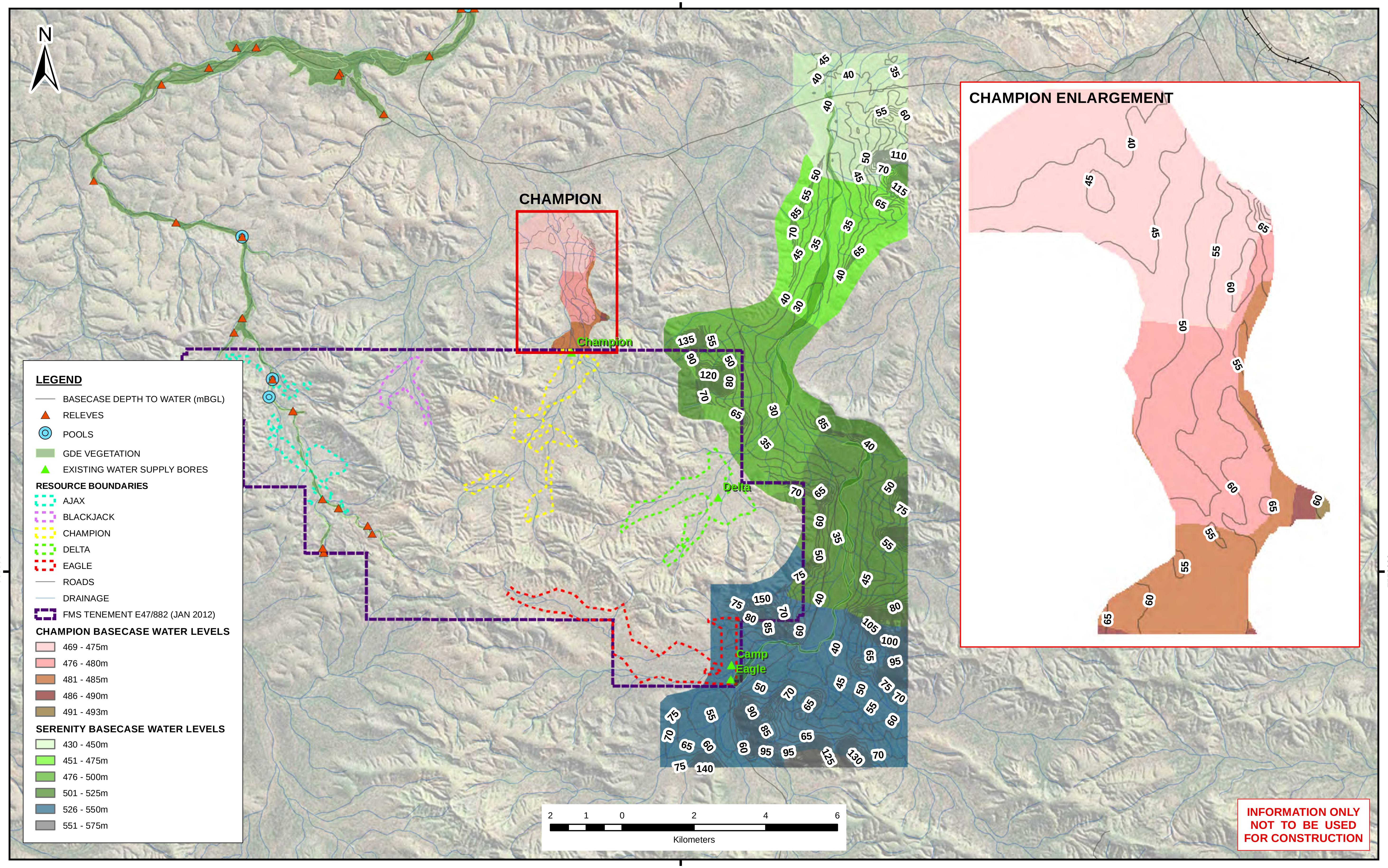

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FIGURE 7-4 - MODELLED GROUNDWATER LEVELS AND DEPTHS
BASE CASE DEWATERING - t = 15 YEARS

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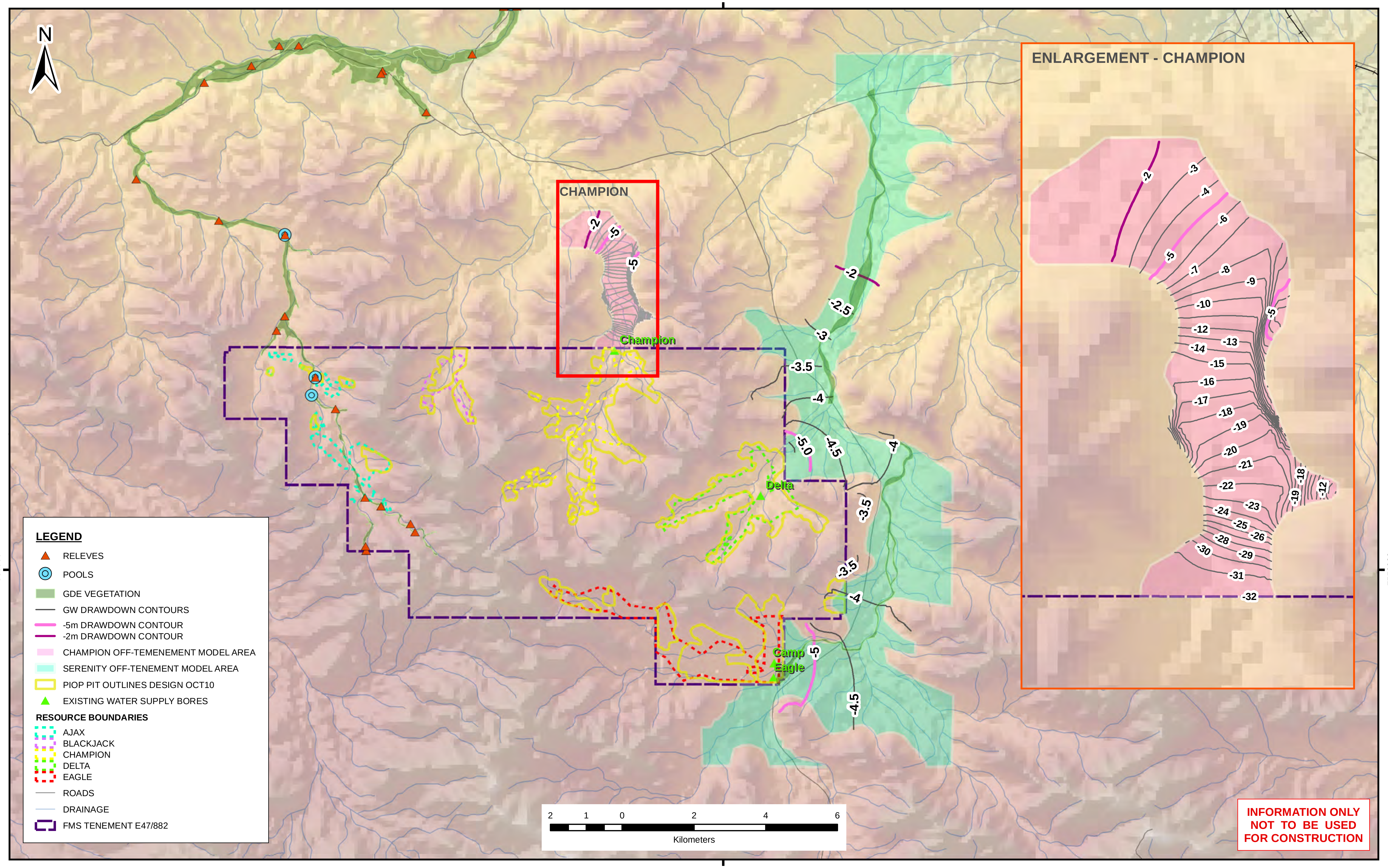

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CLIENT: Flinders Mines

TITLE:
PILBARA IRON ORE PROJECT
GROUNDWATER IMPACT ASSESSMENT REPORT
OFF-TENEMENT GROUNDWATER MODELLING
FIGURE 7-5 - BASE CASE DRAWDOWN SCENARIO

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Table 7-8: Dewatering – Base Case Rainfall Scenario Mass Balance – Annual Averages

Mass Balance Item	IN (GL/yr)	OUT (GL/yr)	TOTAL (GL/yr)
Storage	2.05	0.86	1.19
Constant Head	0.00	7.79	-7.79
Pumping Wells	0.00	2.59	-2.59
Total Recharge	9.18	0.00	9.18
TOTAL MASS BALANCE (GL/yr)			**0.00**

DEWATERING – DRY CASE RAINFALL SCENARIO

The second dewatering scenario was set up as a theoretical ‘worst-case’ scenario, in which an extended dry period acted to compound the effects of mine dewatering on the final drawdown levels. In order to simulate this scenario, the Wittenoom rainfall data was analysed and the monthly rainfall data for the driest year on record (1969) was extracted. This monthly data was then applied to each of the final three years of the mine life as a rainfall recharge. In addition, all other recharge boundaries including Delta, Eagle and the southern Serenity boundaries had their annual inflow volumes reduced by a factor corresponding to the reduction in annual rainfall recharge.

As expected, the water levels throughout Serenity were identical to those of the base case rainfall scenario, until the end of Year 12, when the dry rainfall records were applied. After this point, due to the diminished rainfall recharge and corresponding drop in boundary recharges, water levels were drawn down at an increased rate. The resulting final groundwater levels and drawdowns are shown in Figure 7-6 and Figure 7-7.

Similarly to the results for the base case dewatering simulation, the predicted drawdown along the southern boundary of the model is considered conservative, due to boundary effects. There is a significant volume of groundwater storage south of the model boundary which is not accounted for in the model and is likely to reduce the actual drawdown from mine dewatering.

Table 7-9 presents the cumulative mass balance at the end of the 15-year modelled time period, averaged into gigalitres per year for each parameter. The annual average quantity of recharge has been reduced compared to the base case, due to the final three years of ‘dry’ conditions.

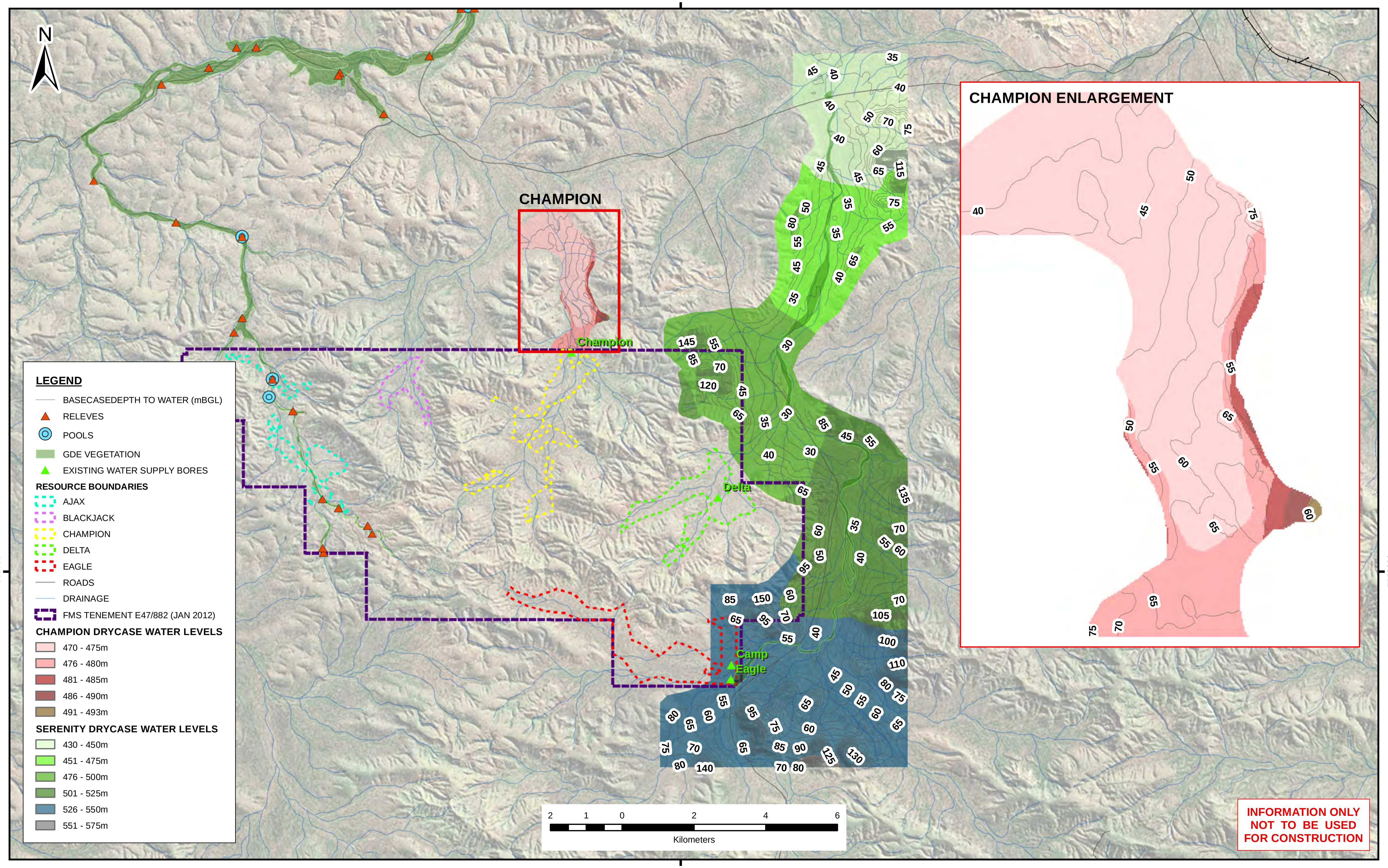

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FIGURE 7-6 - MODELLED GROUNDWATER LEVELS AND DEPTHS
DRY CASE DEWATERING - t = 15 YEARS

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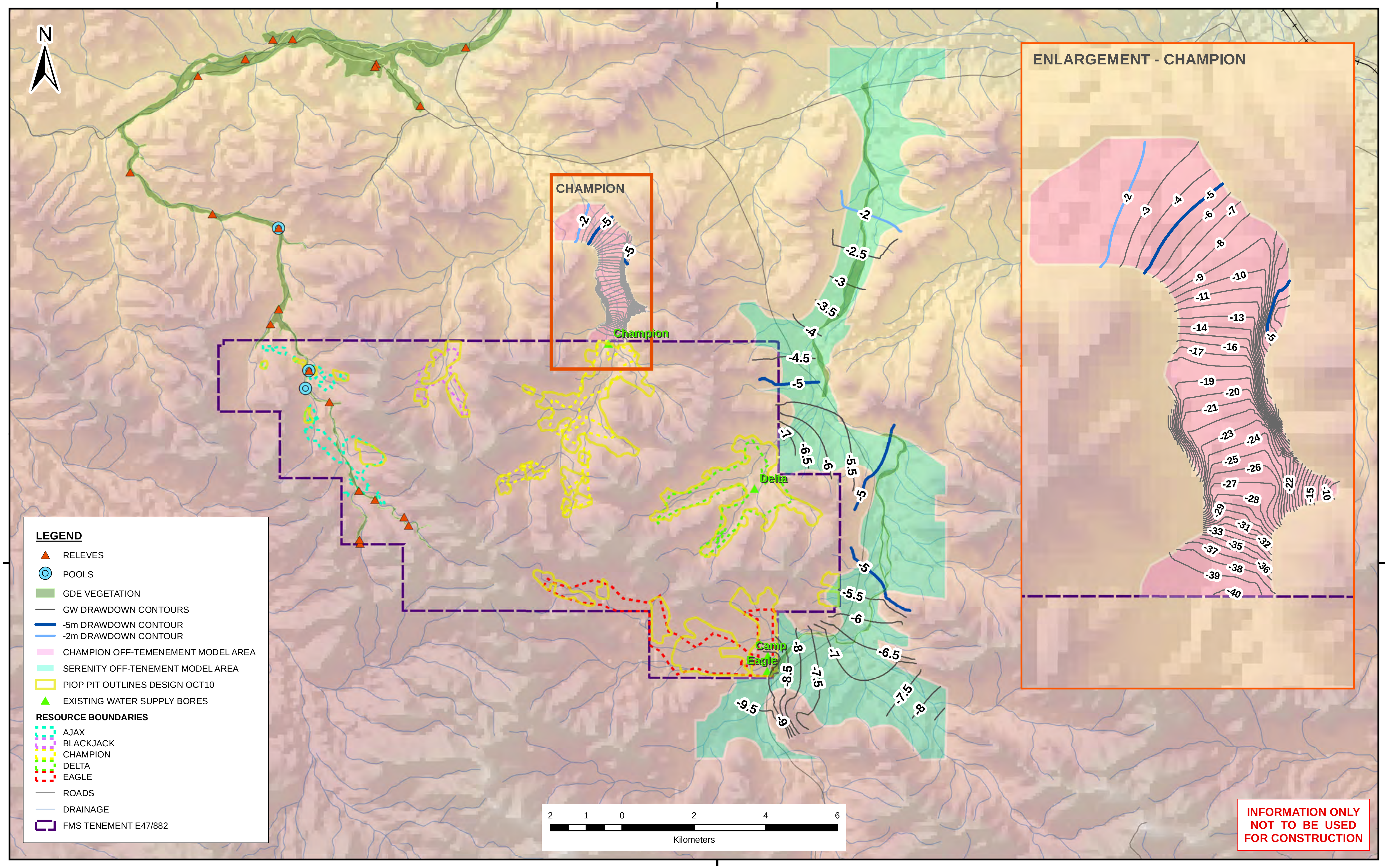

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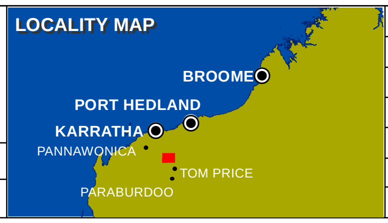

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CLIENT: Flinders Mines

TITLE: PILBARA IRON ORE PROJECT
GROUNDWATER IMPACT ASSESSMENT REPORT
OFF-TENEMENT GROUNDWATER MODELLING
FIGURE 7-7 - DRY CASE DRAWDOWN SCENARIO

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Table 7-9: Dewatering – Dry Case Rainfall Scenario Mass Balance – Annual Averages

Mass Balance Item	IN (GL/yr)	OUT (GL/yr)	TOTAL (GL/yr)
Storage	3.13	0.72	2.42
Constant Head	0.00	7.75	-7.75
Pumping Wells	0.00	2.59	-2.59
Recharges	7.92	0.00	7.92
TOTAL MASS BALANCE (GL/yr)			**0.00**

7.1.7 Sensitivity Analysis

During the model steady-state calibration phase, all parameters were varied between high and low values to arrive at the final calibrated results. This allowed the sensitivity of the model to parameters to be qualitatively described as follows:

- The dominant parameters influencing the modelled steady-state water levels were the boundary conditions – namely, the quantity of recharge assigned at the Eagle, Delta and Serenity Southern boundaries, and the water level assigned to the northern constant head outflow;
- Variations in the parameters applied to the different geological units – specifically, conductivity, storage and porosity values, had comparatively small effects on modelled water levels; and
- Rainfall recharge, including the inclusion or exclusion of the high-recharge flanking zones, had small effects on the modelled water levels.

The current model only simulates the net drawdown impacts resulting from extracting a combined 2.66GL/a from the Eagle and Delta deposits, by assuming that any excess mine dewater is returned to the aquifer.

Sensitivity analysis was performed to assess what the likely impacts may be when dewatering lowers water levels to the base of the mine pits (defined by the top of the BIF unit), without a reinjection system in place. The results suggests that the mine dewatering systems would need to remove more than 4GL/a to lower groundwater levels to the base of the pits (ie. more than the current mine water demand), and that the drawdown impacts would be significant and extend well into the off tenement area.

7.2 Champion System

7.2.1 Model Set Up and Geometry

The Champion model was developed using the Modflow groundwater flow modelling code (Harbaugh & McDonald, 1996) operating under the Visual Modflow Pro graphical user interface (Version 4.3 Pro, Schlumberger Water Services, 2010).

MODEL MESH

The Champion model was set up to extend between Eastings 545,500 and 548,500, and Northings 7,555,850 and 7,560,000N, comprising 84 rows and 100 columns with a grid size of 30 x 50m.

The head of the Champion Deposit forms the southern boundary and the larger river valley constrains the northern extent. The model domain constrains the valley but includes the adjacent slopes to provide recharge. Figure 7-8 shows the model domain in plan view.

Figure 7-8: Champion off-tenement MODFLOW model domain

MODEL LAYERS

The setup of the Champion off-tenement model layers was as follows:

- The model grid was divided into two layers, representing a simplified version of the conceptual geological models used in the FMS on-tenement area at Champion. Layer 1 incorporated the Recent Colluvium and DID geological units, and Layer 2 incorporated the CID and BID units. Both units were modelled as unconfined;
- The base of the model was taken from the basement elevations from the FMS resource database, and an extrapolation of the airborne EM geophysical data collected by GPX (Appendix 2);
- The base of Layer 1 was adopted from the observation and production boreholes at the southern end of Champion deposit. Additionally, the top of the CID was partially modelled into this area in the on-tenement modelling study. This data was used to calculate and extrapolate the base of the unit across the remainder based on the thickness seen in the Champion bores; and
- The elevations of the top layer were extracted from LIDAR terrain data, into a 20m grid.

The layers and geological unit delineations used in the model are also graphically represented in Figure 7-9.

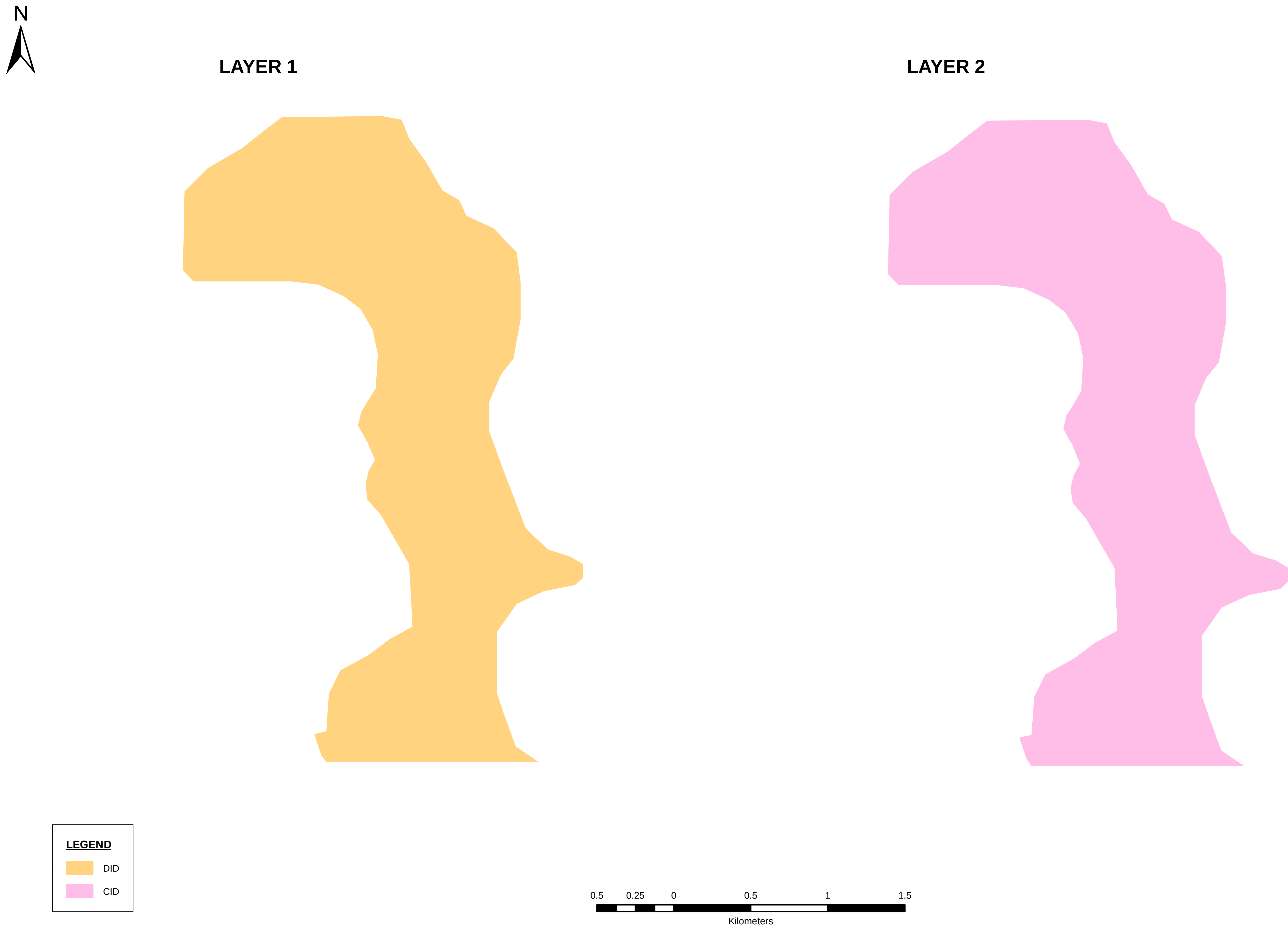
7.2.2 Model Stresses

BOUNDARY CONDITIONS

The model required boundary conditions to represent the groundwater through flow processes assumed to be occurring in the Champion off-tenement area.

The upstream boundary condition, located at the southern end of the model, was a single recharge boundary, which was applied to the main aquifer channel. A conservative estimate for the average annual recharge entering the system through the recharge boundary was calculated by multiplying the contributing catchment area by 5% of the average annual rainfall. The resulting recharge applied at Champion was 0.7 GL/yr (Appendix 7). This was later increased to 1.6GL/a to account for recharge contributions from catchments north of Champion.

The outflow of groundwater at the downstream (northern) boundary of the model was simulated using a constant head boundary. This boundary was set at a level of 470.0mAHD, or approximately 37m mgl. This corresponded to the extrapolated initial head estimated at the northern end of the domain.



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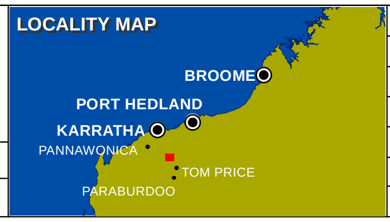

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CLIENT: Flinders Mines

TITLE: PILBARA IRON ORE PROJECT
GROUNDWATER IMPACT ASSESSMENT REPORT
FIGURE 7-9 - CHAMPION GROUNDWATER MODEL
GEOLOGICAL UNITS

DRG NO: 201012-00322-GIS-DSK-104

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Initial Groundwater Levels

Initial groundwater levels in the model were set up using a similar technique to the layer elevation setup. A single surface representing the initial water level was created using Surfer v9. Water levels available from the Champion on-tenement pump test bores were included. Dummy points were inserted at the northern boundary of the model, and the initial water level at these locations was set at the same depth below ground as measured water levels in the Champion pump test bores. Surfer then interpolated an initial groundwater heads surface from these values.

Rainfall Recharge

Rainfall recharge was calculated from the monthly rainfall data from the Wittenoom BoM station (5026) (based on 3% recharge) and was entered for monthly periods to reflect the seasonal variations. This rainfall recharge was applied to the top layer of the model. The values for rainfall recharge are listed in Table 7-10.

The Champion model start time was set as the beginning of July, so that the model would start and end during the dry season.

Table 7-10: Champion Off-Tenement Model Rainfall Recharge Rates

Month	Average rainfall (mm)	Recharge rate in mm/yr (3%)
January	102.7	36.3
February	112.2	43.9
March	70.4	24.9
April	28.7	10.5
May	27.4	9.7
June	28.3	10.3
July	14.3	5.1
August	8.8	3.1
September	3.3	1.2
October	3.7	1.3
November	8.9	3.2
December	50.2	17.7

EVAPOTRANSPIRATION

As the measured groundwater depth was below 30 m, evapotranspiration was considered to be negligible and was not included in the model.

DEWATERING BORES

It is currently planned to pump approximately 1.33 GL/a from the Champion, Eagle and Delta deposits to make up the 4 GL/a needed to meet the project water demand over the life of mine. This groundwater is to be sourced from mine dewatering systems, with any excess mine dewater returned to the aquifer off tenement to minimise drawdown impacts. Therefore a single bore was inserted at the Champion deposit boundary and assigned a pumping rate of 3,644m^3/d, or 1.33GL/a.

Detailed mine dewatering and aquifer reinjection systems have not been included in model simulations. Modelling only assesses the net impact of abstracting 1.33GL/a for the purpose of meeting the project water demand.

INITIAL HEADS

The initial head conditions were estimated using the assumed constant head of 486m elevation at the north-western corner and the values from the observation and production bores in the south. It was extrapolated to reflect the curve of the channel to the northwest approximately 3km.

Reference was made to the bores and the topography to ensure that it was as realistic as possible given the lack of data.

7.2.3 General Modelling Assumptions

- An aquifer reinjection system would be in place if the mine dewatering requirements exceed the 1.33GL/a needed to meet the projects water demand. Therefore we are only modelling the net impact of abstracting 1.33GL/a;
- The Champion mine will be completely dewatered from the beginning of the mine life; this is conservative as this is likely to be stepped process as the mine is excavated and will take a significant time period;
- The CID and BID have been modelled as one unit. This is considered to be pragmatic as there is very limited data on the ground conditions in this area and results for the Champion deposits indicate that the CID and BID in this area have similar properties;
- Recharge occurs across the whole model. This is considered to be a realistic assumption; and
- It has been assumed that the CID/BID deposits are continuous down the valley.

7.2.4 Initial Parameters

Table 7-11 presents the hydraulic parameters adopted for the Champion off-tenement model.

The following parameter assumptions were made for the Champion off-tenement model:

- High conductivity values were assigned to the BID/CID units and low values for the DID to reflect the geology but also to provide a highly conservative view of the system. The difference between the highly conductive BID/CID and the low conductivity DID will mean that changes in the head will be rapidly transferred through the aquifer; and
- Storage and porosity values were based on typical/literature values based on the geological descriptions.

Table 7-11: Hydraulic Parameters Used in the Champion Off-Tenement Model

Geological Unit	K_{xy} (m/d)	Ss (m^{-1})	Sy (1)	Eff. Porosity	Tot. Porosity
DID	0.02	1e-2	0.1	0.3	0.3
BID/CID	40	1e-8	0.15	0.15	0.15

7.2.5 Model Calibration

Calibration Procedure and Results

Due to a lack of available water level data in the Champion off-tenement area, a true model calibration to real data located throughout the modelled area was not possible at the time of this study. However, an attempt was made to perform a steady-state calibration to the observed water levels at the Champion on-tenement monitoring bores.

Conductivity and storage values were adjusted during the calibration to assess sensitivity, however the final model runs used the same parameters as presented in Table 7-11, and the final parameter values used were generally within the minimum and maximum bounds obtained from the on-tenement pump test data.

The constant head outflow boundary at the northern end of the model was varied to achieve a reasonable groundwater level calibration. The recharge boundary condition was not varied as part of the steady-state calibration.

The final steady-state calibration results are presented in Table 7-12. Note that the “Champion Off-Tenement North” water levels are based on inferred water levels, and not on field measurements. The calibration errors were deemed to be acceptable in the context of the current study, and given the lack of site data in the Champion off-tenement area.

The mass balance calculated by MODFLOW for the steady state calibration run is also presented in Table 7-13.

Table 7-12: Steady-State Calibration Results

Location	Observed Water Level (mAHD)	Simulated Water Level (mAHD)	Difference (m)
Champion-Obs-01	514.9	517.8	2.9
Champion-Obs-02	514.7	516.6	1.9
Champion-Obs-03	514.9	517.1	2.2
Champion Off-Tenement North	Varies*	Varies	7 - 17

* Inferred levels based on extrapolation of on tenement data

Table 7-13: Steady-State Calibration Mass Balance

Mass Balance Item	IN (GL/yr)	OUT (GL/yr)	TOTAL (GL/yr)
Storage	0.00	0.00	0.00
Champion Recharge	1.59	0.00	1.59
Northern Head Boundary	0.00	1.62	-1.62
Rainfall Recharge	0.02	0.00	-0.02
TOTAL MASS BALANCE (GL/yr)			**0.00**

7.2.6 Model Results

Once the steady-state calibration was completed, three transient model scenarios were run. The results of these are described in the sections below.

PRE-DEVELOPMENT SCENARIO

The first transient run was a 'pre-development' scenario, which was run for the 15-year mine life, with all model stresses set to the same values as the steady state model. No dewatering was simulated in this scenario, to simulate the natural groundwater fluctuations over a 15-year period.

Modelled water levels were maintained at near steady-state levels throughout the pre-development simulation, with water levels generally showing a slight rise of less than 0.5m over the 15-year period. This rise could be attributed to the constant recharge entering the model, without extended dry periods. This model yielded a set of water levels at the end of the 15-year period, from which drawdowns in the subsequent dewatering scenarios could be calculated.

Table 7-14 presents the cumulative mass balance at the end of the 15-year modelled time period, averaged into gigalitres per year for each parameter. The overall mass balance remained stable throughout the model run.

Figure 7-3 shows the final groundwater level contours for the Pre-Development scenario in metres AHD as well as contours showing the depth to water below ground level.

Table 7-14: Pre-Development Scenario Mass Balance

Mass Balance Item	IN (GL/yr)	OUT (GL/yr)	TOTAL (GL/yr)
Storage	0.02	0.03	-0.02
Constant Head	0.00	1.64	-1.64
Recharges	1.66	0.00	1.66
TOTAL MASS BALANCE (GL/yr)			**0.00**

DEWATERING – BASE CASE RAINFALL SCENARIO

The first dewatering scenario assumed that rainfall during the 15-year mine life would remain at long-term average levels.

Modelled groundwater levels throughout the Champion off-tenement area were observed to show a steady decline in levels over the 15 year model period. The resulting final groundwater and drawdown contours are shown in Figure 7-4 and Figure 7-5.

Table 7-15 presents the cumulative mass balance at the end of the 15-year modelled time period, averaged into gigalitres per year for each parameter. The overall mass balance remained stable throughout the model run.

Table 7-15: Dewatering – Base Case Rainfall Scenario Mass Balance – Annual Averages

Mass Balance Item	IN (GL/yr)	OUT (GL/yr)	TOTAL (GL/yr)
Storage	0.44	0.01	0.43
Constant Head	0.00	0.79	-0.79
Pumping Wells	0.00	1.30	-1.30
Recharges	1.66	0.00	1.66
TOTAL MASS BALANCE (GL/yr)			**0.00**

DEWATERING – DRY CASE RAINFALL SCENARIO

The second dewatering scenario was set up as a theoretical 'worst-case' scenario, in which an extended dry period acted to compound the effects of mine dewatering on the final drawdown levels. In order to simulate this scenario, the Wittenoom rainfall data was analysed and the monthly rainfall data for the driest year on record (1969) was extracted. This monthly data was then applied to each of the final three years of the mine life as a rainfall recharge. In addition, all other recharge boundaries including Delta, Eagle and the southern Serenity boundaries had their annual inflow volumes reduced proportionally to the reduction in annual rainfall recharge.

As expected, the water levels throughout Champion were identical to those of the base case rainfall scenario, until the end of Year 12, when the dry rainfall records were applied. After this point, due to the diminished rainfall recharge and corresponding drop in boundary recharges, water levels were drawn down at an increased rate. The resulting final groundwater levels and drawdowns are shown in Figure 7-6 and Figure 7-7.

Table 7-16 presents the cumulative mass balance at the end of the 15-year modelled time period, averaged into gigalitres per year for each parameter. The annual average quantity of recharge has been reduced compared to the base case, due to the final three years of 'dry' conditions.

Table 7-16: Dewatering – Dry Case Rainfall Scenario Mass Balance – Annual Averages

Mass Balance Item	IN (GL/yr)	OUT (GL/yr)	TOTAL (GL/yr)
Storage	0.54	0.02	0.52
Constant Head	0.00	0.77	-0.77
Pumping Wells	0.00	1.18	-1.18
Recharges	1.43	0.00	1.43
TOTAL MASS BALANCE (GL/yr)			**0.00**

7.2.7 Sensitivity Analysis

During the model steady-state calibration phase, all parameters were varied between high and low values to arrive at the final calibrated results. This allowed the sensitivity of the model to parameters to be qualitatively described as follows:

- The dominant parameters influencing the modelled steady-state water levels were the boundary conditions – namely, the quantity of recharge assigned at the southern boundary of the model near the Champion pump test bores, and the water level assigned to the northern constant head outflow;
- Subsurface channel geometry had a significant effect on water levels, as it governed the volume of groundwater capable of flowing through the main aquifer layer (Layer 2 – CID). However, the current model represents a best approximation given the limited data available;
- Hydraulic parameters, including conductivity and storage, had little impact, as the system rapidly approaches a steady state scenario; and was strongly controlled by the through flow resulting from the southern recharge boundary and the northern constant head outflow; and
- Rainfall recharge applied to the top layer did not have a significant impact, as the modelled water levels were strongly influenced by the through flow resulting from the southern recharge boundary and the northern constant head outflow.

The current model only simulates the net drawdown impacts resulting from extracting 1.33GL/a from the Champion deposit, by assuming that any excess mine dewater is returned to the aquifer.

Sensitivity analysis was performed to assess what the likely impacts may be when dewatering lowers water levels to the base of the mine pits (defined by the top of the BIF unit), without a reinjection system in place. The results suggests that the mine dewatering systems would need to remove more than 4GL/a to lower groundwater levels to the base of the pits (ie. more than the current mine water demand), and that the drawdown impacts would be significant and extend well into the off tenement area.

8. IMPACT ASSESSMENT

This groundwater impact assessment uses the results of modelling and assessment of available regional reports and data to quantify the potential impacts of the PIOP on local and regional groundwater resources.

The impact assessment quantifies the net impact mine dewatering may have on the volume of water stored in the interconnected aquifers in the study area and present the magnitude and extent of drawdown. The results will be discussed in relation to:

- On tenement areas at Champion, Eagle, Delta, Blackjack, and Ajax;
- Off tenement areas at Serenity and immediately north of Champion, Blackjack and Ajax; and
- The Millstream Water Reserve.

8.1 Dewatering Volumes

The PIOP will affect groundwater resources at Champion, Eagle, Delta Blackjack and Ajax and the adjacent off tenement areas. In general, it is assumed that the deposits will be mined from surface down to the BIF bedrock. The CID/BID aquifers are also the host rock deposits, so the majority of groundwater will be removed via dewatering systems to allow mining of the host rock deposits.

Modelling suggests that mine dewatering is likely to draw groundwater from off tenement areas and that the mine dewatering volumes may exceed the mine water demand (4GL/a over 15 years) so excess mine dewater may need to be returned to the aquifer off tenement to minimise drawdown impacts. It is currently planned to pump approximately 1.33 GL/a from the Champion, Eagle and Delta deposits to make up the 4 GL/a needed to meet the project water demand over the life of mine.

8.2 Drawdown

The magnitude and extent of drawdown impacts associated with pumping 1.33 GL/a from the Champion, Eagle and Delta deposits is shown by the groundwater contours generated by groundwater models under average and dry conditions and plotted in Figure 7-5 and Figure 7-7 respectively.

Table 8-1 presents the maximum drawdown predicted across the study area. The maximum predicted drawdown at Serenity is considerably lower due to the significantly greater storage capacity and semi confining properties. Modelling suggests that mine dewatering would depressurise the aquifer at Serenity rather than dry it out.

Figure 7-6 shows the depth to the total head (m) predicted by groundwater models at Serenity and north of Champion after 15 years of pumping 1.33 GL/a from the Champion, Eagle and Delta deposits

(4 GL/a in total) under dry conditions. The depth to total head varies between 30m and 75m within the model areas in the areas where GDEs have been identified. The actual depths to groundwater at Serenity are likely to be greater than shown in Figure 7-6 in areas where there is an extensive clay layer overlying the CID/BID aquifer.

Table 8-1: Maximum Predicted Drawdowns

Mine Area	Maximum reduction in saturated aquifer thickness (m)	Maximum Drawdown in Total Head (m)
Eagle	60	70
Delta	48	70
Champion	66	66
Blackjack	Insufficient data available	Insufficient data available
Ajax	Insufficient data available	Insufficient data available
Off-Tenement at Serenity (at Eagle and Delta)	0	9.5
Off-Tenement at Champion	40	40

8.3 Impacted Aquifers

The areas and volumes of aquifers impacted by mine dewatering have been calculated as the extents and volumes of the aquifers that have been dried out due to dewatering. This assumes that an aquifer is impacted when the saturated thickness is reduced to “dry out” portions of the aquifer (ie. dewatering must lower the total head in the aquifer to a level below the clay layer located at the top of the CID/BID aquifer).

The conceptual model for Serenity has a continuous clay layer present across most of aquifer, which results in semi confined conditions. Therefore mine dewatering would need to reduce the total head by between 15m and 35m at Serenity before it drops below the elevation of the clay layer and reduces the saturated thickness of the aquifer (ie. before the aquifer is impacted).

The calculated areas and volumes are presented in Appendix 8.

8.3.1 Areas

The extent of the interconnected aquifer systems considered in this investigation for the local on and off tenement areas is shown in Figure 6-1. The aquifers cover a combined area of approximately 78.5 km^2. The total area of aquifer impacted by drawdown across the local on and off tenement areas has been assessed and the results presented in Appendix 8 suggest that mine dewatering may have the potential to impact approximately 38% of the local on and off tenement areas considered by groundwater modelling.

The potential extent of the interconnected CID units within the Caliwigina Creek and Weelumurra Creek catchments is shown in Figure 6-2. Although the CID unit mapped in Figure 6-2 contains significant volumes of groundwater, it does not represent the full extent of the potential aquifers because the BID and DID units are also likely to contain groundwater. The area covered by the aquifer extent mapped in Figure 6-1 is approximately 180% greater than the area of CID units mapped in Figure 6-2 within the same area. This factor was used to estimate the total aquifer area within the Caliwigina Creek and Weelumurra Creek catchments. The resulting total aquifer area is 292.6km^2.

The total area of aquifer impacted by drawdown across the Caliwigina Creek and Weelumurra Creek catchment areas has been assessed using this total aquifer area and the results presented in Appendix 8 suggest that mine dewatering may have the potential to impact approximately 10% aquifers within the Caliwigina Creek and Weelumurra Creek catchments.

The impacts associated with mine dewatering are of a transient nature and groundwater flows will be re-established post mining.

8.3.2 Volumes

The total volume of aquifer impacted by drawdown across the on and off tenement areas considered in this modelling exercise has been assessed and the results presented in Appendix 8 suggest that mine dewatering may have the potential to impact approximately 17% of the total aquifer volume considered by the groundwater models, by reducing the saturated aquifer thickness within the combined on and off tenement areas considered.

Similar volume calculations to assess the impact that dewatering may have on the inferred CID aquifer volume across the Caliwigina Creek and Weelumurra Creek catchments (Figure 6-2) were not made due to insufficient data. However comparison of aquifer volumes and areas suggests that the percentage impact mine dewatering may have on the aquifer within the Caliwigina Creek and Weelumurra Creek catchments is expected to be less than 10%.

8.4 Recharge

Groundwater recharge at the Champion, Eagle and Delta deposits will be intercepted and removed by dewatering systems. The combined average annual recharge at these deposits is estimated at approximately 1.8 GL/a by assuming 5% of average annual rainfall (see Appendix 7). Therefore an additional 2.2 GL/a of mine dewater drawing water from off tenement areas would be needed to meet the project water demands (4GL/a) once the groundwater storage within the on tenement aquifer systems have been depleted.

The Champion, Eagle and Delta deposits lie within the Millstream Catchment Area, which is a Priority 2 Public Drinking Water Source Area (PDSWA). Therefore mine dewatering will impact on the volume of recharge at Millstream, which was estimated by Barnett and Davidson (1985) to be 27.7GL/a based on recharge estimates for five contributing catchment areas. The Millstream Status Report (DoW, 2009) presents a slightly lower estimated average annual recharge of 18 GL/a to Millstream and is based on estimates presented in the Hydrologic Investigations for the Harding Dam (SMEC 1982) and Millstream Groundwater Scheme Review (WAWA, 1992). The value of 27.7 GL/a was selected for the calculations presented in Table 8-2 because it is based on more recent work completed by Barnett and Davidson (1985).

The ratio of catchment areas for the Champion, Eagle, Delta deposits, to the Millstream catchment area was multiplied by the estimated Millstream recharge to determine estimate the volume of recharge mine dewatering is likely to remove from the Millstream system. The results presented in Table 8-2 indicate that mine dewatering will remove 1.4% or 0.39 GL of the average annual recharge to the Millstream aquifer over the life of mine (15 years). If we assume a lower average annual recharge at Millstream (18 GL/a) based on the Millstream Status Report (DoW, 2009), then mine dewatering will remove 1.4% or 0.25GL of the average annual recharge to the Millstream aquifer.

Table 8-2: On-Tenement Recharge Estimates

Mine Area	Catchment Area (km^2)	% of Millstream Catchment Area	Recharge (GL)
Ajax	36	0.7%	0.18
Blackjack	11	0.2%	0.06
Champion	31	0.6%	0.16
Delta	19	0.3%	0.09
Eagle	27	0.5%	0.14
Champion, Eagle and Delta Combined	77	**1.4%**	**0.39**
Millstream*	**5,480**	**100%**	**27.7**

* Source: Barnett and Davidson, 1985. Hydrogeology of the Western Fortescue Valley, Pilbara Region, WA, Geological Survey 1985. This area excludes the upper Fortescue River catchment area, which dissipates into the Fortescue Marsh and is not considered to contribute recharge to Millstream.

8.5 Closure

The mine pits are to be backfilled with material that are expected to have similar or higher permeabilities than the existing geological units. This is expected to promote higher recharge rates during rainfall events and result in unconfined aquifer conditions.

The pits will be backfilled to ensure that the finished surface is at a higher elevation than the predicted post development groundwater levels, to prevent the formation of pit lakes. This will prevent salt accumulation which could impact on groundwater quality. The groundwater chemistry within the aquifer systems within the on tenement areas post closure will be a function of the geochemical composition of the backfilling material, which is discussed in detail in the report by Graeme Campbell and Associates (2011).

9. CONCLUSIONS

It is currently planned to pump approximately 1.33 GL/a from the Champion, Eagle and Delta deposits to make up the 4 GL/a needed to meet the project water demand over the life of mine (4GL/a over 15 years). This groundwater is to be sourced from mine dewatering systems, with any excess mine dewater returned to the aquifer off tenement to minimise drawdown impacts. Groundwater modelling was used to assess the net impact the abstraction of 4GL/a has on groundwater resources and whether mine dewatering can be used to meet the projects water demands for life of mine.

Detailed mine dewatering and aquifer reinjection systems have not been included in model simulations. Only the net impact of abstracting 4GL/a has been assessed. However sensitivity analysis was performed to assess the need for reinjection systems.

The results suggest that it may be possible to meet the projects water demands for life of mine (4GL/a over 15 years) by extracting 1.33GL/a from the Delta, Eagle and Champion deposits. The results also suggest that mine dewatering volumes may exceed the mine water demand, and therefore excess mine dewater may need to be returned to the aquifer via reinjection off tenement to minimise drawdown impacts.

Recharge calculations and groundwater modelling suggest that the majority of groundwater recharge at the Champion, Eagle, Delta deposits will be intercepted and removed by dewatering systems. The combined average annual recharge at these deposits is estimated at approximately 1.8 GL/a by assuming 5% of average annual rainfall (see Appendix 7). Therefore an additional 2.2 GL/a of mine dewater may need to be drawn in from off tenement areas to meet the project water demands (4GL/a) once the groundwater storage within the on tenement aquifer systems have been depleted.

The depths to total head (m) predicted by groundwater models at Serenity and north of Champion after 15 years of pumping 1.33 GL/a from the Champion, Eagle and Delta deposits (4 GL/a in total), vary between 30m and 75m within the model areas in the areas where GDEs have been identified. The actual depths to groundwater at Serenity are likely to be even greater in areas where there is an extensive clay layer overlying the CID/BID aquifer (semi confining conditions).

The results of groundwater modelling and impact assessments suggest that the PIOP may have the following impacts on groundwater resources:

- Modelling suggests that mine dewatering will reduce water levels (total head) within aquifers located at the Champion, Eagle, Delta, Blackjack and Ajax deposits and also within hydraulically connected off tenement aquifers. The maximum predicted reduction in total head off tenement at Serenity and Champion are expected to be in the order of 9.5m and 40m respectively;

- It is anticipated that the deposits will be mined from surface down to the BIF bedrock. Therefore the CID/BID aquifers and the water contained within will be removed via dewatering systems. Modelling suggests that mine dewatering may also draw some groundwater from off tenement areas;

- Mine dewatering may have the potential to impact approximately 38% of the estimated total local on and off tenement aquifer ***area*** considered by the groundwater models[4], by reducing the saturated aquifer thickness. This impact reduces to approximately 10% when the entire potential aquifer extent, inferred from available data within the Caliwigina Creek and Weelumurra Creek catchments is considered;

- Mine dewatering may have the potential to impact approximately 17% of the estimated total local on and off tenement aquifer ***volume*** considered by the groundwater models[4], by reducing the saturated aquifer thickness. Although there is insufficient data to assess regional impacts on aquifer volumes, comparison of aquifer volumes and areas suggests that the impact would reduce to less than 10% when the entire potential aquifer extent, inferred from available data within the Caliwigina Creek and Weelumurra Creek catchments is considered; and

- It is anticipated that mining will intercept and remove groundwater recharge at each of the deposits. Average annual recharge from the combined on tenement areas normally accounts for approximately 1.4% or between 0.25 to 0.39GL of the total average annual recharge to the Millstream aquifer. Therefore the intercepted volume is small when compared with the total annual recharge.

The mine pits are to be backfilled with material that are expected to have similar or higher permeabilities than the existing geological units. This is expected to promote higher recharge rates during rainfall events and result in unconfined aquifer conditions.

The pits will be backfilled to ensure that the finished surface is at a higher elevation than the predicted post development groundwater levels, to prevent the formation of pit lakes. This will prevent salt accumulation which could impact on groundwater quality. The groundwater chemistry within the aquifer systems within the on tenement areas post closure will be a function of the geochemical composition of the backfilling material, which is discussed in detail in the report by Graeme Campbell and Associates (2011).

[4] The groundwater models cover a limited area and do not account for the full extent of the interconnected regional aquifer system

10. REFERENCES

ANZECC/NHMRC, 1992. Australian Water Quality Guidelines for Fresh and Marine Waters. National Water Quality Management Strategy Paper No.4

ANZECC/NHMRC, 2000. Australian and New Zealand Guidelines for Fresh and Marine Water Quality.

Barnett,J.C and Commander, D.P. 1985. Hydrogeology of the Western Fortescue Valley, Pilbara Region, western Australia, GSWA Record 1986/8.

Bureau of Meteorology 2009a, *Climate Statistics for Australian Locations* [online] http://www.bom.gov.au/jsp/ncc/cdio/cvg/av accessed 9 November 2009.

Bureau of Meteorology 2009b, *Tropical Cyclones Affecting Inland Pilbara towns* [online]

De la HUNTY, L. E., 1965, Mount Bruce, W.A.: Western Australia Geological Survey, 1:250 000 Geological Series Explanatory Notes, 28p.

Department of Water (DoW), 2009. Millstream status report, A review of management and consolidation of current understanding, Department of Water, Environmental Water Report Series, Report no. 9, September 2009

Fortescue Metals Group, October 2010. Water Management for the Solomon Project. 13th International River Symposium, Perth. FMS, 2010a. Archaean-Proterozoic geology of the Flinders Mines Hamersley Prospects, FMS, 2010

FMS, 2010b. BLACKSMITH MINERALISATION REPORT under Section 74(1)(ca)(ii) of the Mining Act 1978, Document No: PIL-REP-003, Flinders Mines Limited, August 2010.

Freeze and Cherry, 1979. Groundwater. Prentice Hall, Englewood Cliffs, NJ 07632.

Graeme Campbell and Associates, 2011. Flinders Pilbara Iron-Ore Project (FPIOP): Geochemical Characterisation of Mine-Waste Samples from Delta, Eagle, and Champion Pits - Implications for Mine-Waste Management, November 2011.

http://www.flindersdiamonds.com/e47882.html

http://www.riotintoironore.com/ENG/operations/497_geology.asp

Johnson, S.L and Wright, A.H, 2001, Central Pilbara Groundwater Study, Water and Rivers Commission, Hydrogeological Record Series, Report HG 8, 102, p.2001.

NHMRC and NRMMC (2004) Australian Drinking Water Guidelines 2004, National Water Quality Management Strategy, National Health and Medical Research Council and the Natural Resource Management Ministerial Council.

Snowy Mountain Engineering Corporation 1982, Hydrologic Investigations for the Harding Dam Volume 1, prepared for Public Works Department, Western Australia.

Snowy Mountain Engineering Corporation 1982, Hydrologic Investigations for the Harding Dam Volume 2, prepared for Public Works Department, Western Australia.

Thorne, A. M., and Tyler, I. M., 1997, Mount Bruce, W.A. (2nd Edition): 1:250 000 Geological Series Explanatory Notes, 28p.

Public Works Department, WA, 1982. Hydrologic Investigations for the Harding dam, Volumes 1 and 2, April, 1982.

Water Authority of WA 1992, Millstream groundwater scheme review, Report no. WG 136 March 1992, unpublished report.