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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
A	Issued for internal review	L.Siraz	D Cravens	N/A	25-Feb-12	N/A	
B	Issued for Client Review	L.Siraz	D Cravens	S. Atkinson	02-Mar-12		6-Mar-12
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).

CONTENTS

Appendices

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:

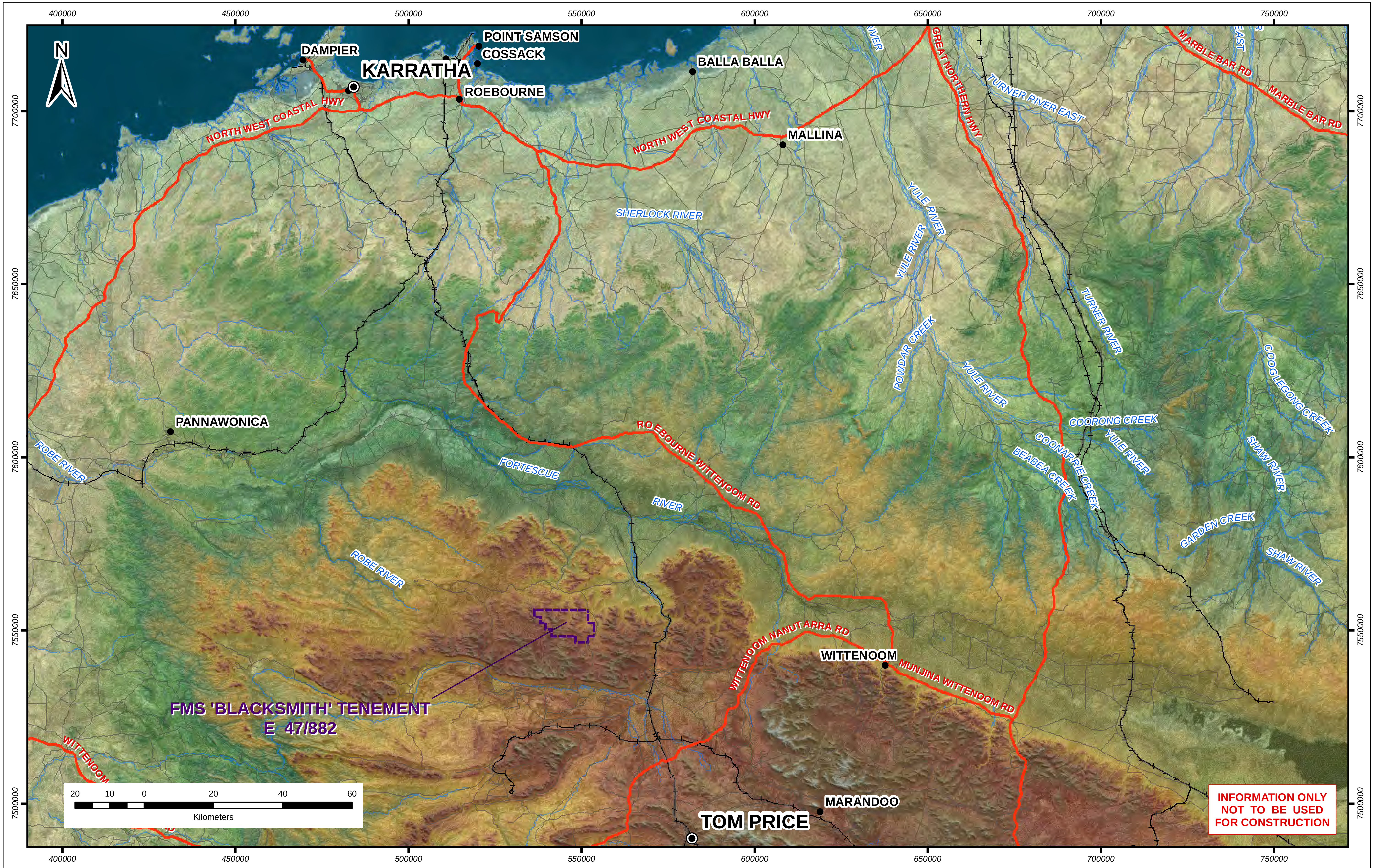
- Impacts of the PIOP on the Millstream Water Resource (quantity and quality);
- Local and regional drawdown impacts associated with the PIOP; and
- Impacts of the PIOP on GDEs: stygofauna. and troglofauna communities.

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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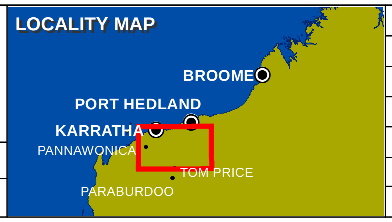
LOCALITY MAP



WORLEYPARSONS PROJECT: 201012-00322

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DATUM: 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	13-02-2012

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).

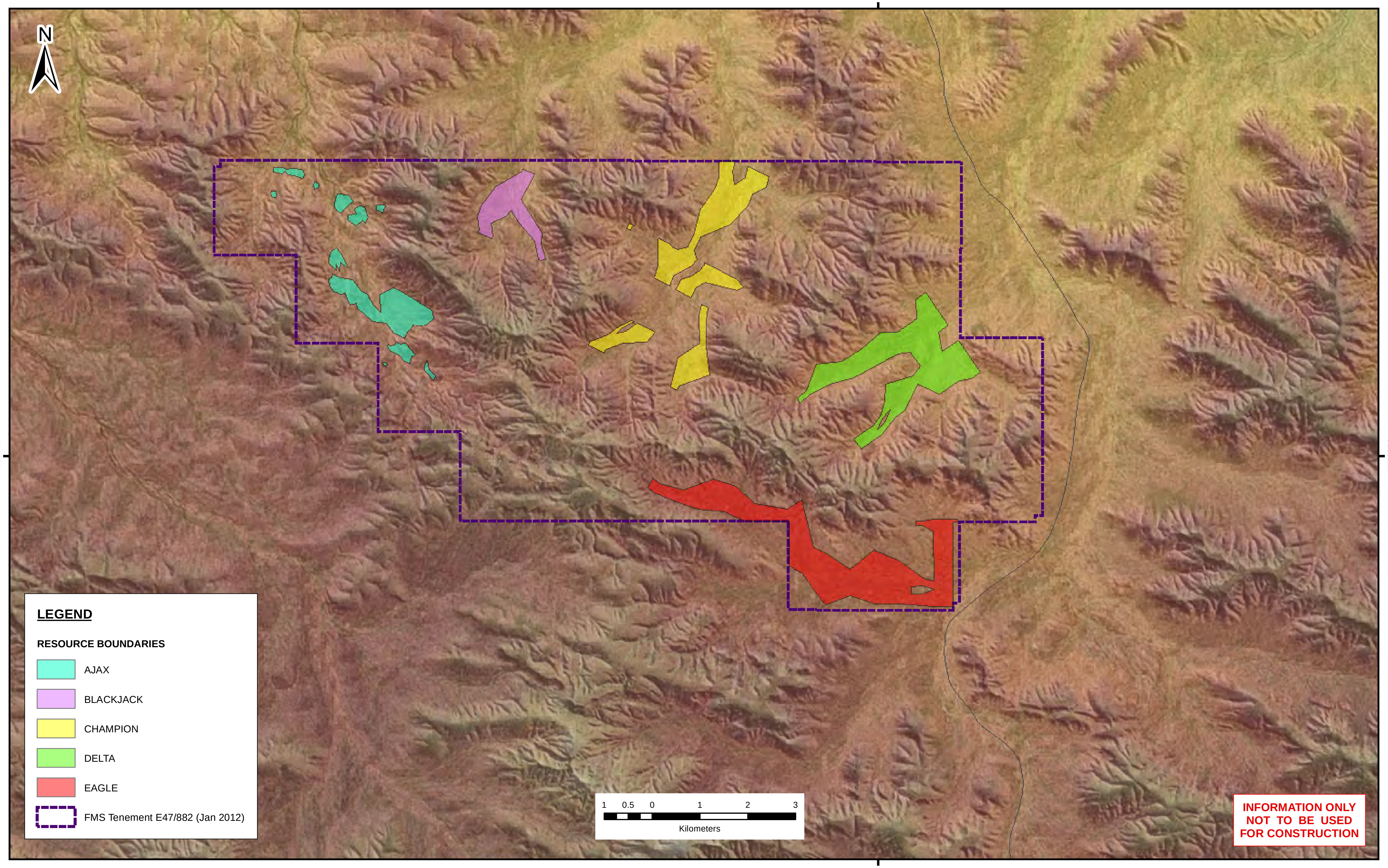
The PIOP comprises the Ajax, Blackjack, Champion, Delta and Eagle deposits located within the Blacksmith tenement area (E47/882) and shown in Figure 3-1. The main ore types of economic interest in the tenement are Detrital Iron Deposits (DID), Channel Iron Deposits (CID), and Bedded Iron Deposits (BID). 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°C and minimum temperatures between 11.5 and 26.1°C. 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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LOCALITY MAP

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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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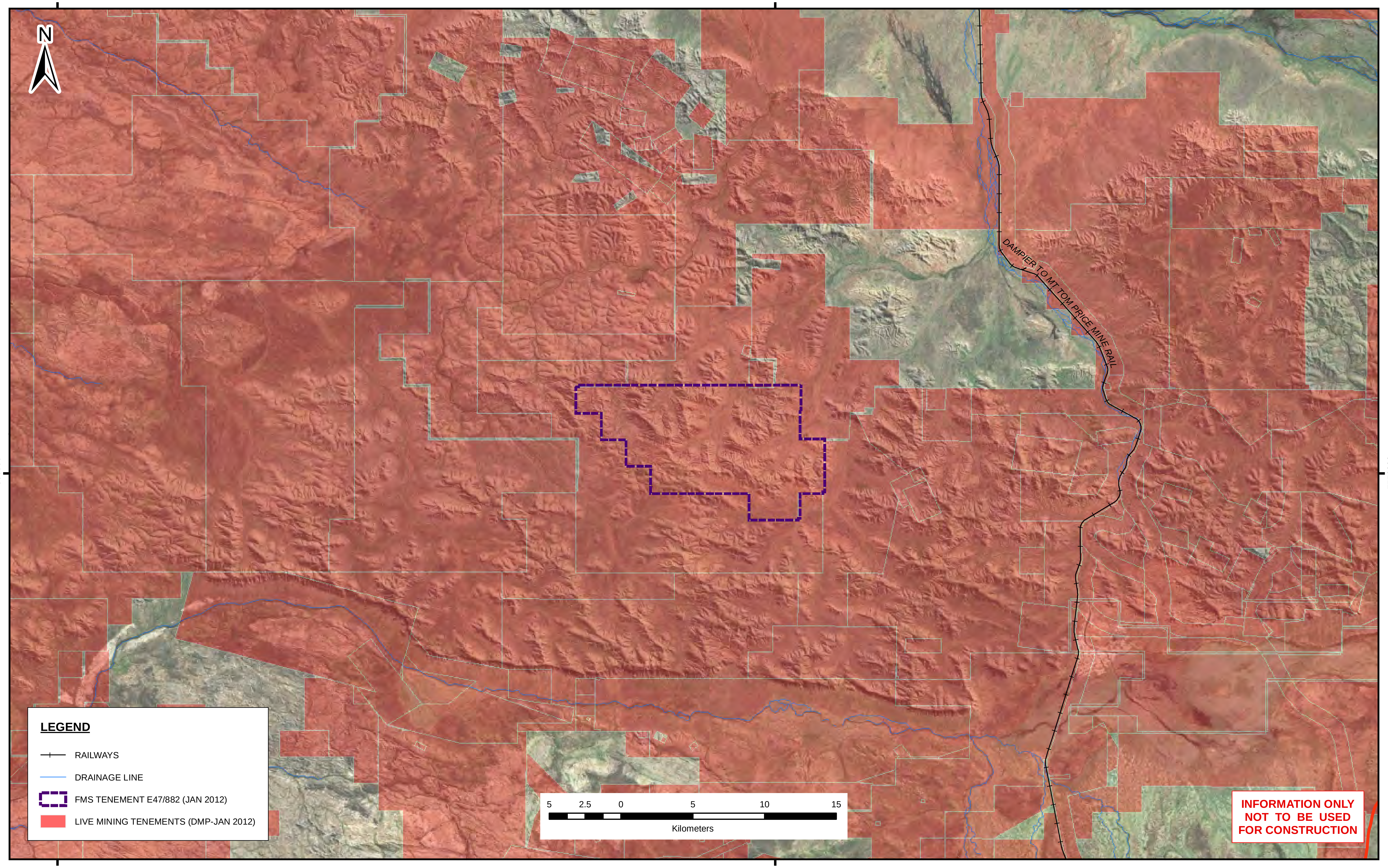

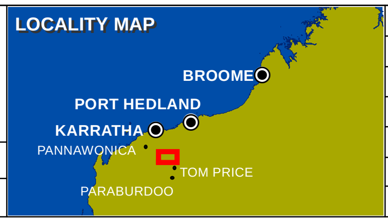

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0	ISSUED TO CLIENT	MR	LS	29-02-2012
A	FOR INFORMATION ONLY	MR	LS	17-05-2011

NOTES
1) Aerial Imagery from Microsoft Virtual Earth.

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FIGURE 3-2 - TENEMENTS WITHIN CENTRAL PILBARA

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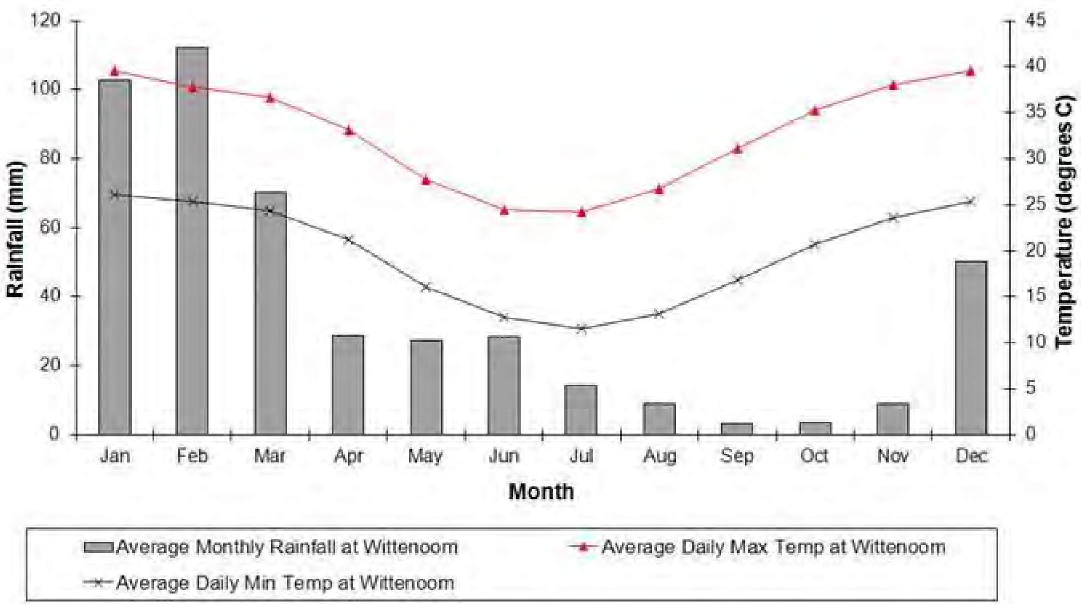


Figure 3-3: Average Monthly Climate Data Wittenoom, 1950 to 2011 (BoM #5026)

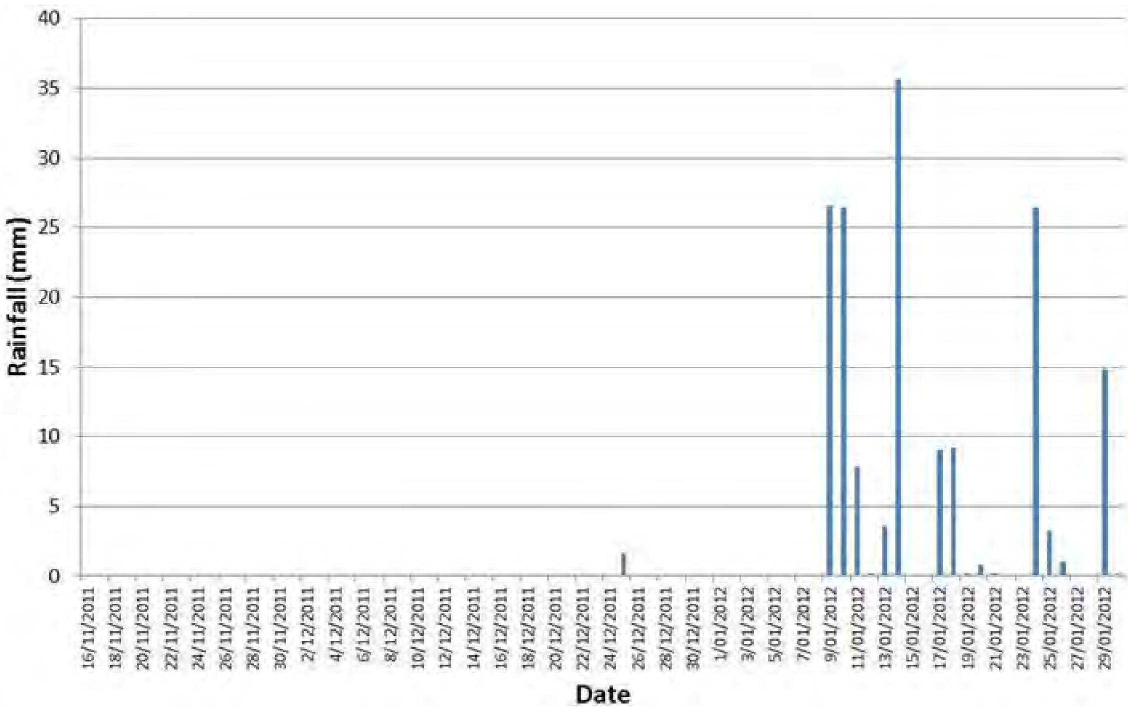


Figure 3-4: Daily rainfall data recorded at Eagle between 16/11/2011 and 30/01/2012

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).

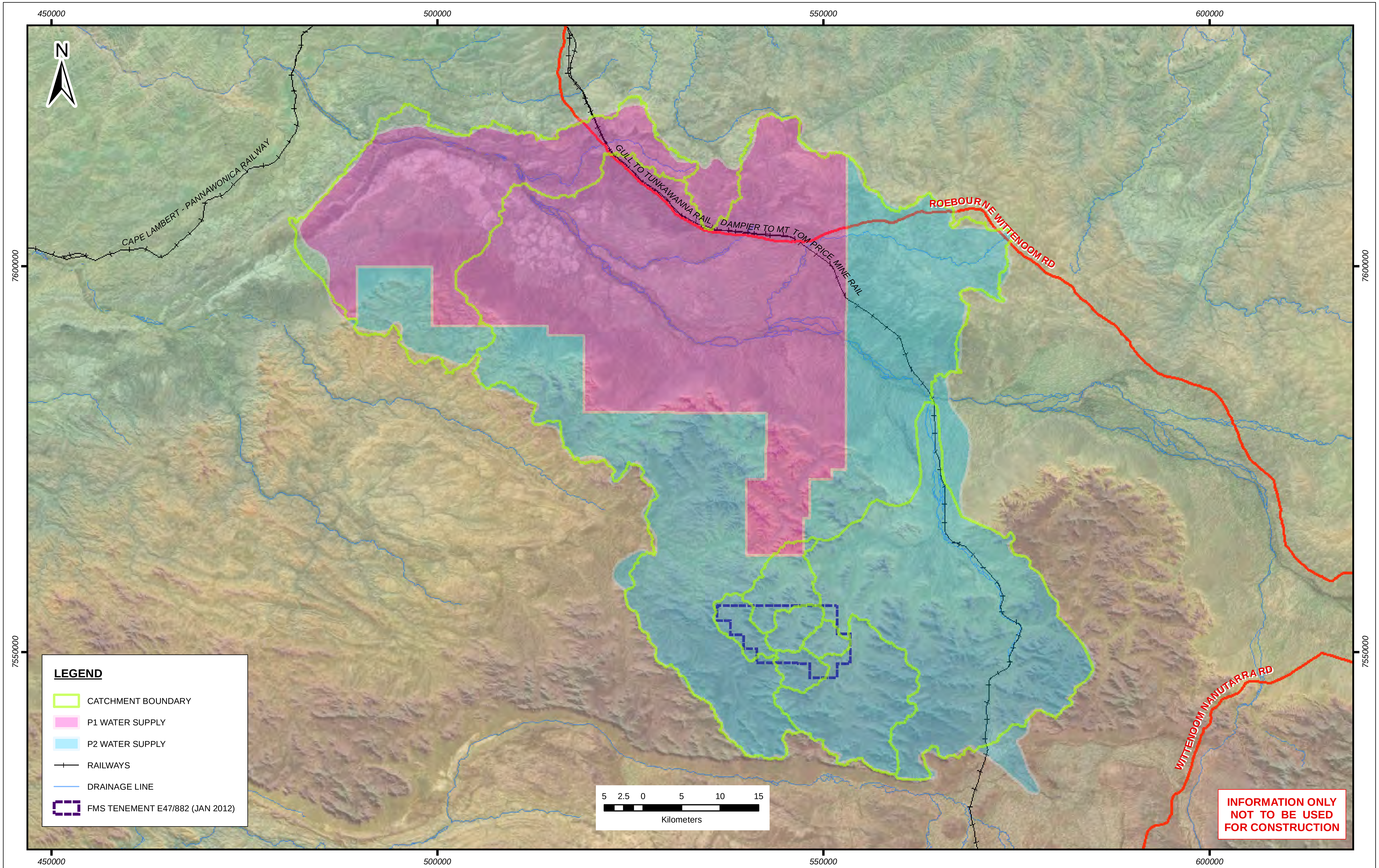
3.4 Hydrology

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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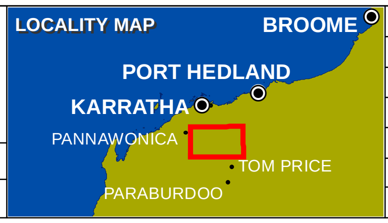

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A	FOR INFORMATION ONLY	MR	LS	13-02-2012

NOTES
1) Aerial Imagery from Microsoft Virtual Earth.
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.

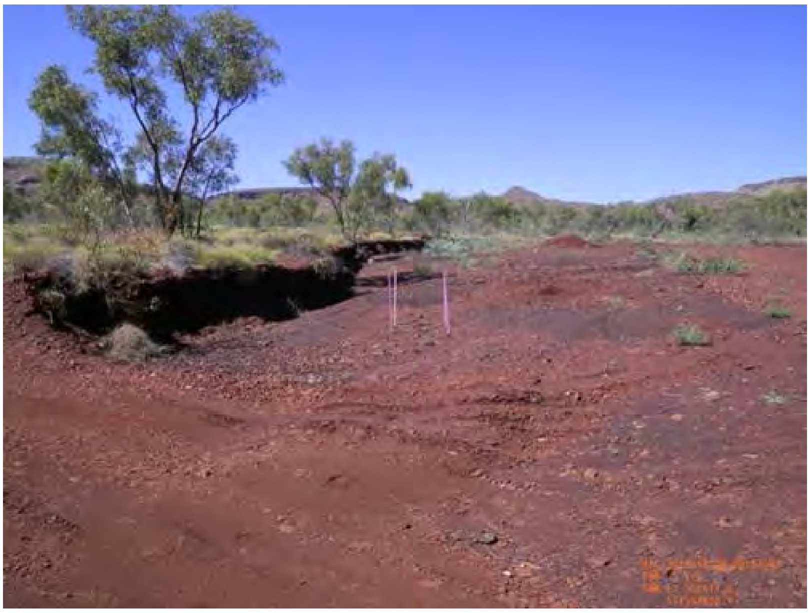


Plate 1: A Typical Ephemeral Creek at Delta, Eagle, Champion and Blackjack

Plate 2: A Permanent Pool at Ajax

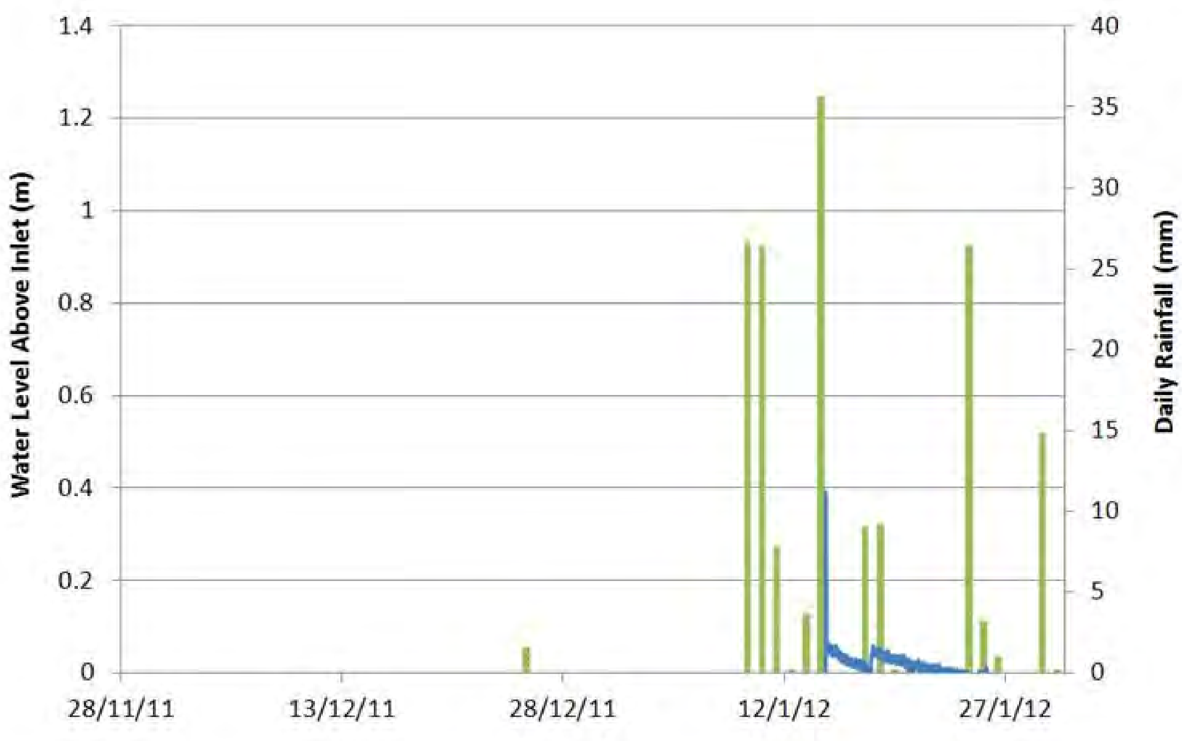


Figure 3-6: Water levels recorded at the stream gauge at Delta compared with Eagle between 28/11/2011 and 30/01/2012

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.

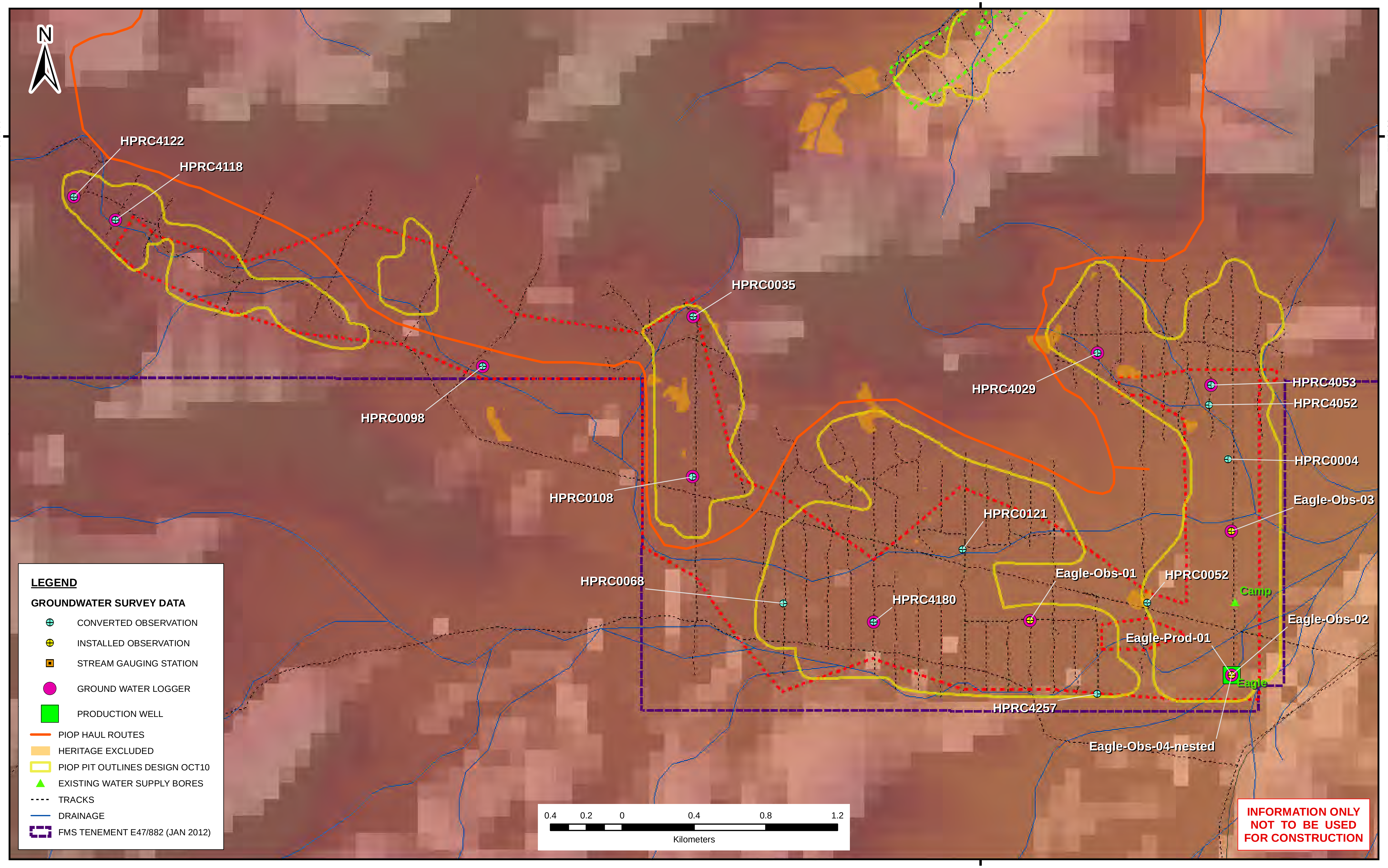
Monitoring bores located within the central part of the catchment, in low lying areas, were screened approximately 2-5 m above the static water level to the base of the aquifer, with the remaining bores located around the flanks of the catchment screened from approximately 2 m below ground level (bgl)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



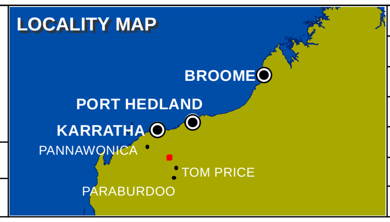


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FIGURE 5-1 - BORE LOCATIONS - EAGLE

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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.

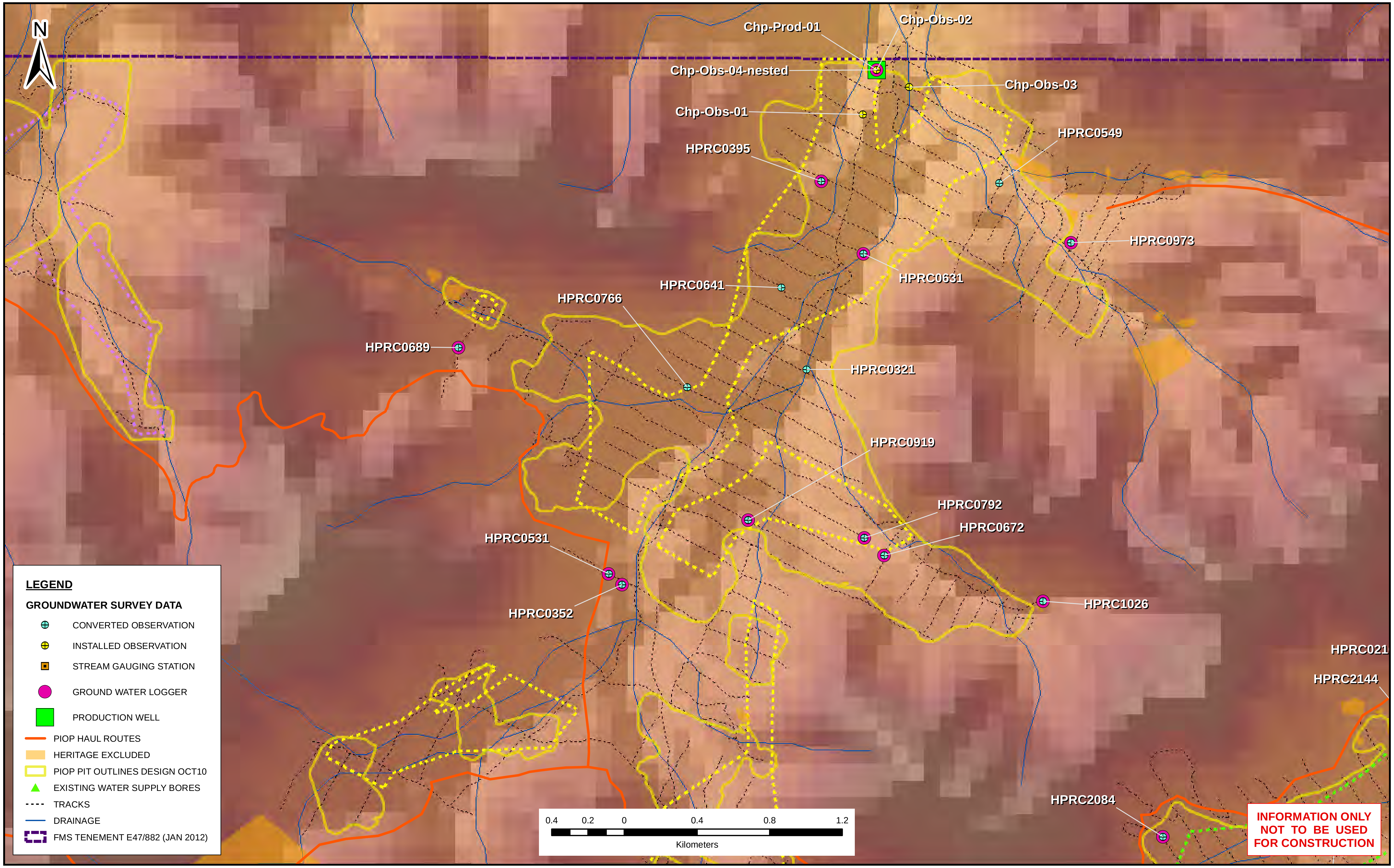
RC Holes Converted to Monitoring Bores:

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

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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:

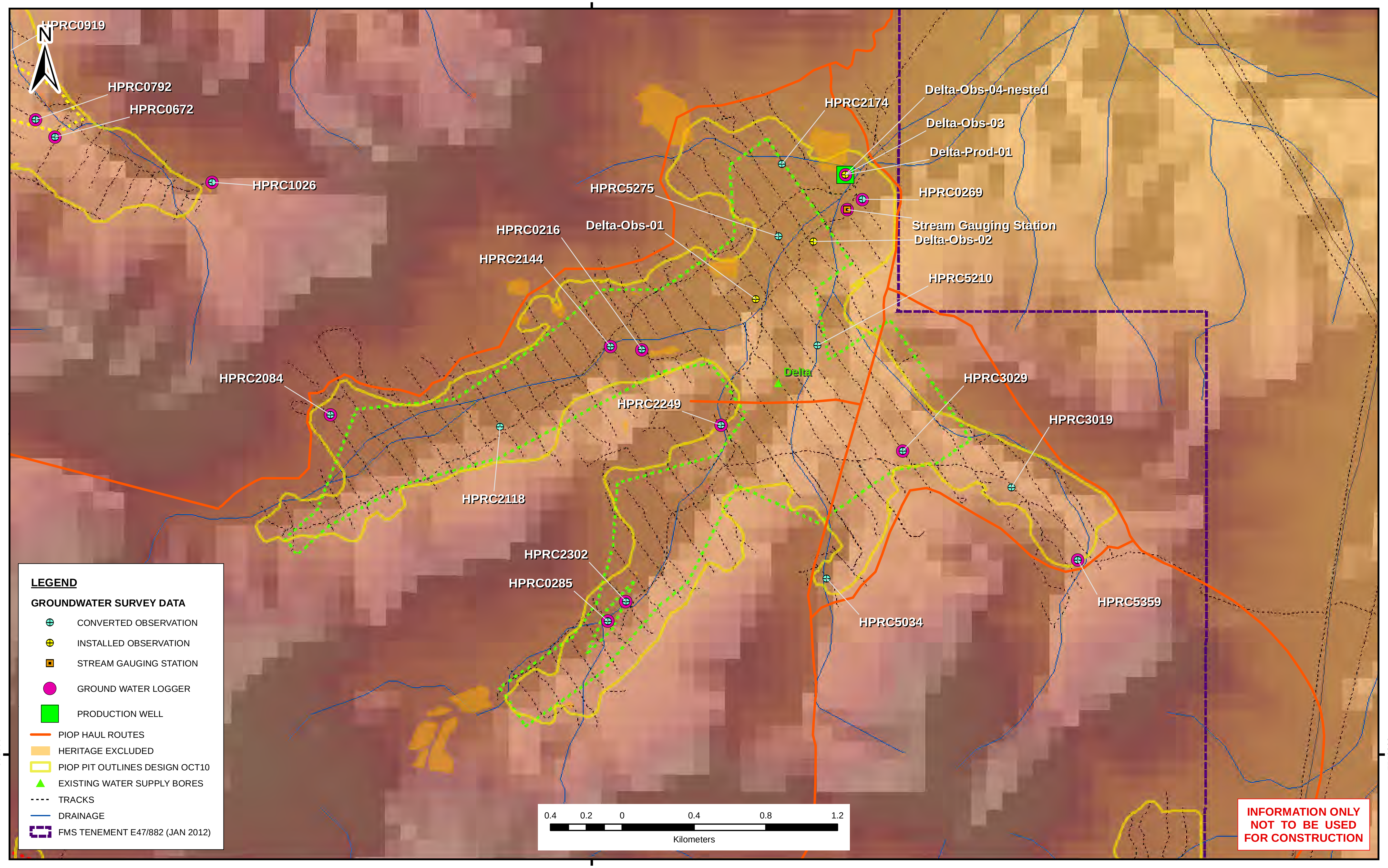
A total of 15 existing holes drilled as part of the exploration works using RC methods, were converted into monitoring bores as part of the works. These bores were selected to provide long-term information on groundwater levels and assist with recharge estimation. At two locations within the tenement, 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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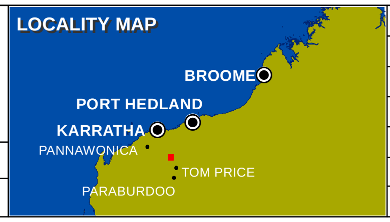

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FIGURE 5-3 - BORE LOCATIONS - DELTA

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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.

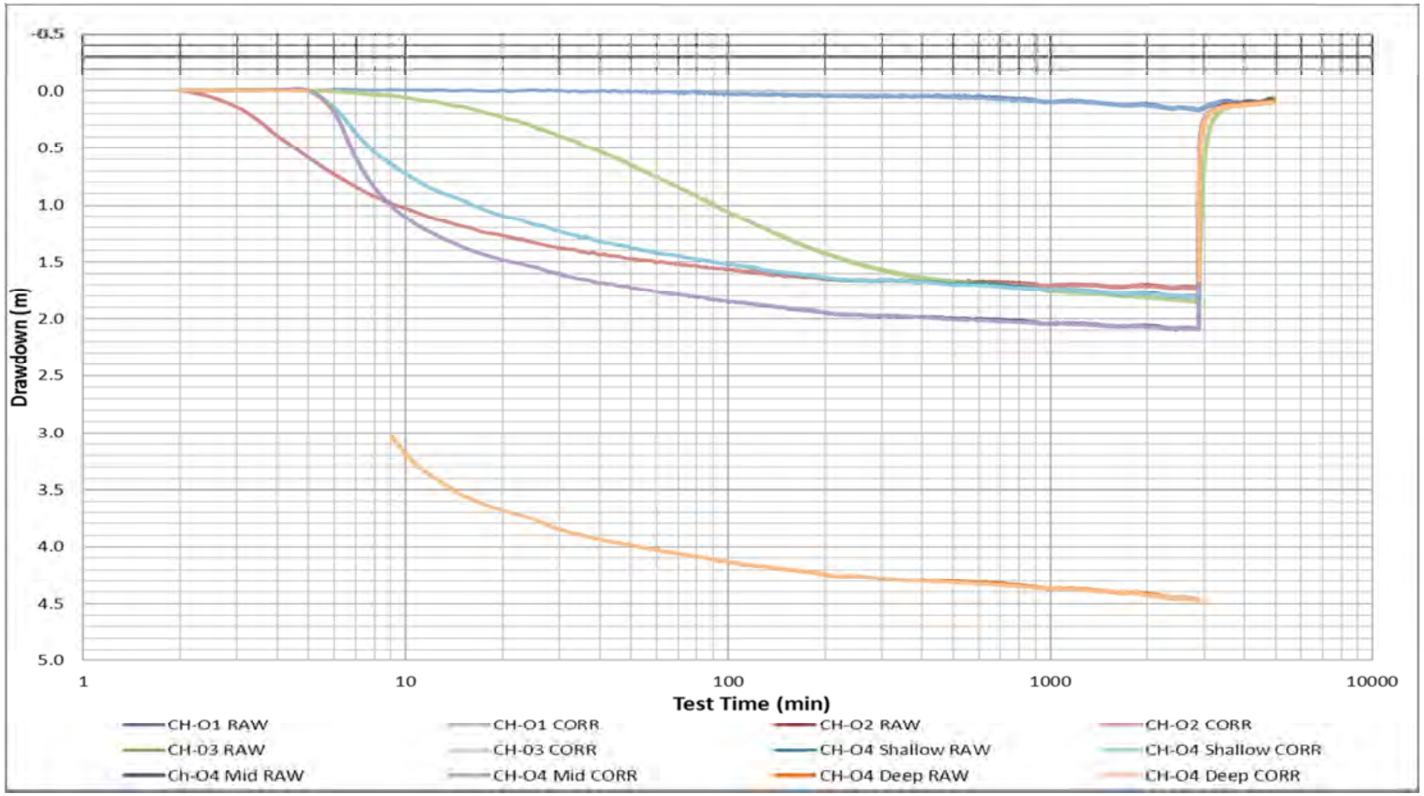

Figure 5-4: Champion Corrected and Uncorrected Drawdown Data

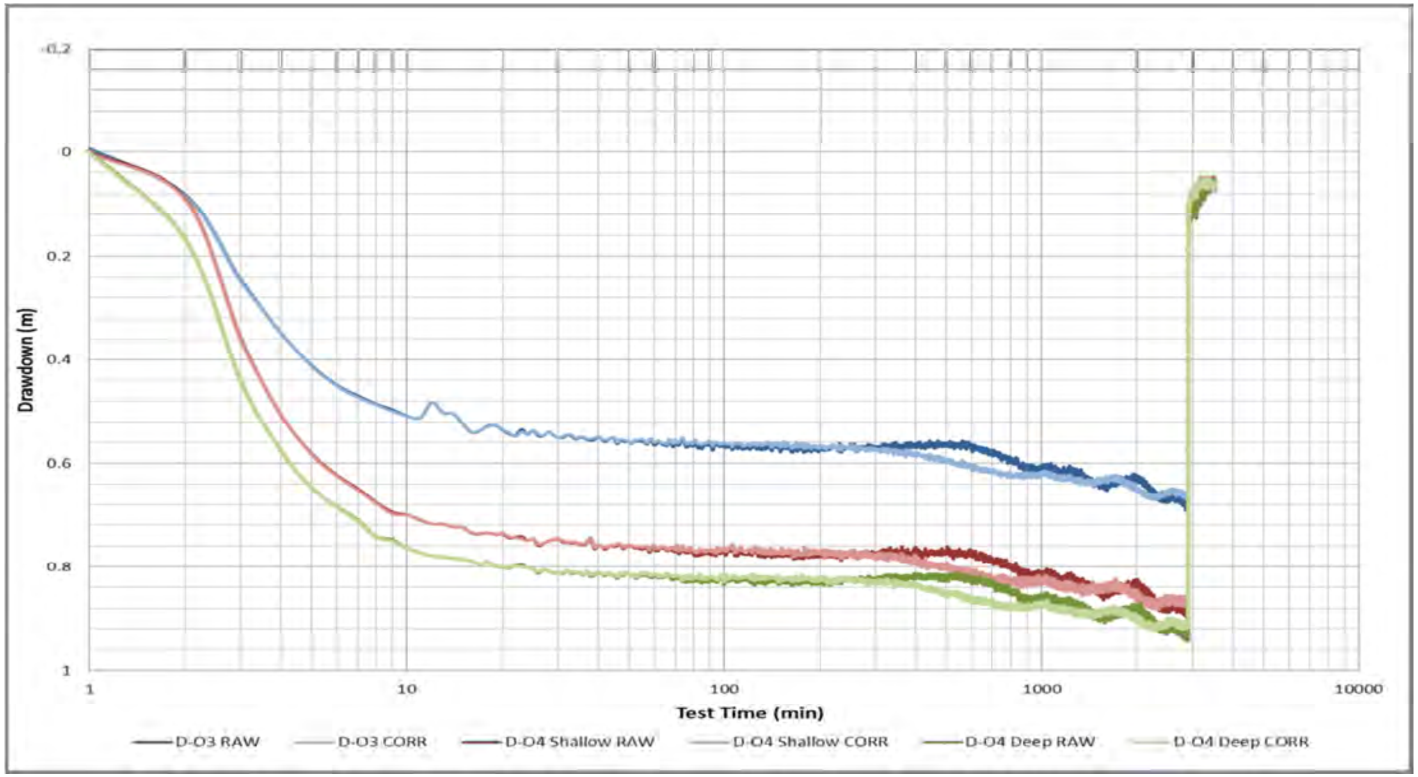

Figure 5-5: Delta Corrected and Uncorrected Drawdown Data

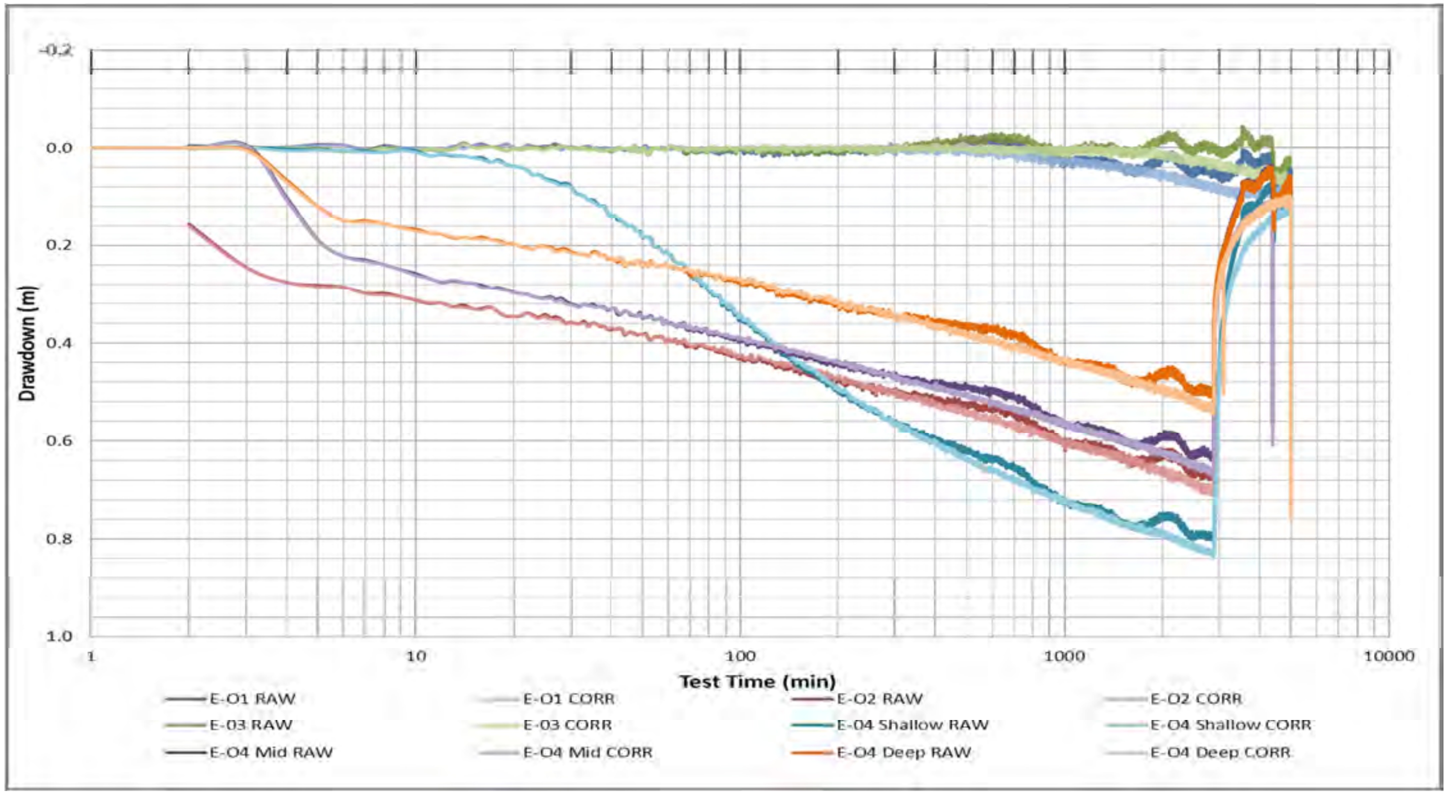

Figure 5-6: Eagle Corrected and Uncorrected Drawdown Data

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

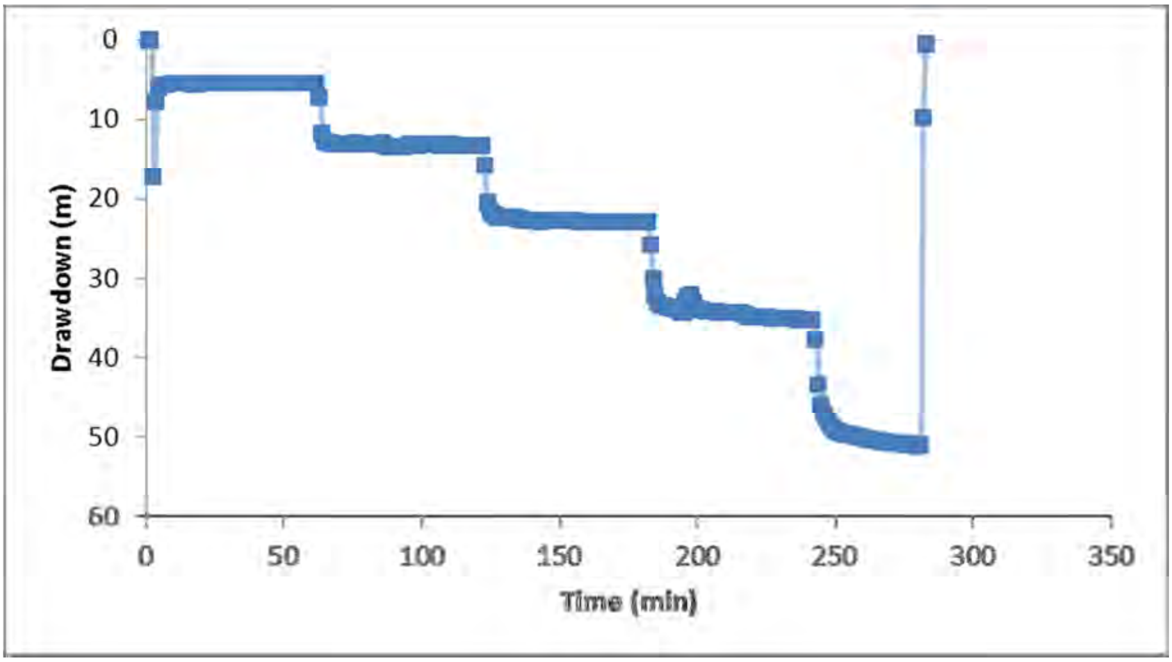

Figure 5-7: Drawdown and Recovery at Delta Production Bore During Step-Discharge Test

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

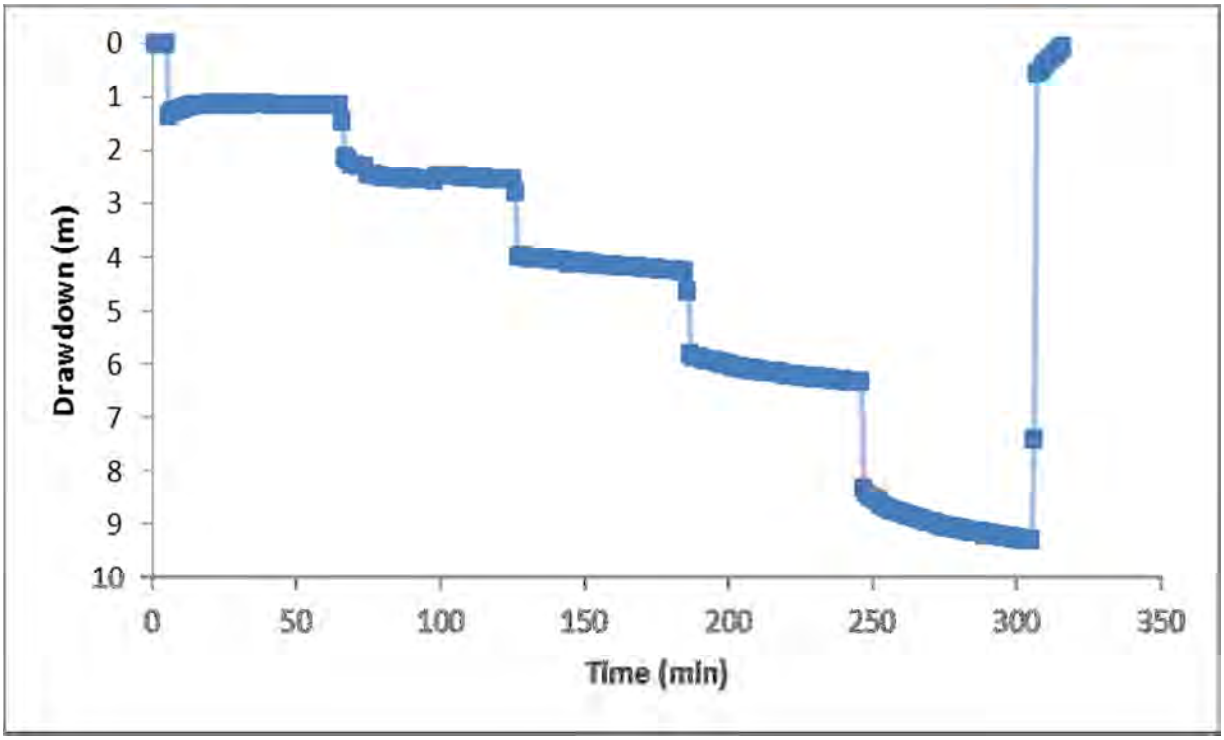

Figure 5-8: Drawdown and Recovery at Eagle Production Bore During Step-Discharge Test

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

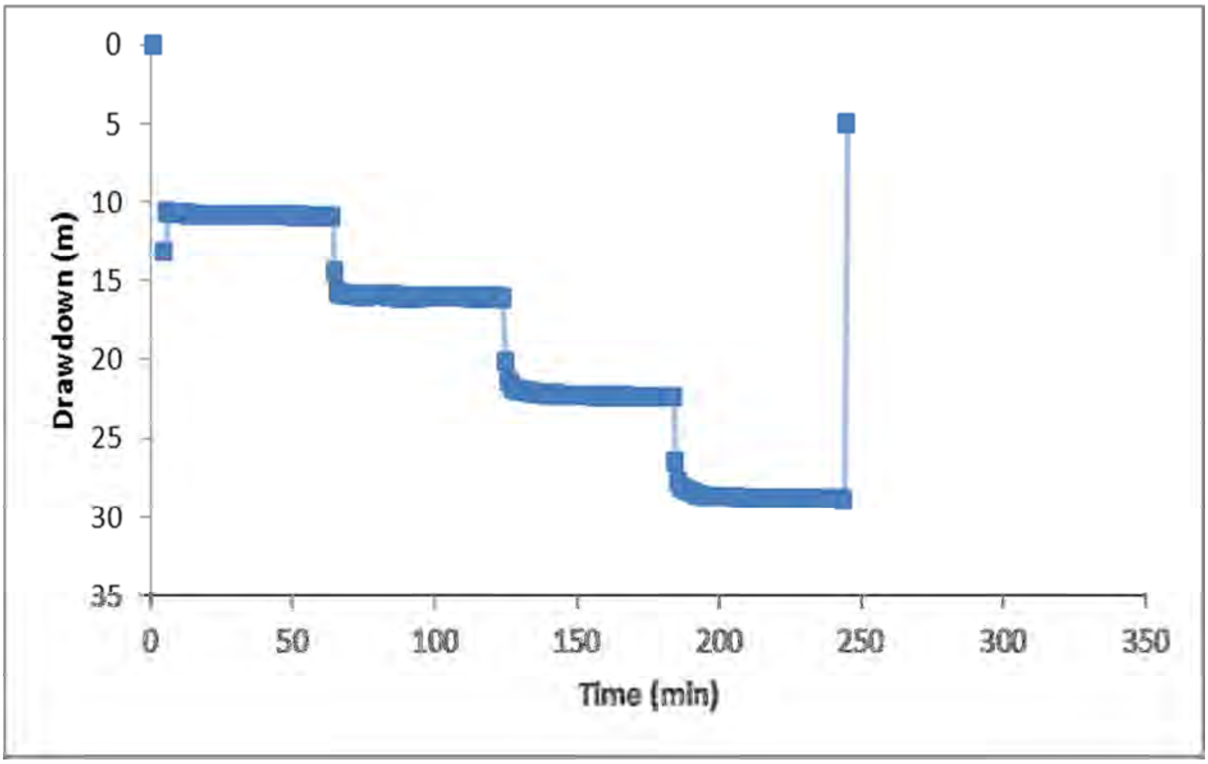

Figure 5-9: Drawdown and Recovery at Champion Production Bore during Step-Discharge Test

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	* residual showed poor curve fit
				Theis (1935) Residual drawdown/recovery	53200.0	917.2			
			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 Av. S = 2.63 x 10^{-8} Av. K = 33.0m/d b = 52m
				Theis (1935) Residual drawdown/recovery	1818.9	35.0			
			Leaky	Hantush (1960) w/aquitard storage	1000.4	19.2	3.66E-08		
	Chp-04m	BID	Confined	Theis (1935)/Hantush (1961)	2125.5	40.9	3.32E-09	1.323	
				Theis (1935) Residual drawdown/recovery	1858.0	35.7			
			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	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]

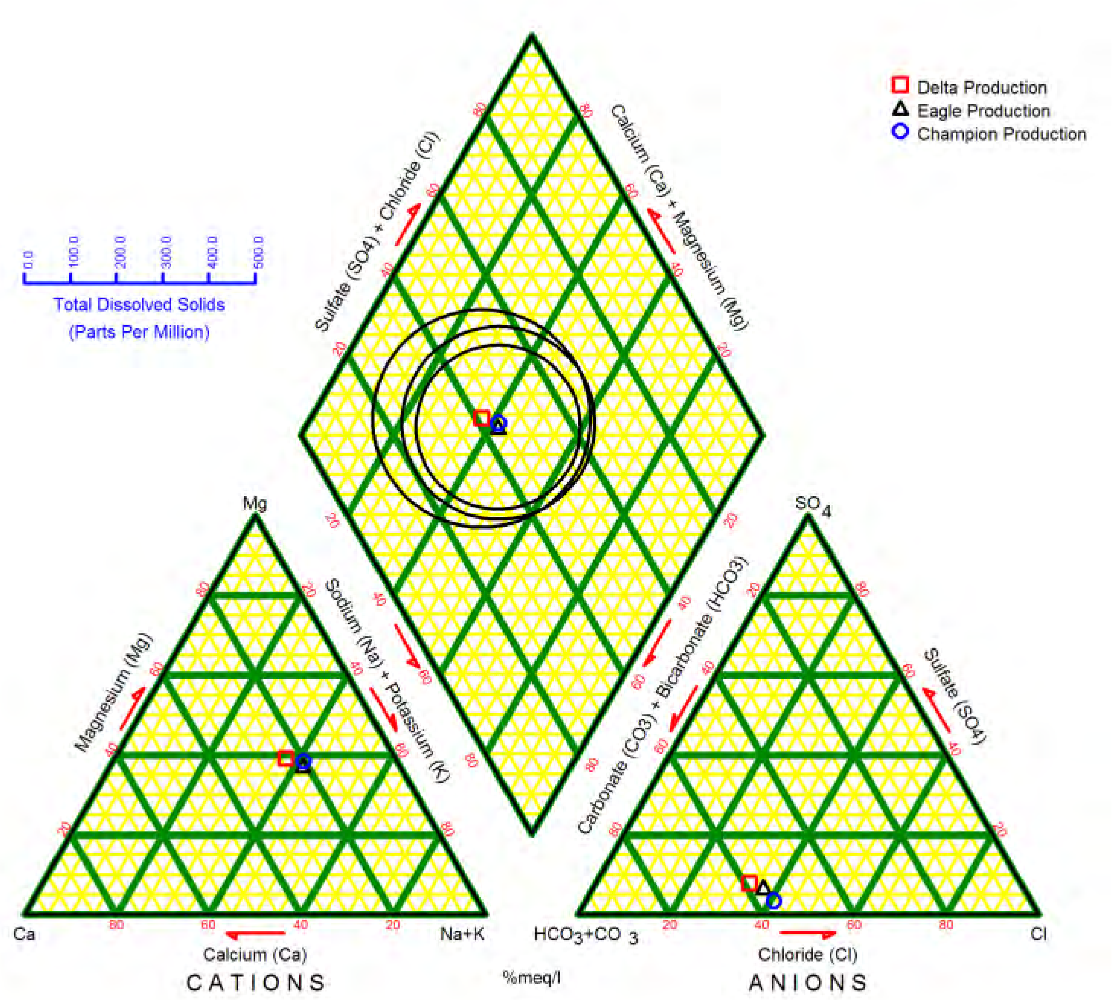

Figure 5-10: Piper Diagram for Production Bore Groundwater

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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.

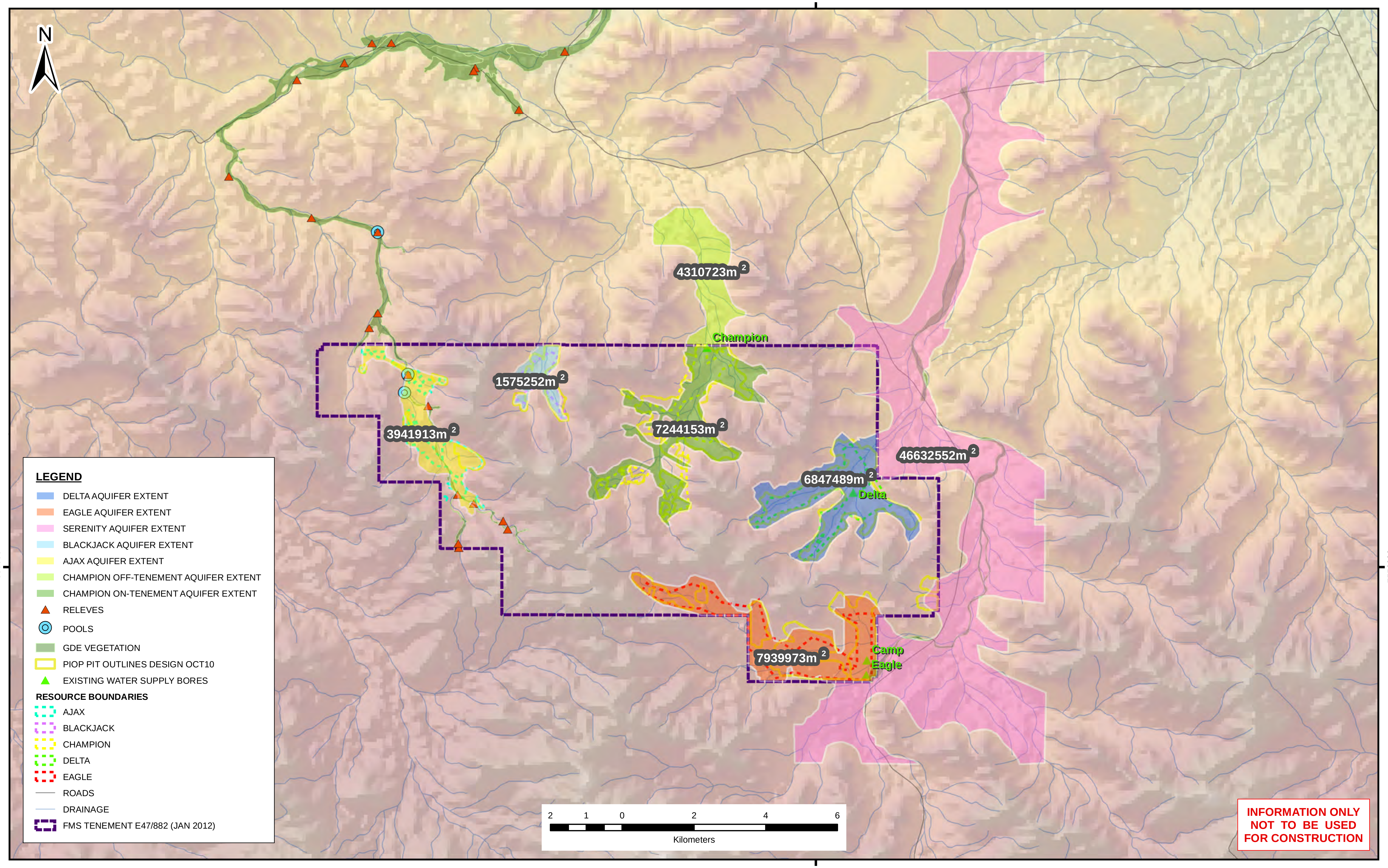
6.4 Groundwater Levels and Recharge

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

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FIGURE 6-1 - INTERPRETED EXTENT OF INTERCONNECTED AQUIFERS

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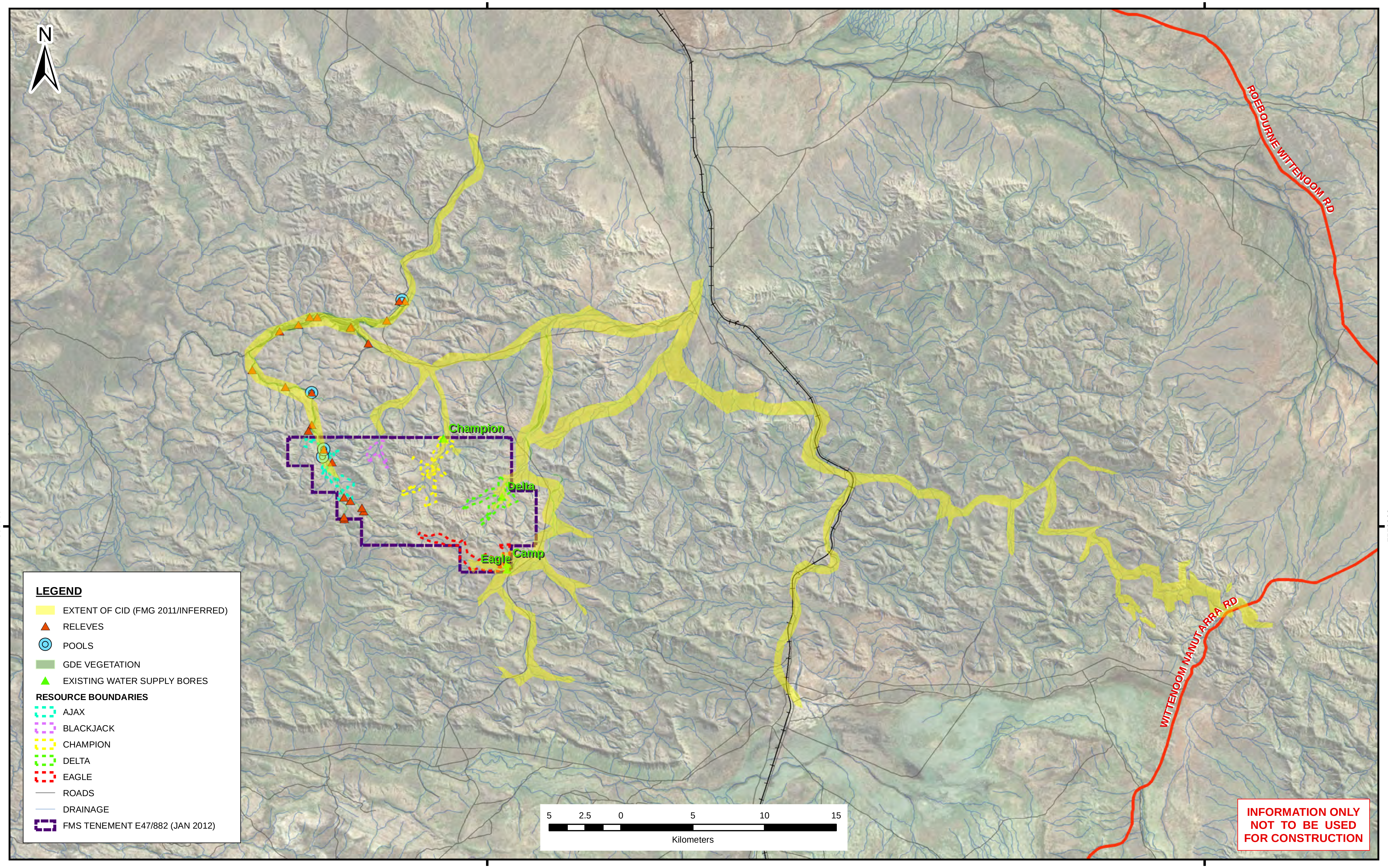

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LOCALITY MAP

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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)

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FIGURE 6-2 - INFERRED REGIONAL EXTENT OF CID

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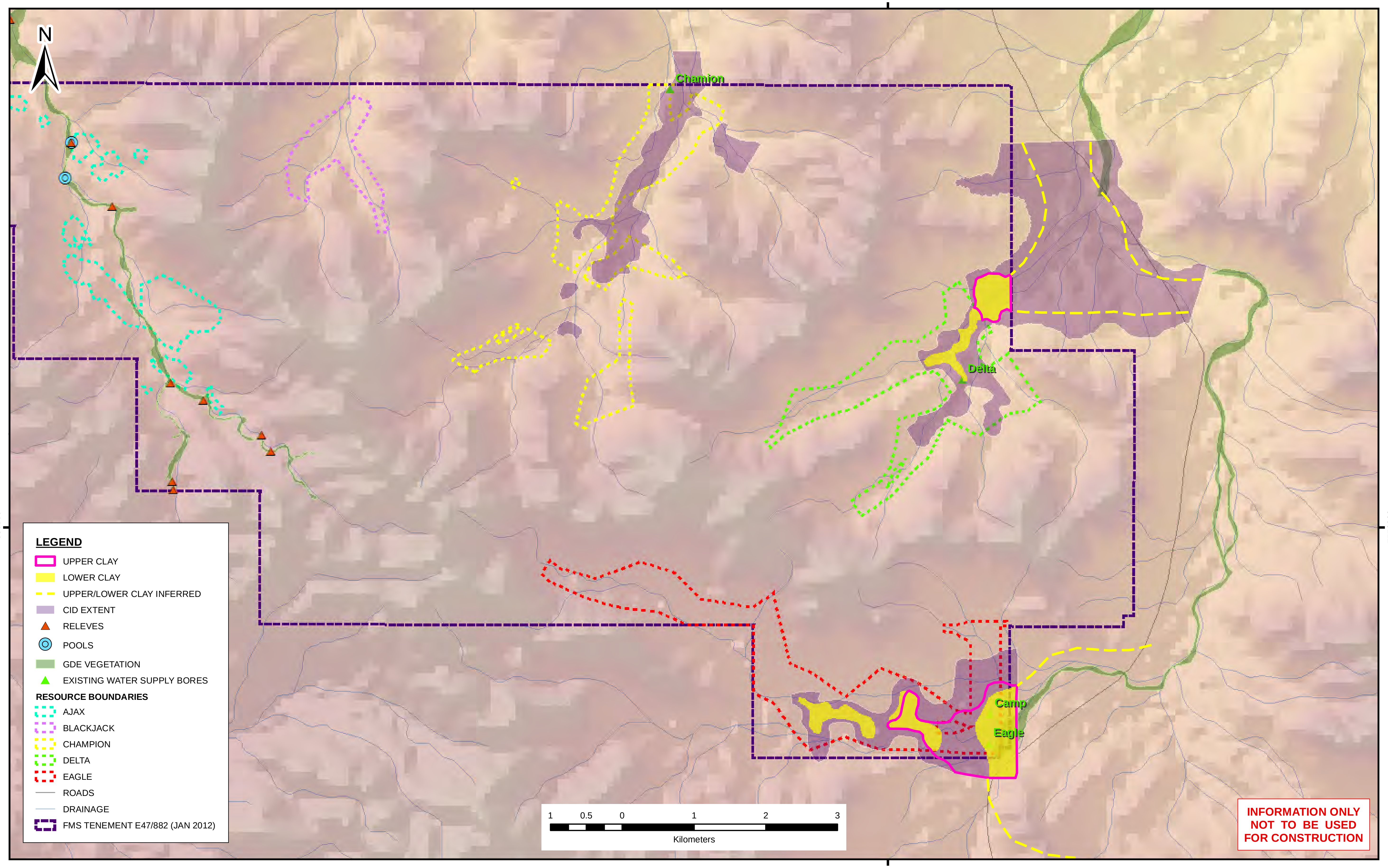

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LOCALITY MAP: BROOME, PORT HEDLAND, KARRATHA, PANNAWONICA, TOM PRICE, PARABURDOO

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FIGURE 6-3 - EXTENT OF CID AND CLAY

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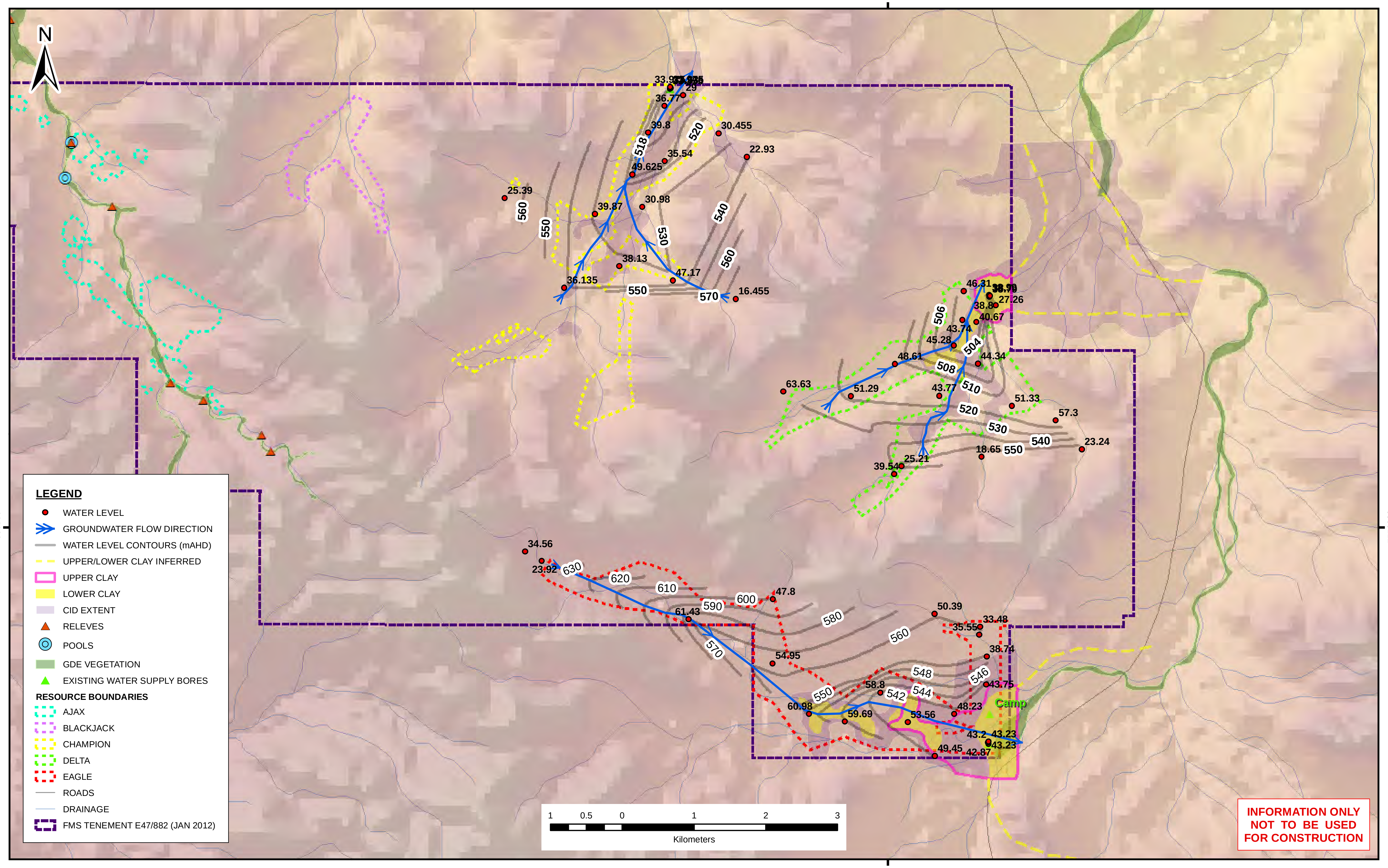

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WORLEYPARSONS PROJECT: 201012-00322	SCALE: 1:50,000 @ A3	DATUM: GDA 1994 MGA Z50S	A	FOR INFORMATION ONLY	MR / LS	25-02-2012
			REV	REVISION DESCRIPTION	DRN / CHK	DATE

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FIGURE 6-4 - GROUNDWATER CONTOURS

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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 Aquifer screened = Dry Saturated thickness of aquifer = N/A	Dry bore; saturated recharge from mounding in BID. 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

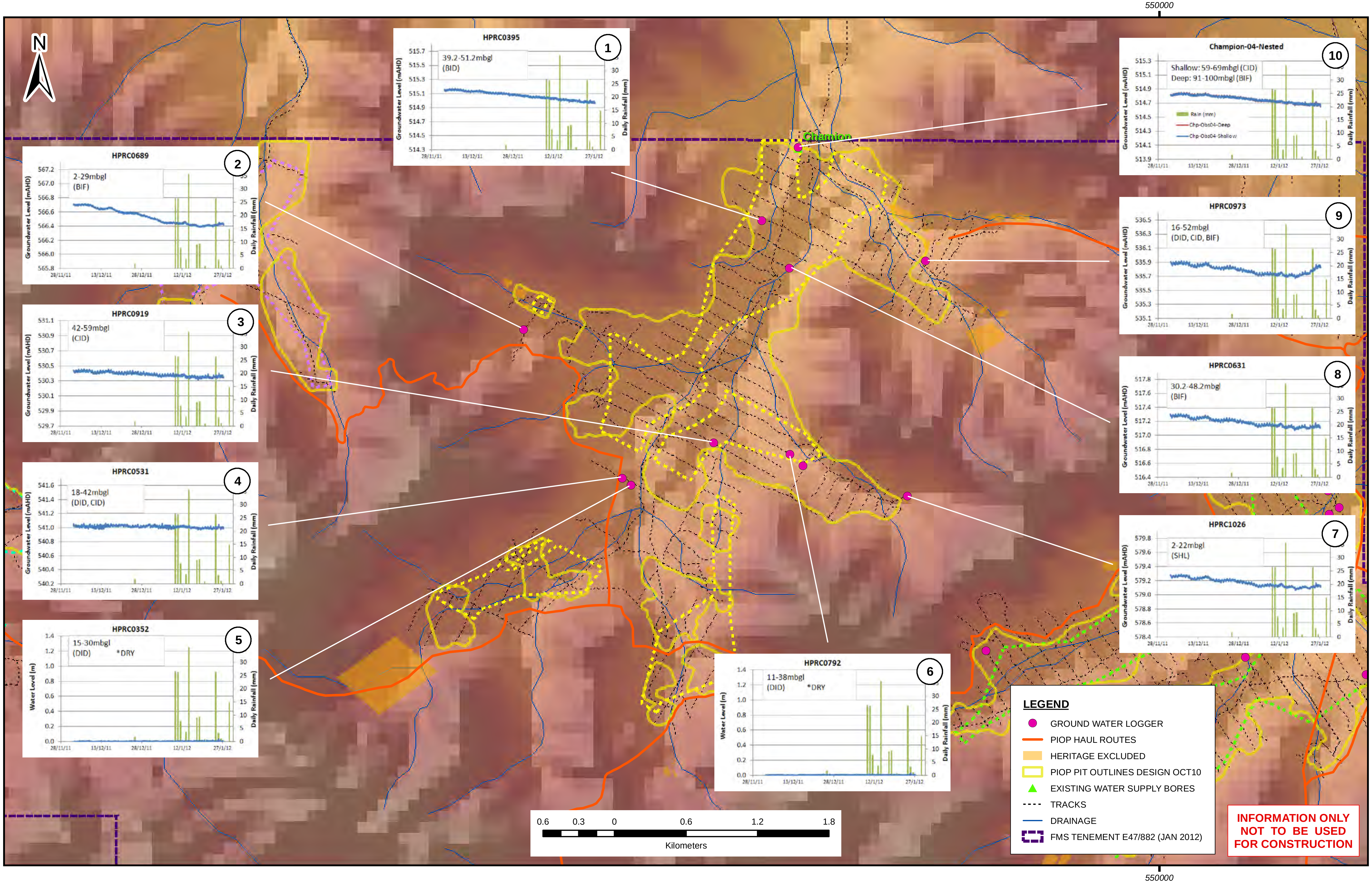
Monitoring ID	Screened Interval (mbgl)	Water Level 26/1/2012 (mAHD)*	Geology of screened interval	Hydrogeological Characteristics	Summary of Discharge and 14/1/2012 Recharge Event Behaviour
				Saturated thickness of aquifer = 0.8m	Minor water BIF
Stream Gauge	Screened in shallow alluvium to base of 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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A	FOR INFORMATION ONLY	MR	MT	07-02-2012

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FIGURE 6-5 - HYDROGRAPHS (CHAMPION)

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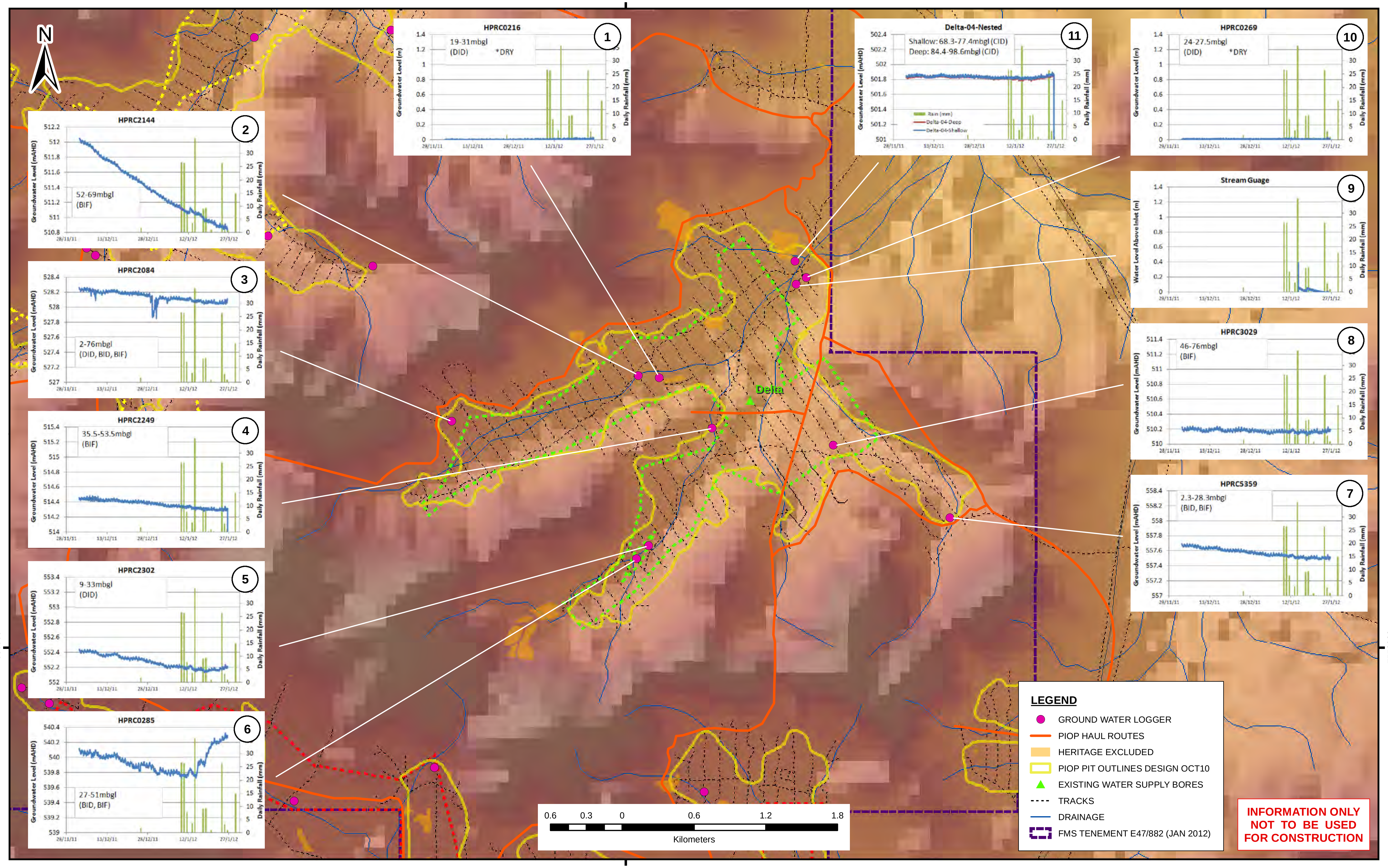

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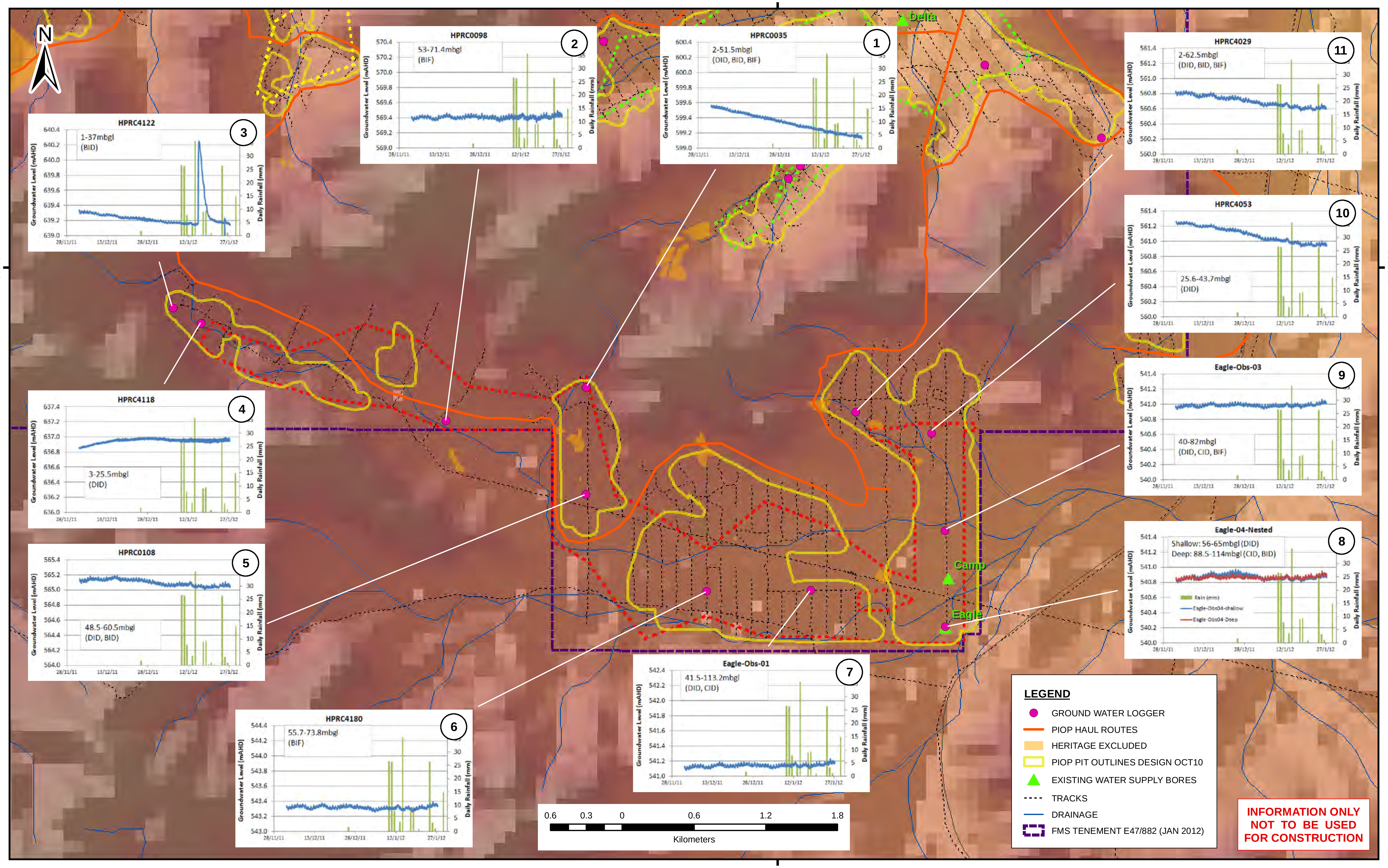

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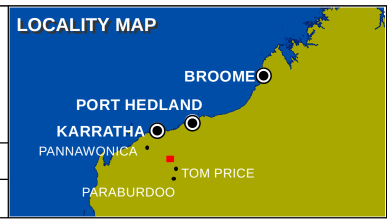

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FIGURE 6-7 - HYDROGRAPHS (EAGLE)

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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.

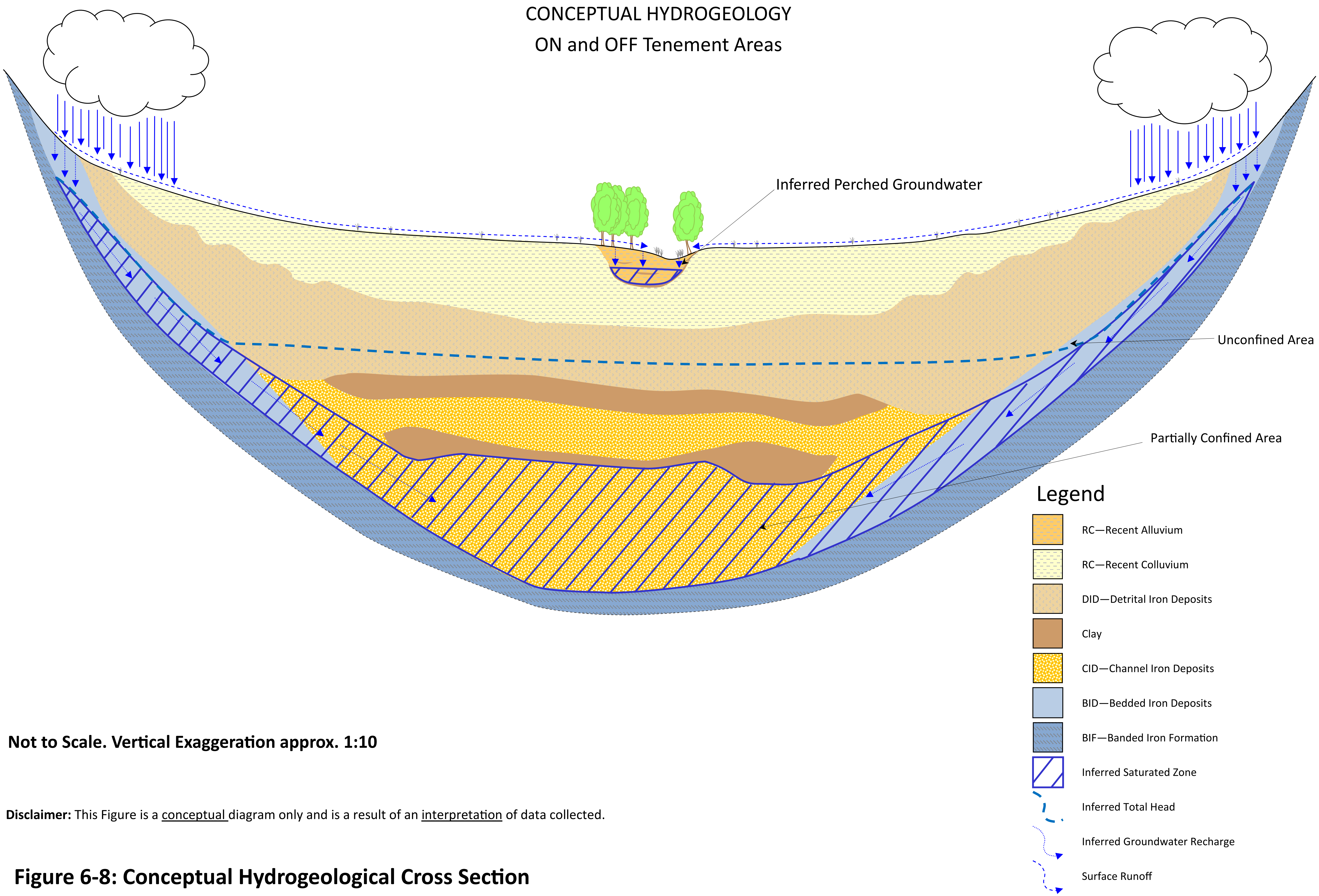
6.5.2 Environmental and Social Considerations

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.

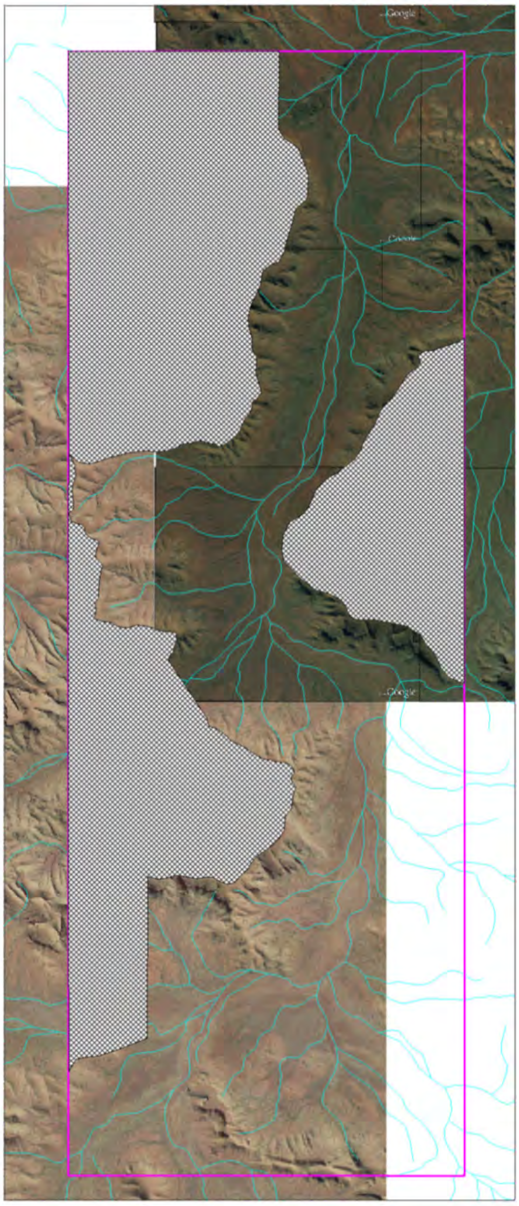
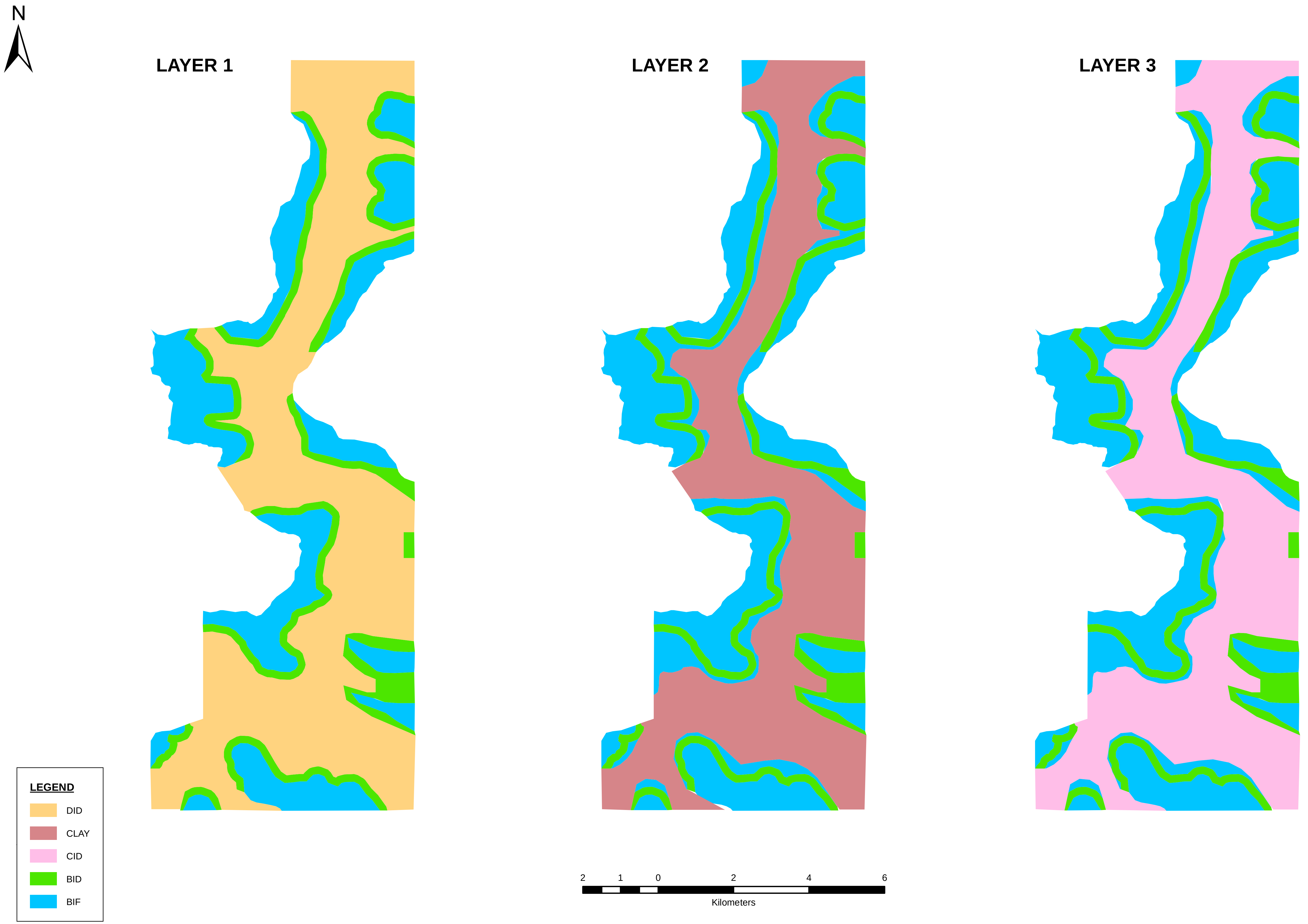


Figure 7-1: Groundwater model domain for the Serenity System

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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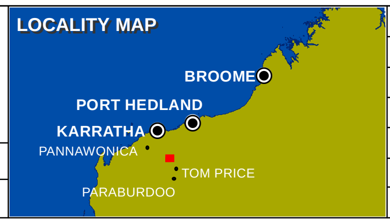

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FIGURE 7-2 - SERENITY GROUNDWATER MODEL
GEOLOGICAL UNITS

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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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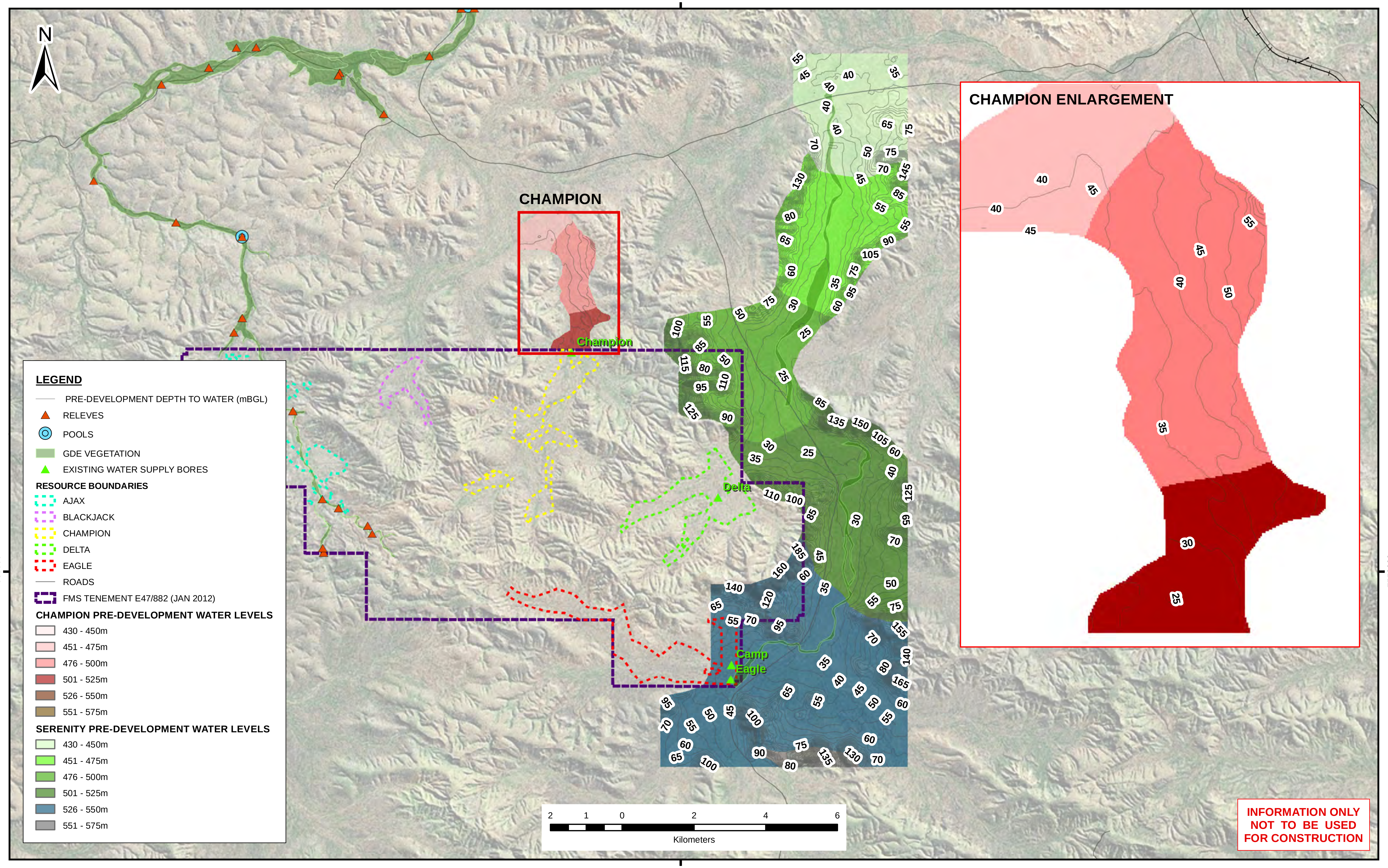

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LOCALITY MAP
BROOME
PORT HEDLAND
KARRATHA
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FIGURE 7-3 - MODELLED GROUNDWATER LEVELS AND DEPTHS
NO DEWATERING - t = 15 YEARS

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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.

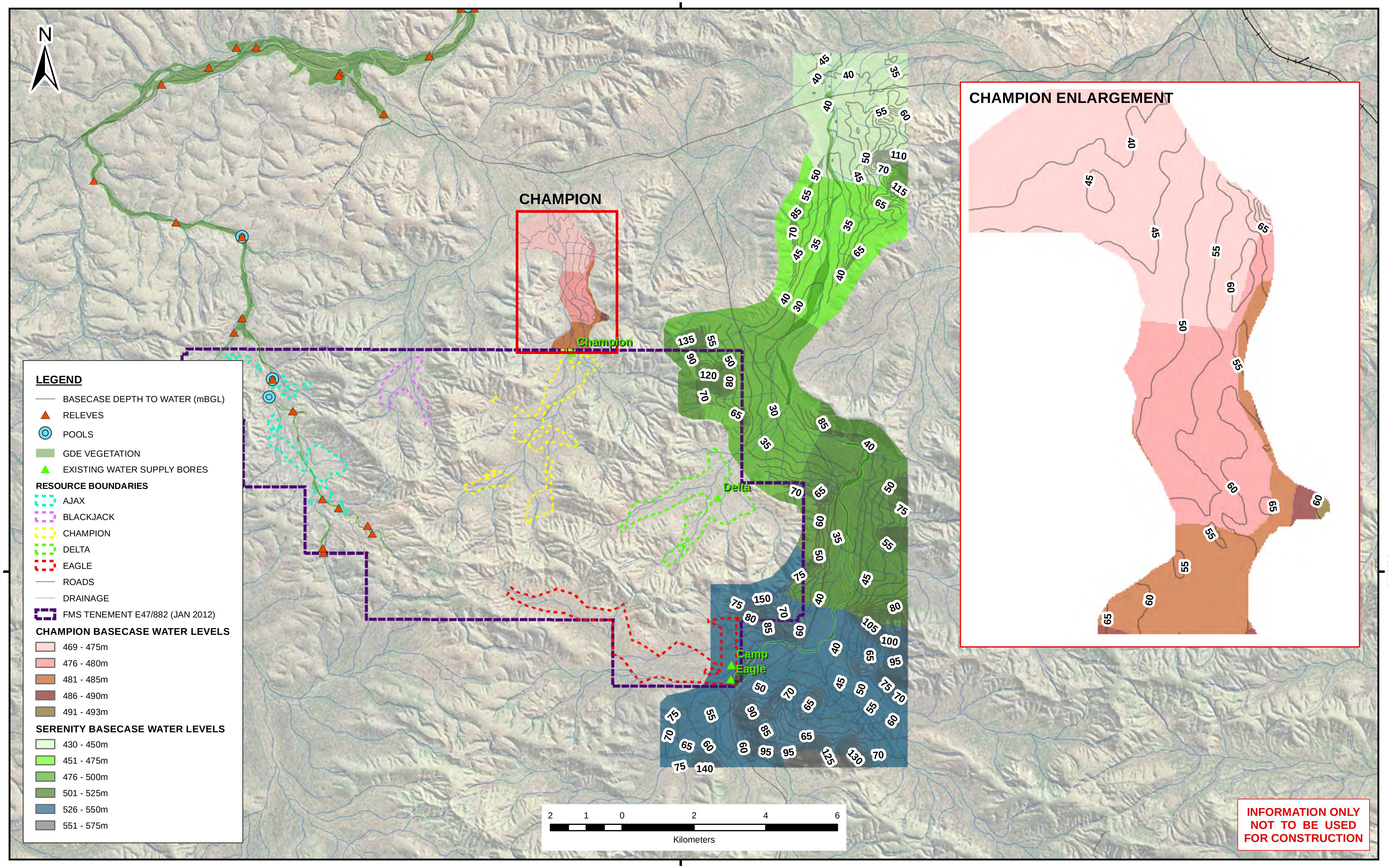

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FIGURE 7-4 - MODELLED GROUNDWATER LEVELS AND DEPTHS
BASE CASE DEWATERING - t = 15 YEARS

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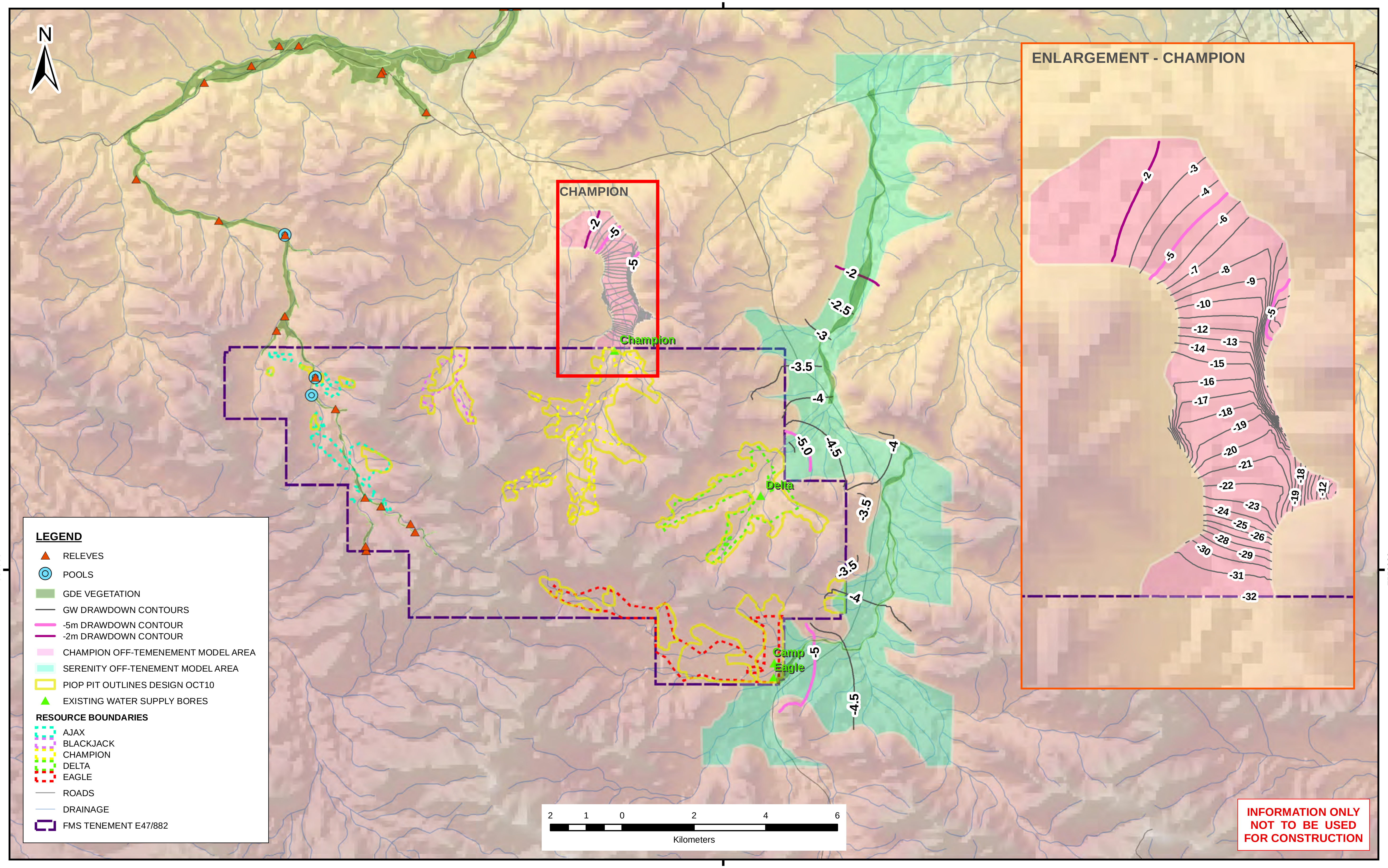

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LOCALITY MAP: BROOME, PORT HEDLAND, KARRATHA, PANNAWONICA, TOM PRICE, PARABURDOO

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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**

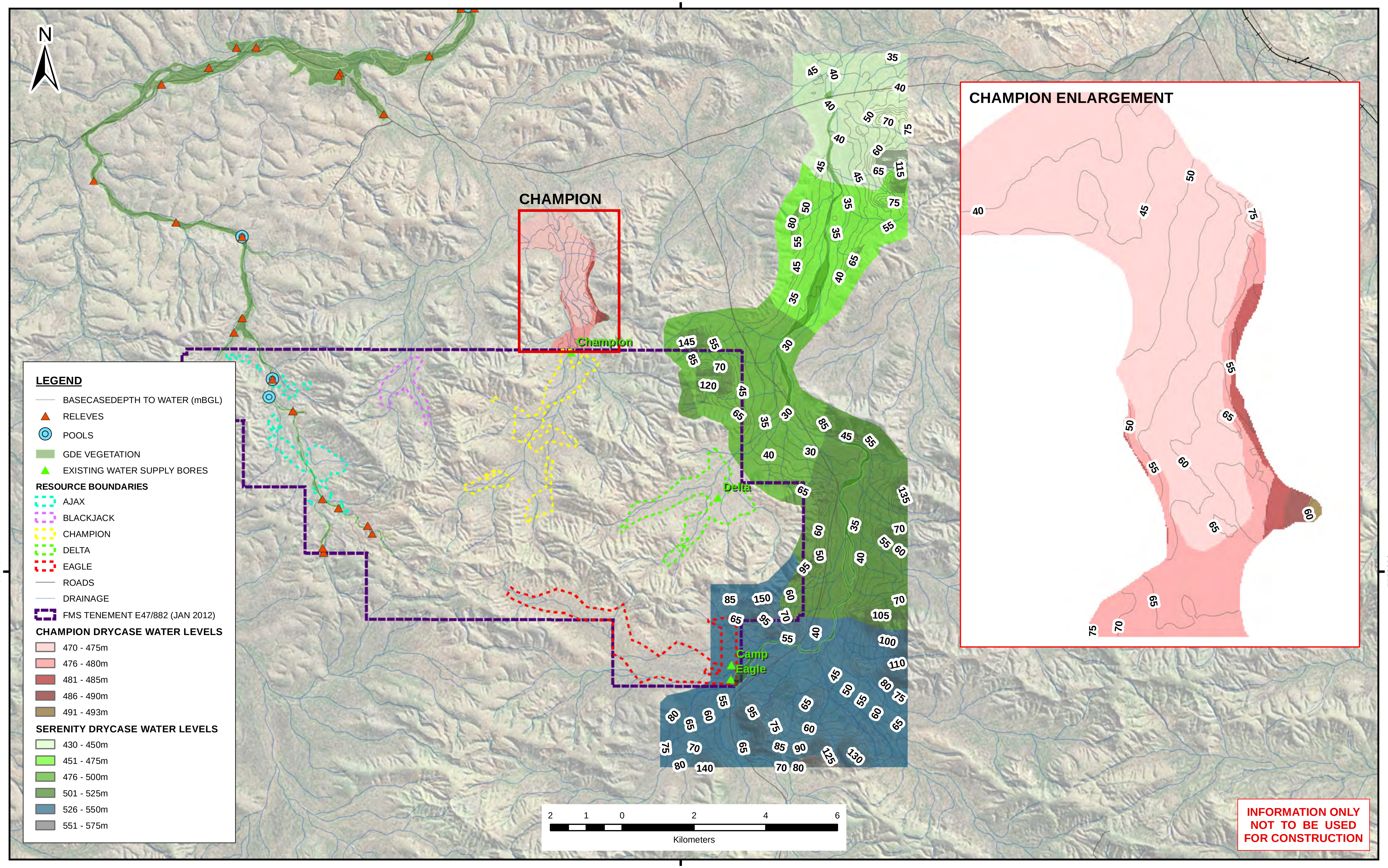
Dewatering – Dry Case Rainfall Scenario

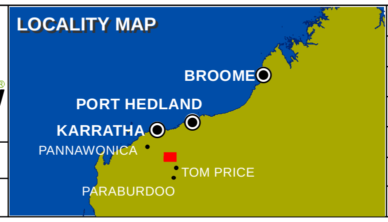
The second dewatering scenario was set up as a theoretical 'worst-case' scenario, in which an extended dry period acted to compound the effects of mine dewatering on the final drawdown levels. In order to simulate this scenario, the Wittenoom rainfall data was analysed and the monthly rainfall data for 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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PILBARA IRON ORE PROJECT
GROUNDWATER IMPACT ASSESSMENT REPORT
FIGURE 7-6 - MODELLED GROUNDWATER LEVELS AND DEPTHS
DRY CASE DEWATERING - t = 15 YEARS

DRG NO 201012-00322-GIS-DSK-107

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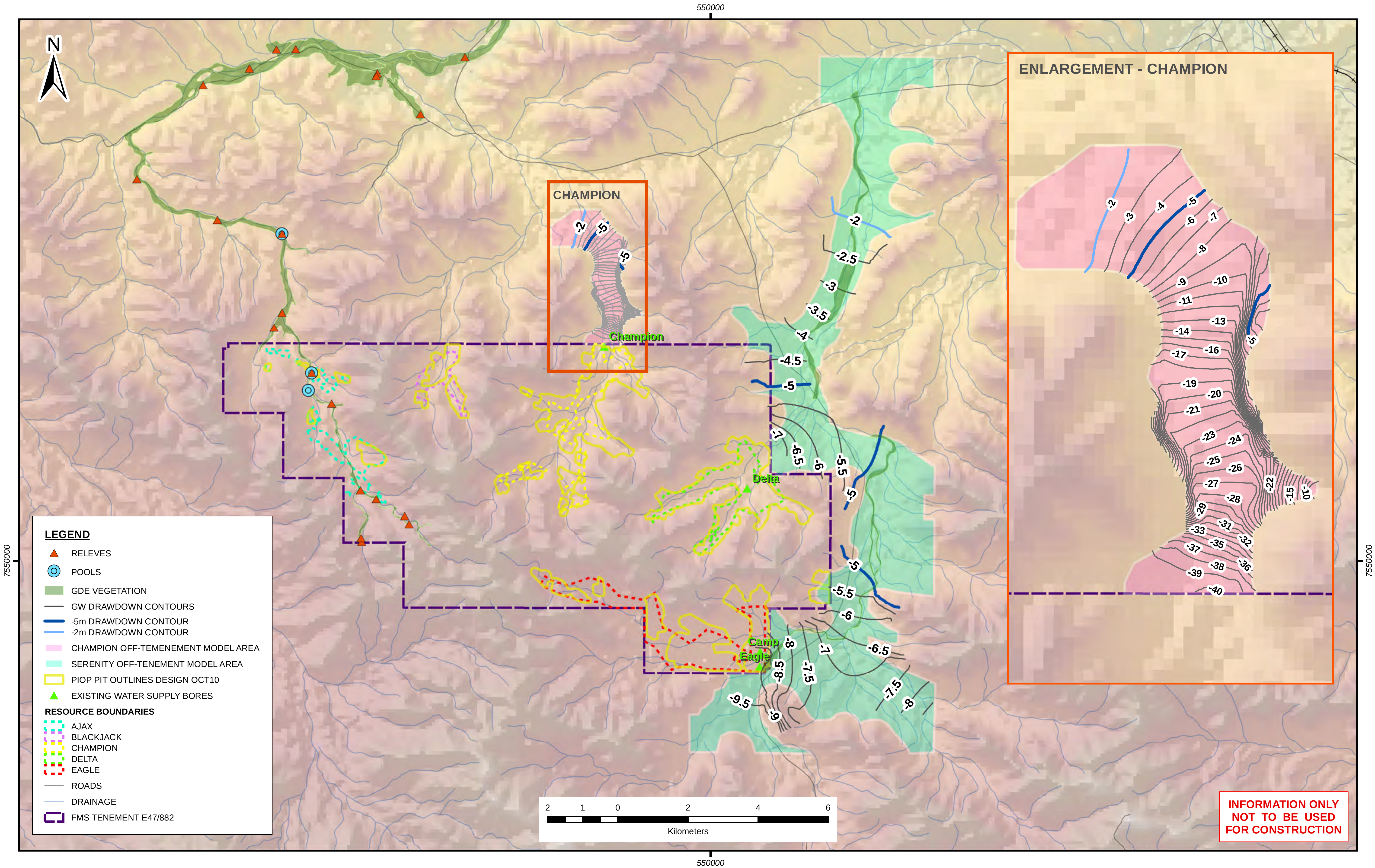

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LOCALITY MAP: BROOME, PORT HEDLAND, KARRATHA, PANNAWONICA, TOM PRICE, PARABURDOO

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B	ISSUED TO CLIENT	MR	MM	29-02-2012
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GROUNDWATER IMPACT ASSESSMENT REPORT
OFF-TENEMENT GROUNDWATER MODELLING
FIGURE 7-7 - DRY CASE DRAWDOWN SCENARIO

DRG NO: 201012-00322-GIS-DSK-098 REV: 0

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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.

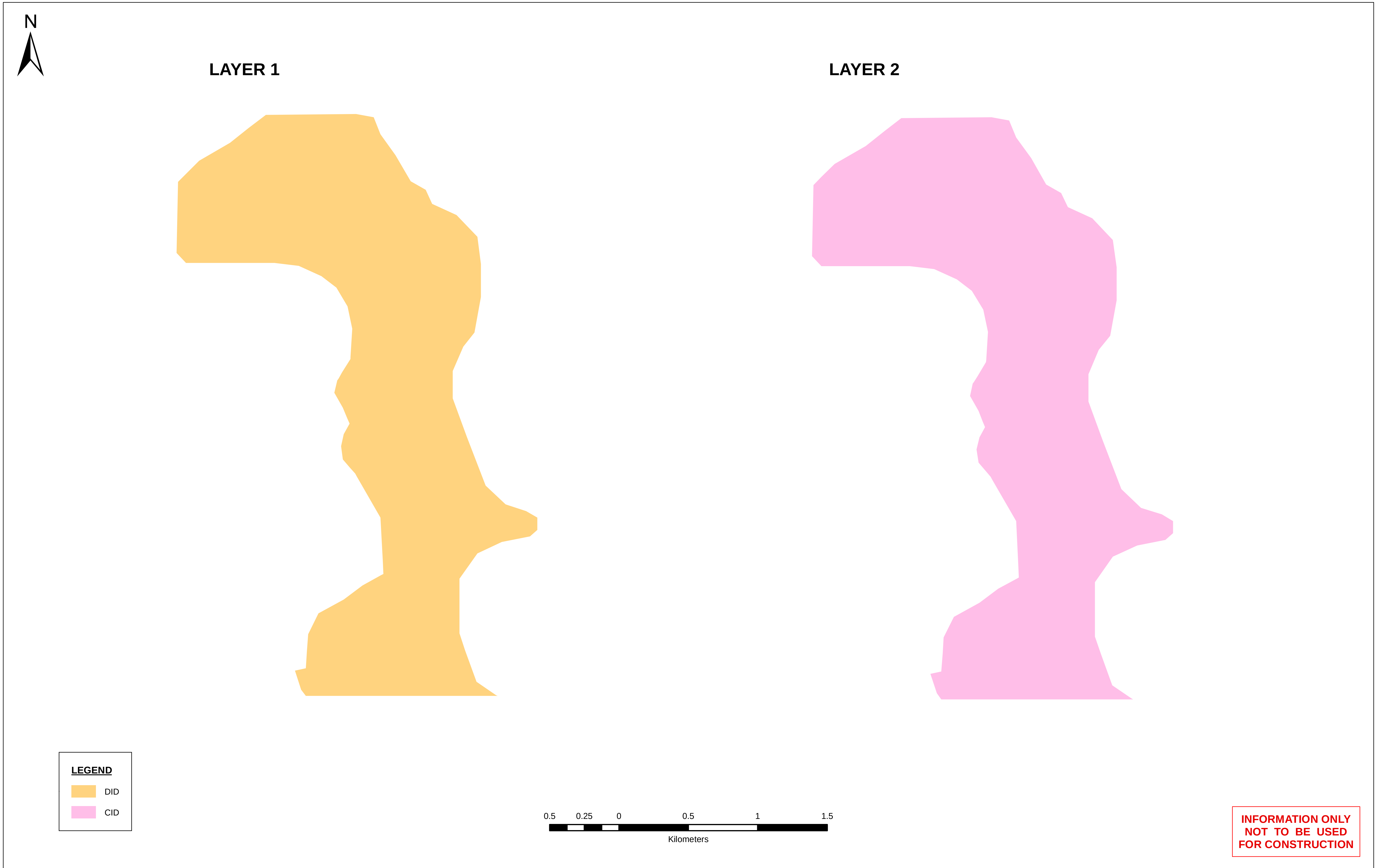
7.2.2 Model Stresses

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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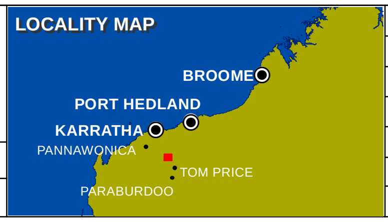

WORLEYPARSONS PROJECT	201012-00322
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FIGURE 7-9 - CHAMPION GROUNDWATER MODEL
GEOLOGICAL UNITS

DRG NO 201012-00322-GIS-DSK-104
REV 0

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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

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Appendix 1: Ajax Characterisation Report

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

2 March 2012

Ref: 201012-00322
File: 201012-00322

Mick Anstey
Flinders Mines Limited
62 Beulah Road
Norwood South Australia 5067

Dear Mick

AJAX SITE CHARACTERISATION REPORT

Background

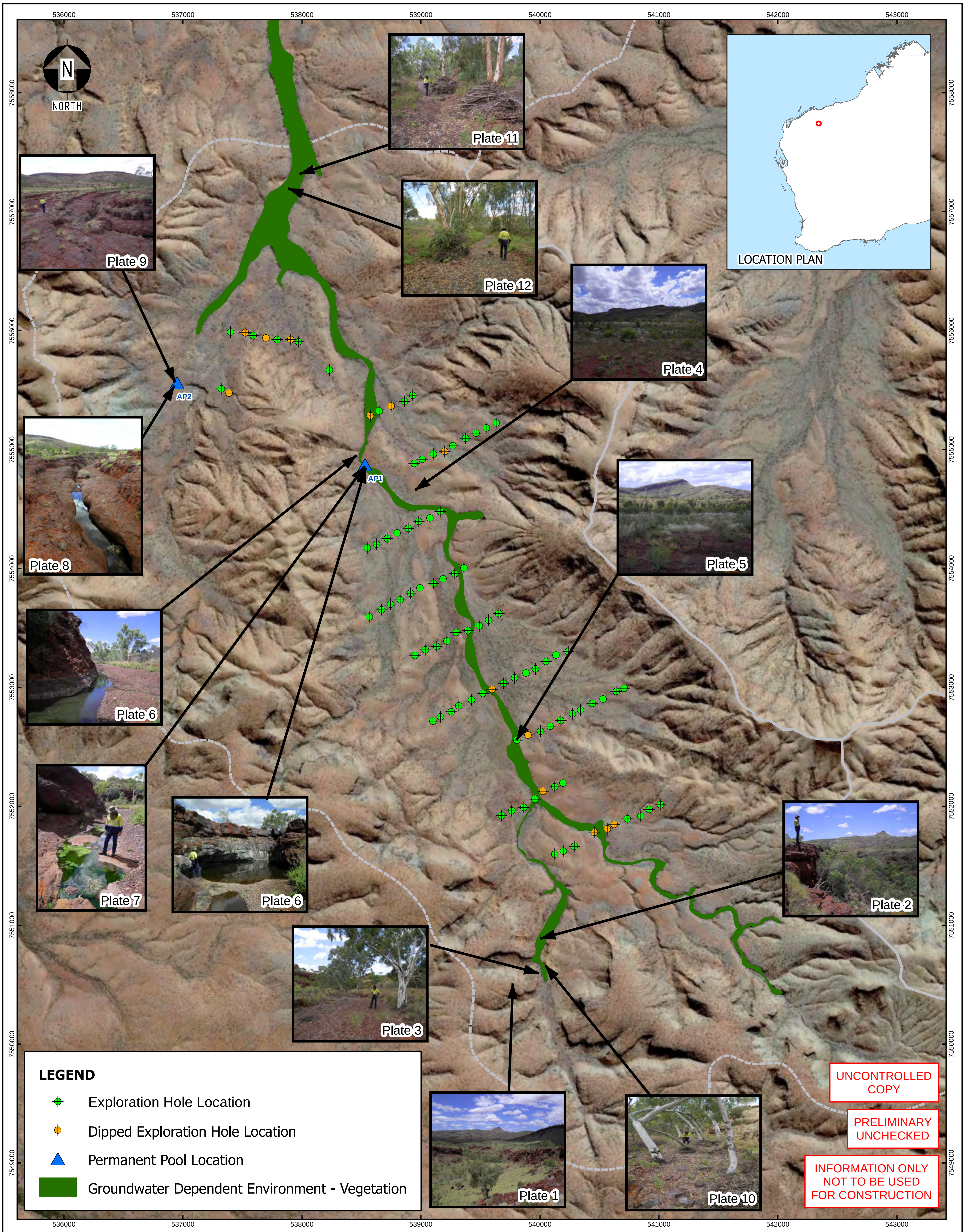
A meeting was held between Flinders, Ecoscape and WorleyParsons in Perth on the 2nd October 2011 to discuss the presence of groundwater dependant ecosystems (GDE) identified during recent surveys at locations within and in proximity to Flinders' Blacksmith and Anvil tenements. Ajax was identified as an area with GDEs including two permanent pools with significant heritage value. Figure 1 shows the Ajax catchment and location of identified GDEs.

In this meeting it was decided that further work was needed to characterise the surface water hydrology and subsurface hydrogeology of the Ajax deposit, with particular reference to GDEs and the pools with significant heritage value. This report presents the results of this investigation work.

Scope of Work

The Scope of Work (SoW) for this investigation included:

- Site visit to collect field data and observations;
- Desk top analysis of available reports and data;
- Characterisation of the hydrology and hydrogeology of the Ajax deposit;
- Discussion on the relationship between the surface hydrology and subsurface hydrogeology relative to the presence of GDEs; and
- Present potential environmental impacts associated with mining at Ajax and corresponding mitigation measures to minimise impacts.



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FLINDERS MINES - SURFACE AND GROUNDWATER FEATURES

FIGURE 1

DATE : 10 Feb 2012 SCALE : 1:30,000

CUSTOMER : FLINDERS MINES AUTHOR : Robert Milton

MAP : Ajax_Figure1_RevD_20120110.mxd

REV : D

Produced By: Robert Milton, Water Resources W.A.

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Site Visit

A site visit was conducted between the 20th and 23rd of November to walk over the Ajax deposit and collect field data and observations needed to evaluate the surface hydrology and hydrogeology of the Ajax deposit. Watercourses, GDEs, permanent pools and geological features were identified and photographed. A selection of these photographs is provided in Appendix A (Plates 1 to 12), while their locations are shown in Figure 1.

Two significant permanent pools with significant heritage value, defined as Ajax Pool 1 (AP1) and Ajax Pool 2 (AP2) in this report, were visited during the site visit (Plates 6 to 9), and measurements taken to estimate the approximate standing water level in mAHD. The location of these pools are shown on Figure 1.

Piles of debris deposited within the main channels of watercourses at Ajax were located and the maximum height of the debris measured and their location recorded using a hand-held GPS. The heights were converted to debris levels (in mAHD) using ground levels estimated using airborne LIDAR survey data. The debris levels represented the maximum water level experienced during recent flood events. All debris level measurements are presented in Appendix B.

Several exploration holes were located at Ajax and the depth to groundwater recorded in the holes that had not collapsed for comparison with standing water levels at the pools. These depths were then converted to water levels (in mAHD) using ground levels estimated using airborne LIDAR survey data.

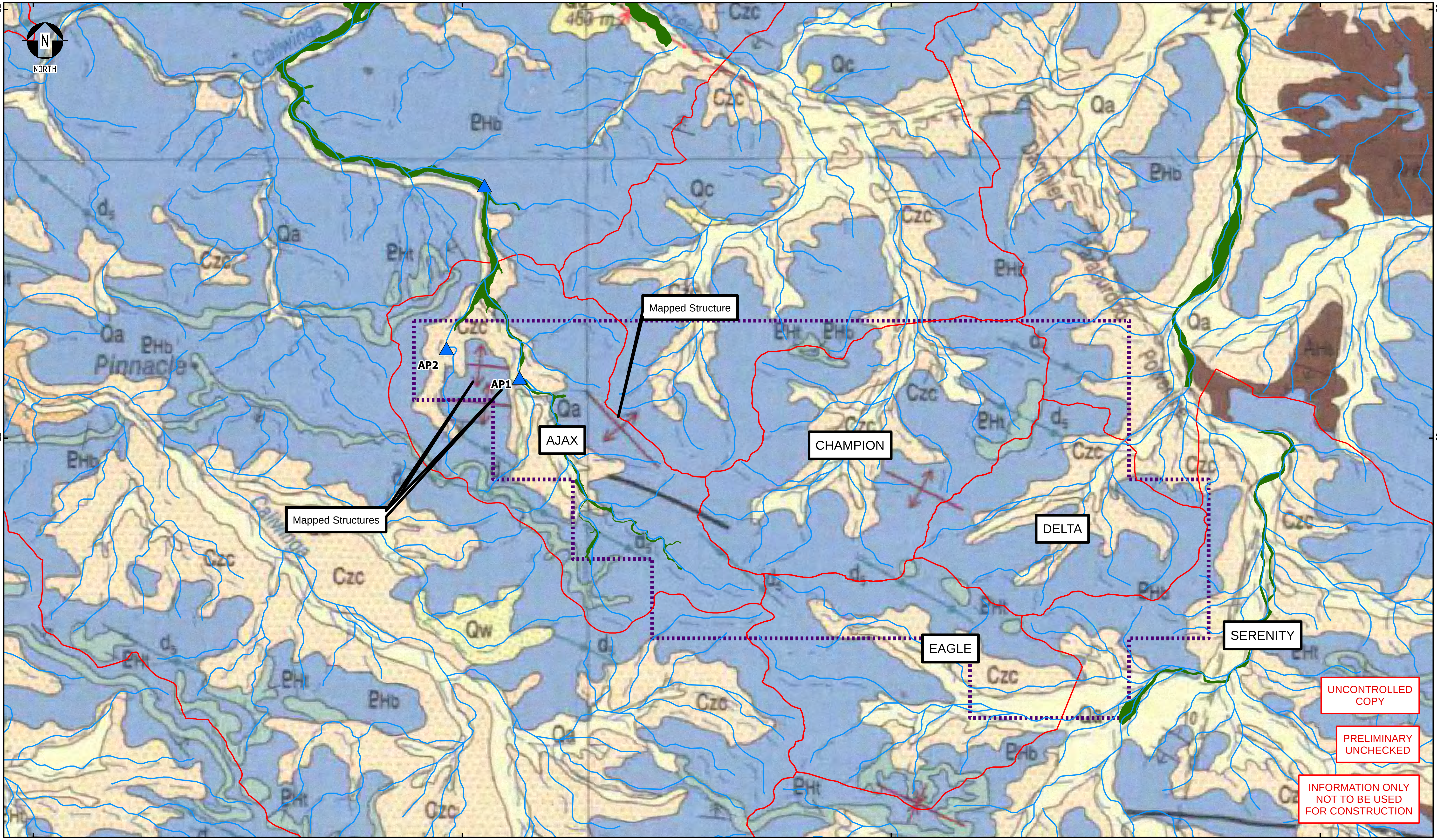
Local Hydrology

The Ajax catchment area shown in Figure 2 has an area of approximately 36km^2 delineated using topographic contours generated using LIDAR survey data and 90m SRTM data. This catchment lies within the Millstream catchment which has an approximate area of 4,770km^2. Therefore the Ajax catchment represents 0.7% of the Millstream catchment area.

The Champion, Eagle and Delta catchments are presented in Figure 1 for comparison and also lie within the Millstream catchment area.

The average annual rainfall at Ajax is 459mm based on rainfall recorded at Wittenoom between 1950 and 2011 (BoM #5026) while the average annual pan evaporation exceeds 3,000mm (BoM). Because annual evaporation greatly exceeds rainfall, the ability of porous sediments within the catchment to capture rainfall recharge, store and discharge groundwater is extremely important for preservation of the permanent pools.

The largest ephemeral creek at Ajax flows north through the centre of the catchment with a channel grade of approximately 1% and bounded by steep and rocky terrain. The majority of surface water runoff generated within the Ajax catchment during rainfall events flows via this ephemeral creek north to Caliwingina Creek before discharging into the Fortescue River (Figure 2).



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Datum : GDA94 Map Grid of Australia Zone 50

LEGEND

- Permanent Pool Locations
- Drainage
- Groundwater Dependent Environment - Vegetation
- Catchment Boundary
- Tenement E 47/882

LOCATION PLAN

FLINDERS MINES - REGIONAL GEOLOGY AND CATCHMENT AREAS

FIGURE 2

DATE : 10 Feb 2012 SCALE : 1:85,000

CUSTOMER : FLINDERS MINES AUTHOR : Rob Milton

MAP : Ajax_Figure2_RevD_20120110.mxd

REV : D

Produced By: Rob Milton, Water Resources, WA

Location: I:\Projects\201012-00322 FMS VIP\10.0 Engineering\Hydrogeology\Ajax investigations\GDE_Report\ArcGIS\Map_Docs\Ajax_Figure2_RevD_20120110.mxd

The channel widths of creeks in this catchment reduce when they pass through deeply incised valleys (Plate 2), then increase in areas where the valley widens (Plate 4 and 5). The creeks have thicker alluvial sediments in areas where the channel grade is low and the channel width is greatest. This is because the flood flows have lower velocities which promote the deposition of sediments. The creeks contain thin alluvial sediments in the areas where they pass through narrow and deeply incised valleys bounded by steep rocky slopes (Plate 10). The flows in these areas are concentrated through a smaller cross sectional area, which increases flow velocities causing scour of sediments and exposure of bedrock. The permanent pools at AP1 and AP2 have been formed by erosion and scour of exposed bedrock while the creeks are in flow (Plates 6 to 9).

Due to the steep and rocky terrain, surface water runoff from this catchment is expected to be rapid in response to rainfall resulting in flash floods during extreme events associated with cyclonic activity or local thunderstorm activity. The steep terrain, incised nature of the creek and presence of exposed and near surface bedrock suggests that the catchment also has limited storage capacity. This means that groundwater recharge is limited and only occurs during a short period when there is stream-flow in the creek, with the majority of water flowing north out of the catchment area.

The Champion, Delta and Eagle catchment areas contribute water into the Serenity catchment to the East and are not linked to the Ajax catchment in any way except that they separately contribute surface water runoff to the Fortescue catchment. These catchments are similar however, in that they are each formed through the weathering and erosion of the Brockman formation and each receive similar rainfall patterns.

Local Geology

The Regional Geology of the area is described in the 1:250,000 Mt Bruce Map Sheet (SF50-11) and associated explanatory notes as first and second editions (de la Hunty, 1965; Thorne et al (GSWA), 1997). An extract from this geological map sheet is presented in Figure 2. The majority of the regional geology has no bearing upon the hydrogeology within the Ajax Catchment however it is important to note that each of the surrounding catchments within tenement E47/882 are also within the Brockman formation's Banded Iron Formation (BIF), Cherts and Shale.

The Ajax Deposit is situated within a valley containing Quaternary and Cainozoic sediments overlying BIF bedrock from the Brockman formation, a part of the Hamersley group. The Brockman Iron Formation, with an estimated maximum thickness of about 550m, is the main iron-bearing formation within the Hamersley Group and has been described in detail by Trendall and Blockley (1970). The various members have been subdivided into the Whaleback Shale member, the Dales Gorge member, the Joffre BIF member, and the Yandicoogina Shale member (Thorne et al (GSWA), 1997). Within Ajax, the particular member could not be determined due to a lack of information however, during 250k geological mapping (GSWA, 1997), several W-E oriented (hinge) folds were encountered on the SW flank and one NW-SE oriented (hinge) fold was encountered on the NE flank of the Ajax catchment.

Large quantities of Banded Iron Formation (BIF), chert and shale are scattered throughout the landscape. Steep slopes can be found within the Ajax catchment covered with remnants of BIF and Detrital Iron and the valley contain some alluvial clay, Channel Iron Deposits (CID's) and Banded Iron Deposits (BID's) overlying BIF, chert and shale bedrock.

Exploration drilling has been performed along a number of cross sections shown in Figure 3. The geological logs and site observations have been used to develop a series of conceptualised cross sections for Ajax (Appendix C). The cross sections suggest that conceptual geology at Ajax differs from the Champion, Eagle and Delta within the FMS tenement, because there is a much shallower soil profile overlying the BIF bedrock, varying between 0m to 26m (in the drilled area). The BID and CID deposits, which are known to be the most transmissive units and most likely to contain groundwater, are thin and not extensive throughout the catchment. Therefore the storage capacity of the CID and BID units at Ajax is likely to be significantly smaller than at Champion, Eagle and Delta.

Local Hydrogeology

Groundwater levels recorded in open exploration holes and at the pools during the recent site visit were have been used to plot groundwater contours (depth bgl) in Figure 4. The contours show that direction of groundwater flow is to the north, and that near surface groundwater is present in the vicinity of the GDEs.

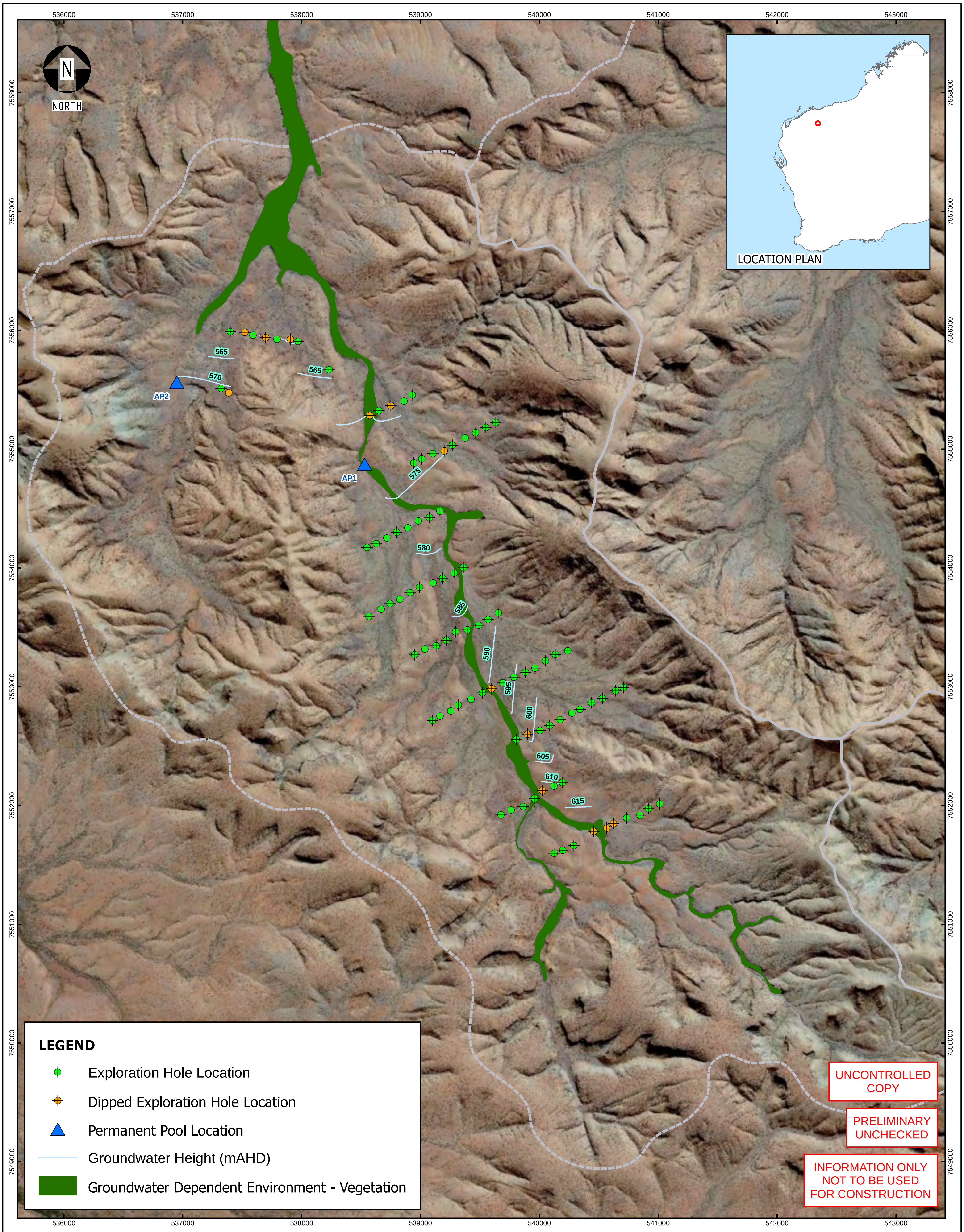
The measured groundwater levels have also been used to develop inferred groundwater levels in the cross sections presented in Appendix C.

Analysis of the geological cross sections and water levels recorded in exploration holes and pools suggests there are two distinctive occurrences of groundwater at Ajax:

1. A more extensive groundwater aquifer located at an elevation within the BID and DID deposits, just above the existing BIF bedrock; and
2. Pockets of perched groundwater associated with less extensive porous zones of alluvial sediments underlain by surface clays and located within or adjacent to creeks.

Local surface aquifers are restricted to saturated zones of a porous material above clay layers resulting from depositional changes during rainfall events. These zones naturally follow creek beds and channels within the top several metres of colluvium. The deeper aquifer tends to follow the surface of the highly-resistant and impermeable Brockman formation (BIF).

The degree of connectivity between the shallow perched groundwater and the deeper aquifer cannot be determined accurately with the existing geological data.



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Metres at A3

Datum : GDA94
Map Grid of Australia
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FLINDERS MINES - GROUNDWATER CONTOURS

FIGURE 3

DATE : 10 Feb 2012 SCALE : 1:30,000

CUSTOMER : FLINDERS MINES AUTHOR : Robert Milton

MAP : Ajax_Figure3_RevA_20120110.mxd

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Produced By: Robert Milton, Water Resources W.A.

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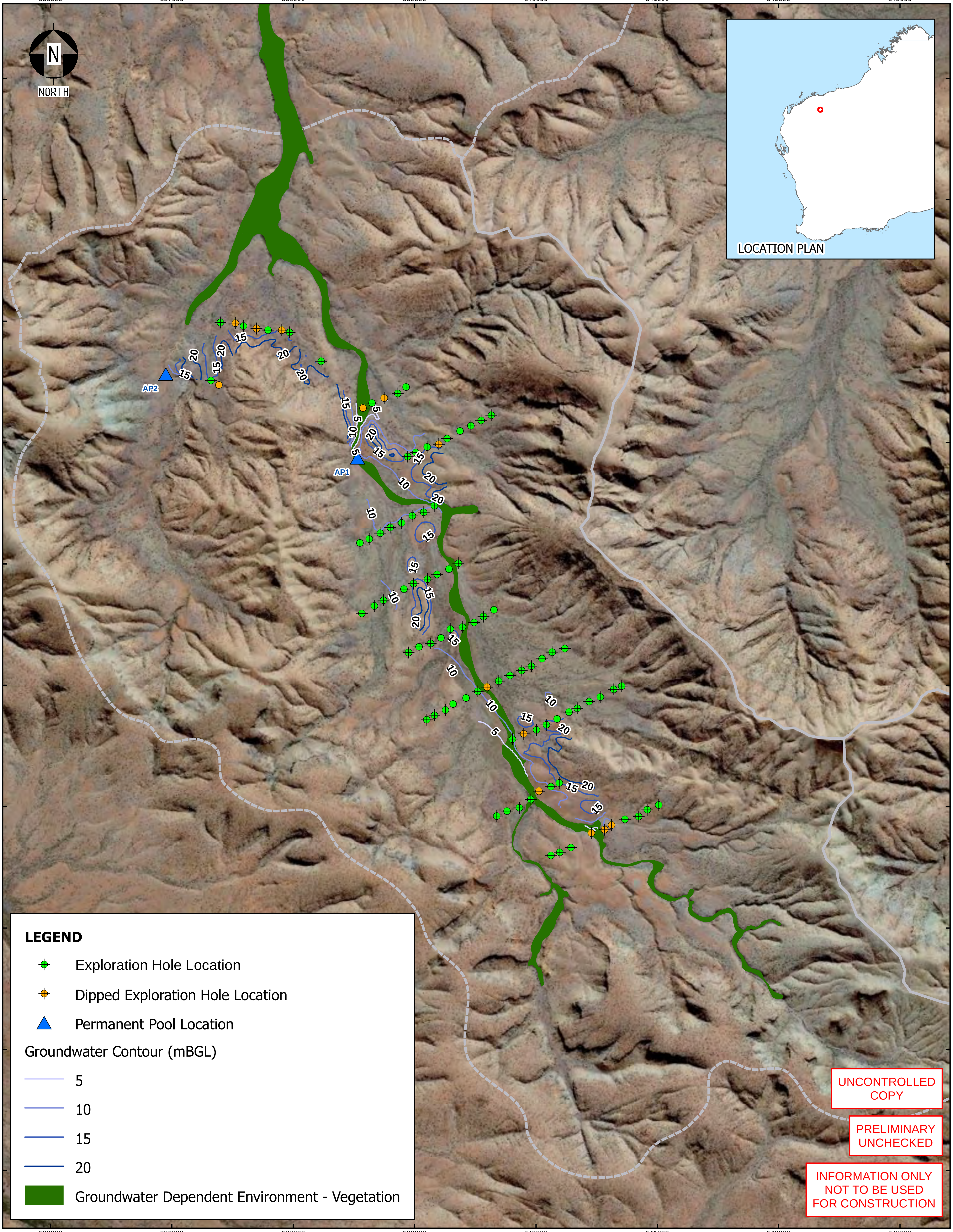

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Metres at A3

Datum : GDA94
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Zone 50

FLINDERS MINES - GROUNDWATER CONTOURS

FIGURE 4

DATE : 10 Feb 2012
SCALE : 1:30,000
CUSTOMER : FLINDERS MINES
AUTHOR : Robert Milton
MAP : Ajax_Figure4_RevA_20120110.mxd
REV : A

Location: I:\Projects\201012-00322 FMS VIP\10.0 Engineering\Hydrogeology\Ajax investigations\GDE_Report\ArcGIS\Map_Docs\Ajax_Figure4_RevA_20120110.mxd

The available geological data and field observations for Ajax has identified potential confining layers within the DID and underlying the shallow alluvial sediments at some locations within the catchment. This suggests that shallow perched groundwater may not be connected in many areas along the creek beds, and potentially connected at some of the deeply incised valleys where BID and CID is in direct contact with shallow alluvial sediments. Further investigation is needed to confirm the degree of connectivity between the shallow perched groundwater and the deep aquifer.

The Mt Bruce 250k map sheet (Figure 2) shows several structures present are likely to have contributed to the presence of near surface BIF bedrock observed at or in the vicinity of the permanent pools AP1 & AP2.

The long section presented in Appendix C shows the elevation of BIF bedrock gradually decreasing to the north, which promotes groundwater flow in that direction. The elevation of the bedrock increases significantly in the vicinity of permanent pool AP1, which forces groundwater to flow up and over the bedrock at this location. This channelling of flow through a thin layer of alluvial sediments causes groundwater to breach the surface, flow overland across or through fractures in exposed bedrock, and into the permanent pool AP1. Similar conditions are observed at AP2.

This continuous flow of groundwater and seasonal flooding scours and erodes the bedrock, deepening the pools and maintaining water levels. Plates 6 to 9 show the presence of the exposed bedrock at both AP1 and AP2.

Groundwater quality data was not collected at Ajax. However the geology is similar to that of Champion, Eagle and Delta, so the water quality is also expected to be similar. Water quality data collected at Champion, Eagle and Delta are presented in Appendix D.

Interpreted Influence of Groundwater on GDEs

The report completed by Ecoscape (19^{th} Dec 2011) shows the locations of several types of GDE's and their dependence upon groundwater (Figure 1). The report does not recognise the presence of shallow perched groundwater and the deeper aquifer found within Ajax nor does it specify the depth at which the GDEs are relying upon subsurface water or the lateral distance GDEs would search for water.

The GDEs identified at Ajax are almost always located in or adjacent to creeks and low lying areas containing alluvial sediments (Figure 1). The majority of GDEs are likely to be relying on pockets of shallow perched groundwater within these sediments which is being fed by shallow through flow from up gradient areas and recharge from seasonal flooding. There may also be some areas where GDEs are accessing groundwater stored in near surface deposits of CID and BID within or adjacent to creek beds. The depth that roots would need to penetrate to access this shallow perched groundwater is not yet known, so additional investigations are needed to confirm the GDEs dependence on groundwater.

Potential Impacts of Mining at Ajax

The aquifers within the upper catchment area supply groundwater flow which supports and maintains the permanent pools and GDEs downstream. The mining of these aquifers is likely to reduce the supply of water so mitigation measures are needed to maintain the groundwater flow and quality of water reaching the permanent pools and GDEs.

The GDE's and permanent pools also rely on seasonal flooding to recharge aquifers, which increases storage and maintains groundwater flows throughout the year. Mining has the potential to starve downstream areas of surface water flow unless managed carefully using diversions and mine planning.

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Conclusions & Recommendations

The proposed mining operation at Ajax has the potential to alter surface and groundwater flows and quality, which could have an adverse environmental impact on GDE's and permanent pools, if left unmanaged.

It is recommended that appropriate management measures are developed and incorporated into mine planning to ensure that surface and groundwater flows, volumes and qualities are maintained at pre development conditions, at the GDE's and permanent pools to minimise adverse environmental impacts.

Management measures may include:

- Acid mine drainage (AMD) will need to be managed during mining operations and at closure to ensure that downstream permanent pools and GDEs are not affected;
- Mining of the aquifer may impact on flows to the permanent pools and GDEs, so mine dewater may need to be pumped to sensitive areas during mining operations to maintain flows;
- Surface water flow through mine areas will need to be managed using diversions, sedimentation ponds and appropriate mine planning to ensure that pre and post development flows and quality at the GDEs and permanent pools are similar;
- Backfilling mine pits with porous sediments to ensure that sufficient water storage is retained is the upper reaches of the catchment which can maintain flow to the permanent pools and GDEs following mine closure; and
- Mine pits should be backfilled and watercourses reinstated at similar locations and using appropriate materials to maintain flow and prevent scour and sedimentation downstream following mine closure.

Yours sincerely
WorleyParsons

Stuart ATKINSON
Water Resources Manager

Dan CRAVENS
Principal Hydrogeologist

cc Appendix A: Site Photos
Appendix B: Debris Levels
Appendix C: Conceptual Hydrogeological Cross Sections
Appendix D: Water Quality Data

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Appendix A: Site Photos

Plate 1. Steep rocky slopes along perimeter of the Ajax catchment

Plate 2. Steep rocky catchments and deeply incised valleys

Plate 3. Creek bed with shallow alluvium, in a narrow valley bounded by steep rocky slopes

Plate 4. Wide Valley Basins

Plate 5. Ephemeral creek flowing through a wide valley

Plate 6. Permanent Pool AP1

Plate 7. Exposed basement rock in the creek bed with little or no alluvium, adjacent Permanent Pool AP1

Plate 8. Permanent Pool AP2, with little or no alluvium

Plate 9. Exposed basement in the creek bed at Permanent Pool AP2

Plate 10. Debris levels recorded at site D01, within a deeply incised valley bounded by steep rocky slopes.

Plate 11. Debris levels recorded at site D02

Plate 12. Debris levels recorded at site D03

Appendix B: Debris Levels

Table 1. Ajax Debris Levels

Site Ref	Photo Ref	Easting	Northing	Estimated Debris Height (m)	Estimated Debris Level (mAHD)
D01	RIMG1124	540030	7550644	0.5	642.36
D02	RIMG1172	537961	7557300	1.8	550.49
D03	RIMG1170	537858	7557211	1.8	552.97

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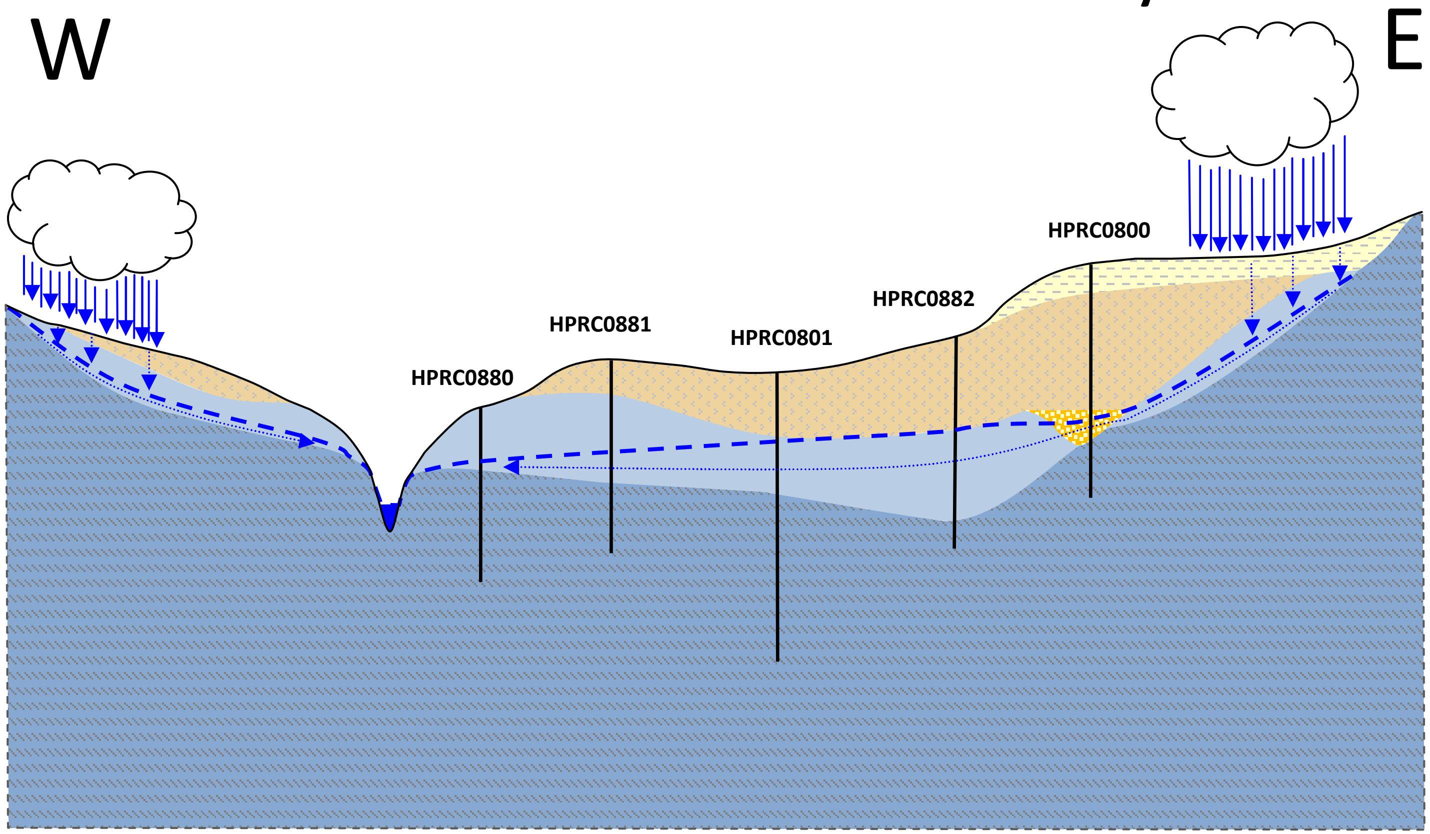
Appendix C: Conceptual Hydrogeological Cross Sections

AJAX - Lower Valley Section



Legend

RC—Recent Colluvium

RC—Recent Alluvium

DID—Detrital Iron Deposits

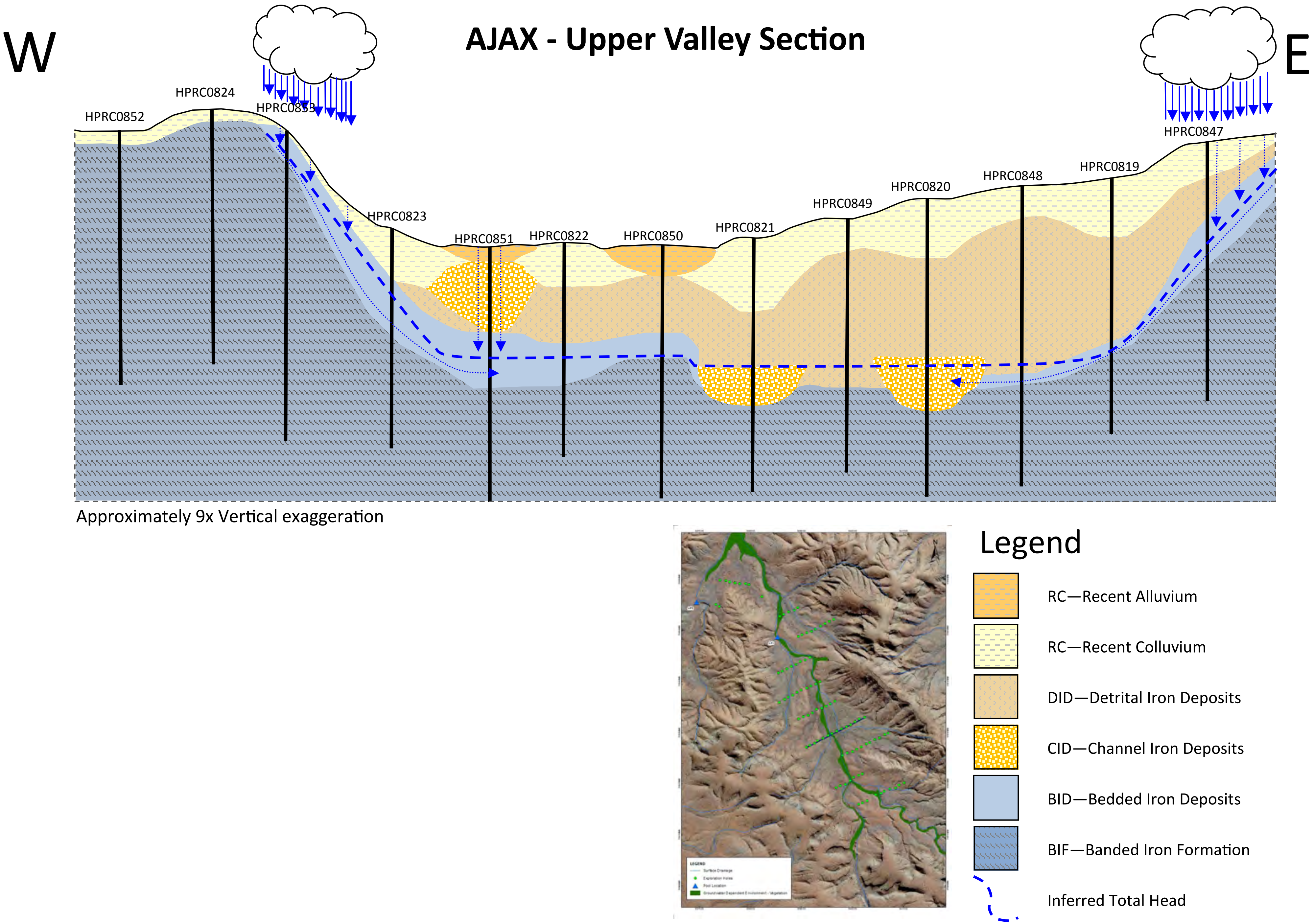
CID—Channel Iron Deposits

BID—Bedded Iron Deposits

BIF—Banded Iron Formation

Inferred Total Head

Approximately 10x Vertical exaggeration


AJAX - Upper Valley Section
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HPRC0824
HPRC0853
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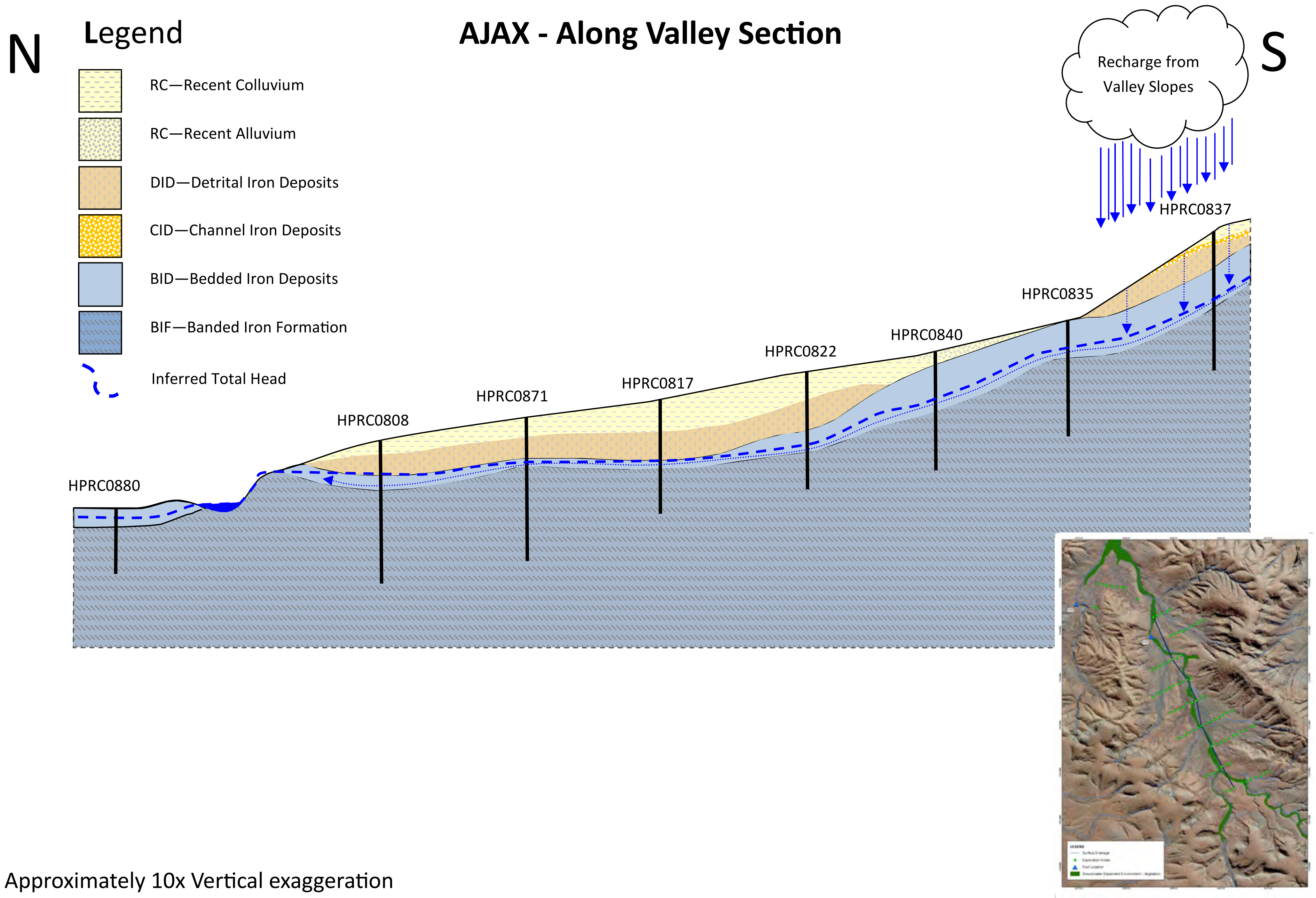
HPRC0851
HPRC0822
HPRC0850
HPRC0821
HPRC0849
HPRC0820
HPRC0848
HPRC0819
HPRC0847
Approximately 9x Vertical exaggeration
Legend
RC—Recent Alluvium
RC—Recent Colluvium
DID—Detrital Iron Deposits
CID—Channel Iron Deposits
BID—Bedded Iron Deposits
BIF—Banded Iron Formation
Inferred Total Head



Approximately 10x Vertical exaggeration

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Appendix D: Water Quality Data Collected at Champion, Eagle and Delta

Analyte	Units	Bore ID			NHMRC Drinking Water Guidelines[1]	
		BH-DP	BH-EP	BH-CHP	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	-	-
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]

Appendix 2: Geophysical Survey Results

Geophysical modelling of palaeochannel aquifer systems in the eastern Blacksmith tenement, W.A.

May - June 2011

FLINDERS MINES

GPX SURVEYS

Job 2455

TABLE OF FIGURES

1 JOB SUMMARY

1.1 INTRODUCTION

In May 2011 GPX Surveys performed an XTEM helicopter electromagnetic survey and interpretation of geophysical and drillhole datasets in the eastern drainage channels of Flinders Mines Blacksmith tenement in the central Pilbara. The aim of the project was to model and gain information on the structure and lithology of the area, targeting palaeochannels following the current drainage network.

Using the data acquired from this XTEM survey along with historical ground gravity, Airborne Frequency Domain EM, geophysical and geological logs and profile interpretations 'On-tenement', GPX Surveys continued to expand outside the tenement and produce a 3D sedimentary interpretation.

The project was completed in five stages:

1.) Interpretation of historical gravity and FDEM datasets for Flinders over the on-tenement areas of the block.
2.) Acquisition QC and processing of XTEM data producing Conductivity/ Depth Images (CDI).
2.) Profile modelling of the EM data comparing with other datasets and separating horizons.
3.) 2/3D expansion and combination of the EM and geological models and comparison with the previous interpretation, drillhole data and outcrop estimates to produce a modelled basement.
4.) Defining sedimentary horizons and 2/3D expansion of profile models to determine major lithology trends comparing with drillhole data.
5.) Production of final images, maps and report.

1.2 LOCATION DIAGRAM

Figure 1 and Figure 2 show maps of the acquired XTEM flight path and the drillhole locations and estimated surface outcrop boundary.

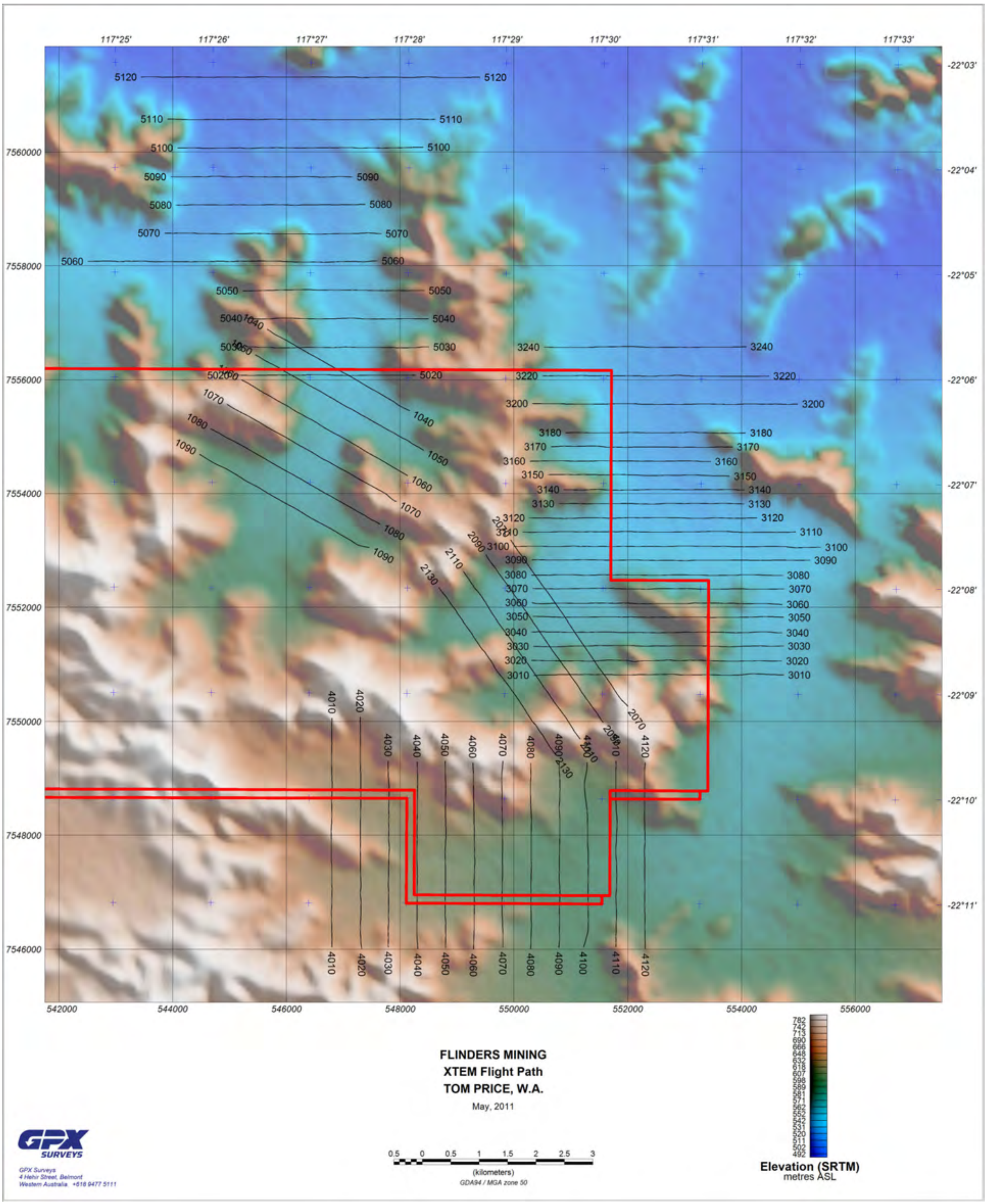


Figure 1: Flight Path map

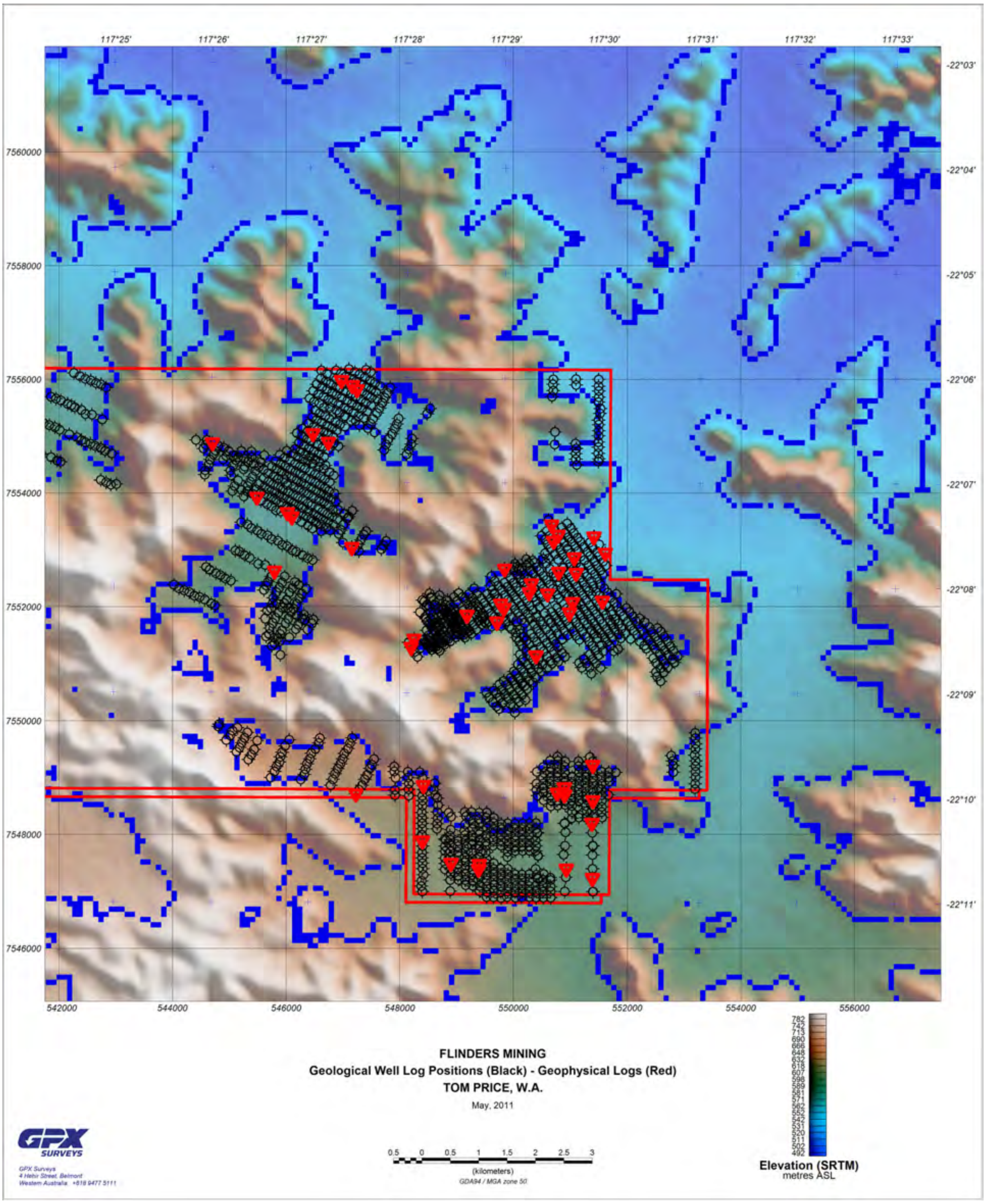


Figure 2: Drillhole Location and Basement Outcrop Map

Figure 3: Overview of the model area shown in red

1.3 PERSONNEL

The following personnel were involved in this project:

<u>Task</u>

Project Manager	Katherine McKenna
XTEM Processing	
- Field Data Processor	Joe Kita
- Final Data Processing	Dean Reynolds
Interpretation and Report	Mark Lowe

1.4 XTEM SURVEY SUMMARY

On the 28th April the GPX Surveys crew began to mobilise from Perth, arriving at Blacksmith Camp on the 30th April 2011. The crew assembled the XTEM rig. The helicopter arrived on site on the 30th April and the crew conducted ground tests. High level test flights required for commencement of survey were also carried out on the 30th April and production commenced the following day. The base station magnetometer was set up near the aircraft landing site which was adjacent to the Blacksmith Camp helicopter pad. Production began on the 1st May and was completed the following day. For safety reasons and data quality line 5120 the most northern line in the survey area was shifted 250m north of its original planned survey path to avoid the 125 feet high power line that ran down the length of the planned line. At the end of each day's flying all data was sent back to the offices of GPX Surveys for further processing and review. The rig was dismantled on the 3rd May 2011 and the aircraft and crew demobilised the same day.

2 SAMPLING TECHNIQUES AND DATASETS

2.1 AIRBORNE XTEM SURVEY

Boundary Coordinates

Start and end coordinates of each line can be found in Appendix A.

Line Specifications

The line specifications for the survey areas are as follows:

Traverse line spacing:	500 metres
Traverse line direction:	000° - 180° (NW / NE)
	090° - 270° (S)
	~135° - 315° (W / Delta)
Traverse line numbers:	1040 – 5120 (54 lines)

2.2 DIGITAL ELEVATION MODEL

The elevation model used in this survey is taken from the freely available SRTM satellite digital terrain model with ~90m cell size spacing.
An interpreted basement outcrop filter file was also created in-house using the DEM.

2.3 AIRBORNE MAGNETICS

Magnetics are used in this interpretation to find major structural features. The data is taken from the merged Australia wide Geoscience Australia (GA) Mag-spec survey with ~400m cell size.

2.4 GEOPHYSICAL AND GEOLOGICAL WELL LOGS AND PROFILE INTERPRETATIONS

A suite of well logs were provided by Flinders Mines with geological, hydrological and geophysical information. All the wells are located inside Flinders tenement boundary accounting for around 35% of the model area. These were accompanied with profile geological interpretations which were used along with the well logs.

2.5 GROUND GRAVITY AND FREQUENCY DOMAIN EM

Flinders Mines provided ground gravity over the delta deposit and 5 – frequency DigHEM data over much of the on-tenement part of the survey and also extending in the northeast. The DigHEM data was limited in penetration depth by the targeted frequencies – 900 Hz, 5500 Hz, 7200 Hz and 56000 Hz.

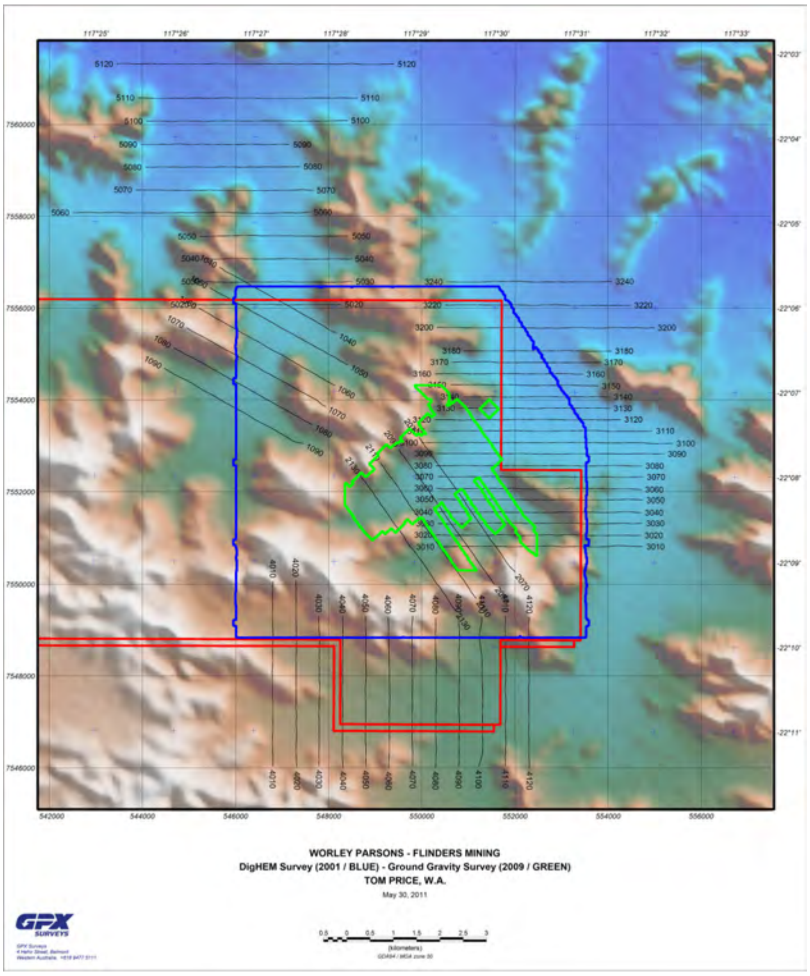


Figure 4: DigHEM and Ground Gravity Survey

2.6 GEOPHYSICAL DATASETS AND RANGE OF INVESTIGATION

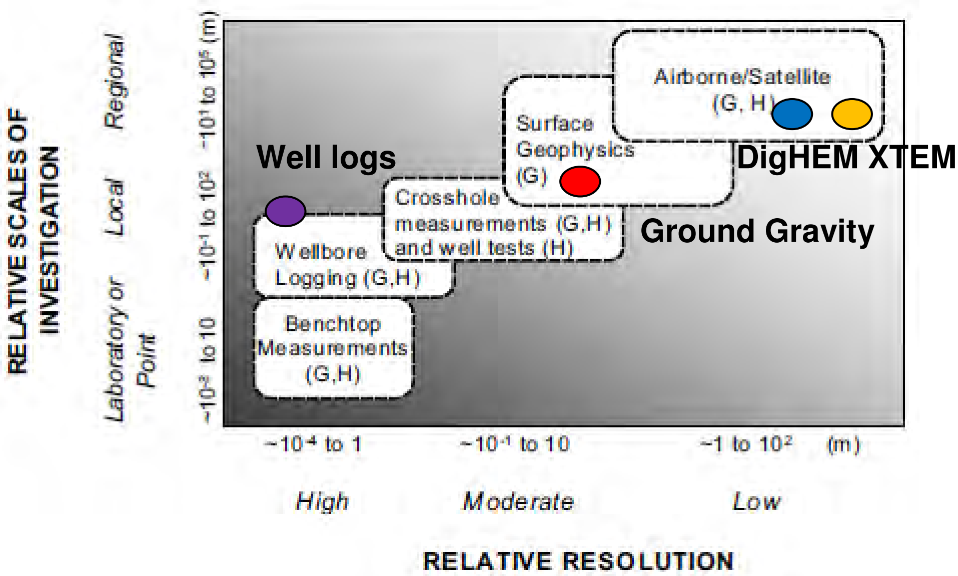


Figure 5: Scale of resolution for each of the survey types used (Rubin Y., 2005)

3 PROCESSING AND INTERPRETATION WORKFLOW

This section focuses on the process of constructing and defining geological models based on the different geophysical datasets and geological borehole and surface observations. Processing steps for airborne EM including creating CDI's are expanded on in the logistics reports for Job's 2455 and have been left out of this report, though parameters for the system are shown in Appendix B: J2455 XTEM Survey Specifications A schematic summary of the geophysical modelling steps involved are illustrated in Figure 6.

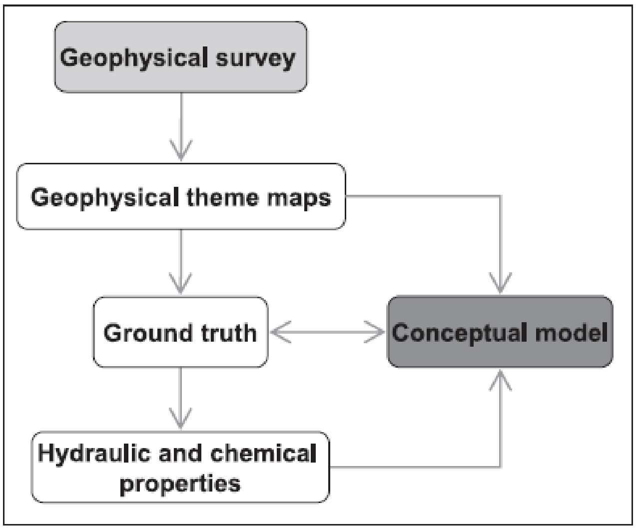


Figure 6: Workflow of a hydrogeophysical survey (Esben Auker, 2003)

In this case a preliminary model was created using historic DigHEM and ground gravity to assess the trend of the targeted basement surface off-tenement and to better focus the flight lines.

3.1 PRELIMINARY MODELLING USING HISTORIC GROUND GRAVITY AND FREQUENCY DOMAIN EM.

Figure 4 shows the extent of the 2009 ground gravity and 2001 DigHEM surveys. The purpose of the DigHEM survey was to detect zones of conductive mineralization and to provide information which could be used to map the geology and structure of the survey area (Fugro Report #3010). The frequencies used for this survey allow for only a moderate depth of penetration given the bulk conductivity of the area. The ground gravity was modelled for a single basement horizon using depth-to-basement and apparent density calculations. This was used to fit the depth solutions from the lowest frequency (900 Hz) DiGHEM response in the thicker parts of the palaeochannel where the EM couldn't penetrate the cover. This produced a preliminary depth-to-basement surface (Figure 7) which was used in the targeting of the XTEM flight lines.

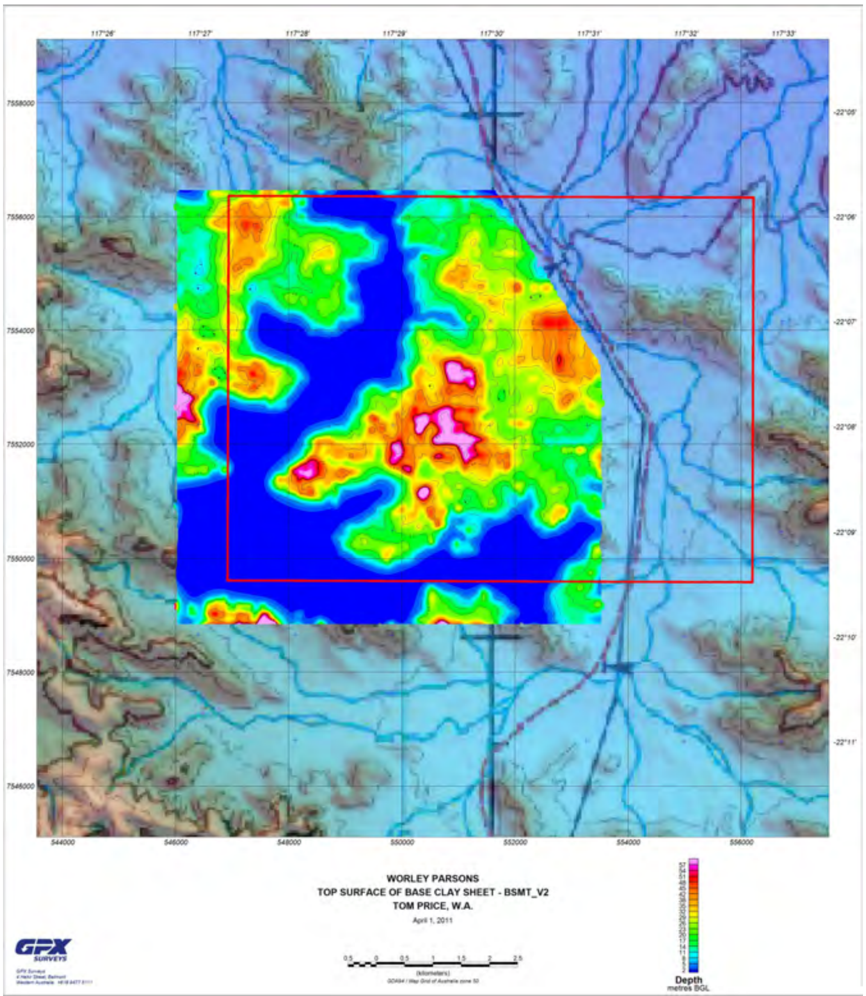


Figure 7: Initial basement clay surface interpretation using DigHEM and ground gravity

3.2 PROFILE MODELLING & CONSTRUCTING THEMATIC MAPS

The next stage of the modelling project involved importing final CDI databases and depthslice grids from XTEM Job 2455. These CDI databases have been produced using EMaxAir software (see Theory section below). 1D filtering was then applied to the EM to produce preliminary depth-to-basement models along the profiles.

3.2.1 Initial processing

Targeting potential fields requires an amount of observation and pass/rejecting of spurious or regionally biased effects based on an understanding of the geological background. The sedimentary geology in this area is assumed to be a lateral sequence of horizons with changing thickness and elevation, determined by the lie of the tectonic basement and having undergone some weathering. Target conductivities are extracted from the TEM profiles by using a suite of 1D filters of the cond vs. depth, cond vs. distance, and depth vs. distance. Horizontal and vertical derivatives are used to seek out lateral changes in EM and separate their apparent magnitude by comparing with the entire along-line dataset. Conductivity vs. depth processing produces conductivity roughness and minima-maxima profiles and grids which are used to determine continuous levels. These target conductivities are used to constrain the limits of 'significant' solutions, i.e. those conductivity solutions assumed to be related to geology at a given depth, and especially those above the level of the tectonic basement.

With these constraints, thematic maps based on changes in bulk conductivity and measurement density distribution are used to highlight any faults or rapid changes in elevation of highly contrasting units.

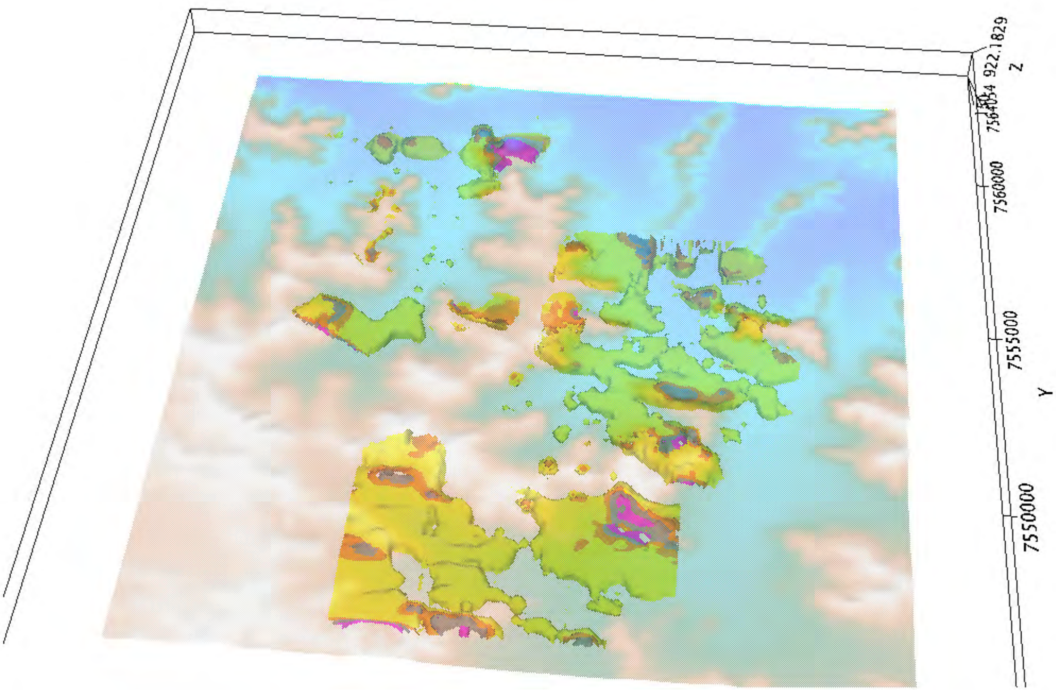
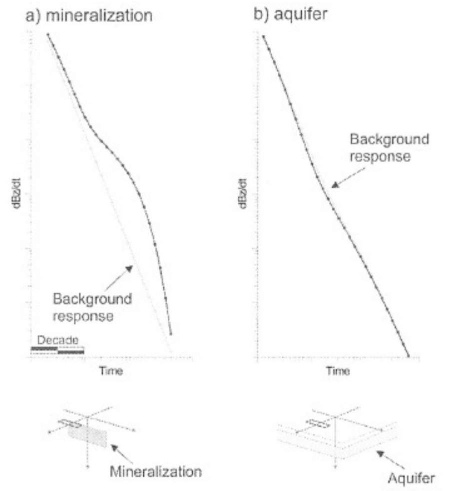


Figure 8: Isosurface map showing areas of high conductivity over the survey area

Theory

3.2.1.1.1 Airborne EM in Groundwater Exploration:

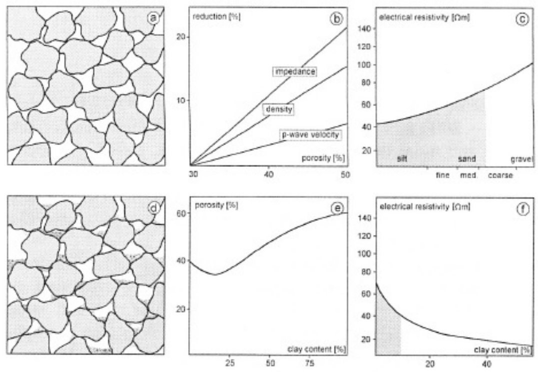
A number of important parameters that are used for groundwater exploration can be derived from variations in conductivity. It is sensitive to variations of porosity, water saturation, conductivity of the pore fluid and the clay content (Kirsch, 2010). If the background geology is known, these variations can be extracted from the conductivity measurements. The example below shows a typical TEM response of a discrete conductor compared to the response from a modelled aquifer.



... Comparison of the responses of a base metal mineral exploration and a hydrological target as approximated by a vertical thin sheet and layered-earth model, respectively. The mineral exploration target is a vertical sheet measuring 90 m by 30 m at a depth of 20 m, with a conductance of 100 S, in a 100 Ωm half space. The parameters for a three-layer hydrological model with a layer representing a sandy aquifer are: ρ_1 = 50 Ωm, ρ_2 = 100 Ωm, ρ_3 = 10 Ωm, t_1 = 30 m, and t_2 = 50 m, where t is the layer thickness. The parameters for the background model (without an aquifer or a sheet) are: ρ_1 = 50 Ωm, ρ_2 = 10 Ωm and t_1 = 80

Figure 9: EM Aquifer target (Kirsch, 2010)

Targetting these aquifers is dependent on relative change in conductivity. Because of the nature of TEM measurement there is only limited sensitivity to high-resistivity layers. This means that the conductivity of resistive layers sandwiched between conductive layers will produce only a minimal distortion and it is up to the accuracy of measurements of the conductive layers to determine the appropriate thickness and relative conductivity of the resistors. This causes models to produce similar results within the measuring error, called equivalent models. The grey shaded areas in the image below denote similar resistivities for clayey and clay-free material (Kirsch, 2010).



Physical properties of pore aquifer material (Gabriel et al 2003, with permission from Elsevier): influence of porosity and clay content on density, seismic velocity, and electrical resistivity: (**a**) well sorted, clay free sediment, (**b**) reduction of p-wave velocity (after Morgan 1969), density, and impedance as a function of porosity, (**c**) electrical resistivity as a function of grain size for fresh water saturated material (after TNO 1976), (**d**) clayey sediments, pore space partly filled with clay minerals, (**e**) porosity related to clay content (artificial sand – clay mixture, Marion et al. 1992), (**f**) electrical resistivity related to clay content after Sen et al. (1988)

Figure 10: Sediment / fluid effect on conductivity (Kirsch, 2010)

Typical values for effective porosity are: clay < 5%, fine sand 10-20%, coarse sand 15-30%. It follows that most geophyiscal aquifer targets are relatively resistive.

3.2.1.1.2 Horizontal and Vertical Derivative

The horizontal and vertical derivatives of profiles are used to find lateral and mixed lateral/vertical changes. These are then combined in the depth-to-basement calculations discussed below.

3.2.1.1.3 Analytic Signal

The Analytic solution uses line profile data to estimate the depth to source. The model assumes that the source is either a vertical or horizontal contact with infinite depth. A window of different width increments slides along the line profile and solutions for both types of sources are generated. The solutions are derived from dx, dy and dz and then interpolated and defined by the window width and increment.

To reduce the number of possible sources the solutions may be clustered. The final clustered solutions are then plotted on a map and a depth analysis can be conducted. The technique is summarised in the following equation by (MacLeod I.N., 1993)

The amplitude of the analytic signal ($|A(x,y)|$) at any location (x,y) is given by:

$$|A(x,y)| = [(\delta T/\delta x)^2 + (\delta T/\delta y)^2 + (\delta T/\delta z)^2]^{1/2}$$

where T is the measured field at (x,y).

Figure 11: The amplitude of the 3D analytic signal (Macleod et al., 1993)

This is used for determining the palaeochannel depth in the ground gravity.

3.2.1.1.4 eMax Air CDI

EM CDI sections of the flight lines are created using eMaxAir software (by Fullagar Geophysics).

> "Conductivity-depth transformation is accomplished in two steps. Measured voltages or B-field at a given delay time are first transformed to apparent conductivity. For dB/dt data, the assigned depth, z(t), at each time is the depth of the electric field or current maximum (Emax depth) in a half-space with conductivity equal to the apparent conductivity. For B-field data, the depth to the halfspace B-field maximum (Bmax depth) is employed. CDI sections based on apparent conductivity provide a vertically smoothed representation of the true conductivity profile. The apparent conductivity at any time can be represented as an inner product of the true conductivity with the Frechet kernel. The Frechet kernel at time t can be approximated as a linear function, decreasing from its maximum value at the surface to zero at a depth d(t). Therefore, given apparent conductivities from the CDI algorithm, a sharper estimate of the true conductivity can be generated via solution of a simple integral equation." (Fullagar, 2001)

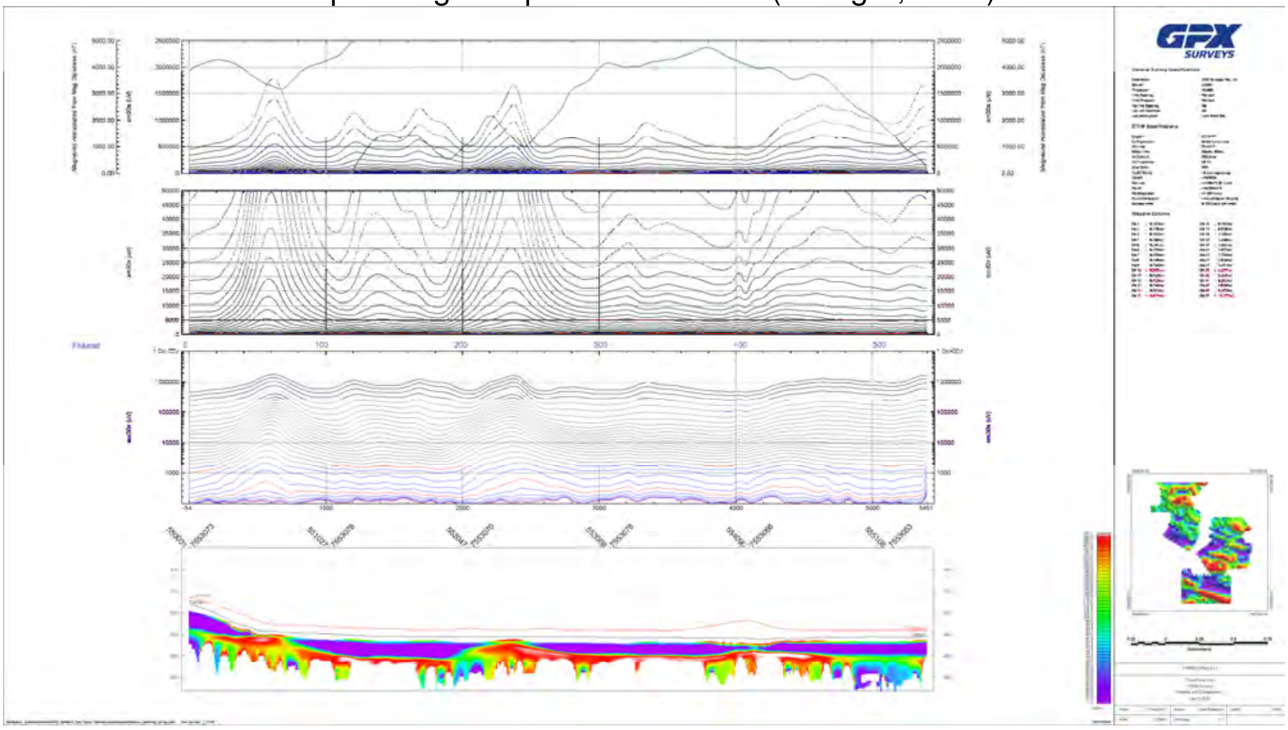


Figure 12: XTEM CDI section example

Processing Summary

A combination of Geosoft Oasis Montaj extensions, 1D-FFT, MAGMAP and Depth-to-Basement (PDepth) was used to generate profile model depths/ densities while the apparent conductivities were produced using eMax Air.

For a good review of 1D filtering methods used and a brief description on their effect on the data GETECH has a published document 'Advanced Processing and Interpretation of Gravity and Magnetic Data, 2007' (GETECH, 2007).

3.3 CONSTRAINTING TO THE GEOLOGY

Geological information is compared to geophysical responses to target horizons and thicknesses, better defining the model along line and then in 3D. Surface outcrop maps and borehole positions are used to fit the horizons between the modelled profiles.

3.3.1 Technique

The process of collaborating information under probabilistic parameters according to the resolution of the different geophysical methods is based on Bayes' Theorem.
"Bayes' theorem serves to update the plausibility of a proposition as the state of information changes because of the availability of new data" (Rubin Y., 2005).

Bulk conductivities and densities are established from the boreholes and surface geology, using any geophysical measurements, or assumptions from the lithology and structural background. The fitting resolution for the targeted geology will be proportional to the resolution of the geophysical and geological surveys. In areas with little geological information, depth to the basement surface determines whether the results are better determined by gravity or TEM models.

It is assumed that there is generally a lower conductivity and density contrast between the sedimentary horizons than the basement/ sediment horizon. The large density contrast between the basement and the sedimentary horizons causes the gravity solutions to be skewed. 'Visible' variation in the near surface for potential field methods is proportional to the difference in depth/thickness * conductivity/density when compared to the surrounding units (see Theory). It follows that when finding the depth-to-basement, in areas with deep basement, the EM will generally have decreased resolution and reduced conductivity contrast, and the gravity solutions will generate a more accurate result. Conversely in areas of complex and highly contrasting near surface, the TEM results are given more preference.

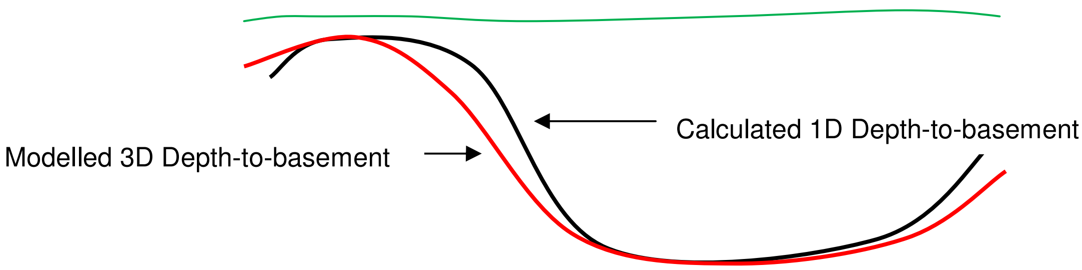
Importing drillhole information

Flinders Mines provided GPX Surveys with a database of the position and extent of the geological groups at the on-tenement drillhole positions. Geophysical information was also interpreted from well-logs of PDF documents though, because of the time-intensive nature of the data format and that the measurement units were not provided, only a small selection of the geophysical well logs were used for calibrating the bulk conductivities for each of the sediment groups. These groups were then gridded with varying levels of expansion to compare with the line data and to assess structural trends.

Expanding the depth-to-basement models to 2/3D.

The next stage of the processing work involved expanding the profiled basement models to an x/y/ value domain. The EM and gravity 1D-model profiles are gridded, expanded and filled in the model area. Results from both survey types are combined using the geological constraints to decrease the uncertainty between the survey lines and increase resolution. An iterative process of fit to the model is then applied with a Gaussian or cosine drop-off filter and increasingly smaller filter lengths decreasing to roughly ¼ cell size of the constraint separation.

The filtering will causes a distortion of the basement level in areas with high gradient responses but will remain true to depth-to-basement calculations in areas with constant depths over distances greater than the minimum filter width. An example of this is shown below.



Separating and extracting layered earth horizons

The bulk conductivities for the assumed sedimentary groups are clustered to the resolution of the model and then the surface horizons are estimated by the level of sharpness in the depth/conductivity gradients and proximity to relative (Downhole geophysics) and 'textbook' results for the modeled rock types. Constraints are applied from the height of the DEM and the depth of the calculated basement depth.

Geological Group	Conductivity (mS/m)
Recent Alluvial (RCT)	70
Detrital Iron (DID)	30
Clay (CLY)	100-500
Channel Iron (CIDg)	120
Channel Iron (CIDh)	80
Banded Iron (BID)	300
Basement (BMT)	250 - 1500

Table 1: Estimated bulk conductivities

Expansion of stratigraphy model to 2/3D

The sedimentary horizons were expanded similar to that applied to the basement calculation. After finalising the profile models the data is gridded and then expanded to the survey area, before being filled. The constraints grid consists of a combination of horizon conflicts and proximity to EM flight lines, drillholes and outcrop (Figure 30). Non-uniqueness is compensated for by accepting the depths and thickness most geological likely and by masking less 'visible' units.

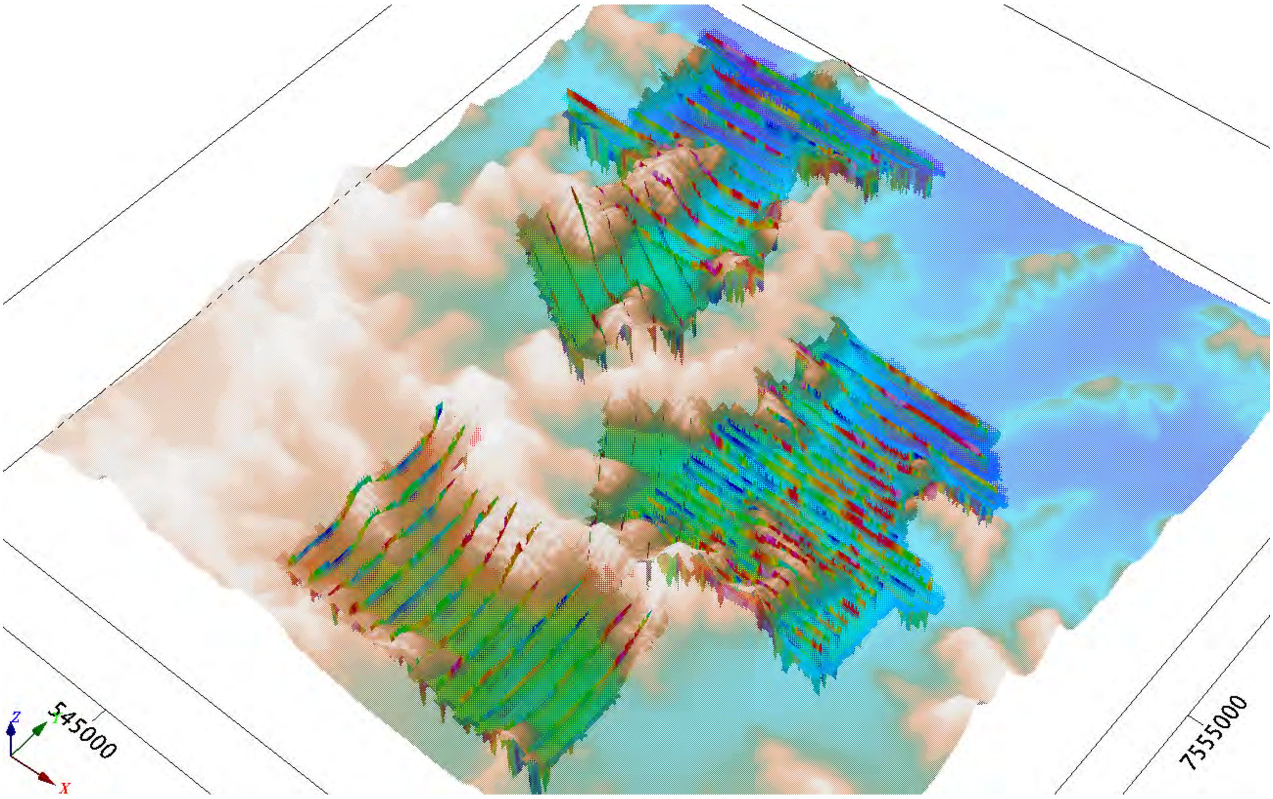


Figure 13: Basement model with CDI profiles

Processing Summary

Yoram Rubin and Susan Hubbard expand on the theory and implications of applying Bayes' Theorem and probability modelling in the section 'Stochastic Forward and Inverse Modeling: The "Hydrogeophysical" Challenge' in their book Hydrogeophysics, 2005.

4 PRODUCTS DELIVERED

Products were delivered throughout the course of the project. EM Channel MapInfo Tiffs were sent at the completion of the survey along with depth slices and CDI's. During the modelling process preliminary and final located images were sent to Flinders Mines consultants.
Final products for the interpretation and report were delivered on 17th June 2011.

DIGITAL PRODUCTS

- CDI profiles and depthslices are included in the 2455 Final Logistics Report.
- Geosoft Grids and MapInfo/ ArcView Tiffs of
  - Recent (RCT) / Detrital Iron (DID) interface Depth Model
  - Detrital Iron (DID) / Channel Iron (CID) interface Depth Model
  - Channel Iron (CID) base surface Depth Model
  - Clay (CLY) top surface Depth Model
  - Clay (CLY) base surface Depth Model
  - Banded Iron (BID) top surface Depth Model
  - Banded Iron (BID) base surface Depth Model
  - Basement (BMT) Depth Model
  - DID Thickness Model
  - Clay Thickness Model
  - Consolidated Channel Iron (CIDg) –Thickness Model
  - Porous Channel Iron (CIDh) – Thickness Model
  - BID Thickness Model
  - Valley Flatness Factor
  - Average Conductivity
  - Conductivity Roughness
  - Uncertainty of measurements
  - Digital Elevation Model
  - Flight Path
- Digital version of the modelling and interpretation report.

HARDCOPY PRODUCTS

Two hardcopies of the final report were sent along with a DVD containing a digital version of the maps, profiles and report.

4.1 FINAL IMAGES AND MAPS

4.1.1 Recent (RCT) / Detrital Iron (DID) interface Depth Model

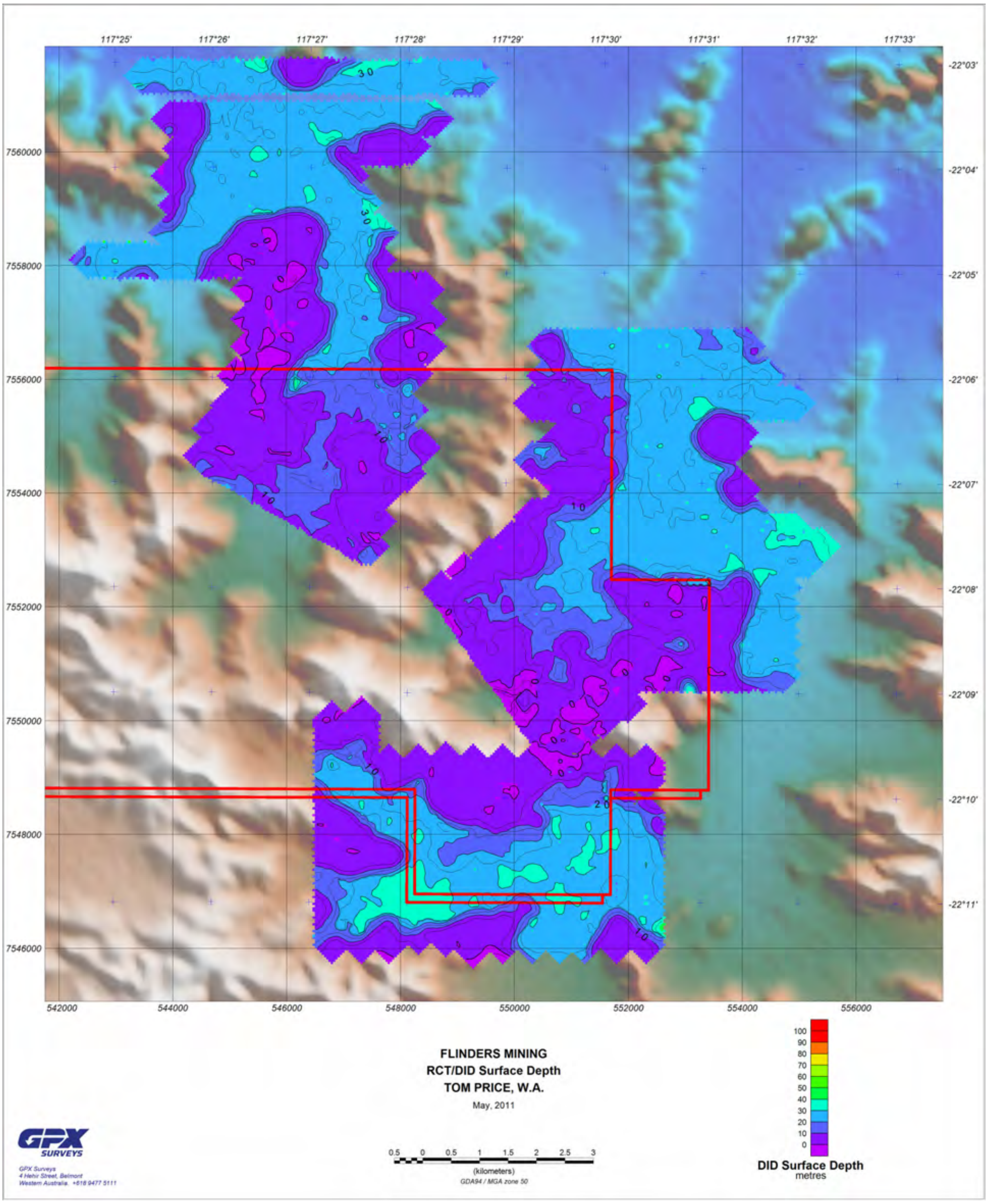


Figure 14: DID Top Surface Depth Model

4.1.2 Detrital Iron (DID) / Channel Iron (CID) interface Depth Model

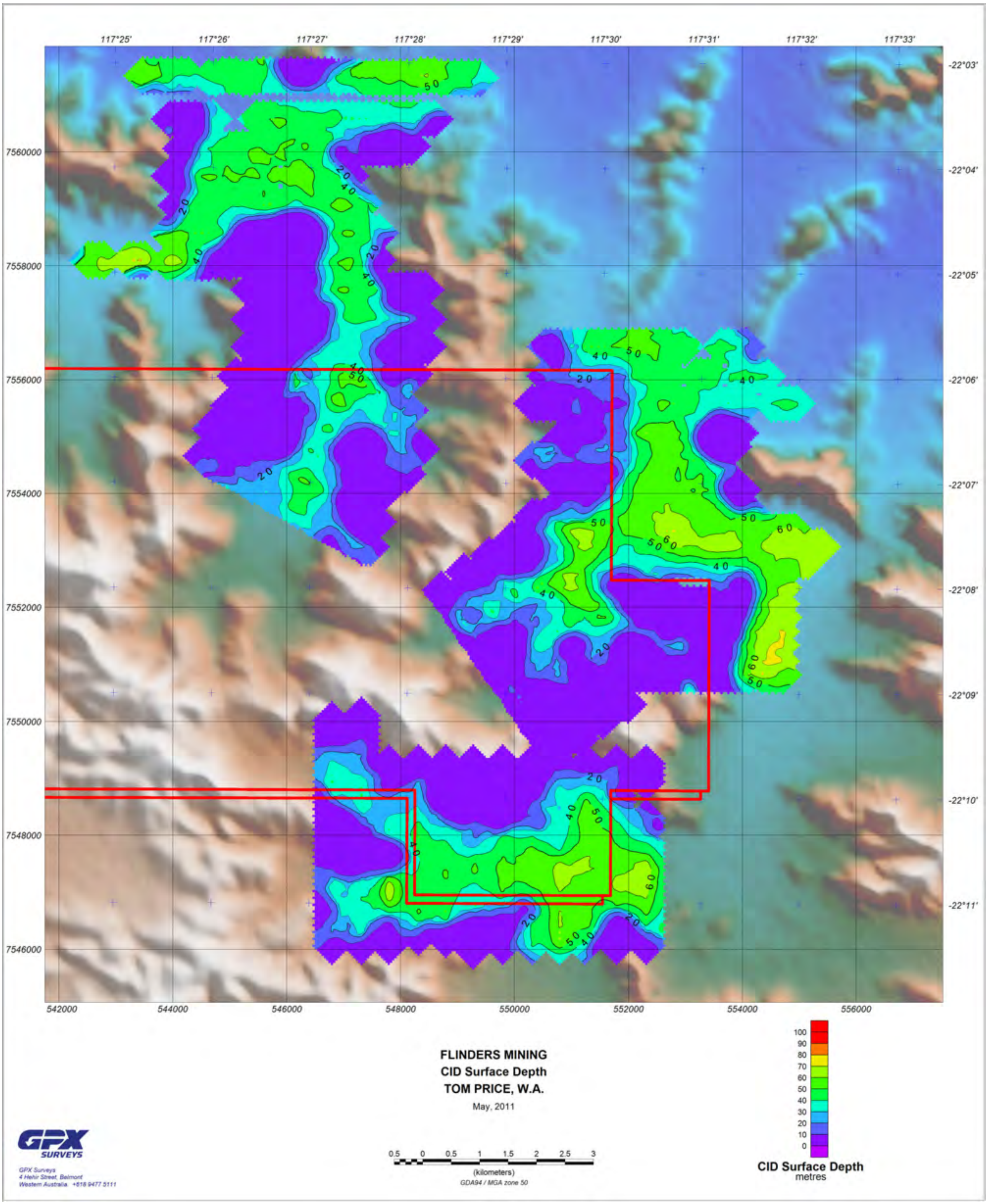


Figure 15: CID Top Surface Depth Model

4.1.3 Channel Iron (CID) base surface Depth Model

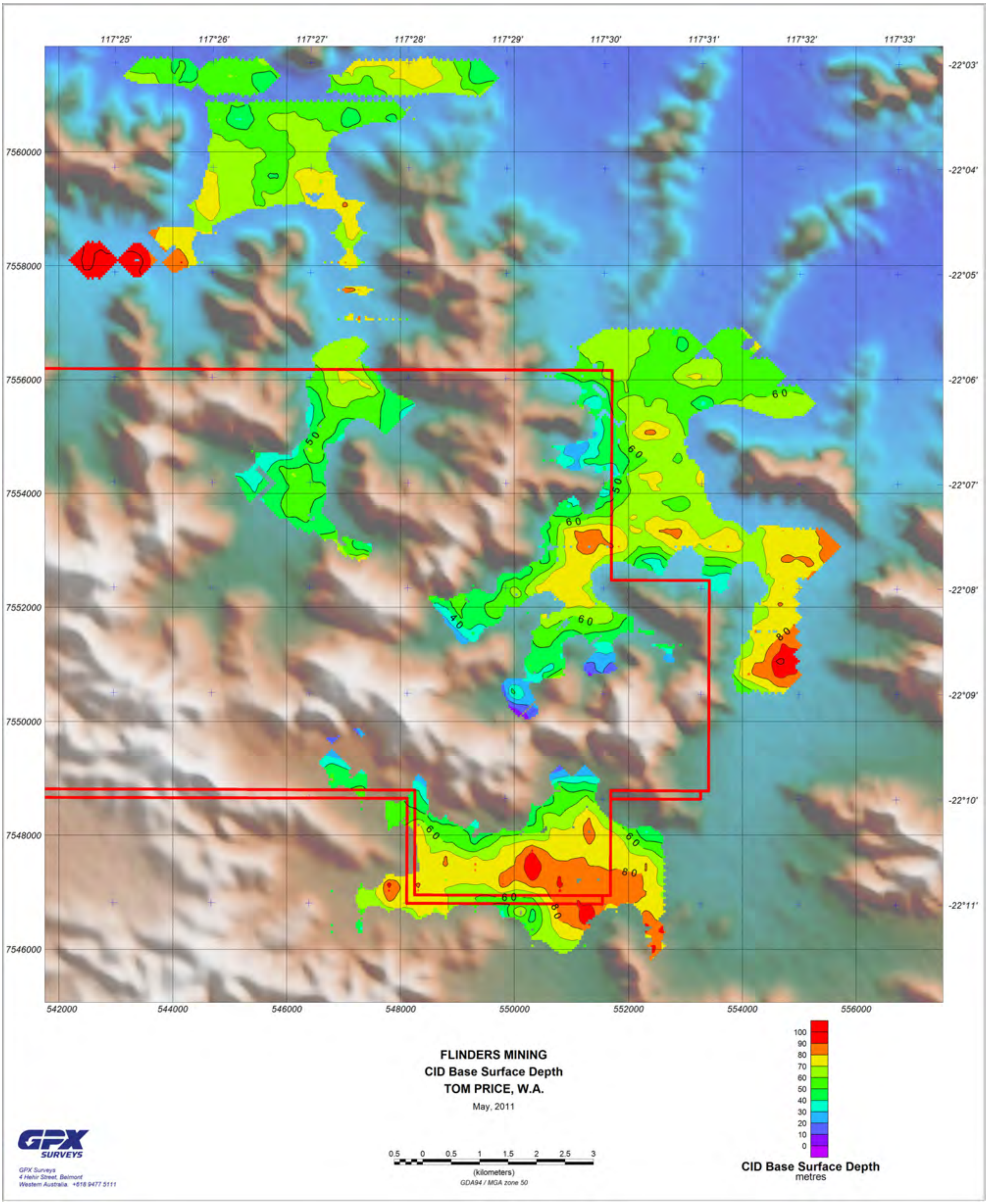


Figure 16: CID Base Surface Depth Model

4.1.4 Clay (CLY) top surface Depth Model

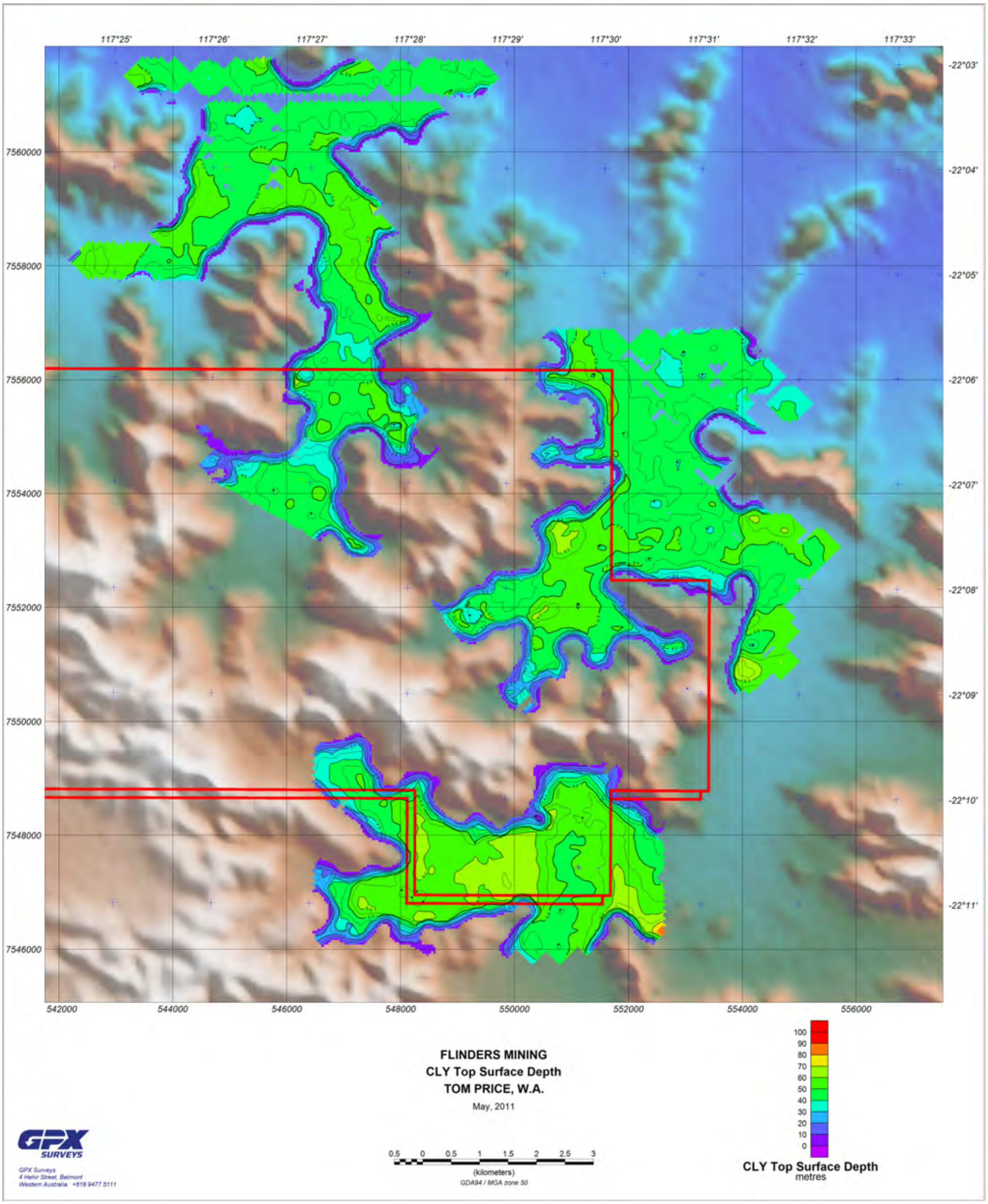


Figure 17: Clay Top Surface Depth Model

4.1.5 Clay (CLY) base surface Depth Model

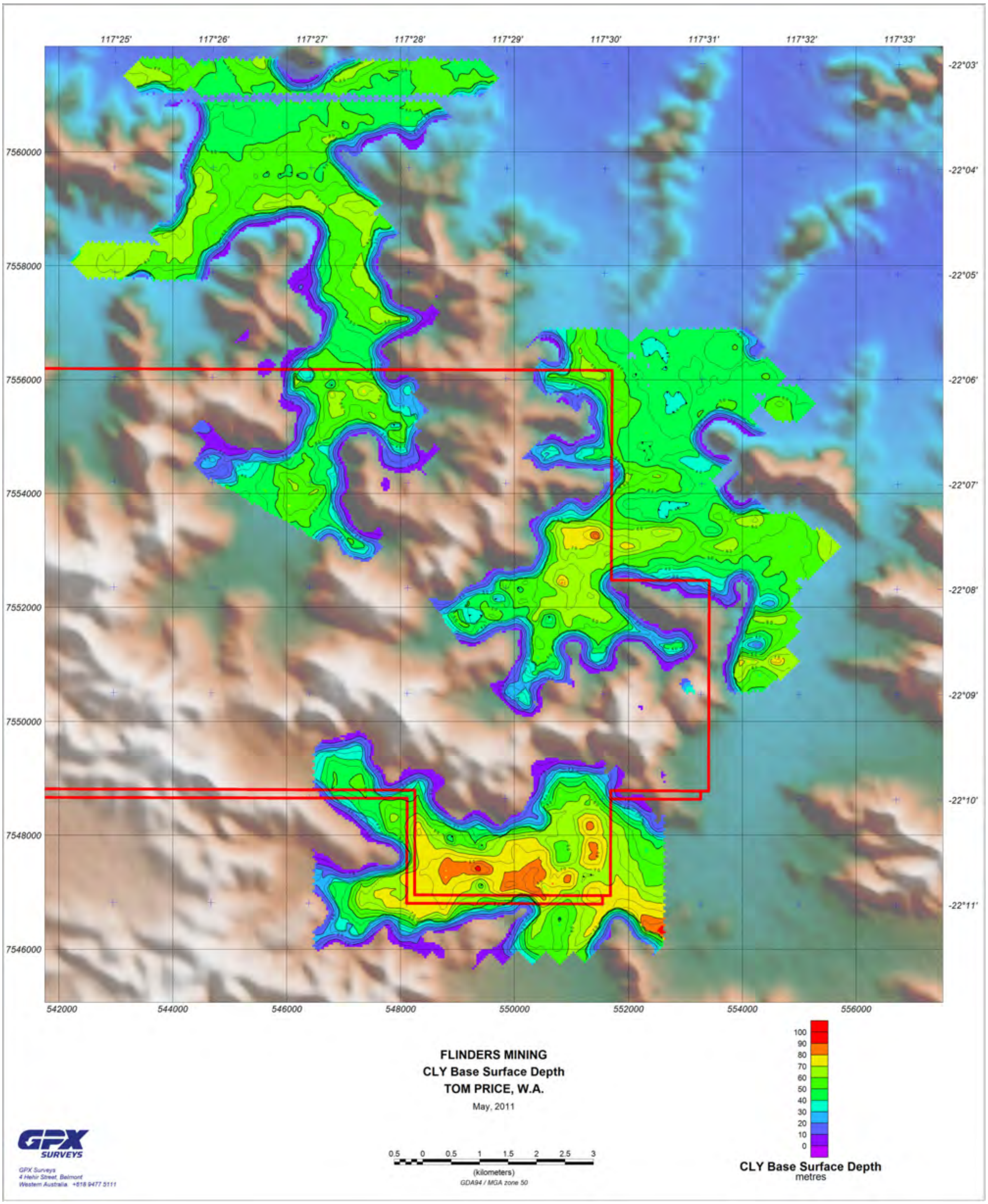


Figure 18: Clay Base Surface Depth Model

4.1.6 Banded Iron (BID) top surface Depth Model

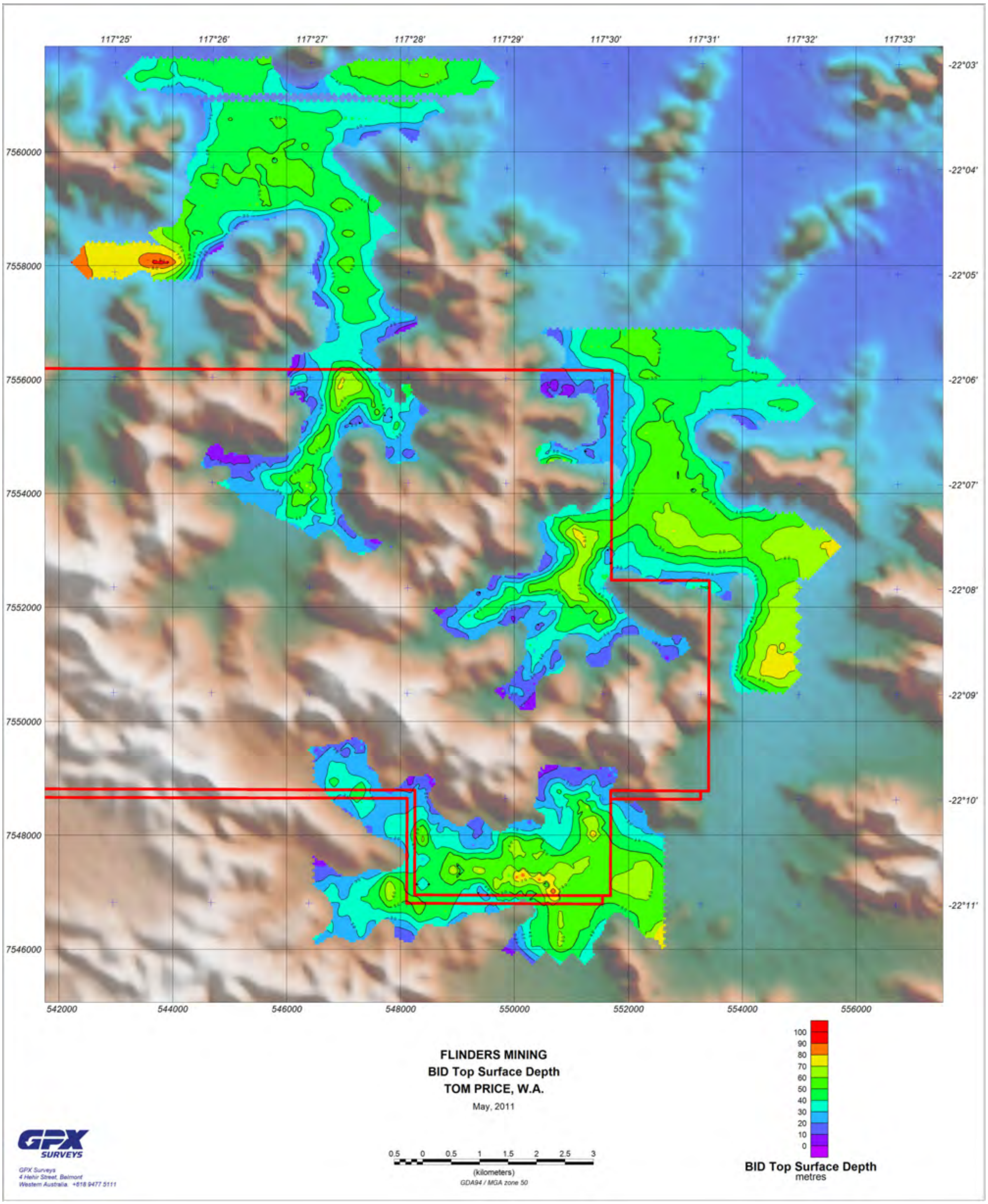


Figure 19: BID Top Surface Depth Model

4.1.7 Banded Iron (BID) base surface Depth Model

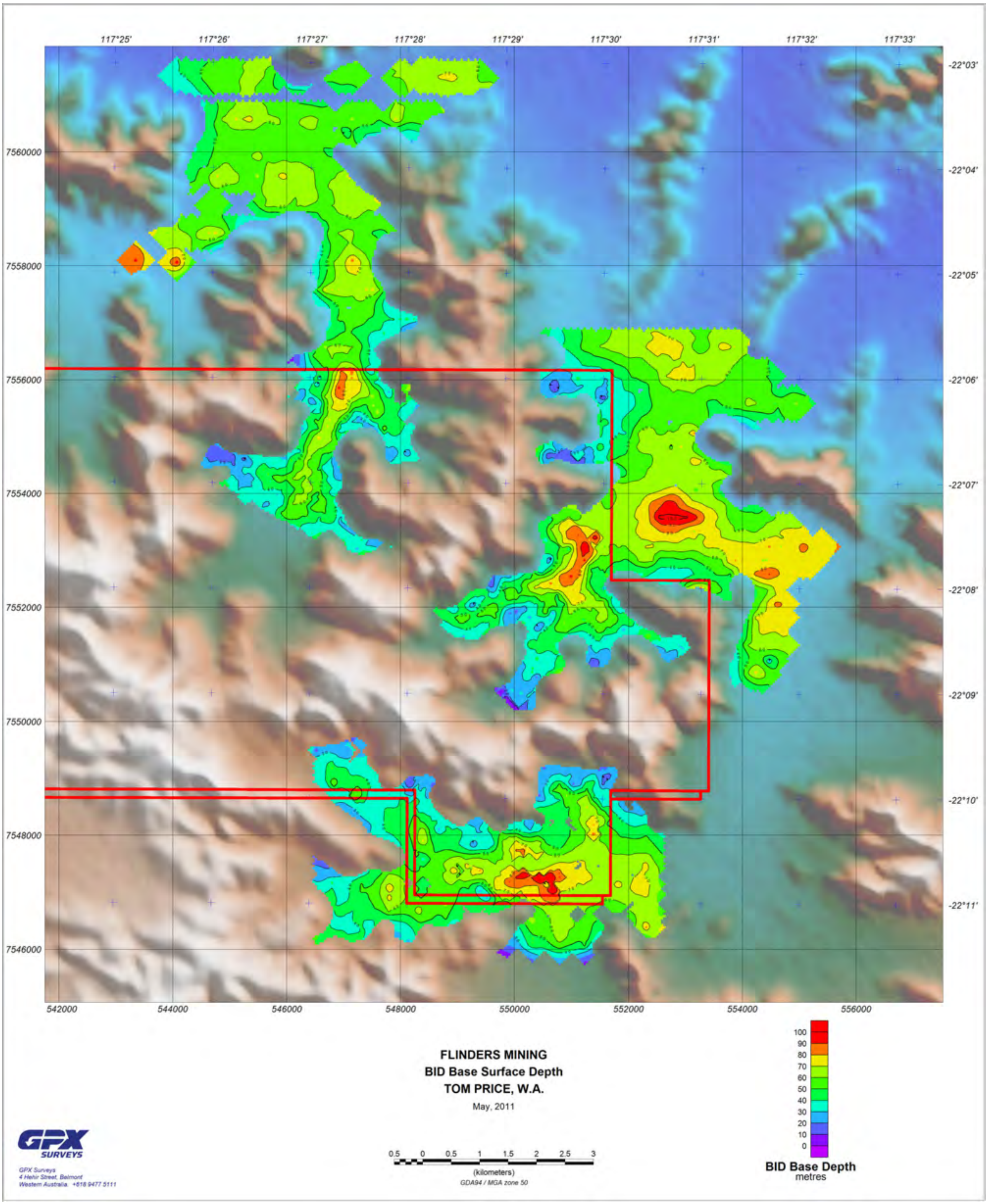


Figure 20: BID Base Surface Depth Model

4.1.8 Basement (BMT) Depth Model

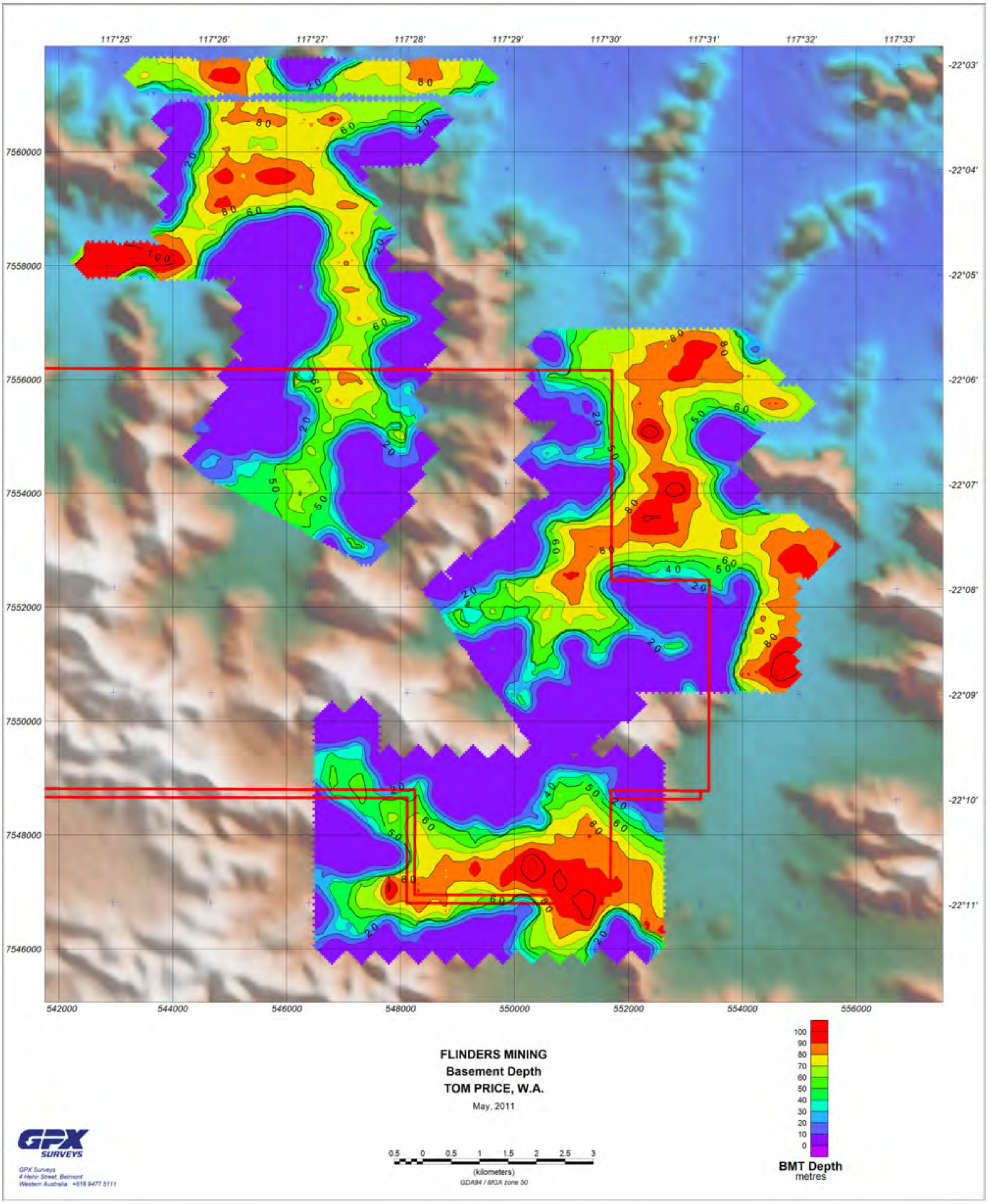


Figure 21: Basement Depth Model

4.1.9 DID Thickness Model

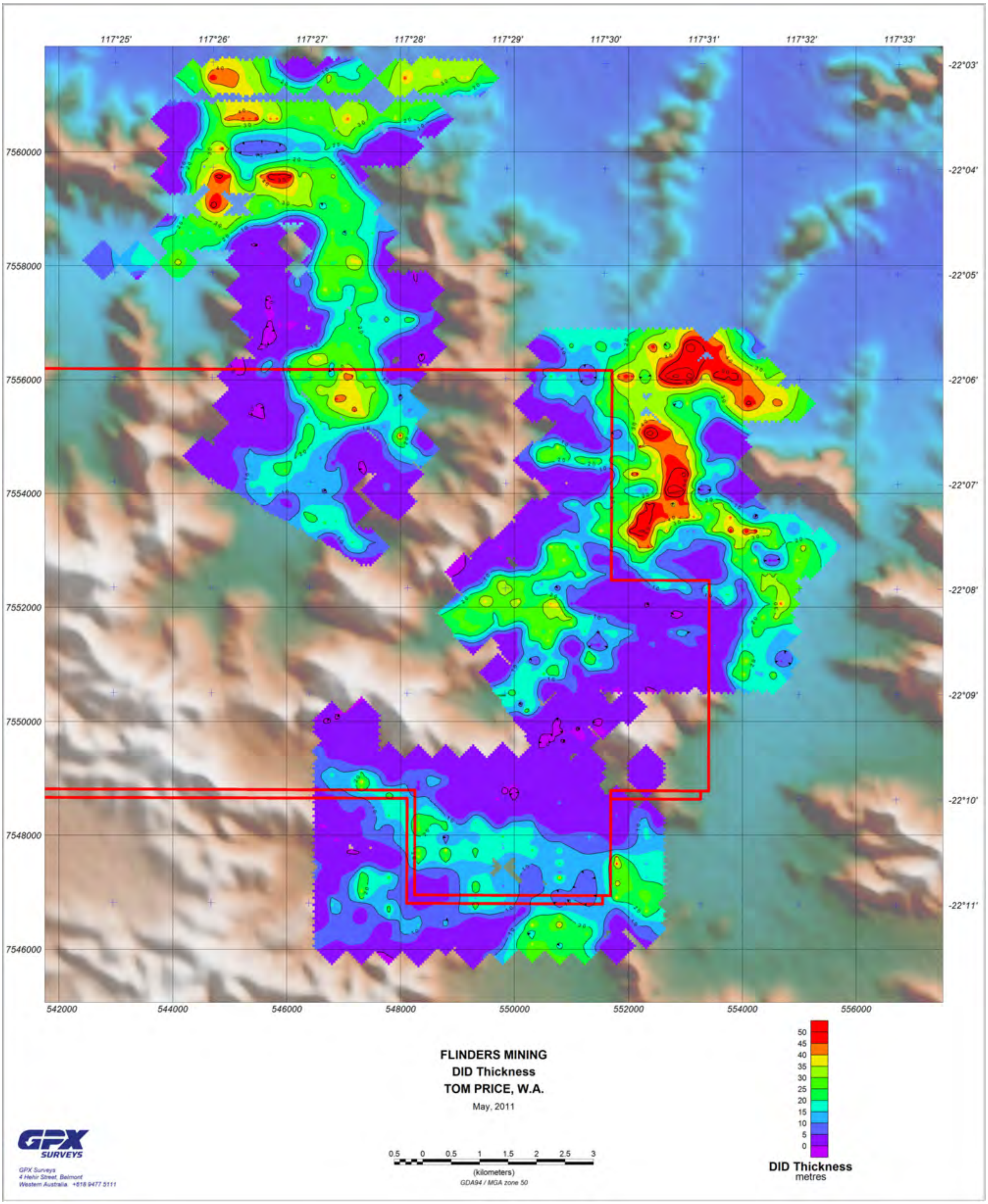


Figure 22: DID Thickness Model

4.1.10 Clay Thickness Model

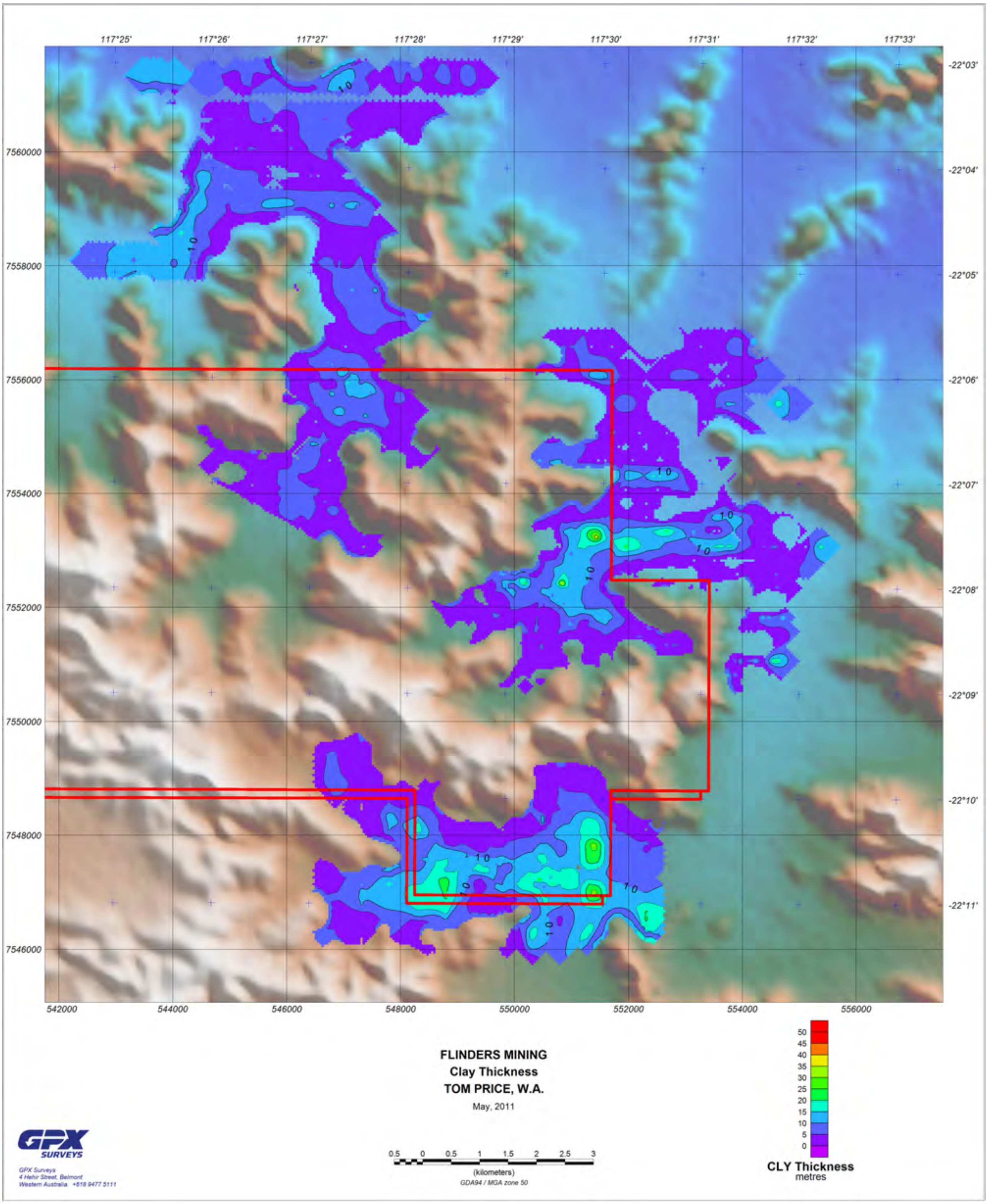


Figure 23: Clay Thickness Model

4.1.11 Consolidated Channel Iron (CIDg) –Thickness Model

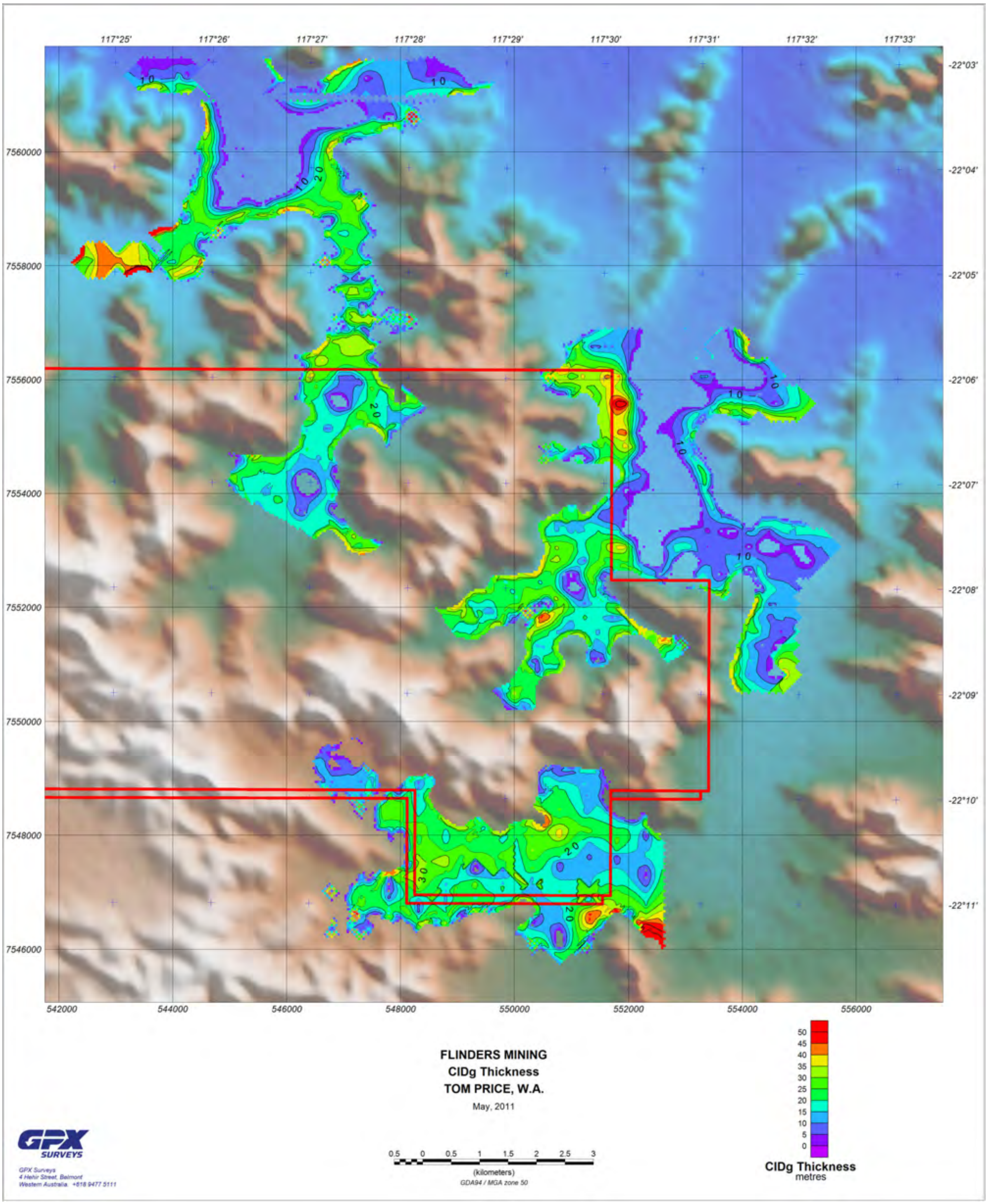


Figure 24: CIDg Thickness Model

4.1.12 Porous Channel Iron (CIDh) – Thickness Model

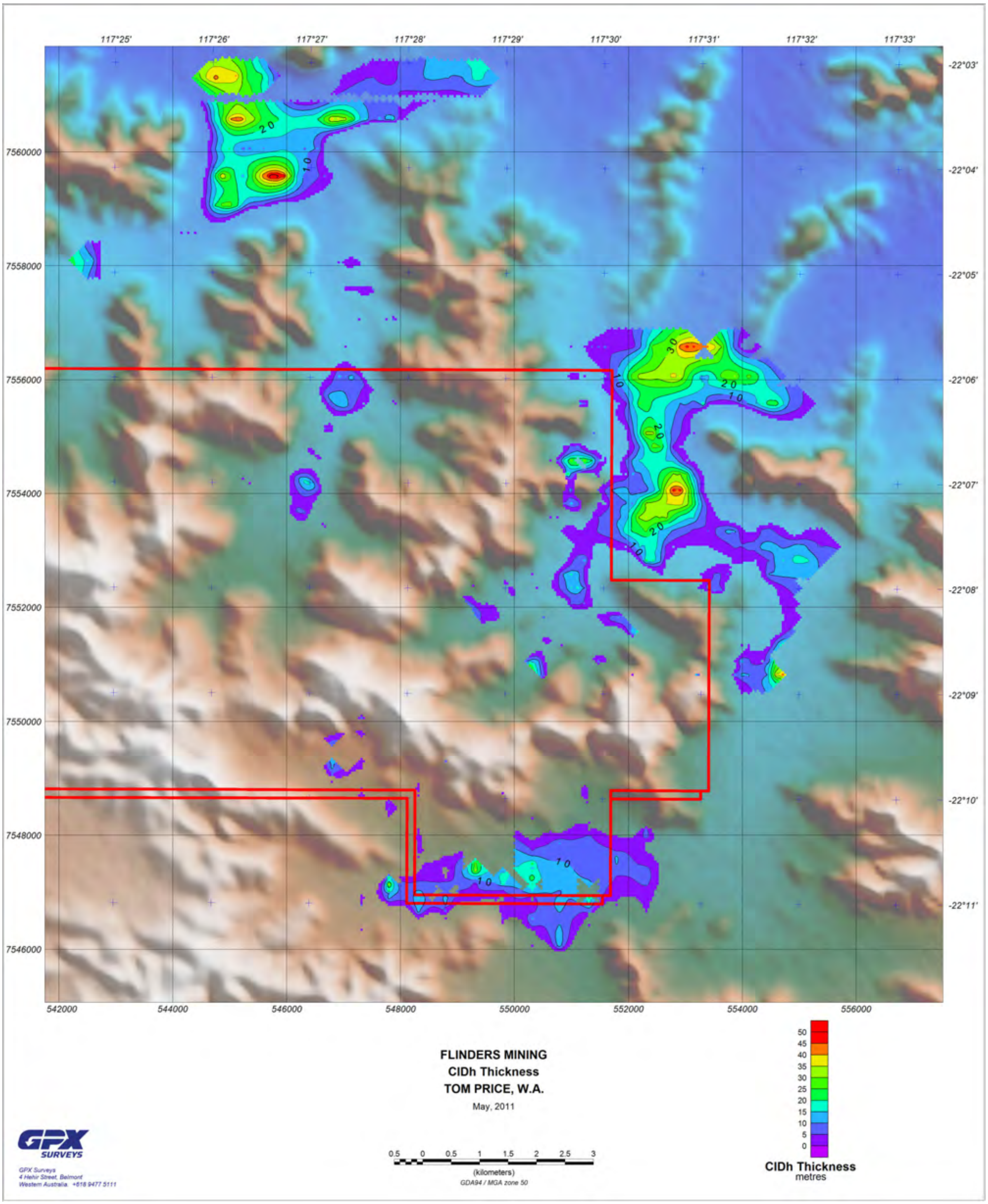


Figure 25: CIDh Thickness Model

4.1.13 BID Thickness Model

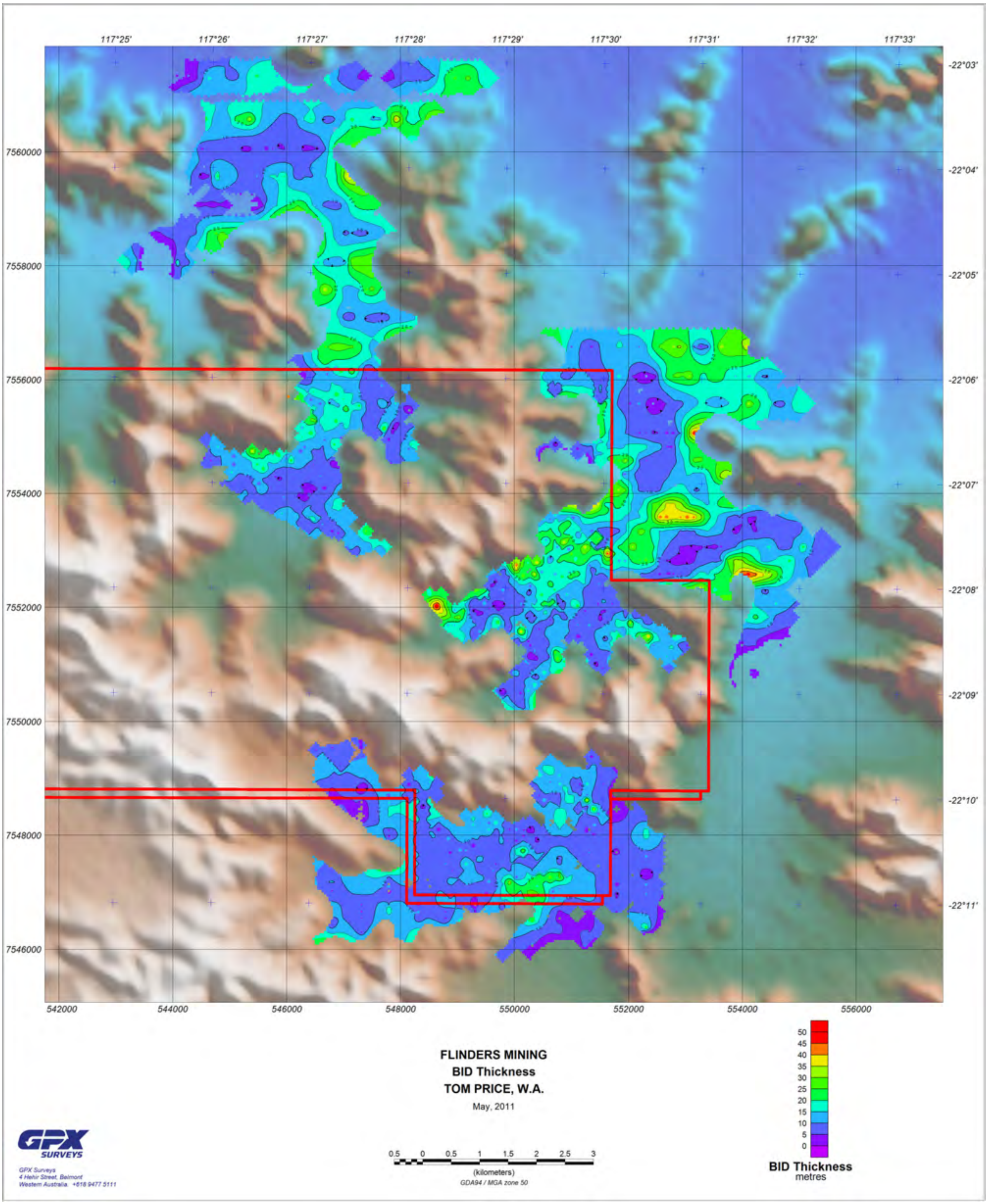


Figure 26: BID Thickness Model

4.1.14 Valley Flatness Factor

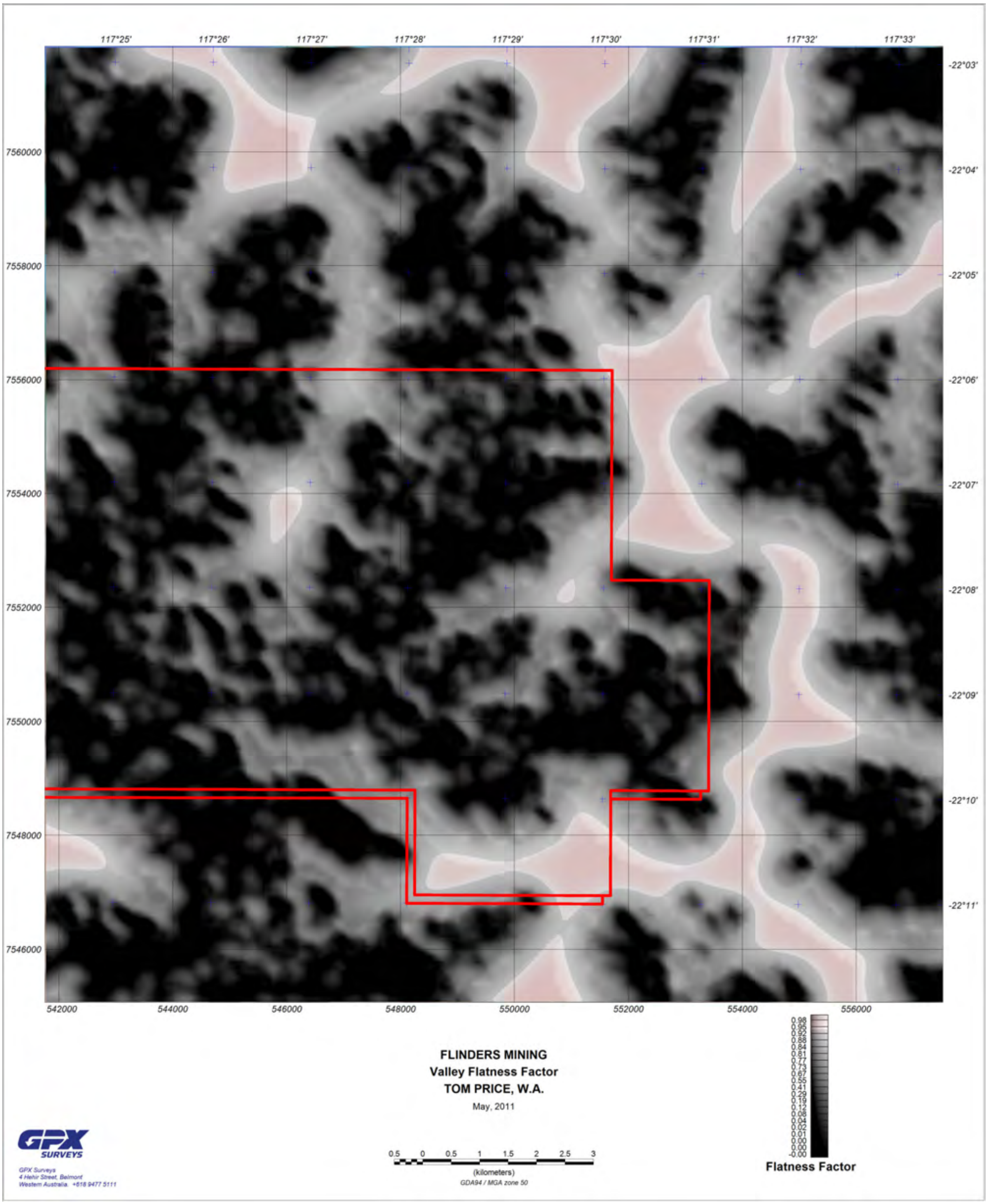


Figure 27: Palaeochannel valley bottom flatness factor - used in outcrop estimates

4.1.15 Average Conductivity

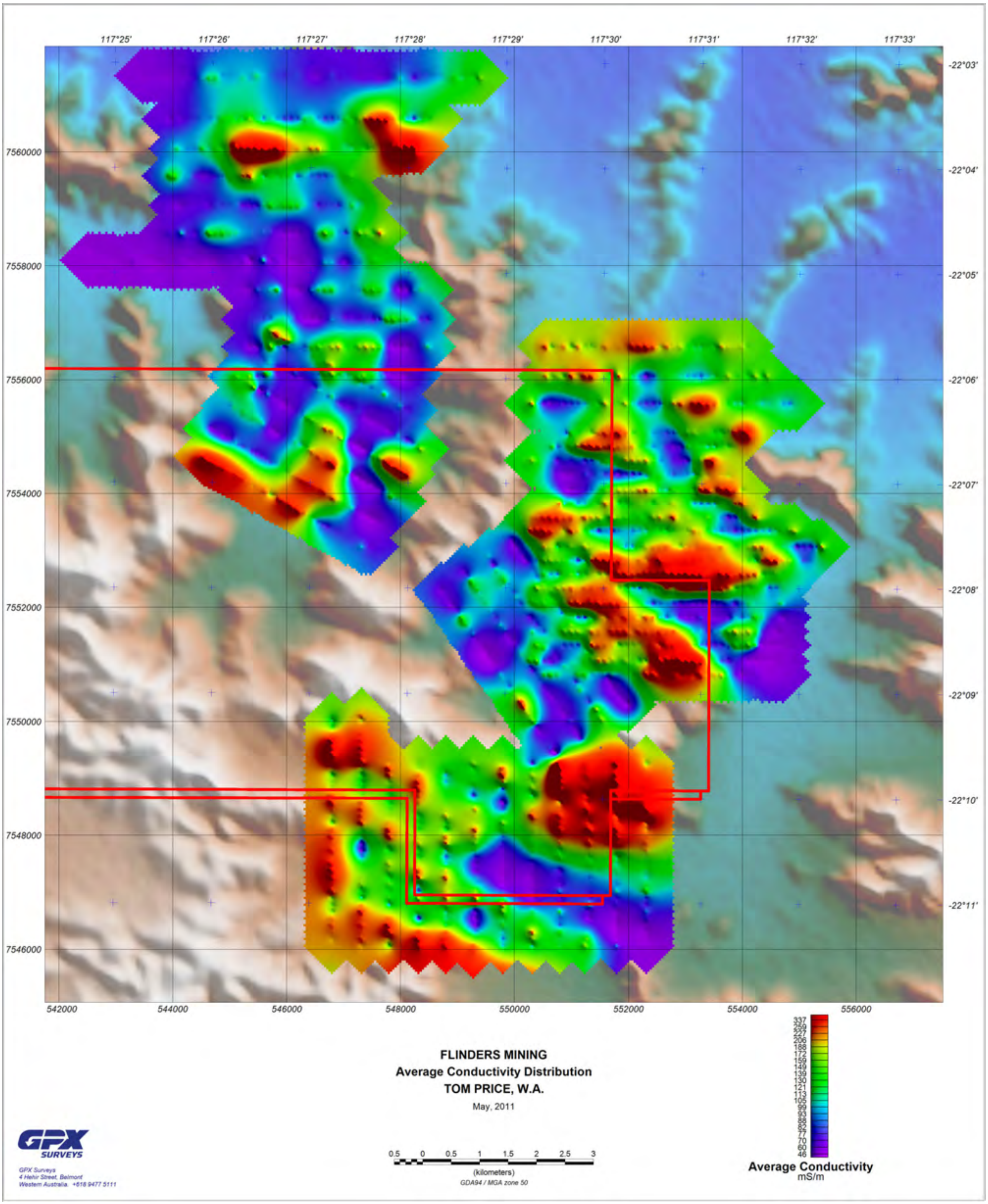


Figure 28: Average conductivity distribution

4.1.16 Conductivity Roughness

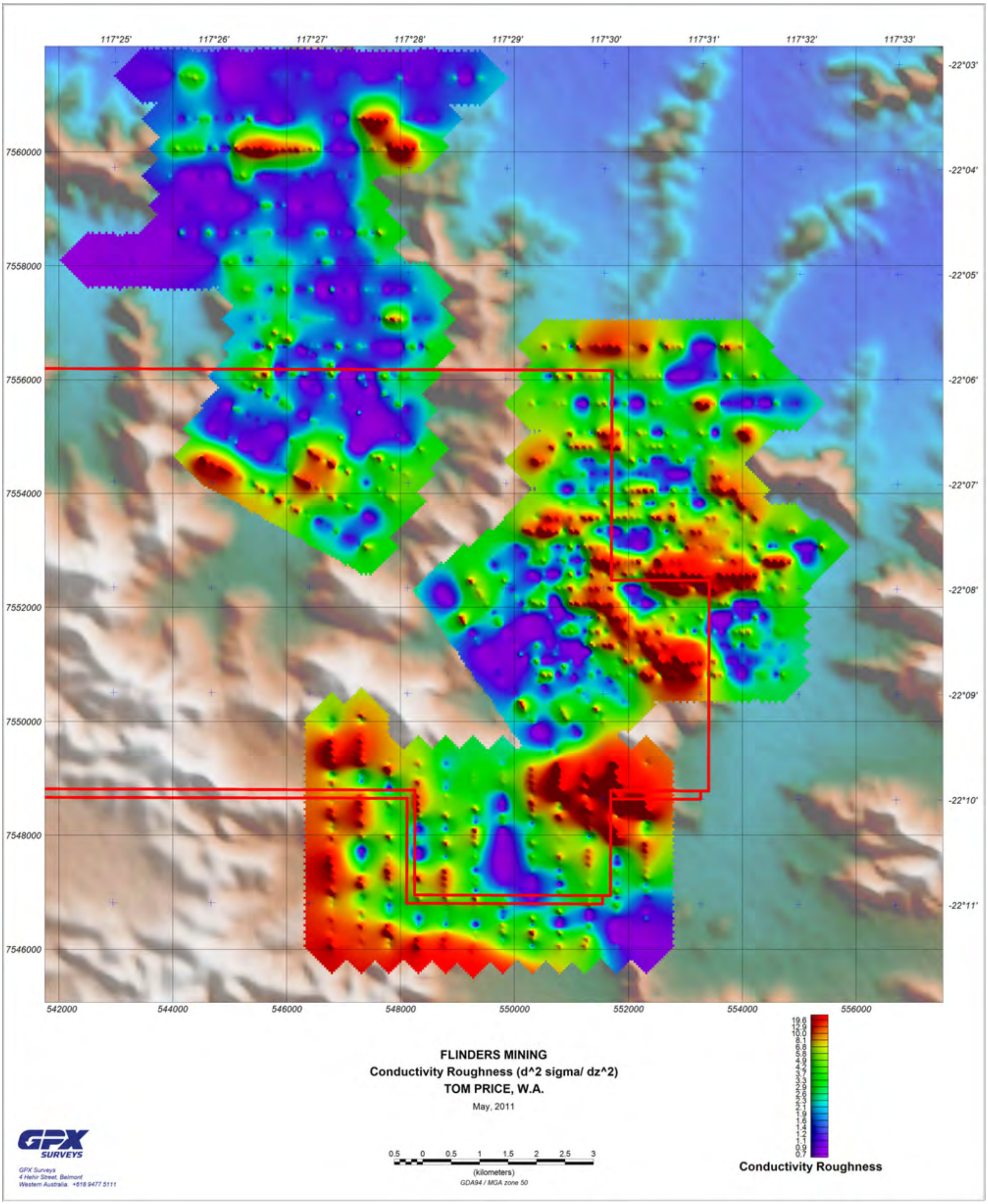


Figure 29: Magnitude of the rate-of-change in conductivity with depth

4.1.17 Uncertainty of measurements

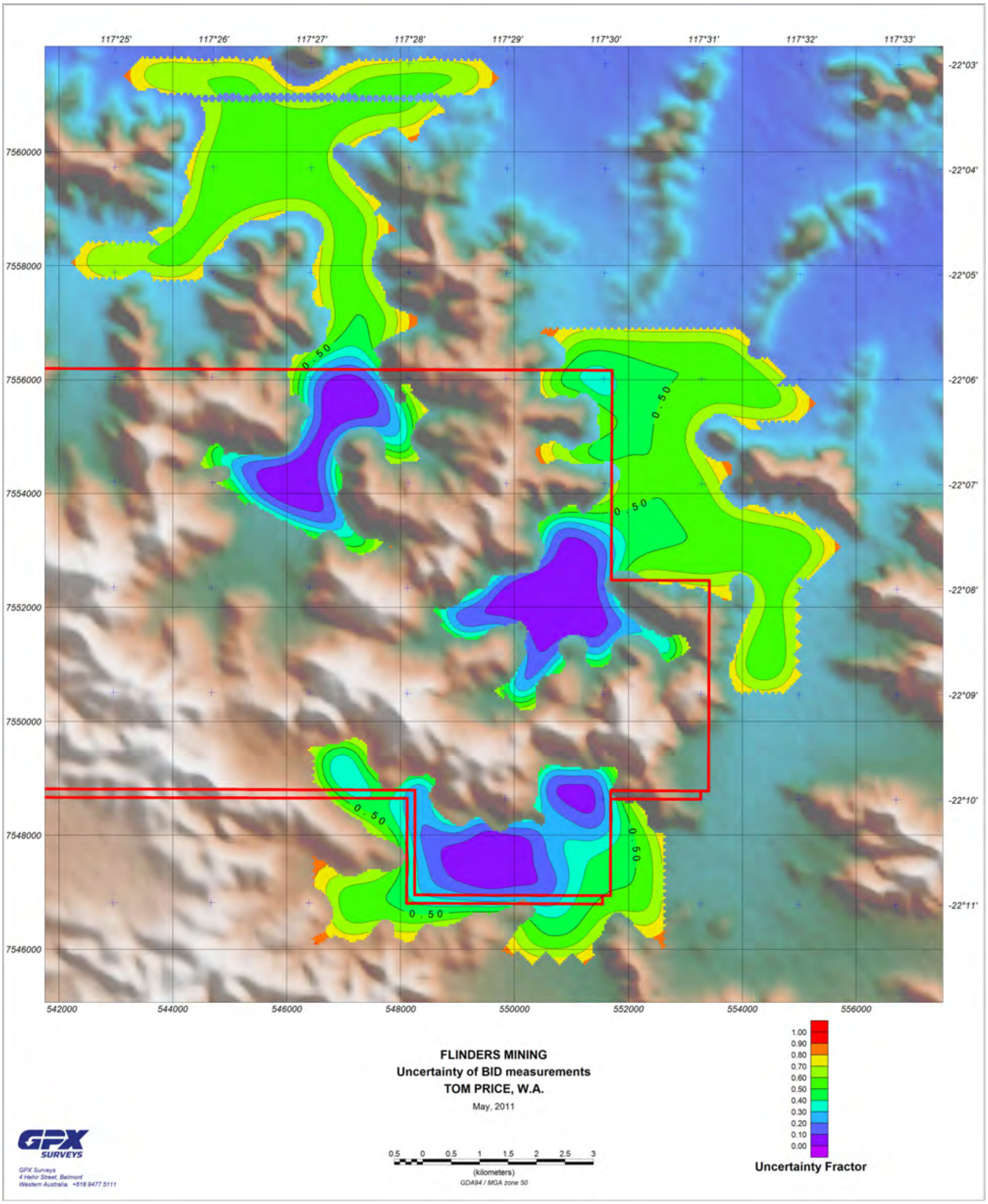


Figure 30: Uncertainty related to borehole proximity and survey density

5 CONCLUSIONS AND RECOMMENDATIONS

5.1 BACKGROUND AND GUIDING FACTORS

There has been extensive geophysical and geological exploration of the survey area, especially in those areas close to the known iron deposits. However, resources in those areas adjacent to and outside the tenement boundary are very limited with no exploration boreholes to use for constraining the model. Through consultation with Flinders Mines consultants, horizons were targeted that would best define the extent of the palaeochannel and these were refined by comparing downhole geophysical measurements and geological interpretations with the airborne EM.

5.2 EXTENT AND CONFIDENCE

The gridded model was extended 500m outside of the EM lines. Depths on the grids are relative to ground level but also based on elevations from the SRTM. The SRTM model takes 400m wide windows and averages the results and causes areas with high gradient and dense changes in topography to become smeared. These areas are filtered based on their valley flatness factor and the availability of other resources.

5.2.1 Noise, misfit and resolution

This is a geophysicist's interpretation and the limits of the model are always changing with the input of more information. With limited access to drillhole information outside of the tenement boundary the variability in the model is proportional to the line spacing of the model along with the distance from the drillholes. In areas with little geological constraints depth resolution is ~10-15m and ¼ line spacing cell size. In those areas near drillholes on-tenement, the resolution is increased due to the constraints of the third-party interpretations and depth estimates.

Figure 30 illustrates the change in the certainty of measurements with distance from the observed drillholes. Higher values show that a wider filter has been applied whereas a lower factor represents constraints defined more by the known geology. Values close to the mean show areas more defined by the depth and conductivity constraints from the XTEM CDI's.

Noise due to increased levels of magnetic permeability is ignored because the targeted horizons have undergone oxidation of the majority of the magnetite content. In those areas with near surface solutions for the basement, the solutions are filtered with a fraction of the valley flatness factor.

5.3 ASSUMPTIONS

5.3.1 Airborne EM - Conductivity

Contrasting susceptibility units are compared between the model profiles and the borehole information. From this information it is assumed that the basement is continuous, dense and highly conductive and the sediments increase in conductivity with decreasing porosity and grain size. Separation of the recently deposited sediments and the DID is based on the first continuous increase in conductivity with depth. To delineate the contrasting horizons, it was assumed that the clayey sediments would have conductivities much higher and thicknesses far less than the surrounding coarser sediments. The CIDg and CIDh horizons are separated by the change in the conductivity gradient of the CID and also the knowledge that the DID is constrained by a clay horizon separating it with the CID. The separation of the basement and BID zones is based on changes in the continuity of the profiles and 2/3D models. Given that they have similar measurements and generally occur very close to each other this is harder to estimate by the EM solutions alone.

5.4 RECOMMENDATIONS

Figure 30 shows how result certainty based on boreholes is heavily skewed to the on-tenement areas of the survey. Ground based surveying, such as downhole geophysics (resistivity and neutron) along with ground gravity traverses will help in fitting this model more accurately in those areas further away from the tenement.

Further Work - 3D Structural Inversion

The previous steps to profile model the EM and expand to 2/3D planes can produce unrealistic crossovers in units and geophysical parameters. By using the downhole geophysical constraints and then inverting back from the forward modelled response, small changes in geophysical constants and depth can be applied iteratively to create a 'more likely' distribution of rock units and parameters.

While it has been possible to produce density and magnetic 3D inversions it is at present not possible to do inversions on TEM-data in more than one dimension. In this case, the inferred relative densities from the downhole geophysics can be used to refine the model, however, further ground gravity work would have to be done to generate an observed gravity plane to run an inversion.

DISCLAIMER

Every effort has been made to make this model a useful general reference. No guarantee can be made that this model is a true representation of the structures and depths. The conclusions made in the interpretation have been based on assumptions about the data collected by GPX Surveys and another party (Flinders Mines/ Worley Parsons supplied historical FDEM, Ground gravity, downhole geophysics, geological logs and geological profile interpretations). GPX SURVEYS BEARS NO RESPONSIBILITY FOR THE RELIABILITY OR ACCURACY OF THIRD PARTY DATA AND RESULTING INTERPRETATION.

6 CONTRACTOR INFORMATION

GPX Surveys Pty Ltd ABN 48 110 619 602

Address: 4 Hehir Street,	T +61 8 9477 5111
Belmont WA 6104 Australia	F +61 8 9477 5211
Postal: PO Box 808,	info@gpxsurveys.com.au
Cloverdale WA 6985	www.gpxsurveys.com.au

7 BIBLIOGRAPHY

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8 APPENDIX A: SURVEY LINES START AND END COORDINATES

Coordinates are GDA94 MAG Z50

XTEM Survey Lines

Line	St East	St Nth	End East	End Nth
1040	545754.40	7556829.65	548569.87	7555231.46
1050	545522.54	7556390.77	548313.16	7554809.14
1060	545307.24	7555943.61	548056.46	7554361.98
1070	545025.69	7555521.29	547857.72	7553914.82
1080	544768.99	7555090.69	547576.17	7553500.78
1090	544545.41	7554643.53	547344.31	7553045.34
2070	551929.00	7550338.00	549984.00	7553116.00
2090	551517.00	7550055.00	549573.00	7552832.00
2110	551105.00	7549771.00	549161.00	7552547.00
2130	550695.00	7549486.00	548751.00	7552262.00
3010	550420.00	7550820.00	554635.00	7550820.00
3020	550420.00	7551070.00	554635.00	7551070.00
3030	550420.00	7551320.00	554638.00	7551320.00
3040	550420.00	7551570.00	554642.00	7551570.00
3050	550420.00	7551820.00	554645.00	7551820.00
3060	550420.00	7552070.00	554649.00	7552070.00
3070	550420.00	7552320.00	554652.00	7552320.00
3080	550420.00	7552570.00	554656.00	7552570.00
3090	550401.00	7552820.00	555095.00	7552820.00
3100	550114.00	7553070.00	555317.00	7553070.00
3110	550237.00	7553320.00	554851.00	7553320.00
3120	550360.00	7553570.00	554216.00	7553570.00
3130	550879.00	7553820.00	553937.00	7553820.00
3140	550988.00	7554070.00	553988.00	7554070.00
3150	550688.00	7554320.00	553688.00	7554320.00
3160	550386.00	7554570.00	553386.00	7554570.00
3170	550739.00	7554820.00	553739.00	7554820.00
3180	551015.00	7555070.00	554015.00	7555070.00
3200	550405.00	7555570.00	554887.00	7555570.00
3220	550612.00	7556070.00	554403.00	7556070.00
3240	550600.00	7556570.00	553977.00	7556570.00
4010	546800.00	7546100.00	546800.00	7549950.00

4020	547300.00	7546100.00	547300.00	7550000.00
4030	547800.00	7546100.00	547800.00	7549200.00
4040	548300.00	7546100.00	548300.00	7549200.00
4050	548800.00	7546100.00	548800.00	7549200.00
4060	549300.00	7546100.00	549300.00	7549200.00
4070	549800.00	7546100.00	549800.00	7549200.00
4080	550300.00	7546100.00	550300.00	7549200.00
4090	550800.00	7546100.00	550800.00	7549200.00
4100	551300.00	7546100.00	551300.00	7549200.00
4110	551800.00	7546100.00	551800.00	7549200.00
4120	552300.00	7546100.00	552300.00	7549200.00
5020	545159.00	7556070.00	548159.00	7556070.00
5030	545423.00	7556570.00	548423.00	7556570.00
5040	545393.00	7557070.00	548393.00	7557070.00
5050	545343.00	7557570.00	548343.00	7557570.00
5060	542605.00	7558070.00	547494.00	7558070.00
5070	543966.00	7558570.00	547609.00	7558570.00
5080	544157.00	7559070.00	547275.00	7559070.00
5090	544075.00	7559570.00	547075.00	7559570.00
5100	544165.00	7560070.00	548303.00	7560070.00
5110	543997.00	7560570.00	548509.00	7560570.00
5120	543549.00	7561070.00	549334.00	7561070.00

9 APPENDIX B: J2455 XTEM SURVEY SPECIFICATIONS

The specifications of the XTEM transmitter, receiver and receiver coil are as follows:

Transmitter

Waveform:	25% duty cycle square wave
Pulse on Time:	5 ms (inc. 1ms cosine ramp on)
Pulse off Time:	15 ms
Pulse Current:	300 Amps
Switch on Ramp:	0.75 ms
Switch off Ramp:	45 µs
Tx Loop Area:	340 m^2
Tx NIA:	103,200
Tx Frequency:	25 Hz

Receiver

A-D Circuitry:	24 bit
Sample Time:	0 – 12 ms
Sampling:	512 Linear channels
Windowed Data:	30 channels

Receiver Coil

Effective NA: 10,000 Square Metres

Bandwidth: 45,000 Hz

EM Data Channel Specifications

NB: Time 0 is at the start of the switch off ramp and all times are in μSec.

30 Channel Sampling Scheme (45 μSec ramp)				
Channel	**Begin Time**	**End Time**	**Centre Time**	**Width in Time**
1	101.01	126.26	113.64	25.25
2	126.26	151.52	138.89	25.25
3	151.52	176.77	164.14	25.25
4	176.77	202.02	189.39	25.25
5	202.02	227.27	214.65	25.25
6	227.27	252.53	239.90	25.25
7	252.53	277.78	265.15	25.25
8	277.78	303.03	290.40	25.25
9	303.03	328.28	315.66	25.25
10	328.28	378.54	353.41	50.25
11	378.54	428.79	403.66	50.25
12	428.79	479.04	453.91	50.25
13	479.04	554.29	516.67	75.25
14	554.29	629.55	591.92	75.25
15	629.55	729.80	679.67	100.25
16	729.80	855.05	792.42	125.25
17	855.05	1005.30	930.18	150.25
18	1005.30	1205.56	1105.43	200.25
19	1205.56	1455.81	1330.68	250.25
20	1455.81	1756.06	1605.93	300.25
21	1756.06	2131.31	1943.69	375.25
22	2131.31	2581.57	2356.44	450.25
23	2581.57	3131.82	2856.69	550.25
24	3131.82	3832.07	3481.94	700.25
25	3832.07	4682.32	4257.20	850.25
26	4682.32	5732.58	5207.45	1050.25
27	5732.58	7032.83	6382.70	1300.25
28	7032.83	8608.08	7820.45	1575.25
29	8608.08	10558.33	9583.21	1950.25
30	10558.33	12908.58	11733.46	2350.25

Table 2: Data channel specifications for XTEM.

Appendix 3: Borehole Logs

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ABN 61001 279 812

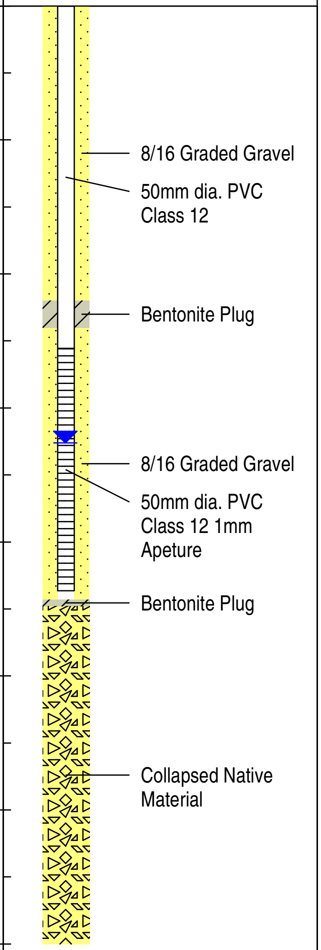
BOREHOLE: *HPRC4053*

CLIENT	FMS	**LOCATION**	EAGLE	**DRILLED DEPTH (m)**	70
PROJECT	PIOP	**PROJECTION**		**SCREEN (mBGL)**	25.56-43.65
DATE DRILLED	40772	**EASTING**	551285.983	**ELEVATION (mAHD)**	594.413
LOGGED BY		**NORTHING**	7548613.494	**WATER LEVEL (mBGL)**	32.6

Contractor		**Drill Bit**	5.5"	**Airlift (L/s)**	0	**Salinity (mS/cm)**	
Rig Type	AIR CORE RC	**Drill Fluid**	A/W	**Temperature (°C)**		**pH**	

Depth (m)	Geological Unit	Graphic Log	Lithology	Field Notes
0	COL		COL: Recent Colluvium	"Development Duration - 15min - airlift ceased thereafter; TDS- 112.0ppm
	ALL		ALL: Recent Alluvium	
10	BID		BIDh: Bedded Iron Deposit - goethite with hematite	
	DIDh		DIDh: Detrital Iron Deposit - hematite dominant	
	BIDg		BIDg: Bedded Iron Deposit - goethite dominant	
60	SHL		SHL: Shale	
70	DOL		DOL: Dolerite	

Bore Construction



SHEET:1 OF 1

Job Number 201012-00322

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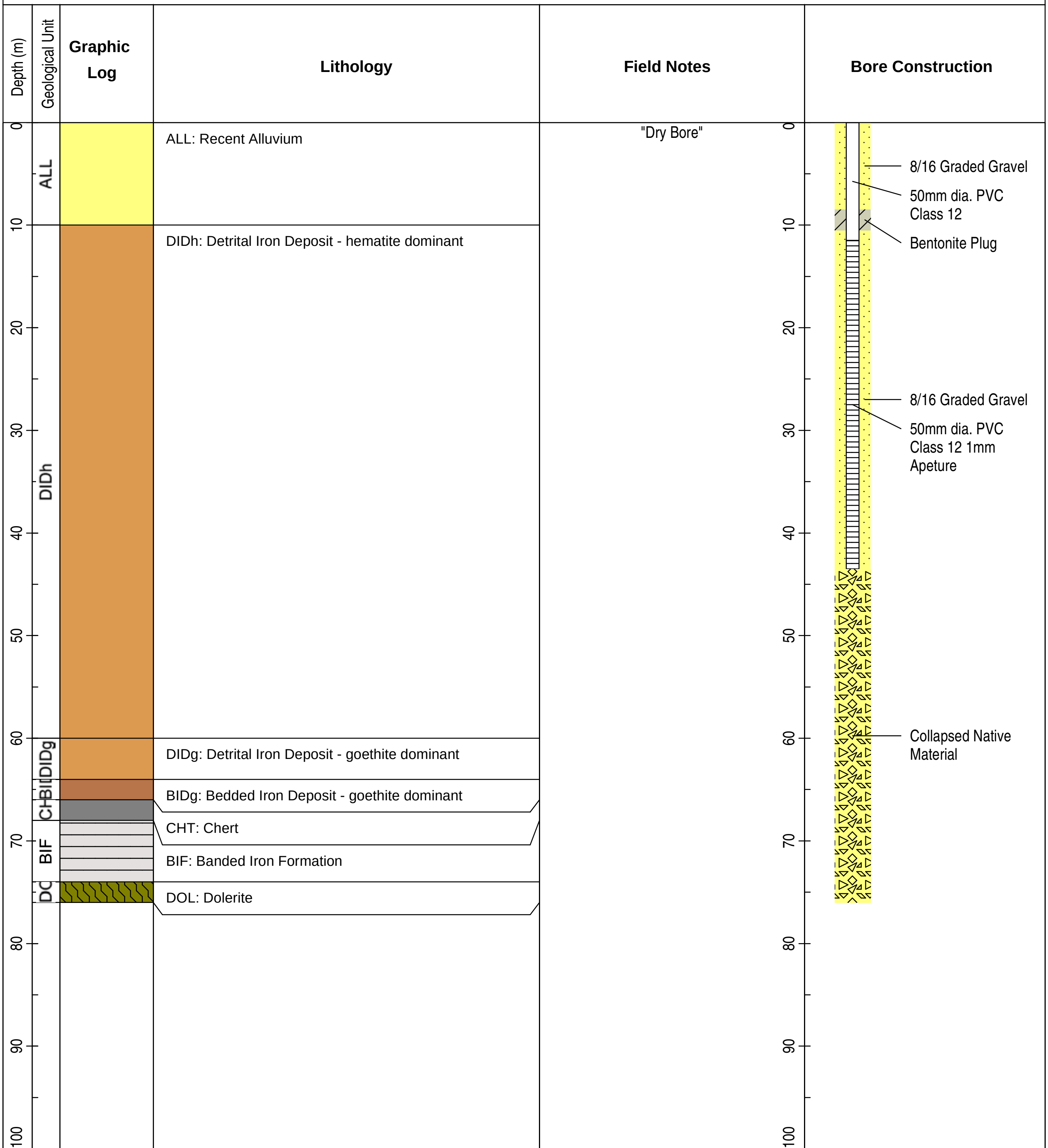
BOREHOLE: *HPRC4052*

CLIENT	FMS	**LOCATION**	EAGLE	**DRILLED DEPTH (m)**	76
PROJECT	PIOP	**PROJECTION**		**SCREEN (mBGL)**	11.50-43.50
DATE DRILLED	01NOV2011	**EASTING**	551272.683	**ELEVATION (mAHD)**	592.768
LOGGED BY		**NORTHING**	7548503.04	**WATER LEVEL (mBGL)**	Dry

Contractor		**Drill Bit**	5.5"	**Airlift (L/s)**	Dry	**Salinity (mS/cm)**	
Rig Type	AIR CORE RC	**Drill Fluid**	A/W	**Temperature (℃)**		**pH**	



SHEET:1 OF 1

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BOREHOLE:
HPRC4029

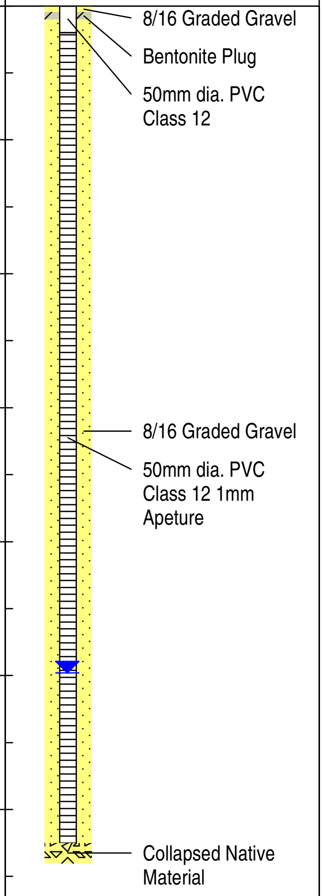
CLIENT	FMS	**LOCATION**	EAGLE	**DRILLED DEPTH (m)**	64
PROJECT	PIOP	**PROJECTION**		**SCREEN (mBGL)**	2.00-62.50
DATE DRILLED	01NOV2011	**EASTING**	550653.063	**ELEVATION (mAHD)**	610.99
LOGGED BY		**NORTHING**	7548792.622	**WATER LEVEL (mBGL)**	49.8

Contractor		**Drill Bit**	5.5"	**Airlift (L/s)**		**Salinity (mS/cm)**	
Rig Type	AIR CORE RC	**Drill Fluid**	A/W	**Temperature (°C)**		**pH**	

Geological Unit	Lithology	Field Notes
COL	COL: Recent Colluvium	"Not enough water to airlift"
CIDh	CIDh: Channel Iron Deposit - hematite dominant	
DIDh	DIDh: Detrital Iron Deposit - hematite dominant	
BIDg	BIDg: Bedded Iron Deposit - goethite dominant	
BIF	BIF: Banded Iron Formation	
CHT	CHT: Chert	
SHL	SHL: Shale	
BIF	BIF: Banded Iron Formation	

Depth (m): 0, 10, 20, 30, 40, 50, 60, 70, 80, 90, 100

Bore Construction



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BOREHOLE: *HPRC3029*

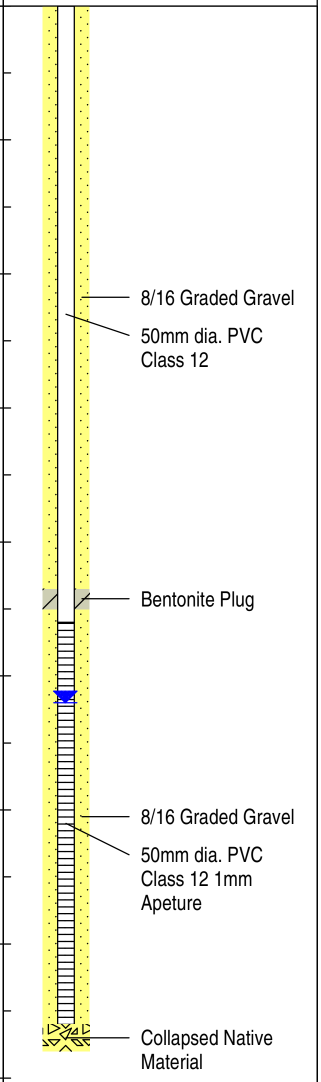
CLIENT	FMS	**LOCATION**	DELTA	**DRILLED DEPTH (m)**	78
PROJECT	PIOP	**PROJECTION**		**SCREEN (mBGL)**	46.00-76.00
DATE DRILLED	29OCT2011	**EASTING**	551731.499	**ELEVATION (mAHD)**	561.529
LOGGED BY		**NORTHING**	7551693.877	**WATER LEVEL (mBGL)**	51.99

Contractor		**Drill Bit**	5.5"	**Airlift (L/s)**	0	**Salinity (mS/cm)**	
Rig Type	AIR CORE RC	**Drill Fluid**	A/W	**Temperature (°C)**		**pH**	

Geological Unit	Lithology	Field Notes
COL	COL: Recent Colluvium	"Development Duration 30min- No Yield, TDS- 398ppm"
DIDh	DIDh: Detrital Iron Deposit - hematite dominant	
BII	BIDh: Bedded Iron Deposit - goethite with hematite	
BIDg	BIDg: Bedded Iron Deposit - goethite dominant	
BIDh	BIDh: Bedded Iron Deposit - goethite with hematite	
BIF	BIF: Banded Iron Formation	
SHL	SHL: Shale	
BIF	BIF: Banded Iron Formation	
CHT	CHT: Chert	
SH	SHL: Shale	
CH	CHT: Chert	
SH	SHL: Shale	
BIF	BIF: Banded Iron Formation	

Depth (m): 0, 10, 20, 30, 40, 50, 60, 70, 80, 90, 100

Bore Construction



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BOREHOLE: *HPRC3019*

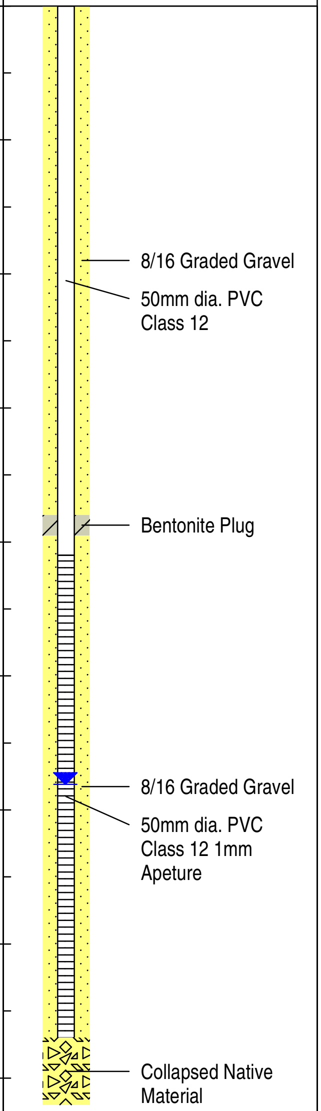
CLIENT	FMS	**LOCATION**	DELTA	**DRILLED DEPTH (m)**	82
PROJECT	PIOP	**PROJECTION**		**SCREEN (mBGL)**	41.00-77.00
DATE DRILLED	29OCT2011	**EASTING**	552339.719	**ELEVATION (mAHD)**	568.504
LOGGED BY		**NORTHING**	7551490.384	**WATER LEVEL (mBGL)**	58.08

Contractor		**Drill Bit**	5.5"	**Airlift (L/s)**	0	**Salinity (mS/cm)**	
Rig Type	AIR CORE RC	**Drill Fluid**	A/W	**Temperature (℃)**		**pH**	

Geological Unit	Lithology
COL	COL: Recent Colluvium
DIDh	DIDh: Detrital Iron Deposit - hematite dominant
BIDh	BIDh: Bedded Iron Deposit - goethite with hematite
CHT	CHT: Chert
SHL	SHL: Shale
BIDh	BIDh: Bedded Iron Deposit - goethite with hematite
CHT	CHT: Chert
SHL	SHL: Shale
BIF	BIF: Banded Iron Formation

Field Notes: "Development Duration 15min - No Yield"

Bore Construction



Depth (m): 0 – 100

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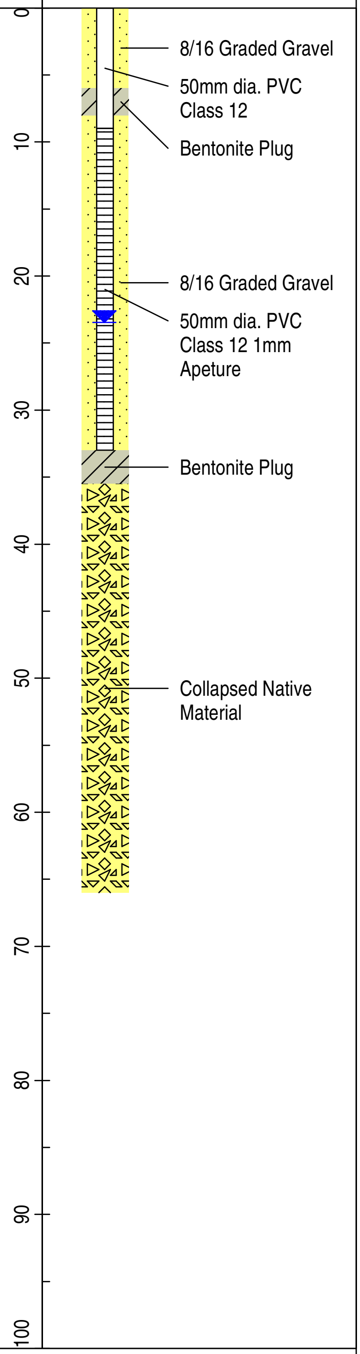
BOREHOLE:
HPRC2302

CLIENT	FMS	**LOCATION**	DELTA	**DRILLED DEPTH (m)**	66
PROJECT	PIOP	**PROJECTION**		**SCREEN (mBGL)**	9.00-33.00
DATE DRILLED	31OCT2011	**EASTING**	550189.613	**ELEVATION (mAHD)**	577.423
LOGGED BY		**NORTHING**	7550852.432	**WATER LEVEL (mBGL)**	23.46

Contractor		**Drill Bit**	5.5"	**Airlift (L/s)**	0	**Salinity (mS/cm)**	
Rig Type	AIR CORE RC	**Drill Fluid**	A/W	**Temperature (℃)**		**pH**	

Depth (m)	Geological Unit	Graphic Log	Lithology	Field Notes
0–2	AL		ALL: Recent Alluvium	"Not enough water to airlift"
2–6	COL		COL: Recent Colluvium	
6–34	DIDh		DIDh: Detrital Iron Deposit - hematite dominant	
34–42	BIDg		BIDg: Bedded Iron Deposit - goethite dominant	
42–48	CHT		CHT: Chert	
48–66	BIF		BIF: Banded Iron Formation	

Bore Construction



Job Number 201012-00322

BOREHOLE: *HPRC2249*

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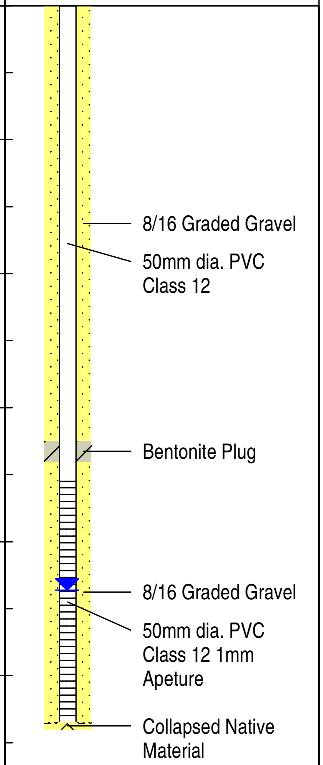
ABN 61001 279 812

CLIENT	FMS	**LOCATION**	DELTA	**DRILLED DEPTH (m)**	54
PROJECT	PIOP	**PROJECTION**		**SCREEN (mBGL)**	35.50-53.50
DATE DRILLED	30OCT2011	**EASTING**	550720.202	**ELEVATION (mAHD)**	558.081
LOGGED BY		**NORTHING**	7551836.465	**WATER LEVEL (mBGL)**	43.61

Contractor		**Drill Bit**	5.5"	**Airlift (L/s)**	0.01	**Salinity (mS/cm)**	
Rig Type	AIR CORE RC	**Drill Fluid**	A/W	**Temperature (°C)**		**pH**	

Depth (m)	Geological Unit	Lithology	Field Notes
0–2	AL	ALL: Recent Alluvium	"Development Duration 15min; TDS-219ppm"
2–12	DIDh	DIDh: Detrital Iron Deposit - hematite dominant	
12–20	BIDh	BIDh: Bedded Iron Deposit - goethite with hematite	
20–28	BIDg	BIDg: Bedded Iron Deposit - goethite dominant	
28–30	CH	CHT: Chert	
30–54	BIF	BIF: Banded Iron Formation	

Bore Construction



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BOREHOLE: *HPRC2174*

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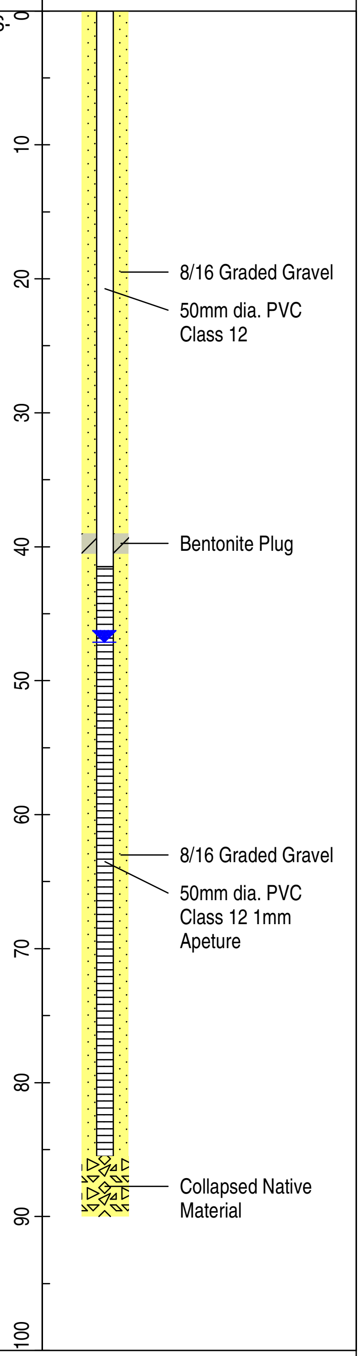
CLIENT	FMS	**LOCATION**	DELTA	**DRILLED DEPTH (m)**	90
PROJECT	PIOP	**PROJECTION**		**SCREEN (mBGL)**	41.50-85.50
DATE DRILLED	28OCT2011	**EASTING**	551059.185	**ELEVATION (mAHD)**	549.187
LOGGED BY		**NORTHING**	7553294.069	**WATER LEVEL (mBGL)**	47.12

Contractor		**Drill Bit**	5.5"	**Airlift (L/s)**	0.13	**Salinity (mS/cm)**	
Rig Type	AIR CORE RC	**Drill Fluid**	A/W	**Temperature (°C)**		**pH**	

Depth (m)	Geological Unit	Graphic Log	Lithology	Field Notes
0–20	COL		COL: Recent Colluvium	"Development Duration 30min; TDS-185ppm"
20–80	DIDh		DIDh: Detrital Iron Deposit - hematite dominant	
80–82	BIDg		BIDg: Bedded Iron Deposit - goethite dominant	
82–86	CHT		CHT: Chert	
86–90	SHL		SHL: Shale	

Bore Construction



Job Number 201012-00322

WorleyParsons
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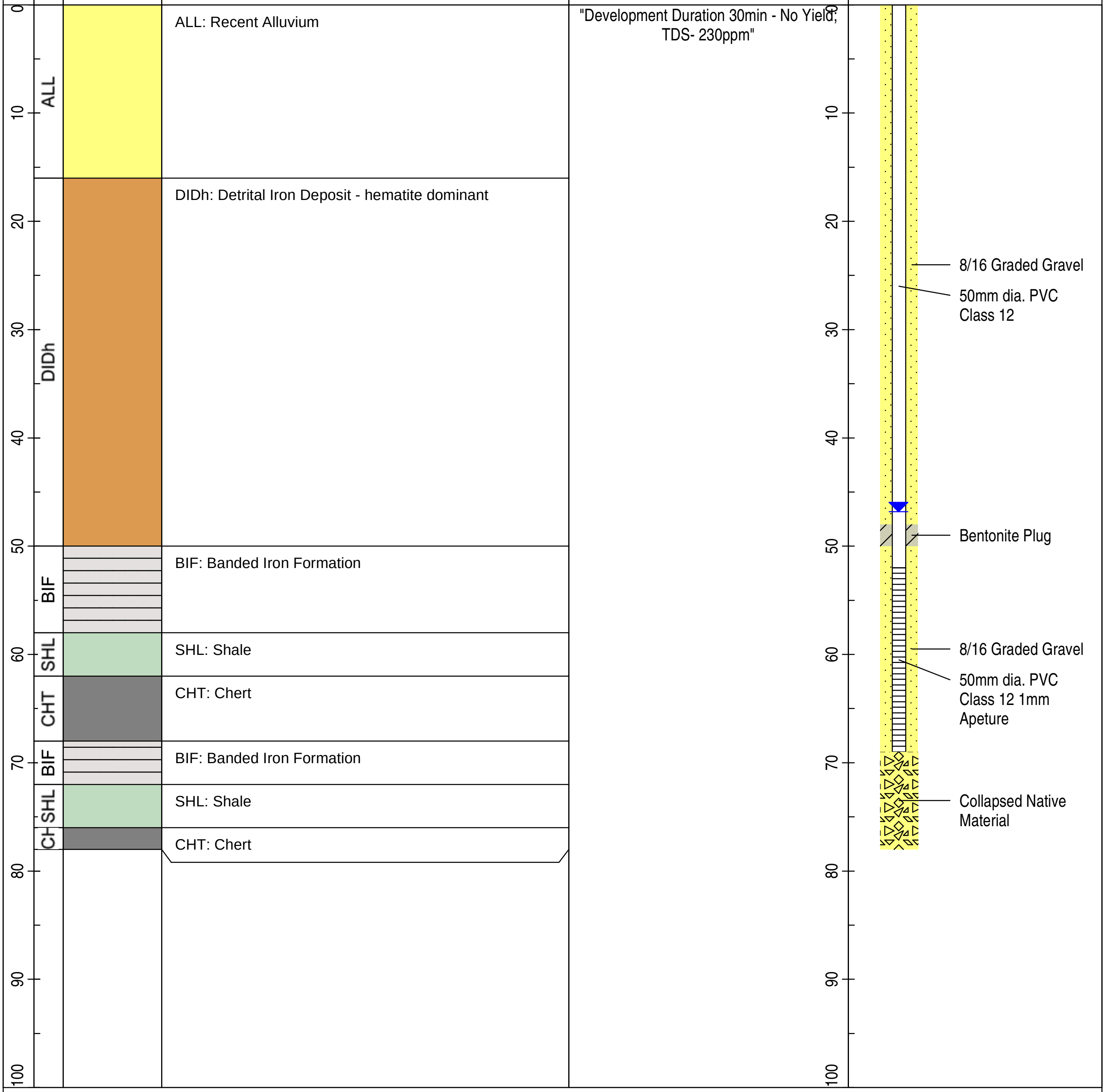
BOREHOLE: *HPRC2144*

CLIENT	FMS	**LOCATION**	DELTA	**DRILLED DEPTH (m)**	78
PROJECT	PIOP	**PROJECTION**		**SCREEN (mBGL)**	52-69
DATE DRILLED	28OCT2011	**EASTING**	550102.991	**ELEVATION (mAHD)**	559.453
LOGGED BY		**NORTHING**	7552276.963	**WATER LEVEL (mBGL)**	46.82

Contractor		**Drill Bit**	5.5"	**Airlift (L/s)**	0	**Salinity (mS/cm)**	
Rig Type	AIR CORE RC	**Drill Fluid**	A/W	**Temperature (°C)**		**pH**	

Depth (m)	Geological Unit	Lithology	Field Notes
0–16	ALL	ALL: Recent Alluvium	"Development Duration 30min - No Yield; TDS- 230ppm"
16–50	DIDh	DIDh: Detrital Iron Deposit - hematite dominant	
50–58	BIF	BIF: Banded Iron Formation	
58–62	SHL	SHL: Shale	
62–68	CHT	CHT: Chert	
68–72	BIF	BIF: Banded Iron Formation	
72–76	SHL	SHL: Shale	
76–78	CH	CHT: Chert	



SHEET:1 OF 1

Job Number 201012-00322

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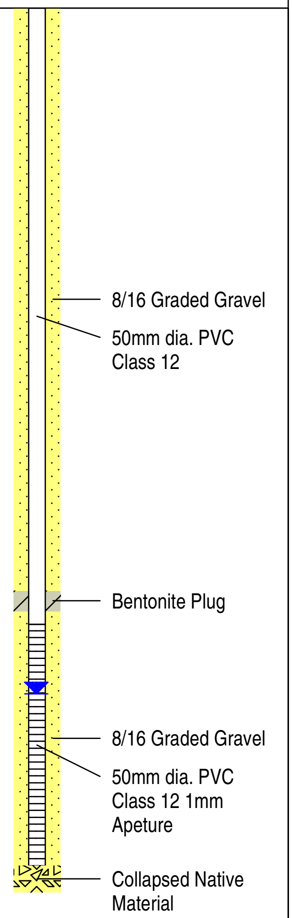
BOREHOLE:
HPRC2118

CLIENT	FMS	**LOCATION**	DELTA	**DRILLED DEPTH (m)**	66
PROJECT	PIOP	**PROJECTION**		**SCREEN (mBGL)**	46.00-64.00
DATE DRILLED	28OCT2011	**EASTING**	549487.191	**ELEVATION (mAHD)**	569.84
LOGGED BY		**NORTHING**	7551828.264	**WATER LEVEL (mBGL)**	51.18

Contractor		**Drill Bit**	5.5"	**Airlift (L/s)**	0L/s	**Salinity (mS/cm)**	
Rig Type	AIR CORE RC	**Drill Fluid**	A/W	**Temperature (℃)**		**pH**	

Depth (m)	Geological Unit	Lithology	Field Notes
0	COL	COL: Recent Colluvium	"Development Duration 30min - No Yield; TDS- 192ppm"
	DIDh	DIDh: Detrital Iron Deposit - hematite dominant	
50	BI[D]	BIDg: Bedded Iron Deposit - goethite dominant	
	CHT	CHT: Chert	

Bore Construction



Depth scale: 0, 10, 20, 30, 40, 50, 60, 70, 80, 90, 100

Job Number 201012-00322

Level 7 | QV1 Building
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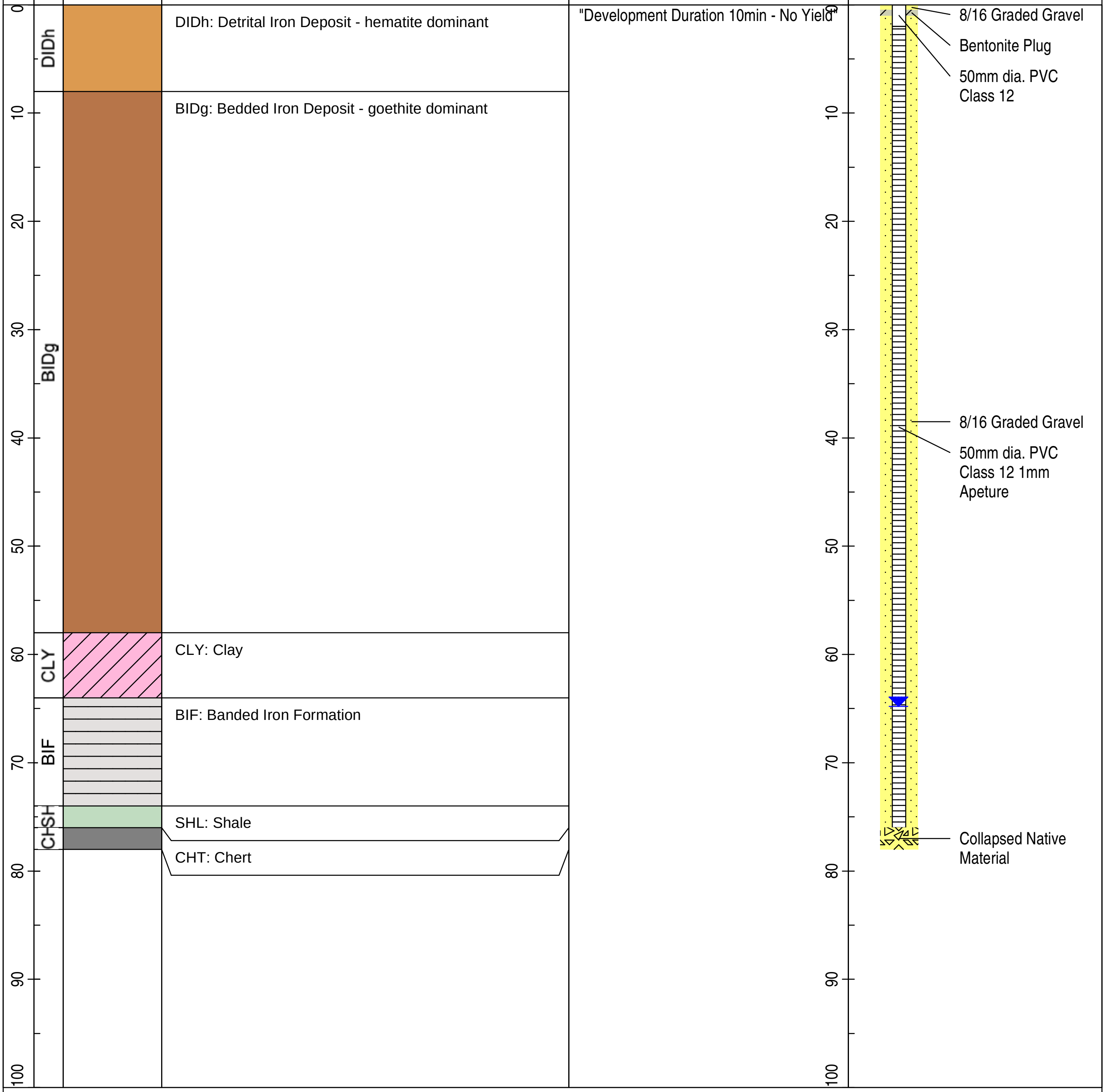
BOREHOLE: *HPRC2084*

CLIENT	FMS	**LOCATION**	DELTA	**DRILLED DEPTH (m)**	78
PROJECT	PIOP	**PROJECTION**		**SCREEN (mBGL)**	2.00-76.00
DATE DRILLED	28OCT2011	**EASTING**	548542.273	**ELEVATION (mAHD)**	591.73
LOGGED BY		**NORTHING**	7551893.928	**WATER LEVEL (mBGL)**	64.79

Contractor		**Drill Bit**	5.5"	**Airlift (L/s)**	0L/s	**Salinity (mS/cm)**	
Rig Type	AIR CORE RC	**Drill Fluid**	A/W	**Temperature (°C)**		**pH**	

Depth (m)	Geological Unit	Graphic Log	Lithology	Field Notes	Bore Construction
0–8	DIDh		DIDh: Detrital Iron Deposit - hematite dominant	"Development Duration 10min - No Yield"	
8–58	BIDg		BIDg: Bedded Iron Deposit - goethite dominant		
58–64	CLY		CLY: Clay		
64–74	BIF		BIF: Banded Iron Formation		
74–76	SH		SHL: Shale		
76–78	CH		CHT: Chert		



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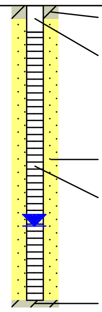
BOREHOLE: *HPRC1026*

CLIENT	FMS	**LOCATION**	CHAMPION	**DRILLED DEPTH (m)**	22
PROJECT	PIOP	**PROJECTION**		**SCREEN (mBGL)**	2.00-22.00
DATE DRILLED	23OCT2011	**EASTING**	547882.973	**ELEVATION (mAHD)**	595.701
LOGGED BY		**NORTHING**	7553186.708	**WATER LEVEL (mBGL)**	16.46

Contractor		**Drill Bit**	5.5"	**Airlift (L/s)**	0	**Salinity (mS/cm)**	
Rig Type	AIR CORE RC	**Drill Fluid**	A/W	**Temperature (°C)**		**pH**	

Depth (m)	Geological Unit	Graphic Log	Lithology	Field Notes
0–4	ALL		ALL: Recent Alluvium	"Development Duration 10min- No Yield"
4–22	SHL		SHL: Shale	

Bore Construction



Depth scale: 0, 10, 20, 30, 40, 50, 60, 70, 80, 90, 100

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BOREHOLE: *HPRC0973*

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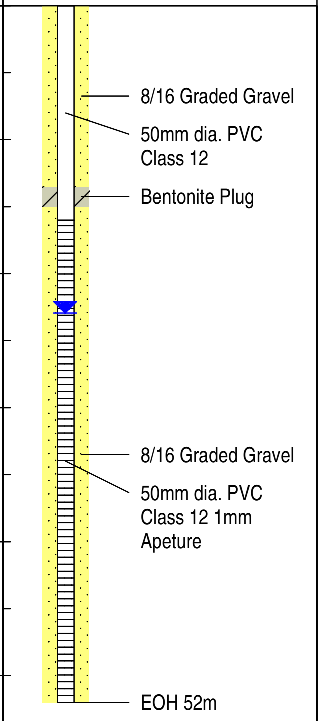
CLIENT	FMS	**LOCATION**	CHAMPION	**DRILLED DEPTH (m)**	52
PROJECT	PIOP	**PROJECTION**		**SCREEN (mBGL)**	16.00-52.00
DATE DRILLED	26OCT2011	**EASTING**	548034.734	**ELEVATION (mAHD)**	562.843
LOGGED BY		**NORTHING**	7555166.046	**WATER LEVEL (mBGL)**	22.93

Contractor		**Drill Bit**	5.5"	**Airlift (L/s)**	0.38	**Salinity (mS/cm)**	
Rig Type	AIR CORE RC	**Drill Fluid**	A/W	**Temperature (°C)**		**pH**	

Depth (m)	Geological Unit	Lithology	Field Notes
0–14	ALL	ALL: Recent Alluvium	"Development Duration 30min; TDS-152ppm"
14–26	DIDh	DIDh: Detrital Iron Deposit - hematite dominant	
26–40	CIDh	CIDh: Channel Iron Deposit - hematite dominant	
40–48	SHL	SHL: Shale	
48–52	BIF	BIF: Banded Iron Formation	

Bore Construction



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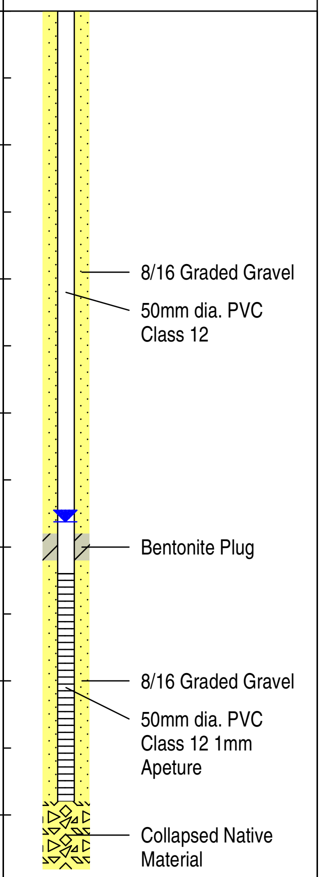
BOREHOLE: *HPRC0919*

CLIENT	FMS	**LOCATION**	CHAMPION	**DRILLED DEPTH (m)**	64
PROJECT	PIOP	**PROJECTION**		**SCREEN (mBGL)**	42.00-59.00
DATE DRILLED	27OCT2011	**EASTING**	546259.945	**ELEVATION (mAHD)**	568.602
LOGGED BY		**NORTHING**	7553639.857	**WATER LEVEL (mBGL)**	38.13

Contractor		**Drill Bit**	5.5"	**Airlift (L/s)**	0.12	**Salinity (mS/cm)**	
Rig Type	AIR CORE RC	**Drill Fluid**	A/W	**Temperature (℃)**		**pH**	

Depth (m)	Geological Unit	Graphic Log	Lithology	Field Notes
0	AL		ALL: Recent Alluvium	"Development Duration 30min; TDS-218ppm"
	DIDh		DIDh: Detrital Iron Deposit - hematite dominant	
40	CIDg		CIDg: Channel Iron Deposit - goethite dominant	
	CHT		CHT: Chert	
	BIF		BIF: Banded Iron Formation	

Bore Construction



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BOREHOLE: *HPRC0792*

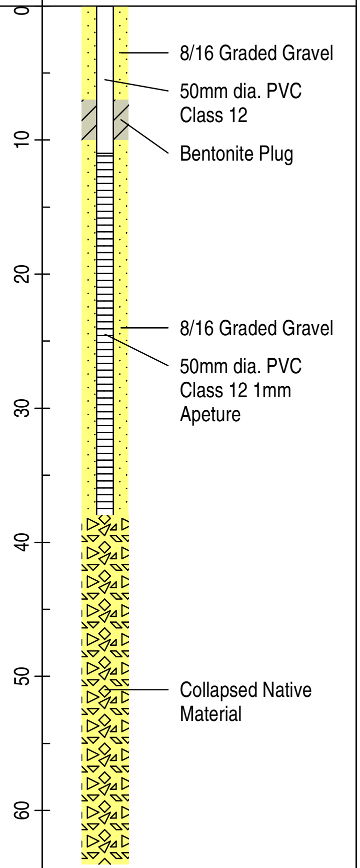
CLIENT	FMS	**LOCATION**	CHAMPION	**DRILLED DEPTH (m)**	64
PROJECT	PIOP	**PROJECTION**		**SCREEN (mBGL)**	11.00-38.00
DATE DRILLED	25OCT2011	**EASTING**	546895.888	**ELEVATION (mAHD)**	574.932
LOGGED BY		**NORTHING**	7553541.338	**WATER LEVEL (mBGL)**	Dry

Contractor		**Drill Bit**	5.5"	**Airlift (L/s)**		**Salinity (mS/cm)**	
Rig Type	AIR CORE RC	**Drill Fluid**	A/W	**Temperature (°C)**		**pH**	

Depth (m)	Geological Unit	Graphic Log	Lithology	Field Notes
0–10	ALL		ALL: Recent Alluvium	"Dry Bore"
10–44	DIDh		DIDh: Detrital Iron Deposit - hematite dominant	
44–54	BIF		BIF: Banded Iron Formation	
54–64	SHL		SHL: Shale	

Depth scale: 0, 10, 20, 30, 40, 50, 60, 70, 80, 90, 100

Bore Construction



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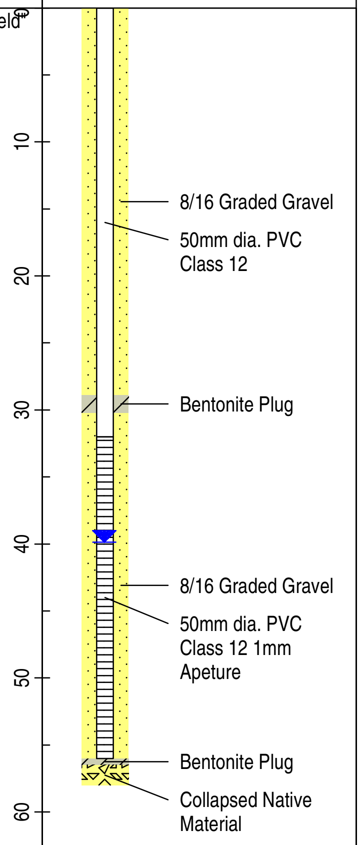
BOREHOLE: *HPRC0766*

CLIENT	FMS	**LOCATION**	CHAMPION	**DRILLED DEPTH (m)**	58
PROJECT	PIOP	**PROJECTION**		**SCREEN (mBGL)**	32.00-56.00
DATE DRILLED	24OCT2011	**EASTING**	545920.967	**ELEVATION (mAHD)**	568.461
LOGGED BY		**NORTHING**	7554368.005	**WATER LEVEL (mBGL)**	39.87

Contractor		**Drill Bit**	5.5"	**Airlift (L/s)**	0	**Salinity (mS/cm)**	
Rig Type	AIR CORE RC	**Drill Fluid**	A/W	**Temperature (℃)**		**pH**	

Depth (m)	Geological Unit	Graphic Log	Lithology	Field Notes
0–8	COL		COL: Recent Colluvium	"Development Duration 10min- No Yield"
8–32	DIDh		DIDh: Detrital Iron Deposit - hematite dominant	
32–38	BIDg		BIDg: Bedded Iron Deposit - goethite dominant	
38–58	BIF		BIF: Banded Iron Formation	

Bore Construction



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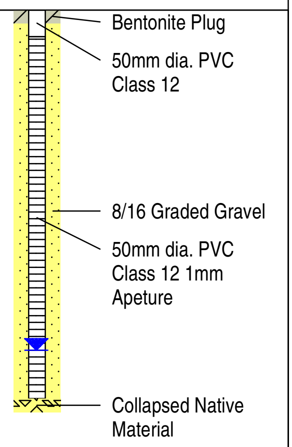
BOREHOLE:
HPRC0689

CLIENT	FMS	**LOCATION**	CHAMPION	**DRILLED DEPTH (m)**	30
PROJECT	PIOP	**PROJECTION**		**SCREEN (mBGL)**	2.00-29.00
DATE DRILLED	24OCT2011	**EASTING**	544663.444	**ELEVATION (mAHD)**	592.44
LOGGED BY		**NORTHING**	7554588.262	**WATER LEVEL (mBGL)**	25.39

Contractor		**Drill Bit**	5.5"	**Airlift (L/s)**	0	**Salinity (mS/cm)**	
Rig Type	AIR CORE RC	**Drill Fluid**	A/W	**Temperature (°C)**		**pH**	

Depth (m)	Geological Unit	Graphic Log	Lithology	Field Notes	Bore Construction
0	COL		COL: Recent Colluvium	"Development Duration 10min- No Yield"	
	BID		BIDg: Bedded Iron Deposit - goethite dominant		
10, 20	BIF		BIF: Banded Iron Formation		
30	SHL		SHL: Shale		
40, 50, 60, 70, 80, 90, 100					



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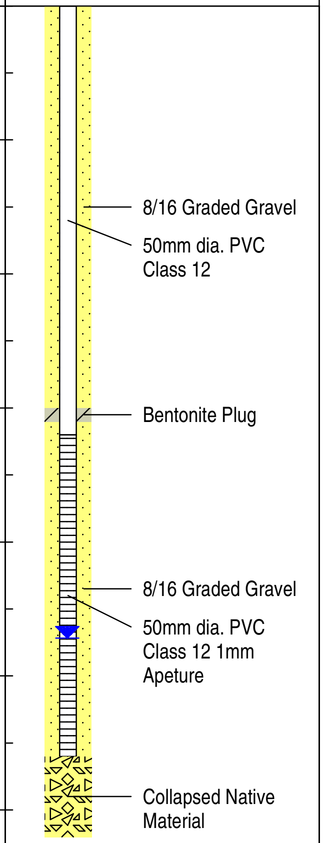
BOREHOLE:
HPRC0672

CLIENT	FMS	**LOCATION**	CHAMPION	**DRILLED DEPTH (m)**	62
PROJECT	PIOP	**PROJECTION**		**SCREEN (mBGL)**	32.00-56.00
DATE DRILLED	23OCT2011	**EASTING**	547008.045	**ELEVATION (mAHD)**	577.397
LOGGED BY		**NORTHING**	7553444.277	**WATER LEVEL (mBGL)**	47.17

Contractor		**Drill Bit**	5.5"	**Airlift (L/s)**	0	**Salinity (mS/cm)**	
Rig Type	AIR CORE RC	**Drill Fluid**	A/W	**Temperature (℃)**		**pH**	

Depth (m)	Geological Unit	Lithology	Field Notes
0–8	COL	COL: Recent Colluvium	"Development Duration 10min- No Yield"
8–42	DIDh	DIDh: Detrital Iron Deposit - hematite dominant	
42–46	BIF	BIF: Banded Iron Formation	
46–60	CHT	CHT: Chert	
60–62	BIF	BIF: Banded Iron Formation	

Bore Construction



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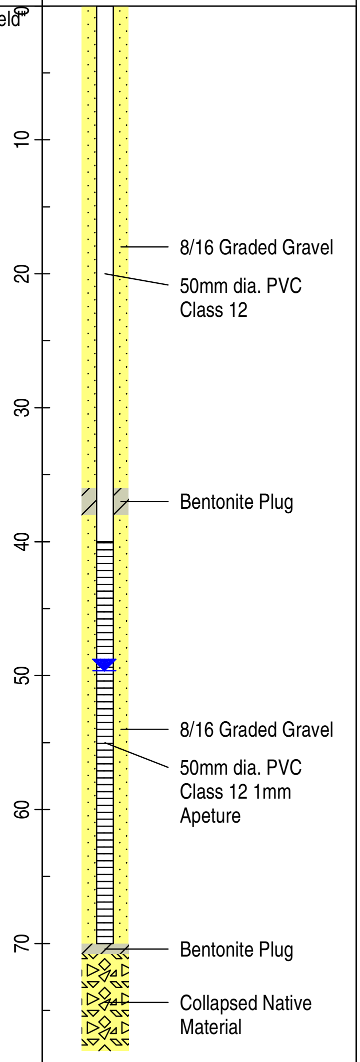
BOREHOLE: *HPRC0641*

CLIENT	FMS	**LOCATION**	CHAMPION	**DRILLED DEPTH (m)**	78
PROJECT	PIOP	**PROJECTION**		**SCREEN (mBGL)**	40.00-70.00
DATE DRILLED	24OCT2011	**EASTING**	546441.869	**ELEVATION (mAHD)**	566.984
LOGGED BY		**NORTHING**	7554919.119	**WATER LEVEL (mBGL)**	49.63

Contractor		**Drill Bit**	5.5"	**Airlift (L/s)**	0	**Salinity (mS/cm)**	
Rig Type	AIR CORE RC	**Drill Fluid**	A/W	**Temperature (°C)**		**pH**	

Depth (m)	Geological Unit	Lithology	Field Notes
0–56	DIDh	DIDh: Detrital Iron Deposit - hematite dominant	"Development Duration 10min- No Yield"
56–66	CIDg	CIDg: Channel Iron Deposit - goethite dominant	
66–70	BIF	BIF: Banded Iron Formation	
70–72	SHL	SHL: Shale	
72–74	BIF	BIF: Banded Iron Formation	
74–76	DOL	DOL: Dolerite	
76–78	SHL	SHL: Shale	

Bore Construction



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BOREHOLE:
HPRC0631

CLIENT	FMS	**LOCATION**	CHAMPION	**DRILLED DEPTH (m)**	54
PROJECT	PIOP	**PROJECTION**		**SCREEN (mBGL)**	30.2-48.2
DATE DRILLED	07SEP2011	**EASTING**	546893.535	**ELEVATION (mAHD)**	552.823
LOGGED BY		**NORTHING**	7555104.519	**WATER LEVEL (mBGL)**	35.54

Contractor		**Drill Bit**	5.5"	**Airlift (L/s)**	0	**Salinity (mS/cm)**	
Rig Type	AIR CORE RC	**Drill Fluid**	A/W	**Temperature (℃)**		**pH**	

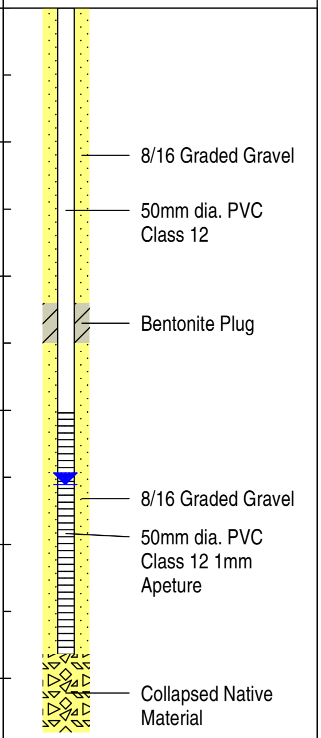
Geological Unit	Lithology
ALL	ALL: Recent Alluvium
DIDh	DIDh: Detrital Iron Deposit - hematite dominant
BIDg	BIDg: Bedded Iron Deposit - goethite dominant
BID	BIDh: Bedded Iron Deposit - goethite with hematite
BIF	BIF: Banded Iron Formation
CHT	CHT: Chert
BIF	BIF: Banded Iron Formation

Depth (m): 0, 10, 20, 30, 40, 50, 60, 70, 80, 90, 100

Field Notes

"Development Duration 10min- No Yield"

Bore Construction



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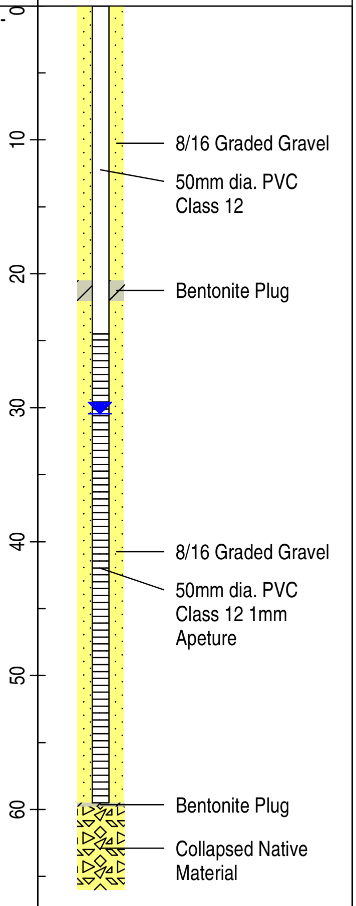
BOREHOLE:
HPRC0549

CLIENT	FMS	**LOCATION**	CHAMPION	**DRILLED DEPTH (m)**	66
PROJECT	PIOP	**PROJECTION**		**SCREEN (mBGL)**	24.50-59.50
DATE DRILLED	26OCT2011	**EASTING**	547642.192	**ELEVATION (mAHD)**	553.989
LOGGED BY		**NORTHING**	7555493.228	**WATER LEVEL (mBGL)**	30.46

Contractor		**Drill Bit**	5.5"	**Airlift (L/s)**	0.2	**Salinity (mS/cm)**	
Rig Type	AIR CORE RC	**Drill Fluid**	A/W	**Temperature (℃)**		**pH**	

Depth (m)	Geological Unit	Graphic Log	Lithology	Field Notes
0–6	COL		COL: Recent Colluvium	"Development Duration 30min; TDS-164ppm"
6–46	DIDh		DIDh: Detrital Iron Deposit - hematite dominant	
46–52	BIDg		BIDg: Bedded Iron Deposit - goethite dominant	
52–54	DIDh		DIDh: Detrital Iron Deposit - hematite dominant	
54–56	BIF		BIF: Banded Iron Formation	
56–58	CHT		CHT: Chert	
58–66	BIF		BIF: Banded Iron Formation	

Bore Construction



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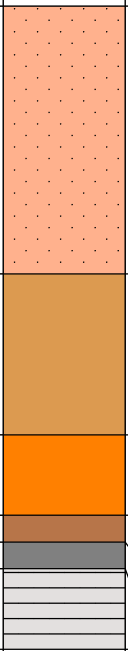
BOREHOLE:
HPRC0531

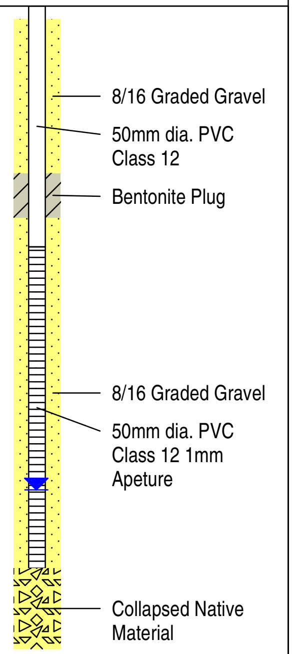
CLIENT	FMS	**LOCATION**	CHAMPION	**DRILLED DEPTH (m)**	48
PROJECT	PIOP	**PROJECTION**		**SCREEN (mBGL)**	18.00-42.00
DATE DRILLED	23OCT2011	**EASTING**	545490.472	**ELEVATION (mAHD)**	577.112
LOGGED BY		**NORTHING**	7553341.661	**WATER LEVEL (mBGL)**	36.14

Contractor		**Drill Bit**	5.5"	**Airlift (L/s)**	0	**Salinity (mS/cm)**	
Rig Type	AIR CORE RC	**Drill Fluid**	A/W	**Temperature (℃)**		**pH**	

Depth (m)	Geological Unit	Graphic Log	Lithology	Field Notes
0–20	COL		COL: Recent Colluvium	"Development Duration 10min- No Yield"
20–32	DIDh		DIDh: Detrital Iron Deposit - hematite dominant	
32–38	CIDh		CIDh: Channel Iron Deposit - hematite dominant	
38–40	BI[D]		BIDg: Bedded Iron Deposit - goethite dominant	
40–42	CH[T]		CHT: Chert	
42–48	BIF		BIF: Banded Iron Formation	



Bore Construction



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250 St George's Terrace
Perth WA 6000
ABN 61001 279 812

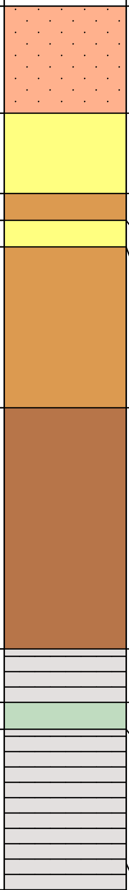
BOREHOLE: *HPRC0395*

CLIENT	FMS	**LOCATION**	CHAMPION	**DRILLED DEPTH (m)**	66
PROJECT	PIOP	**PROJECTION**		**SCREEN (mBGL)**	39.20-51.20
DATE DRILLED	07SEP2011	**EASTING**	546661.13	**ELEVATION (mAHD)**	555.13
LOGGED BY		**NORTHING**	7555504.01	**WATER LEVEL (mBGL)**	39.8

Contractor		**Drill Bit**	5.5"	**Airlift (L/s)**	0	**Salinity (mS/cm)**	
Rig Type	AIR CORE RC	**Drill Fluid**	A/W	**Temperature (℃)**		**pH**	

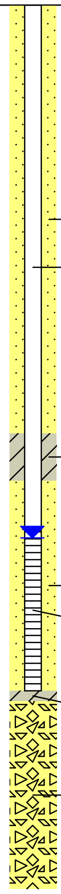
Depth (m)	Geological Unit	Lithology
0–8	COL	COL: Recent Colluvium
8–14	ALL	ALL: Recent Alluvium
14–16	DIDh	DIDh: Detrital Iron Deposit - hematite dominant
16–18	ALL	ALL: Recent Alluvium
18–30	DIDh	DIDh: Detrital Iron Deposit - hematite dominant
30–48	BIDg	BIDg: Bedded Iron Deposit - goethite dominant
48–52	BIF	BIF: Banded Iron Formation
52–54	SH	SHL: Shale
54–66	BIF	BIF: Banded Iron Formation
66		BIF

Graphic Log



Field Notes: "Development Duration 10min- No Yield"

Bore Construction



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WorleyParsons
resources & energy

Level 7 | QV1 Building
250 St George's Terrace
Perth WA 6000
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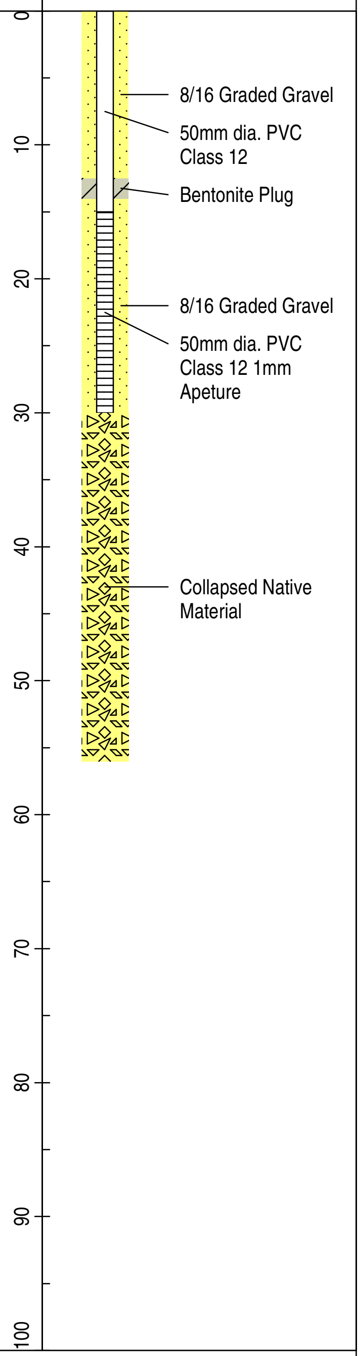
BOREHOLE: *HPRC0352*

CLIENT	FMS	**LOCATION**	CHAMPION	**DRILLED DEPTH (m)**	56
PROJECT	PIOP	**PROJECTION**		**SCREEN (mBGL)**	15.00-30.00
DATE DRILLED	25OCT2011	**EASTING**	545564.959	**ELEVATION (mAHD)**	577.199
LOGGED BY		**NORTHING**	7553282.635	**WATER LEVEL (mBGL)**	Dry

Contractor		**Drill Bit**	5.5"	**Airlift (L/s)**		**Salinity (mS/cm)**	
Rig Type	AIR CORE RC	**Drill Fluid**	A/W	**Temperature (°C)**		**pH**	

Depth (m)	Geological Unit	Lithology	Field Notes
0–8	COL	COL: Recent Colluvium	"Dry Bore"
8–14	ALL	ALL: Recent Alluvium	
14–30	DIDh	DIDh: Detrital Iron Deposit - hematite dominant	
30–46	CIDh	CIDh: Channel Iron Deposit - hematite dominant	
46–56	BIF	BIF: Banded Iron Formation	

Bore Construction



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250 St George's Terrace
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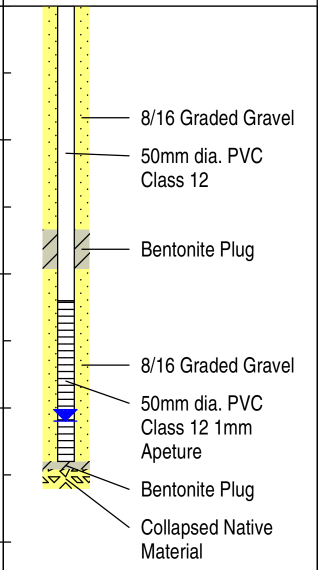
BOREHOLE:
HPRC0321

CLIENT	FMS	**LOCATION**	CHAMPION	**DRILLED DEPTH (m)**	36
PROJECT	PIOP	**PROJECTION**		**SCREEN (mBGL)**	22.00-34.00
DATE DRILLED	24OCT2011	**EASTING**	546581.314	**ELEVATION (mAHD)**	559.275
LOGGED BY		**NORTHING**	7554467.782	**WATER LEVEL (mBGL)**	30.98

Contractor		**Drill Bit**	5.5"	**Airlift (L/s)**	0	**Salinity (mS/cm)**	
Rig Type	AIR CORE RC	**Drill Fluid**	A/W	**Temperature (℃)**		**pH**	

Depth (m)	Geological Unit	Graphic Log	Lithology	Field Notes
0–6	COL		COL: Recent Colluvium	"Development Duration 10min- No Yield"
6–28	DIDh		DIDh: Detrital Iron Deposit - hematite dominant	
28–36	BIF		BIF: Banded Iron Formation	

Bore Construction



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WorleyParsons
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250 St George's Terrace
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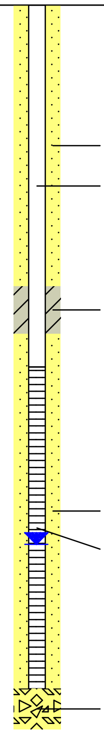
BOREHOLE: *HPRC0285*

CLIENT	FMS	**LOCATION**	DELTA	**DRILLED DEPTH (m)**	54
PROJECT	PIOP	**PROJECTION**		**SCREEN (mBGL)**	27.00-51.00
DATE DRILLED	31OCT2011	**EASTING**	550088.931	**ELEVATION (mAHD)**	579.832
LOGGED BY		**NORTHING**	7550744.462	**WATER LEVEL (mBGL)**	40.22

Contractor		**Drill Bit**	5.5"	**Airlift (L/s)**	~0	**Salinity (mS/cm)**	
Rig Type	AIR CORE RC	**Drill Fluid**	A/W	**Temperature (℃)**		**pH**	

Depth (m)	Geological Unit	Lithology	Field Notes
0–8	ALL	ALL: Recent Alluvium	"Development Duration 30min - only dribble; TDS-177ppm"
8–24	DIDh	DIDh: Detrital Iron Deposit - hematite dominant	
24–34	BIDg	BIDg: Bedded Iron Deposit - goethite dominant	
34–38	BIF	BIF: Banded Iron Formation	
38–42	SHL	SHL: Shale	
42–46	CHT	CHT: Chert	
46–54	BIF	BIF: Banded Iron Formation	

Bore Construction



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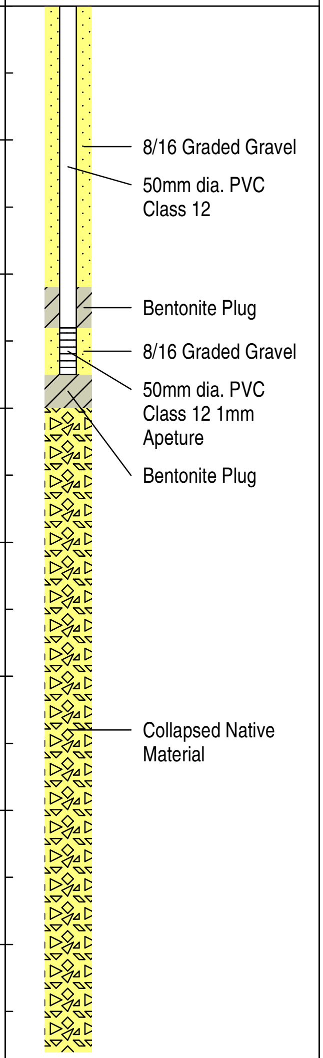
BOREHOLE:
HPRC0269

CLIENT	FMS	**LOCATION**	DELTA	**DRILLED DEPTH (m)**	78
PROJECT	PIOP	**PROJECTION**		**SCREEN (mBGL)**	24.00-27.5
DATE DRILLED	30OCT2011	**EASTING**	551507.881	**ELEVATION (mAHD)**	539.518
LOGGED BY		**NORTHING**	7553095.877	**WATER LEVEL (mBGL)**	Dry

Contractor		**Drill Bit**	5.5"	**Airlift (L/s)**	0	**Salinity (mS/cm)**	
Rig Type	AIR CORE RC	**Drill Fluid**	A/W	**Temperature (℃)**		**pH**	

Depth (m)	Geological Unit	Lithology	Field Notes
0–16	COL	COL: Recent Colluvium	
16–36	DIDh	DIDh: Detrital Iron Deposit - hematite dominant	
36–52	CLY	CLY: Clay	
52–74	CIDg	CIDg: Channel Iron Deposit - goethite dominant	
74–78	CHT	CHT: Chert	

Bore Construction



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Level 7 | QV1 Building
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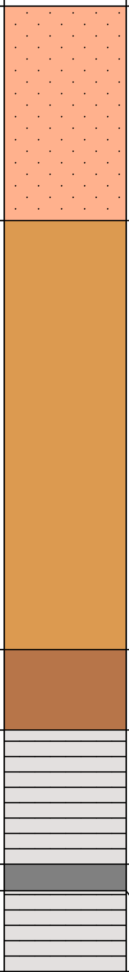
BOREHOLE:
HPRC0216

CLIENT	FMS	**LOCATION**	DELTA	**DRILLED DEPTH (m)**	72
PROJECT	PIOP	**PROJECTION**		**SCREEN (mBGL)**	19.00-31.00
DATE DRILLED	31OCT2011	**EASTING**	550278.222	**ELEVATION (mAHD)**	556.827
LOGGED BY		**NORTHING**	7552257.507	**WATER LEVEL (mBGL)**	29.7

Contractor		**Drill Bit**	5.5"	**Airlift (L/s)**	0	**Salinity (mS/cm)**	
Rig Type	AIR CORE RC	**Drill Fluid**	A/W	**Temperature (℃)**		**pH**	

Depth (m)	Geological Unit	Lithology	Field Notes
0	COL	COL: Recent Colluvium	"Not enough water to airlift"
16	DIDh	DIDh: Detrital Iron Deposit - hematite dominant	
48	BIDg	BIDg: Bedded Iron Deposit - goethite dominant	
54	BIF	BIF: Banded Iron Formation	
64	CH	CHT: Chert	
66	BIF	BIF: Banded Iron Formation	
72			

Graphic Log



Bore Construction

Depth scale: 0, 10, 20, 30, 40, 50, 60, 70, 80, 90, 100

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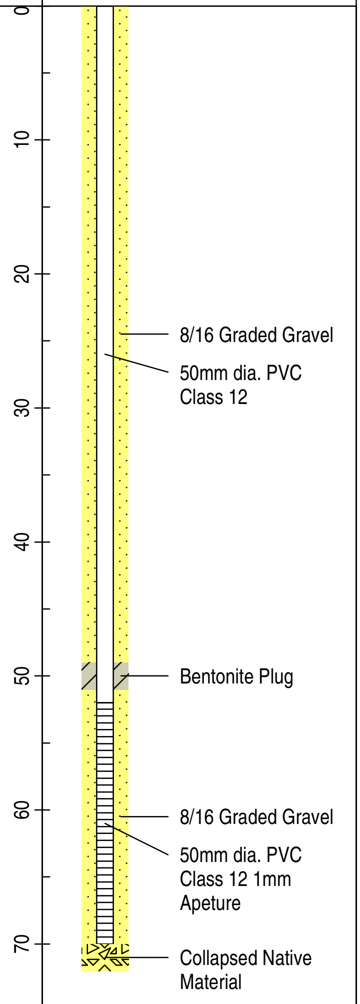
BOREHOLE:
HPRC0121

CLIENT	FMS	**LOCATION**	EAGLE	**DRILLED DEPTH (m)**	72
PROJECT	PIOP	**PROJECTION**		**SCREEN (mBGL)**	52.0-70.0
DATE DRILLED	01NOV2011	**EASTING**	549899.447	**ELEVATION (mAHD)**	599.975
LOGGED BY		**NORTHING**	7547696.095	**WATER LEVEL (mBGL)**	Dry

Contractor		**Drill Bit**	5.5"	**Airlift (L/s)**		**Salinity (mS/cm)**	
Rig Type	AIR CORE RC	**Drill Fluid**	A/W	**Temperature (°C)**		**pH**	

Depth (m)	Geological Unit	Lithology	Field Notes
0–8	COL	COL: Recent Colluvium	"Not enough water to airlift"
8–12	ALL	ALL: Recent Alluvium	
12–50	DIDh	DIDh: Detrital Iron Deposit - hematite dominant	
50–54	BIF	BIF: Banded Iron Formation	
54–62	BIDg	BIDg: Bedded Iron Deposit - goethite dominant	
62–72	BIF	BIF: Banded Iron Formation	

Bore Construction



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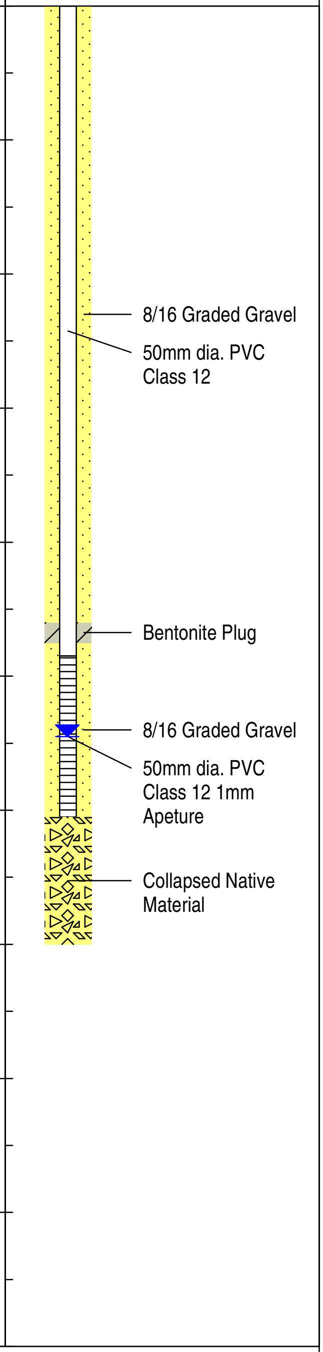
BOREHOLE:
HPRC0108

CLIENT	FMS	**LOCATION**	EAGLE	**DRILLED DEPTH (m)**	70
PROJECT	PIOP	**PROJECTION**		**SCREEN (mBGL)**	48.5-60.5
DATE DRILLED	02NOV2011	**EASTING**	548395.622	**ELEVATION (mAHD)**	619.982
LOGGED BY		**NORTHING**	7548102.472	**WATER LEVEL (mBGL)**	54.5

Contractor		**Drill Bit**	5.5"	**Airlift (L/s)**		**Salinity (mS/cm)**	
Rig Type	AIR CORE RC	**Drill Fluid**	A/W	**Temperature (°C)**		**pH**	

Depth (m)	Geological Unit	Lithology	Field Notes
0–24	COL	COL: Recent Colluvium	"Yield ceased after 15min; TDS-902ppm"
24–56	DIDh	DIDh: Detrital Iron Deposit - hematite dominant	
56–62	BIDg	BIDg: Bedded Iron Deposit - goethite dominant	
62–66	CHT	CHT: Chert	
66–70	BIF	BIF: Banded Iron Formation	

Bore Construction



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BOREHOLE: *HPRC0098*

CLIENT	FMS	**LOCATION**	EAGLE	**DRILLED DEPTH (m)**	72
PROJECT	PIOP	**PROJECTION**		**SCREEN (mBGL)**	53.00-71.40
DATE DRILLED	01NOV2011	**EASTING**	547225.338	**ELEVATION (mAHD)**	630.841
LOGGED BY		**NORTHING**	7548717.863	**WATER LEVEL (mBGL)**	61.6

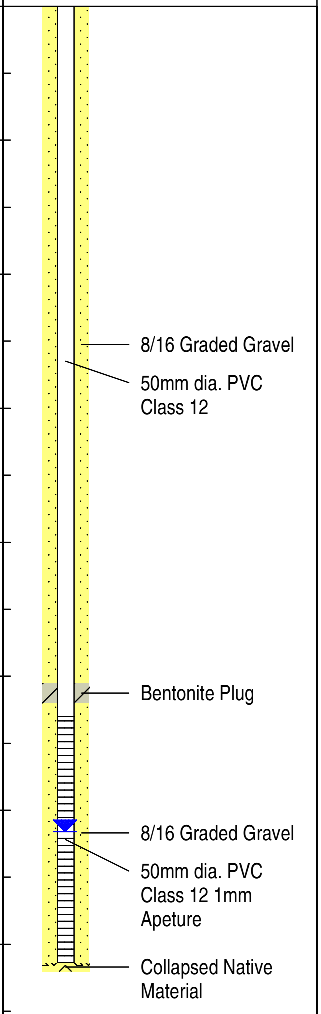
Contractor		**Drill Bit**	5.5"	**Airlift (L/s)**	0	**Salinity (mS/cm)**	
Rig Type	AIR CORE RC	**Drill Fluid**	A/W	**Temperature (℃)**		**pH**	

Depth (m)	Geological Unit	Graphic Log	Lithology
0–8	COL		COL: Recent Colluvium
8–16	ALL		ALL: Recent Alluvium
16–48	DIDh		DIDh: Detrital Iron Deposit - hematite dominant
48–54	BIDg		BIDg: Bedded Iron Deposit - goethite dominant
54–56	SH		SHL: Shale
56–62	CHT		CHT: Chert
62–72	BIF		BIF: Banded Iron Formation

Field Notes

"Yield ceased after 10min; TDS-255ppm"

Bore Construction



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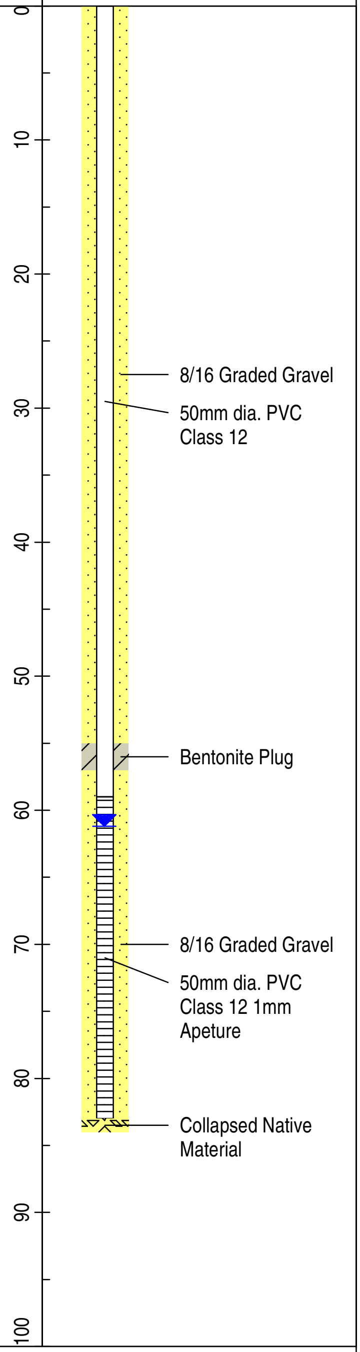
BOREHOLE: *HPRC0068*

CLIENT	FMS	**LOCATION**	EAGLE	**DRILLED DEPTH (m)**	84
PROJECT	PIOP	**PROJECTION**		**SCREEN (mBGL)**	59.00-83.00
DATE DRILLED	17AUG2011	**EASTING**	548902.035	**ELEVATION (mAHD)**	607.706
LOGGED BY		**NORTHING**	7547396.143	**WATER LEVEL (mBGL)**	61.2

Contractor		**Drill Bit**	5.5"	**Airlift (L/s)**	0	**Salinity (mS/cm)**	
Rig Type	AIR CORE RC	**Drill Fluid**	A/W	**Temperature (°C)**		**pH**	

Depth (m)	Geological Unit	Graphic Log	Lithology	Field Notes
0–28	ALL		ALL: Recent Alluvium	"Not enough Water to airlift"
28–44	DIDh		DIDh: Detrital Iron Deposit - hematite dominant	
44–74	CIDg		CIDg: Channel Iron Deposit - goethite dominant	
74–76	BIDg		BIDg: Bedded Iron Deposit - goethite dominant	
76–84	BIF		BIF: Banded Iron Formation	

Bore Construction



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Level 7 | QV1 Building
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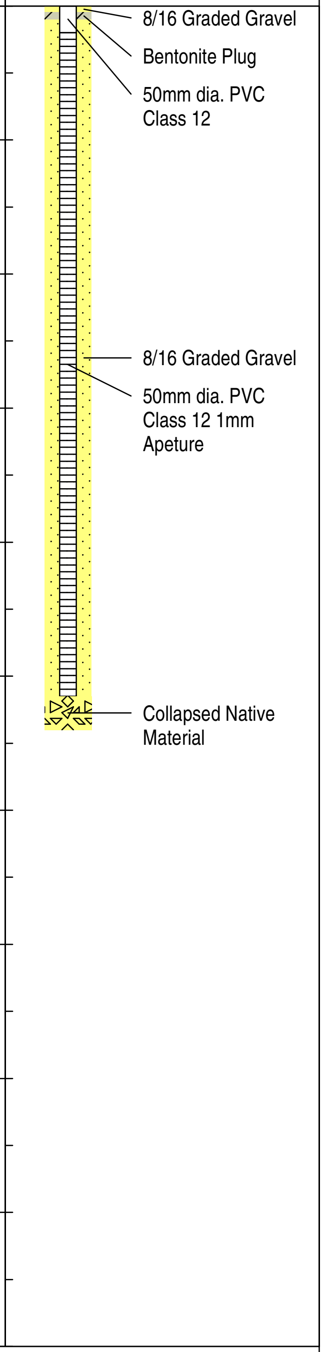
BOREHOLE: *HPRC0035*

CLIENT	FMS	**LOCATION**	EAGLE	**DRILLED DEPTH (m)**	54
PROJECT	PIOP	**PROJECTION**		**SCREEN (mBGL)**	2.00-51.50
DATE DRILLED	01NOV2011	**EASTING**	548398.962	**ELEVATION (mAHD)**	646.919
LOGGED BY		**NORTHING**	7548996.028	**WATER LEVEL (mBGL)**	Dry

Contractor		**Drill Bit**	5.5"	**Airlift (L/s)**		**Salinity (mS/cm)**	
Rig Type	AIR CORE RC	**Drill Fluid**	A/W	**Temperature (℃)**		**pH**	

Depth (m)	Geological Unit	Graphic Log	Lithology	Field Notes
0–26	DIDh		DIDh: Detrital Iron Deposit - hematite dominant	"Not enough water to airlift"
26–36	BIDg		BIDg: Bedded Iron Deposit - goethite dominant	
36–40	CHT		CHT: Chert	
40–54	BIF		BIF: Banded Iron Formation	

Bore Construction



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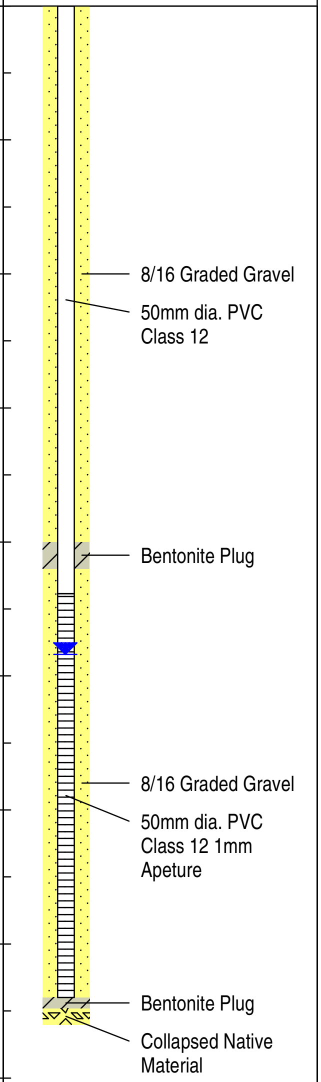
BOREHOLE: *HPRC0004*

CLIENT	FMS	**LOCATION**	EAGLE	**DRILLED DEPTH (m)**	76
PROJECT	PIOP	**PROJECTION**		**SCREEN (mBGL)**	43.85-74.00
DATE DRILLED	16AUG2011	**EASTING**	550929.499	**ELEVATION (mAHD)**	589.115
LOGGED BY		**NORTHING**	7547398.306	**WATER LEVEL (mBGL)**	48.4

Contractor		**Drill Bit**	5.5"	**Airlift (L/s)**	0.1	**Salinity (mS/cm)**	
Rig Type	AIR CORE RC	**Drill Fluid**	A/W	**Temperature (°C)**		**pH**	

Depth (m)	Geological Unit	Lithology	Field Notes
0–14	COL	COL: Recent Colluvium	"Development Duration - 30min; TDS-172.0ppm
14–38	ALL	ALL: Recent Alluvium	
38–50	DIDh	DIDh: Detrital Iron Deposit - hematite dominant	
50–62	BIDg	BIDg: Bedded Iron Deposit - goethite dominant	
62–64	BIF	BIF: Banded Iron Formation	
64–66	CH	CHT: Chert	
66–76	BIF	BIF: Banded Iron Formation	

Bore Construction



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BOREHOLE: *EAGLE-PROD-1*

WorleyParsons resources & energy

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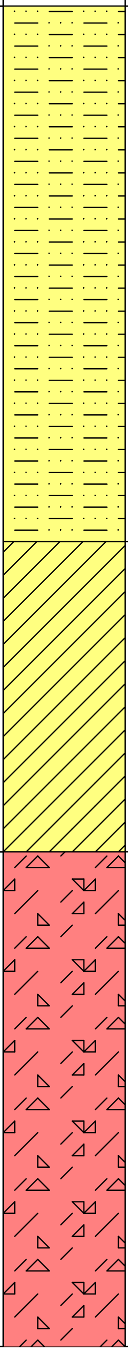
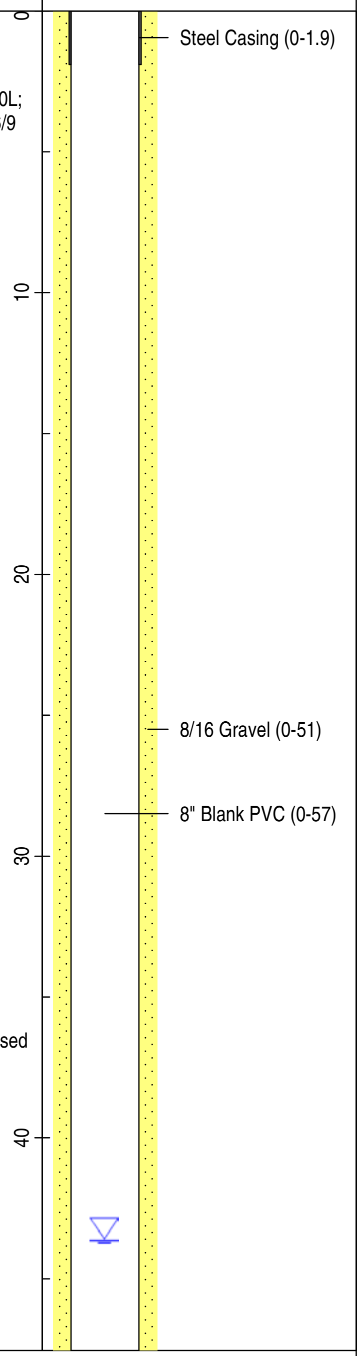
CLIENT	FMS	**LOCATION**	EAGLE DEPOSIT	**TOTAL DEPTH (m)**	119.5
PROJECT	PIOP	**PROJECTION**	GDA94 MGA Zone 50	**SCREEN (mBGL)**	57-114.3
DATE DRILLED	10-18 SEP 2011	**EASTING**	551396.24	**ELEVATION (mAHD)**	584.08
LOGGED BY	R BAIRD	**NORTHING**	7547002.15	**WATER LEVEL (mBGL)**	43.28

Contractor	AUSTRAL	**Drill Bit**	12.25" Tricone	**Airlift (L/s)**	15	**Salinity (mS/cm)**	0.36
Rig Type	SCHRAMM T64	**Drill Fluid**	Mud Rotary	**Temperature (℃)**	29.2	**pH**	8.25

Depth (m)	Geological Unit	Graphic Log	Lithology	Field Notes
0	Colluvium		SILTY SAND: matrix with gravels of BIF, chert and shale, red brown, gravels subrounded to angular up to 30mm.	Mud usage volume: 11/9 27kL; 12/9 0L; 13/9 12kL; 14/9 36kL; 15/9 54kL; 16/9 48kL; 17/9 36kL; 18/9 48kL
10				4.17min/m
20			SILTY CLAY: with gravels of BIF, chert and shale, red brown, subrounded to angular, gravels up to 30mm.	5.83min/m; 4.17min/m
30	DID		GRAVELLY CLAY: with gravels of BIF, chert, shale, subrounded to angular, pisoliths.	7.5min/m; Pulled out of hole. Blocked bit. Collapsed 8m into bottom of hole
40				viscosity 60 secs I 14.7min/m



Bore Construction



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WorleyParsons resources & energy

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Perth WA 6000
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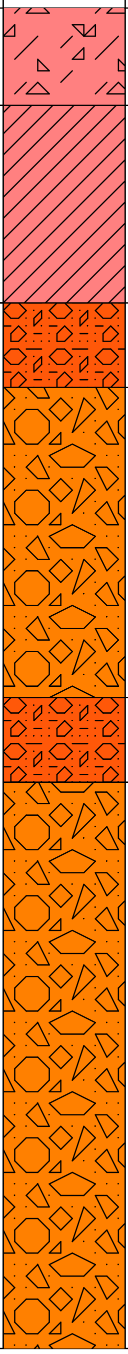
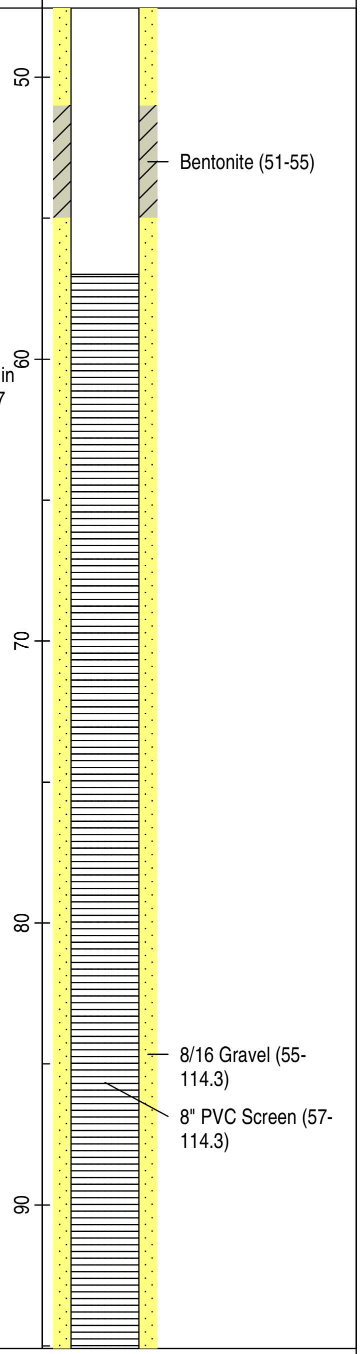
BOREHOLE: *EAGLE-PROD-1*

CLIENT	FMS	**LOCATION**	EAGLE DEPOSIT	**TOTAL DEPTH (m)**	119.5
PROJECT	PIOP	**PROJECTION**	GDA94 MGA Zone 50	**SCREEN (mBGL)**	57-114.3
DATE DRILLED	10-18 SEP 2011	**EASTING**	551396.24	**ELEVATION (mAHD)**	584.08
LOGGED BY	R BAIRD	**NORTHING**	7547002.15	**WATER LEVEL (mBGL)**	43.28

Contractor	AUSTRAL	**Drill Bit**	12.25" Tricone	**Airlift (L/s)**	15	**Salinity (mS/cm)**	0.36
Rig Type	SCHRAMM T64	**Drill Fluid**	Mud Rotary	**Temperature (℃)**	29.2	**pH**	8.25

Depth (m)	Geological Unit	Graphic Log	Lithology	Field Notes	Bore Construction
50				4.0min/m	
	Clay		Clay: with minor gravels, mottled grey, yellow, medium plasticity, sticky, minor gravels of BIF, chert, shale, may be contamination due to different up hole velocities of clay and BIF.	very slow penetration	Bentonite (51-55)
60			CLAYEY GRAVEL: alternating bands of yellow clay (40%), with gravels of BIF, chert, shale (50%), subangular.	Pulled rod out. End of clay. Tagged in morning at 54. 7m collapse I 14.17	
			GRAVEL: with BIF, chert, shale, red brown silty matrix, gravel subangular up to 20mm, minor clay lenses <5%, ooids and peloids.		
70				15min/m	
			CLAYEY GRAVEL: beige-grey, gravels of BIF, chert, shale, poor samples.		
80	CID		GRAVEL: yellow brown, partially cemented, medium grained gravel, BIF and chert, subangular, red brown matrix, minor clay <5%	Mud loss started I 8.3min/m	
			From 90m increase in clay content to 10%	End of day. Mud loss increased I 11.67min/m	8/16 Gravel (55-114.3)
			From 100m partially cemented gravels of BIF, chert, shale, yellow-brown, ooids and peloids, subangular gravels up to 18mm, minor lenses of thinly banded clay <5%		8" PVC Screen (57-114.3)
90			From 114m slight increase in clay		





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250 St George's Terrace
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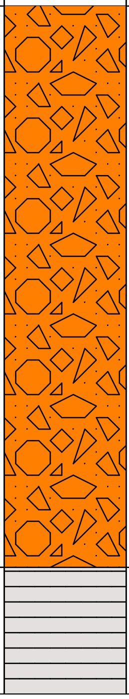
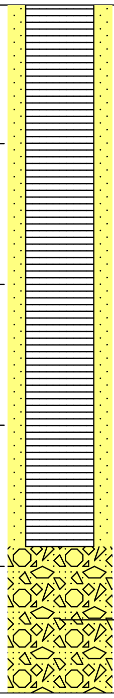
BOREHOLE:
EAGLE-PROD-1

CLIENT	FMS	**LOCATION**	EAGLE DEPOSIT	**TOTAL DEPTH (m)**	119.5
PROJECT	PIOP	**PROJECTION**	GDA94 MGA Zone 50	**SCREEN (mBGL)**	57-114.3
DATE DRILLED	10-18 SEP 2011	**EASTING**	551396.24	**ELEVATION (mAHD)**	584.08
LOGGED BY	R BAIRD	**NORTHING**	7547002.15	**WATER LEVEL (mBGL)**	43.28

Contractor	AUSTRAL	**Drill Bit**	12.25" Tricone	**Airlift (L/s)**	15	**Salinity (mS/cm)**	0.36
Rig Type	SCHRAMM T64	**Drill Fluid**	Mud Rotary	**Temperature (°C)**	29.2	**pH**	8.25

Depth (m)	Geological Unit	Graphic Log	Lithology	Field Notes	Bore Construction
100					
110				Poor sample returns	
	BIF		BIF: grey, fresh, angular chips, slow penetration	Very slow drilling Thinned viscosity out to 48 secs prior to completing bore	Collapse (114.3-119)

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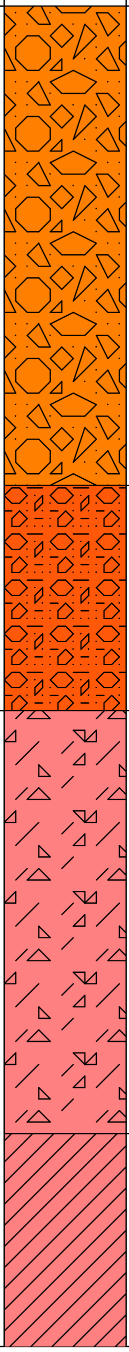
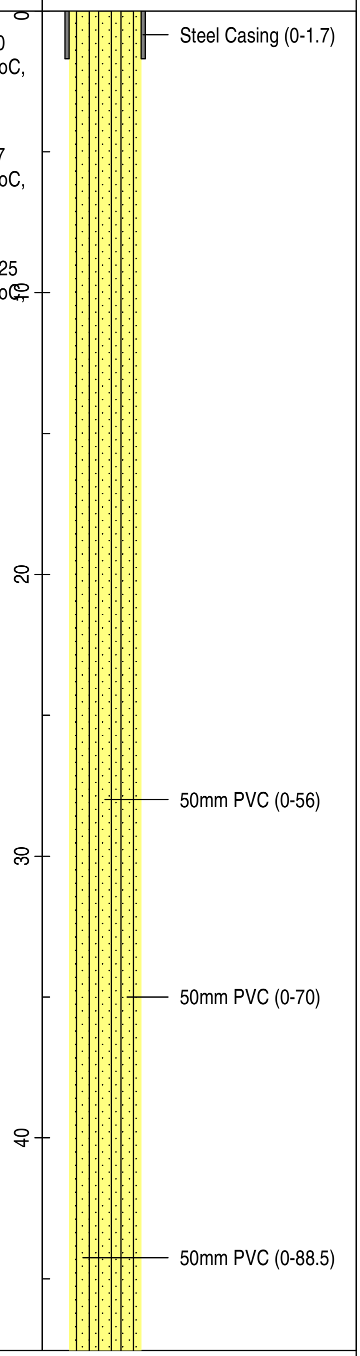
BOREHOLE:
EAGLE-OBS-4-NESTED

CLIENT	FMS	**LOCATION**	EAGLE	**TOTAL DEPTH (m)**	120
PROJECT	FLINDERS PIOP	**PROJECTION**	GDA94 MGA Zone 50	**SCREEN (mBGL)**	see field notes
DATE DRILLED	23-26SEP2011	**EASTING**	551406.96	**ELEVATION (mAHD)**	584.1
LOGGED BY	S BEAR	**NORTHING**	7547011.00	**WATER LEVEL (mBGL)**	see field notes

Contractor	AUSTRAL	**Drill Bit**	8.5"	**Airlift (L/s)**	see field notes	**Salinity (mS/cm)**	see field notes
Rig Type	SCHRAMM T640	**Drill Fluid**	Mud Rotary	**Temperature (°C)**	see field notes	**pH**	see field notes

Depth (m)	Geological Unit	Graphic Log	Lithology	Field Notes
0–17	Alluvium		SANDY GRAVEL: red brown, gravels of BIF, chert and shale, subrounded to angular	Bore A: Screened 56-65, WL 43.30 mAHD, 0.27 mS/cm, 550 mg/L, 28.1 oC, pH 8.81 Bore B: Screened 70-82, WL 43.27 mAHD, 0.25 mS/cm, 490 mg/L, 29.2 oC, pH 8.56 Bore C: Screened 88.5-114, WL 43.25 mAHD, 0.17 mS/cm, 340 mg/L, 29.6 oC, pH 8.13
17–25	Alluvium		CLAYEY GRAVEL: red brown, rounded to subangular, BIF, hematite	3.5min/m
25–40	DID		GRAVELLY CLAY: red brown, rounded to subangular, BIF, hematite	
40–	DID		CLAY: red brown, minor gravels of BIF, pisoliths, decreasing gravel with depth From 50m, mottled grey yellow, very hard, minor gravels at base	2.5min/m

Bore Construction



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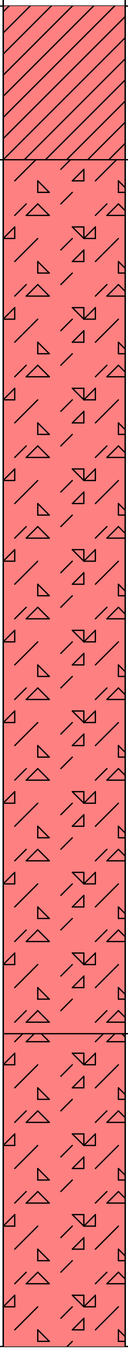
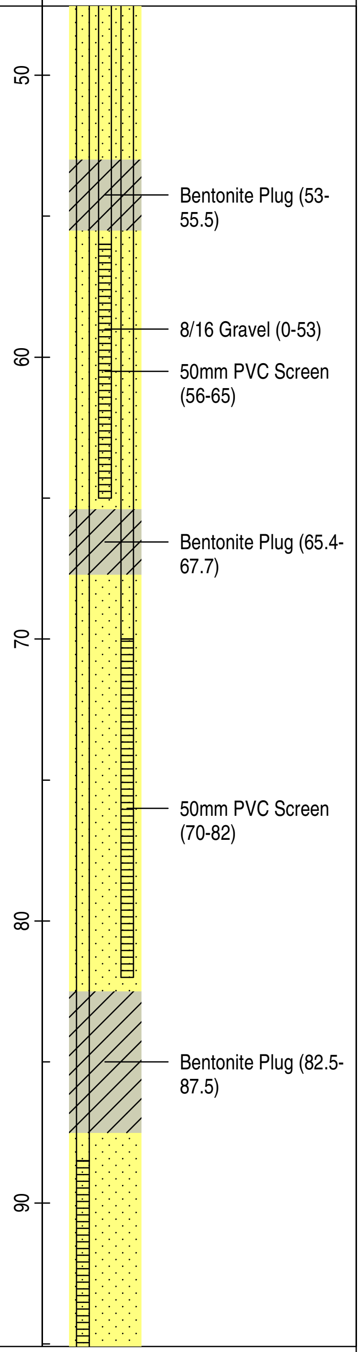
BOREHOLE:
EAGLE-OBS-4-NESTED

CLIENT	FMS	**LOCATION**	EAGLE	**TOTAL DEPTH (m)**	120
PROJECT	FLINDERS PI0P	**PROJECTION**	GDA94 MGA Zone 50	**SCREEN (mBGL)**	see field notes
DATE DRILLED	23-26SEP2011	**EASTING**	551406.96	**ELEVATION (mAHD)**	584.1
LOGGED BY	S BEAR	**NORTHING**	7547011.00	**WATER LEVEL (mBGL)**	see field notes

Contractor	AUSTRAL	**Drill Bit**	8.5"	**Airlift (L/s)**	see field notes	**Salinity (mS/cm)**	see field notes
Rig Type	SCHRAMM T640	**Drill Fluid**	Mud Rotary	**Temperature (°C)**	see field notes	**pH**	see field notes

Depth (m)	Geological Unit	Graphic Log	Lithology	Field Notes	Bore Construction
50				4.17min/m	
	CID		GRAVELLY CLAY: yellow brown, cemented ooids in goethite clay matrix, vitrious goethite and hematite present from 65-68m, clay content increased from 79m, woody fragments present	8.17min/m	Bentonite Plug (53-55.5) 8/16 Gravel (0-53) 50mm PVC Screen (56-65)
60				6.83min/m	
				11.67min/m	Bentonite Plug (65.4-67.7)
70				10.5min/m	50mm PVC Screen (70-82)
80				10min/m	
			GRAVELLY CLAY: yellow brown, clay content increasing from 95m, yellow brown with minor gravels of CIDg	3.17min/m	Bentonite Plug (82.5-87.5)
90				2.5min/m	





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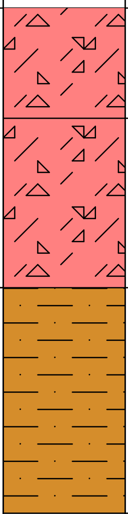
BOREHOLE:
EAGLE-OBS-4-NESTED

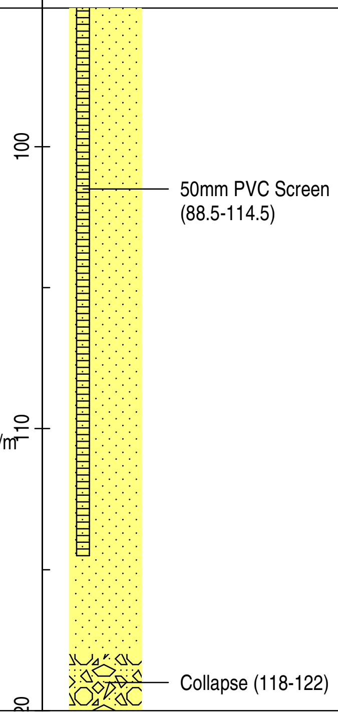
CLIENT	FMS	**LOCATION**	EAGLE	**TOTAL DEPTH (m)**	120
PROJECT	FLINDERS PI0P	**PROJECTION**	GDA94 MGA Zone 50	**SCREEN (mBGL)**	see field notes
DATE DRILLED	23-26SEP2011	**EASTING**	551406.96	**ELEVATION (mAHD)**	584.1
LOGGED BY	S BEAR	**NORTHING**	7547011.00	**WATER LEVEL (mBGL)**	see field notes

Contractor	AUSTRAL	**Drill Bit**	8.5"	**Airlift (L/s)**	see field notes	**Salinity (mS/cm)**	see field notes
Rig Type	SCHRAMM T640	**Drill Fluid**	Mud Rotary	**Temperature (°C)**	see field notes	**pH**	see field notes

Depth (m)	Geological Unit	Graphic Log	Lithology	Field Notes
				3.75min/m
100			GRAVELLY CLAY: yellow brown with cemented ooids, altered goethite matrix	3.33min/m
	BIDg		BID: grey yellow, goethitic clay altered BIF, quartz present, gravels are more angular, no ooids	
110				Lost circulation 113-120m I 2.67min/m
			Lost circulation and returns	0.38min/m
120				



Bore Construction



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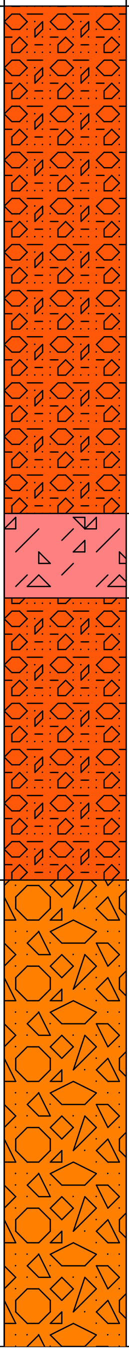
BOREHOLE: *EAGLE-OBS-3*

CLIENT	FMS	**LOCATION**	EAGLE	**TOTAL DEPTH (m)**	82.5
PROJECT	FLINDERS PI0P	**PROJECTION**	GDA94 MGA Zone 50	**SCREEN (mBGL)**	40-82
DATE DRILLED	24-25 AUG 2011	**EASTING**	551373.0	**ELEVATION (mAHD)**	584.75
LOGGED BY	R BAIRD	**NORTHING**	7547809.75	**WATER LEVEL (mBGL)**	43.78

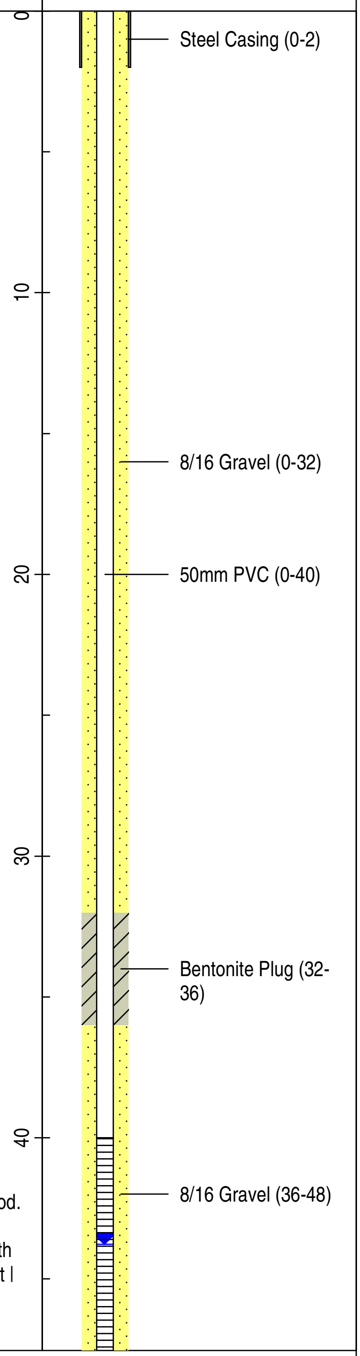
Contractor	AUSTRAL	**Drill Bit**	5.5"	**Airlift (L/s)**	1.5	**Salinity (mS/cm)**	0.24
Rig Type	SCHRAMM T640	**Drill Fluid**	AirCore/RC Hammer	**Temperature (℃)**	26.9	**pH**	8.23

Depth (m)	Geological Unit	Graphic Log	Lithology	Field Notes
0	Colluvium		CLAYEY GRAVEL: red brown matrix with fragments of shale, chert, BIF, subangular to subrounded, 30% clayey silt, 70% fragments, fragments up to 30mm.	hammer with foam and water
18	Colluvium		GRAVELLY CLAY: red, soft, gravels of shale, chert and BIF.	
21	Colluvium		CLAYEY GRAVEL: red brown matrix with fine to coarse gravel consisting of shale, chert, BIF, subangular to subrounded, 30mm fragments, unconsolidated.	2.6min/m
31	DID		GRAVEL: red, fine to coarse, subangular to subrounded, pisoliths, well rounded, gravel consists of shale, chert, BIF, some clay and silt ~20%.	Pisoliths presents, less clay; Hammer blocked with clay. Missed rod. No samples laid out from 44-50m. happened when they tripped out with hammer and back in with air core bit I 1.92min/m

Graphic Log



Bore Construction



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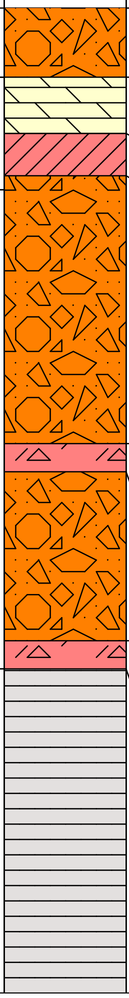
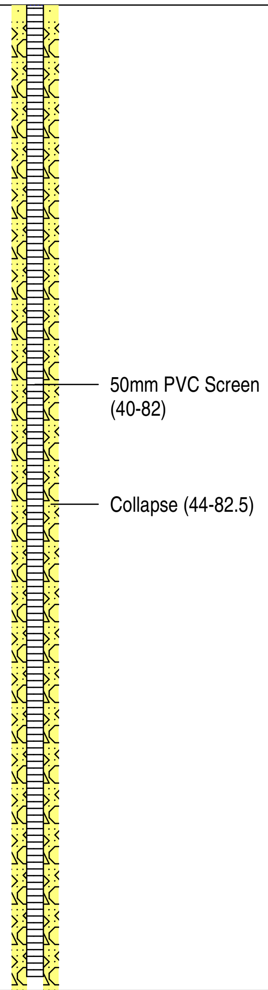
BOREHOLE: *EAGLE-OBS-3*

CLIENT	FMS	**LOCATION**	EAGLE	**TOTAL DEPTH (m)**	82.5
PROJECT	FLINDERS PI0P	**PROJECTION**	GDA94 MGA Zone 50	**SCREEN (mBGL)**	40-82
DATE DRILLED	24-25 AUG 2011	**EASTING**	551373.0	**ELEVATION (mAHD)**	584.75
LOGGED BY	R BAIRD	**NORTHING**	7547809.75	**WATER LEVEL (mBGL)**	43.78

Contractor	AUSTRAL	**Drill Bit**	5.5"	**Airlift (L/s)**	1.5	**Salinity (mS/cm)**	0.24
Rig Type	SCHRAMM T640	**Drill Fluid**	AirCore/RC Hammer	**Temperature (℃)**	26.9	**pH**	8.23

Depth (m)	Geological Unit	Graphic Log	Lithology	Field Notes	Bore Construction
50	Oakover Fo		SILCRETE: biege, very hard, chemical precipitation of carbonates and silica.		
			CLAY: mottled grey green, stiff, tight, high plasticity.	water cut l0.14mS l 0.07ppt l pH7.91 l 28.6°C l 12min/m l 0.44L/s	
	CID		GRAVEL: yellow grey, gravels of shale and BIF, subangular. From 58m fine to coarse gravel in matrix of yellow silty clay, goethite, gravel up to 20mm.		
60				0.26mS l 0.13ppt l pH7.90 l 27.0°C l 5min/m l 0.11L/s	50mm PVC Screen (40-82)
			GRAVELLY CLAY: tan to yellow, sticky, medium plasticity.		Collapse (44-82.5)
			GRAVEL: cemented CID	0.19mS l 0.09ppt l pH7.63 l 29.6°C l 5min/m l 0.74L/s	
70			GRAVELLY CLAY: light brown, gravel 20%, clay 80%, sticky, medium plasticity.	0.19mS l 0.09ppt l pH7.71 l 28.9°C l 4.17min/m l 0.4L/s	
	BIF		BIF: grey, weathered, overturned. From 75m, weathered with white clay lenses. From 80m, grey fresh BIF & chert.	0.22mS l 0.11ppt l pH7.69 l 30.0°C l 10min/m l 1.33L/s	
80				0.24mS l 0.12ppt l pH7.74 l 29.5°C l	





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250 St George's Terrace
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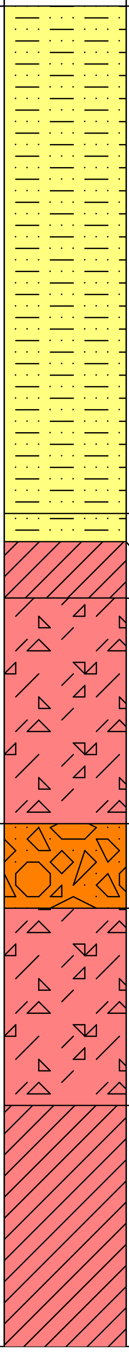
BOREHOLE:
EAGLE-OBS-2

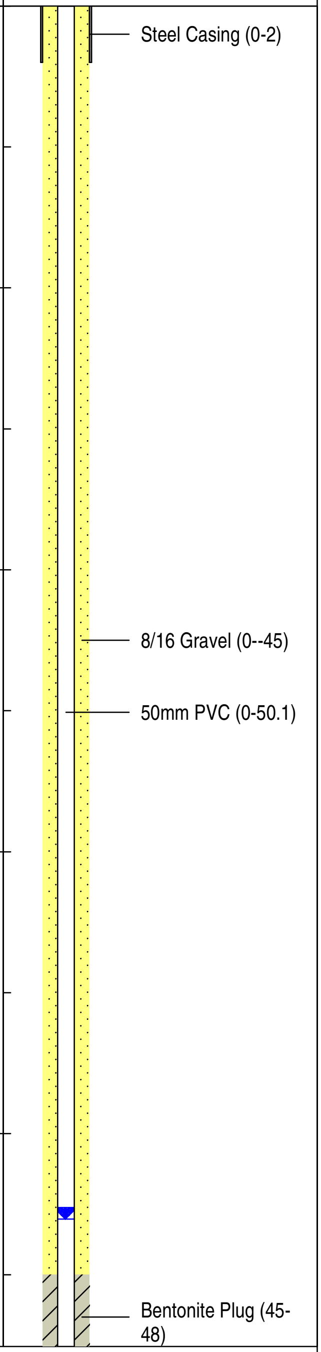
CLIENT	FMS	**LOCATION**	EAGLE	**TOTAL DEPTH (m)**	118
PROJECT	FLINDERS PI0P	**PROJECTION**	GDA94 MGA Zone 50	**SCREEN (mBGL)**	50.1-116.1
DATE DRILLED	21-23 AUG 2011	**EASTING**	551403.55	**ELEVATION (mAHD)**	583.78
LOGGED BY	R BAIRD	**NORTHING**	7546985.32	**WATER LEVEL (mBGL)**	43.03

Contractor	AUSTRAL	**Drill Bit**	5.5"	**Airlift (L/s)**	6.5	**Salinity (mS/cm)**	0.29
Rig Type	SCHRAMM T640	**Drill Fluid**	AirCore/RC Hammer	**Temperature (℃)**	27.6	**pH**	8.03

Depth (m)	Geological Unit	Graphic Log	Lithology	Field Notes
0	Colluvium		SILTY SAND: brown, fine grained, fragments of chert, shale, BIF, subrounded to angular, fragments up to 50mm in size.	
10				5.38min/m
			CLAYEY SILT: red, dry, sticky when wet.	
20			CLAY: red, sticky, high plasticity.	Wet samples - added water
			GRAVELLY CLAY: red, sticky, high plasticity, fragments of chert and BIF, subrounded to angular, gravel 30%, clay 70%.	Hammer blocked with clay.Trip out, put on air core bit. Dry samples, not adding water
30	DID		GRAVEL: red brown, fragments of chert and BIF up to 30mm, subangular, minor silt and sand.	9.06 min/m
			GRAVELLY CLAY: red, medium plasticity, contains fragments of BIF and chert up to 20mm, subrounded, Gravel 30%, Clay 70%.	Hole in cyclone hose, 1hr to repair
40			CLAY: red, medium plasticity, sticky. From 49m, grey green yellow, mottled, very stiff, tight. From 53m, red, medium plasticity. From 54m, red, minor grey green mottling, high plasticity.	8.08 min/m



Bore Construction



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BOREHOLE:

EAGLE-OBS-2

CLIENT	FMS	**LOCATION**	EAGLE	**TOTAL DEPTH (m)**	118
PROJECT	FLINDERS PI0P	**PROJECTION**	GDA94 MGA Zone 50	**SCREEN (mBGL)**	50.1-116.1
DATE DRILLED	21-23 AUG 2011	**EASTING**	551403.55	**ELEVATION (mAHD)**	583.78
LOGGED BY	R BAIRD	**NORTHING**	7546985.32	**WATER LEVEL (mBGL)**	43.03

Contractor	AUSTRAL	**Drill Bit**	5.5"	**Airlift (L/s)**	6.5	**Salinity (mS/cm)**	0.29
Rig Type	SCHRAMM T640	**Drill Fluid**	AirCore/RC Hammer	**Temperature (℃)**	27.6	**pH**	8.03

Depth (m)	Geological Unit	Lithology	Field Notes
50–57.5	Clay		3.75 min/m Colour change from red to yellow
57.5–60	CIDh	CLAY: yellow red, alternating bands of medium to coarse grained gravel with minor clay lenses, highly cemented in layers with goethite and hematite matrix.	
60–61	Cl	CLAY: red, minor grey yellow mottling, stiff, tight.	Drillers noted water cut
61–72	CID / Cla	CLAYEY GRAVEL: yellow red, alternating bands of medium to coarse grained gravel with minor clay lenses, highly cemented in layers with goethite and hematite matrix, minor yellow clay, gravels of chert and BIF, angular, some ooids and pisoliths.	0.28mS I pH8.16 I 2.92min/m I 0.8L/s 0.28mS I 0.14ppt I pH7.98 I 28.6°C I 1.33L/s
72–73		CLAY: beige, tight, very stiff, hard, high plasticity.	
73–74		GRAVELLY CLAY: beige, gravel 10%, clay 90%, sticky, medium plasticity.	
74–80		GRAVEL: red brown grey, partially cemented, medium grained gravels of BIF and chert, subangular, minor clay <5%. From 80m, cemented fine to medium gravel with ooids and peloids, grey red brown, minor vugs and cavities.	0.28mS I 0.14ppt I pH8.01 I 27.9°C I 5.42min/m I 2.86L/s
80–81	CID	GRAVEL: yellow, cemented, geothite matrix, vuggy, ooids and peloids.	
81–97	CID	GRAVEL: red, cemented, hematite matrix, vuggy, ooids and peloids. Wood fragments at 90m. From 95m higher cementation, finer grained, cemented ooids and peloids, red-yellow, vuggy clay matrix.	0.29mS I 0.14ppt I pH8.06 I 28.3°C I 3.33L/s 0.28mS I 0.14ppt I pH8.05 I 27.6°C I 3.75min/m I 4.0L/s

Bore Construction:
- 8/16 Gravel (48-81)
- 50mm PVC Screen (50.1-116.1)

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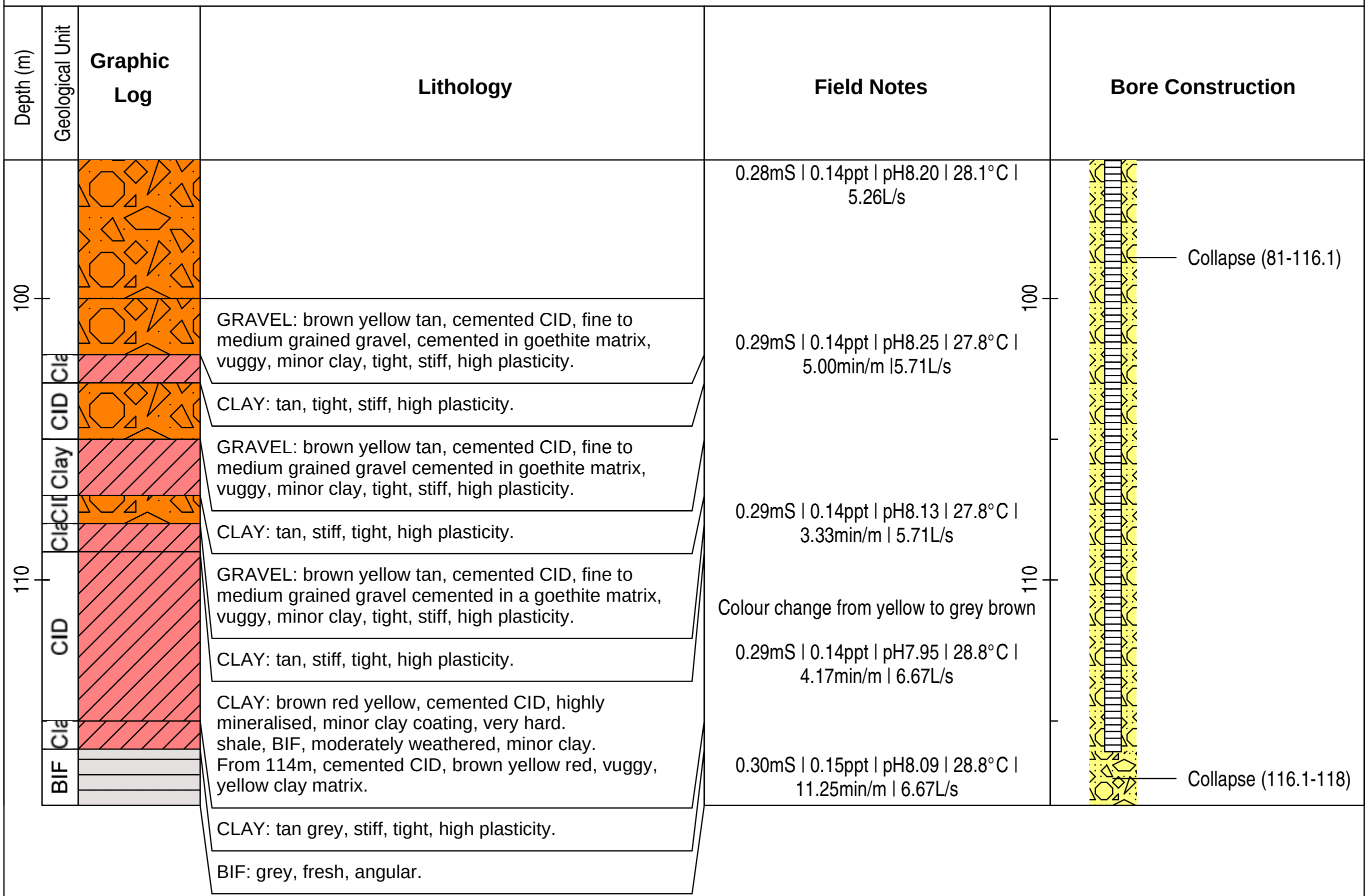
BOREHOLE: *EAGLE-OBS-2*

CLIENT	FMS	**LOCATION**	EAGLE	**TOTAL DEPTH (m)**	118
PROJECT	FLINDERS PI0P	**PROJECTION**	GDA94 MGA Zone 50	**SCREEN (mBGL)**	50.1-116.1
DATE DRILLED	21-23 AUG 2011	**EASTING**	551403.55	**ELEVATION (mAHD)**	583.78
LOGGED BY	R BAIRD	**NORTHING**	7546985.32	**WATER LEVEL (mBGL)**	43.03

Contractor	AUSTRAL	**Drill Bit**	5.5"	**Airlift (L/s)**	6.5	**Salinity (mS/cm)**	0.29
Rig Type	SCHRAMM T640	**Drill Fluid**	AirCore/RC Hammer	**Temperature (°C)**	27.6	**pH**	8.03



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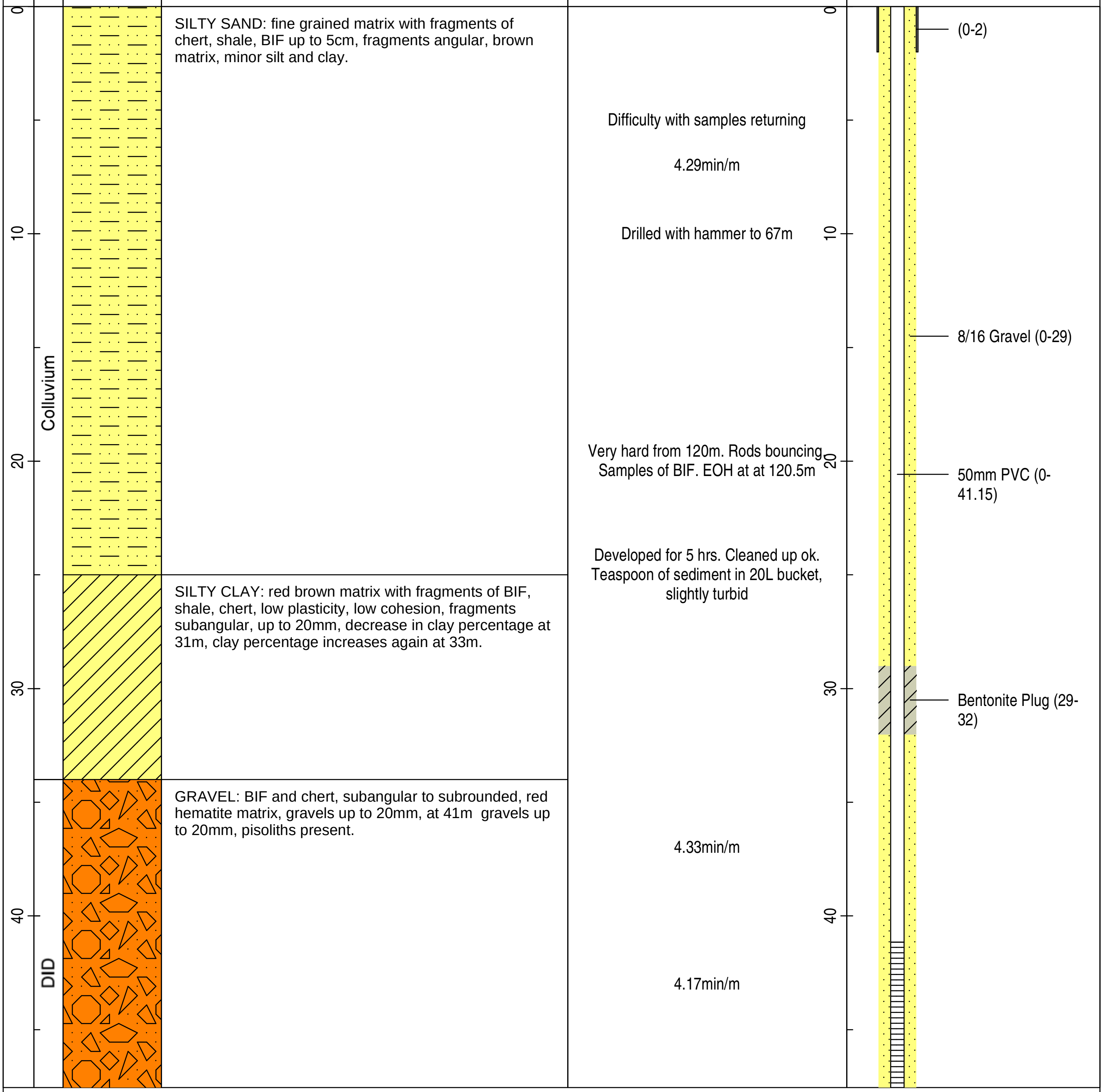
BOREHOLE:
EAGLE-OBS-1

CLIENT	FMS	**LOCATION**	EAGLE	**TOTAL DEPTH (m)**	120.5
PROJECT	FLINDERS PI0P	**PROJECTION**	GDA94 MGA Zone 50	**SCREEN (mBGL)**	41.15-113.15
DATE DRILLED	14-20 AUG 2011	**EASTING**	550278.4	**ELEVATION (mAHD)**	594.7
LOGGED BY	R BAIRD	**NORTHING**	7547283.5	**WATER LEVEL (mBGL)**	53.69

Contractor	AUSTRAL	**Drill Bit**	5.5"	**Airlift (L/s)**	4	**Salinity (mS/cm)**	0.35
Rig Type	SCHRAMM T640	**Drill Fluid**	AirCore/RC Hammer	**Temperature (℃)**	29.2	**pH**	8.1

Depth (m)	Geological Unit	Graphic Log	Lithology	Field Notes	Bore Construction
0–25	Colluvium		SILTY SAND: fine grained matrix with fragments of chert, shale, BIF up to 5cm, fragments angular, brown matrix, minor silt and clay.	Difficulty with samples returning 4.29min/m Drilled with hammer to 67m Very hard from 120m. Rods bouncing. Samples of BIF. EOH at at 120.5m Developed for 5 hrs. Cleaned up ok. Teaspoon of sediment in 20L bucket, slightly turbid	(0-2) 8/16 Gravel (0-29) 50mm PVC (0-41.15)
25–34	Colluvium		SILTY CLAY: red brown matrix with fragments of BIF, shale, chert, low plasticity, low cohesion, fragments subangular, up to 20mm, decrease in clay percentage at 31m, clay percentage increases again at 33m.		Bentonite Plug (29-32)
34–	DID		GRAVEL: BIF and chert, subangular to subrounded, red hematite matrix, gravels up to 20mm, at 41m gravels up to 20mm, pisoliths present.	4.33min/m 4.17min/m	



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250 St George's Terrace
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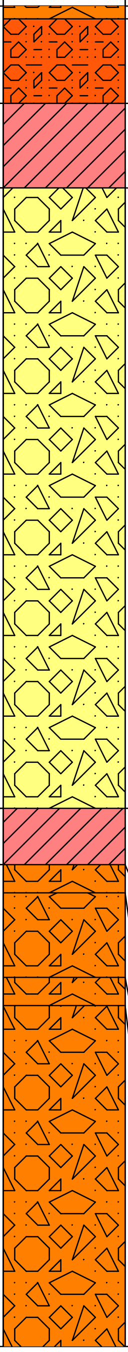
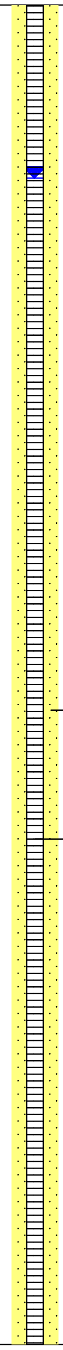
BOREHOLE:
EAGLE-OBS-1

CLIENT	FMS	**LOCATION**	EAGLE	**TOTAL DEPTH (m)**	120.5
PROJECT	FLINDERS PIOP	**PROJECTION**	GDA94 MGA Zone 50	**SCREEN (mBGL)**	41.15-113.15
DATE DRILLED	14-20 AUG 2011	**EASTING**	550278.4	**ELEVATION (mAHD)**	594.7
LOGGED BY	R BAIRD	**NORTHING**	7547283.5	**WATER LEVEL (mBGL)**	53.69

Contractor	AUSTRAL	**Drill Bit**	5.5"	**Airlift (L/s)**	4	**Salinity (mS/cm)**	0.35
Rig Type	SCHRAMM T640	**Drill Fluid**	AirCore/RC Hammer	**Temperature (°C)**	29.2	**pH**	8.1

Depth (m)	Geological Unit	Graphic Log	Lithology	Field Notes	Bore Construction
50			CLAYEY GRAVEL: as above with ~30% clay	4.17min/m	
	Clay		CLAY: brown-red, medium plasticity with minor fragments of BIF and chert, grading to yellow brown from 53-54m.		
	CID		GRAVELLY SILT: CID, yellow brown, fine grained silty matrix with fragments of BIF, chert, shale, partially cemented matrix, contains ooids and peloids, cemented in layers, minor clay <10%, iron rich matrix.	Becoming moist | 5.0min/m	
60				Water cut. Difficult to determine exactly where because adding water/foam | 5.0min/m | 0.05L/s	
				slow penetration | 15min/m	
				Finish for day. Hole colapsed to 44m. Cleaned out hole overnight. Hammer jammed twice. Switch to air core drilling	
70					8/16 Gravel (32-113.15)
				13min/m | 0.16L/s	
	Clay		CLAY: yellow-light brown, tight and hard, confining layer, dry, minor grey brown red medium to coarse grained gravel, up to 10mm.		50mm PVC Screen (41.15-113.15)
80	CID		GRAVEL: red brown grey, medium to coarse grained gravel consisting of BIF and chert, up to 10mm, subangular.		
			GRAVEL: yellow, contains ooids and peloids, minor BIF and chert fragments	End of day. Resumed from 84m. Collapsed to 59m overnight | 7.14 | 1.6L/s	
			GRAVEL: red brown grey, medium to coarse grained gravels of BIF and chert, up to 10mm, subangular.		
90			GRAVEL: red brown grey, medium to coarse grained gravels of BIF and chert, up to 10mm, subangular, colour change at 90m to grey-black with minor red.		

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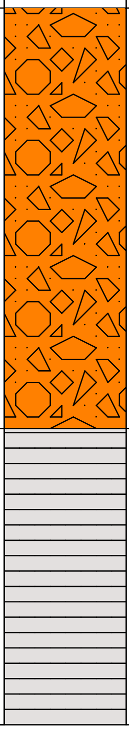
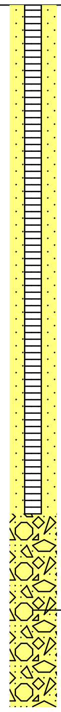
BOREHOLE:
EAGLE-OBS-1

CLIENT	FMS	**LOCATION**	EAGLE	**TOTAL DEPTH (m)**	120.5
PROJECT	FLINDERS PI0P	**PROJECTION**	GDA94 MGA Zone 50	**SCREEN (mBGL)**	41.15-113.15
DATE DRILLED	14-20 AUG 2011	**EASTING**	550278.4	**ELEVATION (mAHD)**	594.7
LOGGED BY	R BAIRD	**NORTHING**	7547283.5	**WATER LEVEL (mBGL)**	53.69

Contractor	AUSTRAL	**Drill Bit**	5.5"	**Airlift (L/s)**	4	**Salinity (mS/cm)**	0.35
Rig Type	SCHRAMM T640	**Drill Fluid**	AirCore/RC Hammer	**Temperature (°C)**	29.2	**pH**	8.1

Depth (m)	Geological Unit	Graphic Log	Lithology	Field Notes	Bore Construction
100				0.33mS I 2L/s 0.34mS I 2.8L/s 0.33mS I 3.3L/s	
110	BIF		BIF: grey, weathered 112m cemented ooids and peltiods red brown grey 116m with pisoliths 118m BIF, slightly weathered to fresh at 120.5m	0.45mS I 6.67min/m I 4L/s Colour change from red/hemalite to yellowish/geothite 0.32mS I 4L/s	Collapse (113.15-120.5)
120					

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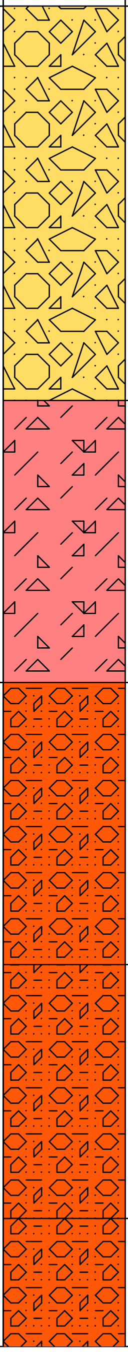
BOREHOLE:
DELTA-PROD-1

CLIENT	FMS	**LOCATION**	DELTA	**TOTAL DEPTH (m)**	108
PROJECT	PI0P	**PROJECTION**	GDA94 MGA Zone 50	**SCREEN (mBGL)**	68-106
DATE DRILLED	30SEP2011	**EASTING**	551424.94	**ELEVATION (mAHD)**	540.82
LOGGED BY	S BEAR	**NORTHING**	7553228.15	**WATER LEVEL (mBGL)**	38.70

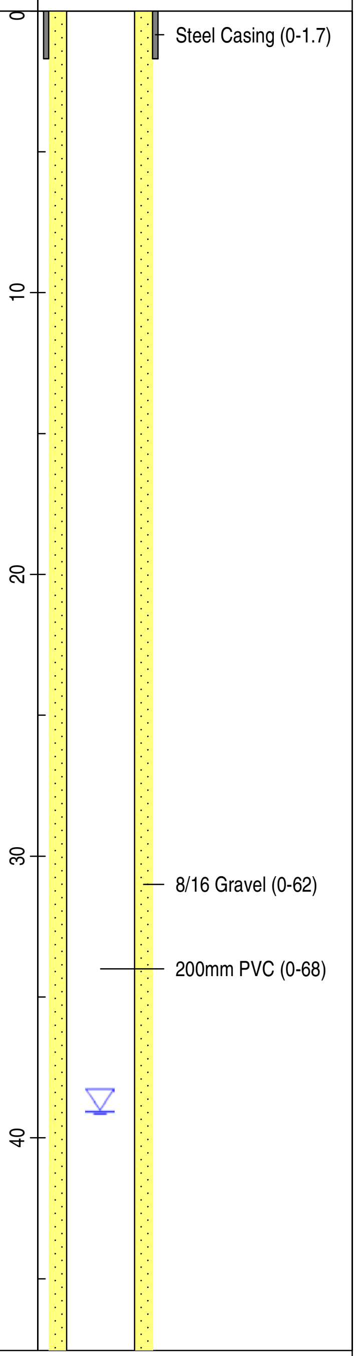
Contractor	AUSTRAL	**Drill Bit**	12.25" Tricone	**Airlift (L/s)**	13	**Salinity (mS/cm)**	0.182
Rig Type	SCHRAMM T64	**Drill Fluid**	Mud Rotary	**Temperature (℃)**	29.7	**pH**	7.22

Depth (m)	Geological Unit	Lithology	Field Notes
0	Colluvium	SILTY GRAVEL: red brown, subangular gravels of BIF, shale & chert, poorly sorted, clay increasing with depth	1.75min/m
10	Colluvium		3.5min/m
	Colluvium	GRAVELLY CLAY: red brown, subrounded gravels of BIF, shale & chert	3.0min/m
20			4.83min/m
	DID	CLAYEY GRAVEL: red brown, subangular gravels of BIF, shale , chert & ooids	2.83min/m
30		CLAYEY GRAVEL: red brown, pisoliths present	3.17min/m
40			3.0min/m
	DID	CLAYEY GRAVEL: red brown, increased clay ~30%, more ooids	2.17min/m

Graphic Log



Bore Construction



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BOREHOLE:
DELTA-PROD-1

CLIENT	FMS	**LOCATION**	DELTA	**TOTAL DEPTH (m)**	108
PROJECT	PI0P	**PROJECTION**	GDA94 MGA Zone 50	**SCREEN (mBGL)**	68-106
DATE DRILLED	30SEP2011	**EASTING**	551424.94	**ELEVATION (mAHD)**	540.82
LOGGED BY	S BEAR	**NORTHING**	7553228.15	**WATER LEVEL (mBGL)**	38.70

Contractor	AUSTRAL	**Drill Bit**	12.25" Tricone	**Airlift (L/s)**	13	**Salinity (mS/cm)**	0.182
Rig Type	SCHRAMM T64	**Drill Fluid**	Mud Rotary	**Temperature (℃)**	29.7	**pH**	7.22

Depth (m)	Geological Unit	Graphic Log	Lithology	Field Notes	Bore Construction
50				3.83min/m	
			CLAYEY GRAVEL: red brown, increased clay ~40%		
			GRAVELLY CLAY: red brown, gravels of BIF, hematite, chert	10.0min/m	
60					
			CLAY: red brown, minor gravels of hematite & BIF, cemented yellow green clay nodules	9.83min/m	Bentonite Plug (62-66)
			CLAY: yellow brown goethitic matrix with ooids		
70				3.67min/m	
			CLAY: gravels of hematite and BIF present	5.17min/m	
			CLAY: white grey with minor ooids & gravels of hematite		
80				3.17min/m	
	CID		CLAYEY GRAVEL: yellow brown, mineralised ooids, hematite gravels, white clay		8/16 Gravel (66-106)
				1.67min/m	200mm PVC Screen (68-106)
90			GRAVELLY CLAY: incresing clay content		
			GRAVELLY CLAY: white and yellow mottled clay present	2.17min/m	

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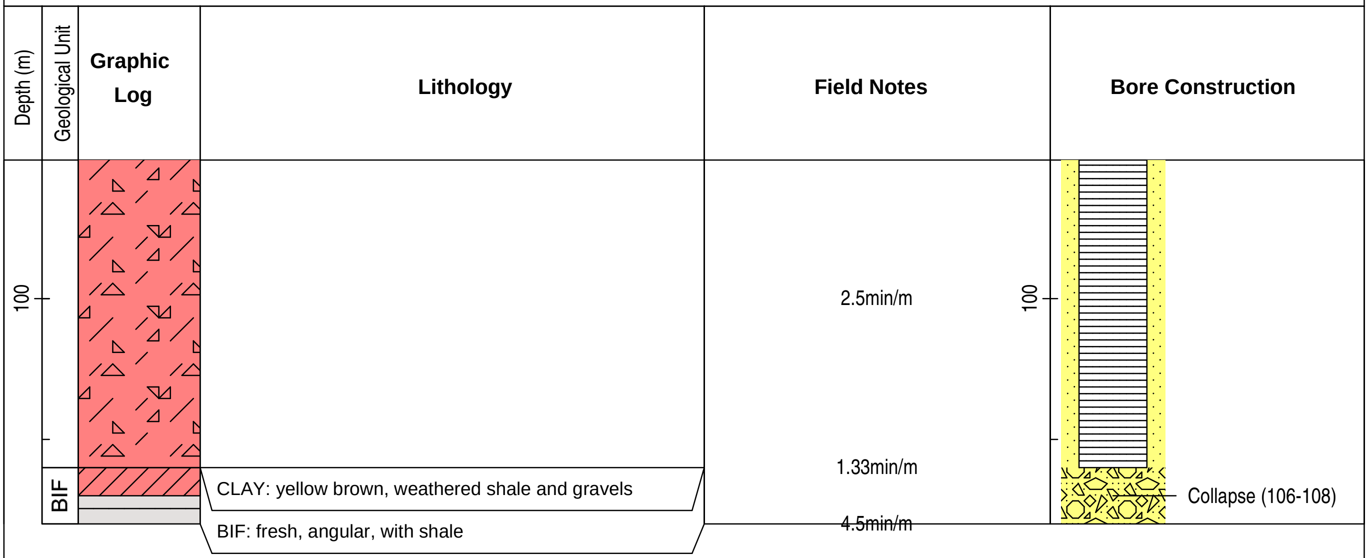
BOREHOLE: *DELTA-PROD-1*

CLIENT	FMS	**LOCATION**	DELTA	**TOTAL DEPTH (m)**	108
PROJECT	PI0P	**PROJECTION**	GDA94 MGA Zone 50	**SCREEN (mBGL)**	68-106
DATE DRILLED	30SEP2011	**EASTING**	551424.94	**ELEVATION (mAHD)**	540.82
LOGGED BY	S BEAR	**NORTHING**	7553228.15	**WATER LEVEL (mBGL)**	38.70

Contractor	AUSTRAL	**Drill Bit**	12.25" Tricone	**Airlift (L/s)**	13	**Salinity (mS/cm)**	0.182
Rig Type	SCHRAMM T64	**Drill Fluid**	Mud Rotary	**Temperature (℃)**	29.7	**pH**	7.22



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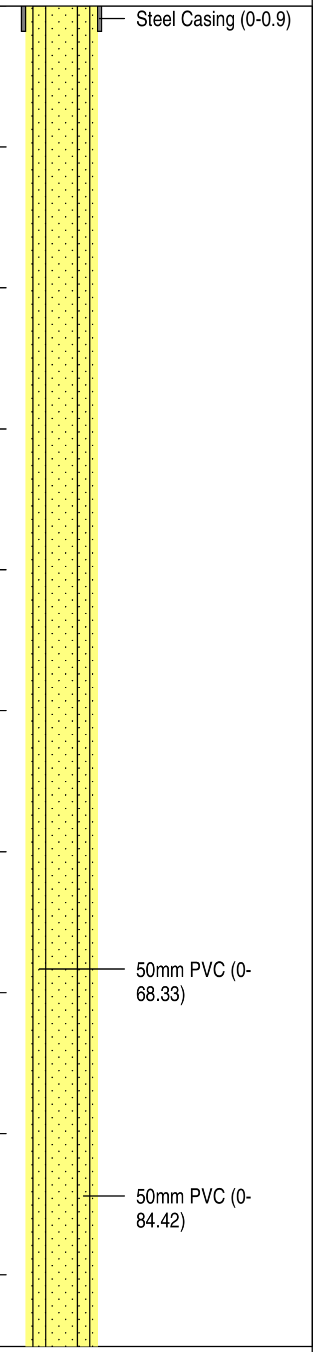
BOREHOLE:
DELTA-OBS-4-NEST

CLIENT	FMS	**LOCATION**	DELTA	**TOTAL DEPTH (m)**	100
PROJECT	PI0P	**PROJECTION**	GDA94 MGA Zone 50	**SCREEN (mBGL)**	see field notes
DATE DRILLED	08-09 OCT 2011	**EASTING**	551418.36	**ELEVATION (mAHD)**	540.65
LOGGED BY	R BAIRD	**NORTHING**	7553214.16	**WATER LEVEL (mBGL)**	see field notes

Contractor	AUSTRAL	**Drill Bit**	8.5" Tricone	**Airlift (L/s)**	see field notes	**Salinity (mS/cm)**	see field notes
Rig Type	SCHRAMM T64	**Drill Fluid**	Mud Rotary	**Temperature (℃)**	see field notes	**pH**	see field notes

Depth (m)	Geological Unit	Graphic Log	Lithology	Field Notes
0	Colluvium		CLAYEY GRAVEL: red brown, gravels of BIF, chert & shale up to 30mm diameter, subrounded to subangular, minor silt and clay in matrix ~20%, poorly sorted	Bore A: Screened 68.33-77.41, WL 38.79 mAHD, 0.18 mS/cm, 332 mg/L, 30.4 oC, pH 8.80 Bore B: Screened 84.42-98.55, WL 38.80 mAHD, 0.20 mS/cm, 363 mg/L, 30.1 oC, pH 9.16 2.5min/m 3.33min/m
			CLAYEY GRAVEL: increased clay content to ~40%	4.17min/m
	DID		CLAYEY GRAVEL: red brown, poorly sorted subrounded gravels of BIF & chert 50% with pisoliths, 50% clay	
			SILTY GRAVEL: red brown, gravels of BIF, chert & shale 30mm dia, subrounded, minor pisoliths, silt 10%	3.33min/m 2.5min/m 3.33min/m
			SILTY GRAVEL: as above, abundant pisoliths	3.33min/m
			CLAYEY GRAVEL: red brown, gravels of BIF chert & shale, subrounded, minor pisoliths, clay 30%	

Bore Construction



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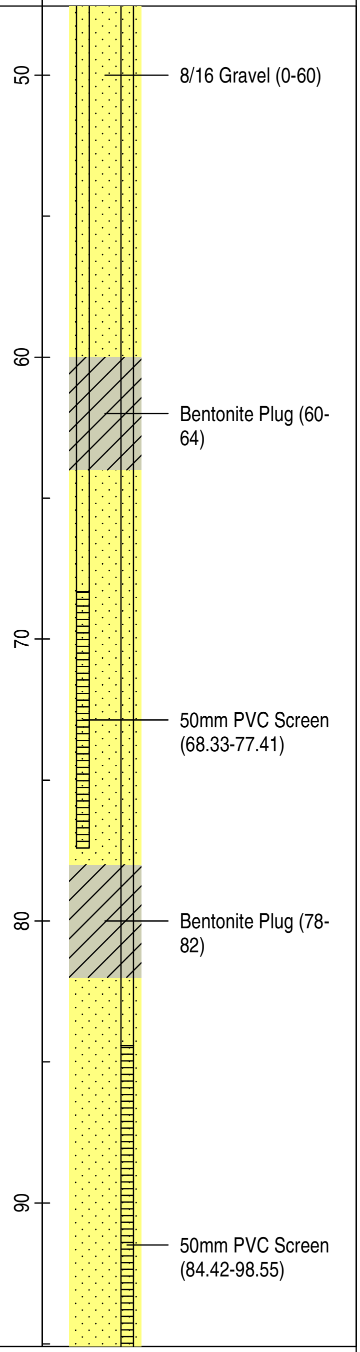
BOREHOLE: *DELTA-OBS-4-NEST*

CLIENT	FMS	**LOCATION**	DELTA	**TOTAL DEPTH (m)**	100
PROJECT	PI0P	**PROJECTION**	GDA94 MGA Zone 50	**SCREEN (mBGL)**	see field notes
DATE DRILLED	08-09 OCT 2011	**EASTING**	551418.36	**ELEVATION (mAHD)**	540.65
LOGGED BY	R BAIRD	**NORTHING**	7553214.16	**WATER LEVEL (mBGL)**	see field notes

Contractor	AUSTRAL	**Drill Bit**	8.5" Tricone	**Airlift (L/s)**	see field notes	**Salinity (mS/cm)**	see field notes
Rig Type	SCHRAMM T64	**Drill Fluid**	Mud Rotary	**Temperature (°C)**	see field notes	**pH**	see field notes

Depth (m)	Geological Unit	Graphic Log	Lithology	Field Notes
50				3.33min/m
			SILTY CLAY: red brown, medium plasticity, sticky, gravels <10% of BIF and chert, minor pisoliths	"Slow penetration through clay" | 7.5min/m
60				
	CID		SILTY CLAY: yellow grey brown, low plasticity, minor gravels of BIF	5.0min/m
70			CLAYEY GRAVEL: yellow grey, clay 50%, gravels of BIF with pisoliths, subangular, poorly sorted, goethitic clay matrix, yellow	4.17min/m
			CLAY : green light grey, medium to high plasticity, sticky	7.5min/m
80				
			CLAYEY GRAVEL: red brown yellow, partially cemented, gravels of BIF and chert 10mm diameter, poorly sorted, ooids, peloids & pisoliths, vuggy, minor lenses of clay	3.33min/m
90				3.33min/m

Bore Construction



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BOREHOLE:
DELTA-OBS-4-NEST

CLIENT	FMS	**LOCATION**	DELTA	**TOTAL DEPTH (m)**	100
PROJECT	PI0P	**PROJECTION**	GDA94 MGA Zone 50	**SCREEN (mBGL)**	see field notes
DATE DRILLED	08-09 OCT 2011	**EASTING**	551418.36	**ELEVATION (mAHD)**	540.65
LOGGED BY	R BAIRD	**NORTHING**	7553214.16	**WATER LEVEL (mBGL)**	see field notes

Contractor	AUSTRAL	**Drill Bit**	8.5" Tricone	**Airlift (L/s)**	see field notes	**Salinity (mS/cm)**	see field notes
Rig Type	SCHRAMM T64	**Drill Fluid**	Mud Rotary	**Temperature (°C)**	see field notes	**pH**	see field notes

Depth (m)	Geological Unit	Graphic Log	Lithology	Field Notes	Bore Construction
100	BIF		BIF: grey, clean, angular chips, very hard	Refusal- basement very hard I ~100min/m	100

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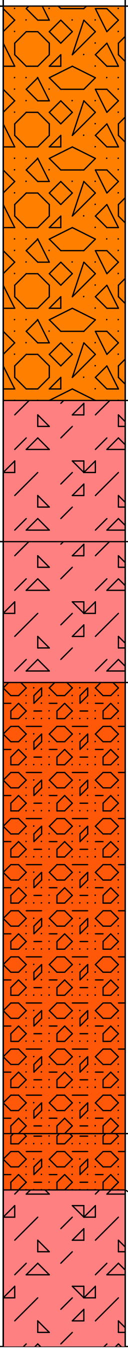
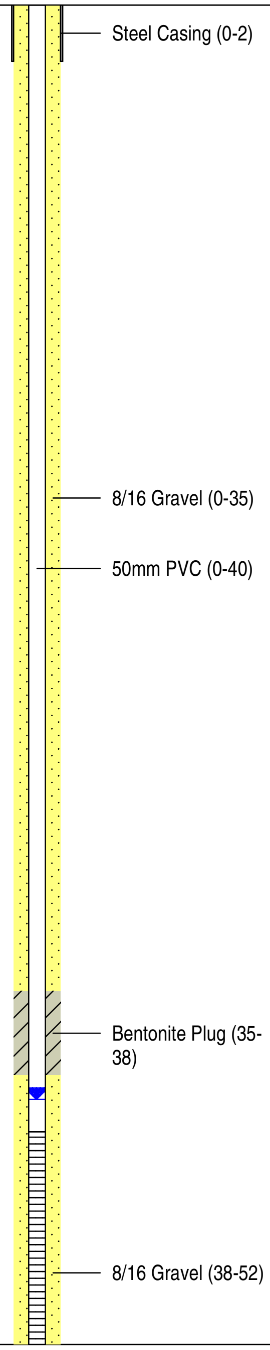
BOREHOLE:
DELTA OBS 3

CLIENT	FMS	**LOCATION**	DELTA	**TOTAL DEPTH (m)**	106
PROJECT	FLINDERS PIOP	**PROJECTION**	DELTA OBS 3	**SCREEN (mBGL)**	40-106
DATE DRILLED	29-31 AUG 2011	**EASTING**	551411.90	**ELEVATION (mAHD)**	540.82
LOGGED BY	S BEAR	**NORTHING**	7553238.58	**WATER LEVEL (mBGL)**	38.85

Contractor	AUSTRAL	**Drill Bit**	5.5"	**Airlift (L/s)**	7	**Salinity (mS/cm)**	0.40
Rig Type	SCHRAMM T64	**Drill Fluid**	AirCore/RC Hammer	**Temperature (℃)**	30.2	**pH**	8.2

Depth (m)	Geological Unit	Graphic Log	Lithology	Field Notes	Bore Construction
0	Colluvium		GRAVEL: red brown, some silt and clay, angular to subangular, poorly sorted, BIF, chert, coarse grained gravels >15mm, clay 20% from 1m		
10	Colluvium			Hammer to 13m, switching to Air Core RC	
	Colluvium		GRAVELLY CLAY: red brown, gravels subangular to subrounded, poorly sorted >30mm diameter, loose, dry, with minor ooids		
20			GRAVELLY CLAY: red brown with increasing ooids and less gravel, 15mm diameter, ooid rich clay		
30			CLAYEY GRAVEL: red brown, ooids, poorly sorted >15mm diameter, predominantly 10-20mm, subangular to subrounded, 20% clay Cemented fragments present from 26m Larger ooids and pisoliths >5mm diameter and increasing clay 40% at 29m Large gravels at 30m, >30mm diameter Pisoliths 5-7mm diameter at 38m	Rig overheated I 0.8m/min	
40			CLAYEY GRAVEL: dark red brown, poorly sorted, >40mm diameter, pisoliths 2-7mm diameter, clay 10%		
	DIDh		GRAVELLY CLAY: red brown, ooids in clay matrix, subangular gravels of BIF Nodules of hard clay with ooids at 44m		

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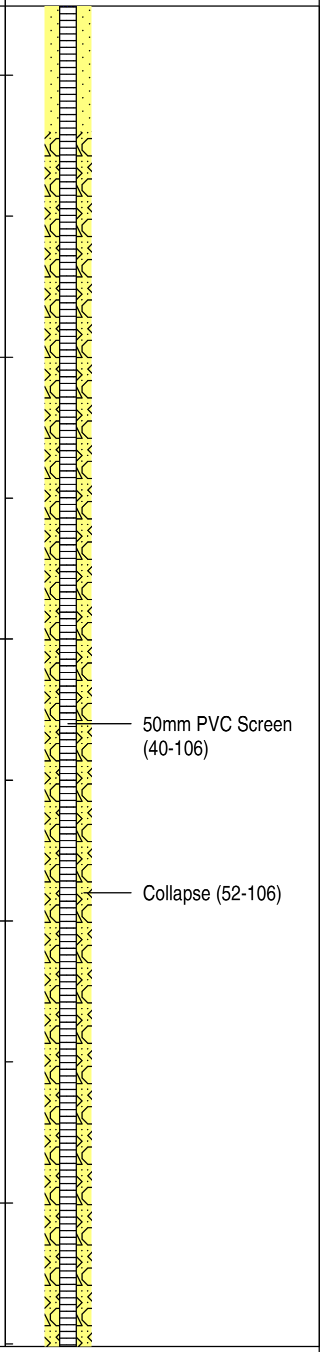
BOREHOLE: *DELTA OBS 3*

CLIENT	FMS	**LOCATION**	DELTA	**TOTAL DEPTH (m)**	106
PROJECT	FLINDERS PI0P	**PROJECTION**	DELTA OBS 3	**SCREEN (mBGL)**	40-106
DATE DRILLED	29-31 AUG 2011	**EASTING**	551411.90	**ELEVATION (mAHD)**	540.82
LOGGED BY	S BEAR	**NORTHING**	7553238.58	**WATER LEVEL (mBGL)**	38.85

Contractor	AUSTRAL	**Drill Bit**	5.5"	**Airlift (L/s)**	7	**Salinity (mS/cm)**	0.40
Rig Type	SCHRAMM T64	**Drill Fluid**	AirCore/RC Hammer	**Temperature (°C)**	30.2	**pH**	8.2

Depth (m)	Geological Unit	Graphic Log	Lithology	Field Notes
50				Water added at 42m
				0.42mS I 0.21ppt I pH8.18 I 30.7°C I 0L/s
			CLAY: red brown, minor ooids >10% Nodules of cemented yellow/green clay from 63m (opaline silica)	
60				1.5min/m I 0L/s
				0.32mS I 0.16ppt I pH8.19 I 29.5°C I 1.2min/m I 0.1L/s
			CLAYEY GRAVEL: red brown, 30% clay ooids in clay matrix	
			GRAVELLY CLAY: red brown mottled yellow, ooid rich hard nodules of green clay from 69m	
70				3.8min/m I 0L/s
			GRAVELLY CLAY: yellow with grey green mottling	
				0.40mS I 0.20ppt I pH8.18 I 29.5°C I 3.8min/m I 0.9L/s
			GRAVEL: red brown, gravels of BIF, angular, poorly sorted, coarse grained	
80			CLAY: green white	
	CID		CLAYEY GRAVEL: white red brown, fragments of cemented ooids and wood, vuggy becoming gravelly sand at 83m, coarse grained brown with cemented ooids/wood goethite from 85-87m, red brown (hematite) from 89-90m, dark red brown and coarser grained gravels of BIF >10mm, angular at 90.0m	0.40mS I 0.20ppt I pH8.25 I 30.1°C I 4.5min/m I 3L/s
90				0.40mS I 0.20ppt I pH8.26 I 30.2°C I >7L/s
			CLAY: yellow brown white, coarse grained up to 10mm diameter gravels, angular	

Bore Construction



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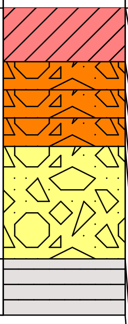
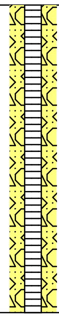
BOREHOLE:
DELTA OBS 3

CLIENT	FMS	**LOCATION**	DELTA	**TOTAL DEPTH (m)**	106
PROJECT	FLINDERS PI0P	**PROJECTION**	DELTA OBS 3	**SCREEN (mBGL)**	40-106
DATE DRILLED	29-31 AUG 2011	**EASTING**	551411.90	**ELEVATION (mAHD)**	540.82
LOGGED BY	S BEAR	**NORTHING**	7553238.58	**WATER LEVEL (mBGL)**	38.85

Contractor	AUSTRAL	**Drill Bit**	5.5"	**Airlift (L/s)**	7	**Salinity (mS/cm)**	0.40
Rig Type	SCHRAMM T64	**Drill Fluid**	AirCore/RC Hammer	**Temperature (℃)**	30.2	**pH**	8.2

Depth (m)	Geological Unit	Graphic Log	Lithology	Field Notes	Bore Construction
			CLAY: sandy, cemented nodules of clay with green mottling	0.41mS I 0.20ppt I pH8.32 I 28.8°C I >7L/s	
			CLAY: yellow brown and green grey mottling with gravels of BIF >10mm		
100			GRAVEL: yellow brown, fine grained		
			GRAVEL: light red brown, minor clay 5%, rounded to subangular, poorly to moderately sorted	0.41mS I 0.20ppt I pH8.32 I 29.5°C I >7L/s	
	BIF		GRAVEL: brown, sandy, fragments of BIF >10mm	0.41mS I 0.20ppt I pH8.32 I 29.2°C I >7L/s	
			GRAVELLY SAND: brown, medium grained, gravels of CID and BIF >10mm, subangular to subrounded Becoming yellow brown with cemented clay, BIF and chert at 104m Becoming mottled white with angular BIF at 105m		
			BIF: BIF		

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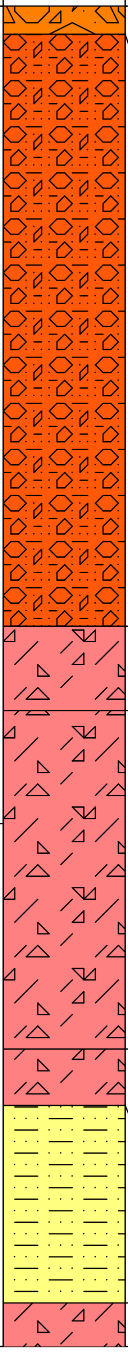
Perth WA 6000
ABN 61001 279 812

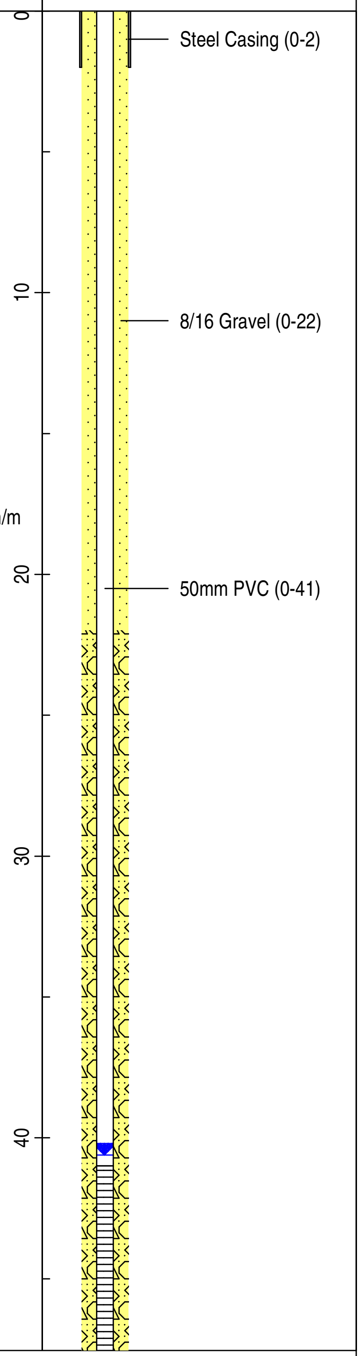
BOREHOLE:
DELTA OBS 2

CLIENT	FMS	**LOCATION**	DELTA	**TOTAL DEPTH (m)**	101
PROJECT	FLINDERS PI0P	**PROJECTION**	GDA94 MGA Zone 50	**SCREEN (mBGL)**	41-101
DATE DRILLED	27-29 AUG 2011	**EASTING**	551237.26	**ELEVATION (mAHD)**	543.24
LOGGED BY	S BEAR	**NORTHING**	7552861.77	**WATER LEVEL (mBGL)**	40.61

Contractor	AUSTRAL	**Drill Bit**	5.5"	**Airlift (L/s)**	7	**Salinity (mS/cm)**	0.44
Rig Type	SCHRAMM T64	**Drill Fluid**	AirCore/RC Hammer	**Temperature (℃)**	30.4	**pH**	8.25

Depth (m)	Geological Unit	Graphic Log	Lithology	Field Notes	Bore Construction
0	Alluvium		GRAVEL: red brown, fine to coarse grained, moderately sorted, angular to subangular, clay matrix 5%, dry, loose	RC hammer	Steel Casing (0-2)
			CLAYEY GRAVEL: red brown, fine to coarse grained, poorly sorted, angular to subrounded, clay approximately 20% Becomes gravelly clay/silt at 12m Gravels finer at 14m, 1-2mm diameter and subangular to subrounded Larger gravels up to 25mm from 15m Becomes clayey/silty gravel at 18m, gravels 2-20mm diameter in clay matrix 30-40%, subangular to subrounded	6.15min/m changed to air core at 18m | 20.0min/m	8/16 Gravel (0-22) 50mm PVC (0-41)
20			GRAVELLY CLAY: red brown, subrounded to rounded, fine grained 1-5mm, pisoliths at 26m	8.33min/m	
			GRAVELLY CLAY: red brown, subrounded to rounded, fine grained 1-5mm, pisoliths at 26m From 29m dark red brown, fine grained gravels, 1-2mm pisoliths, rounded, some larger gravels of BIF up to 10mm diameter Pisoliths become larger and more abundant at 34m >5mm diameter	11.67min/m	
30	DIDh		GRAVELLY CLAY: dark red brown, moderately sorted, subangular to subrounded, coarse grained up to 50mm diameter		
40			CLAYEY SILT: red brown, moist, cohesive, abundant pisoliths	water added at 41m 3.33min/m	
			GRAVELLY CLAY: red brown, pisoliths present hard nodules of clay at 50m		





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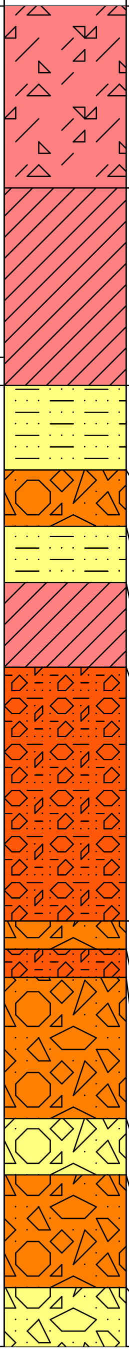
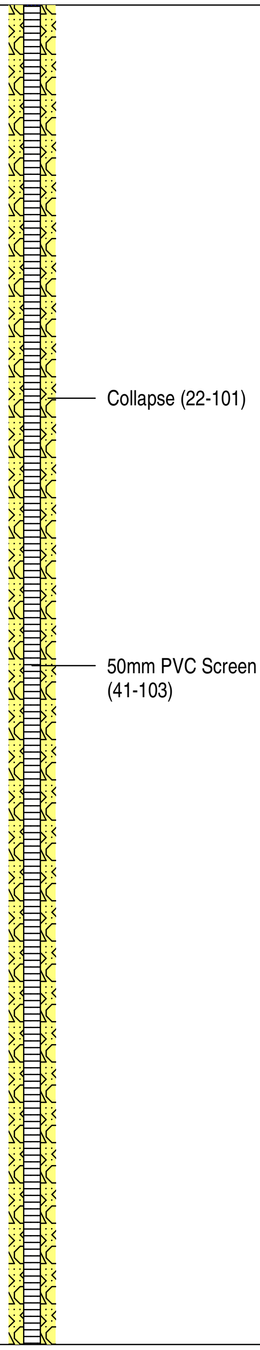
BOREHOLE:
DELTA OBS 2

CLIENT	FMS	**LOCATION**	DELTA	**TOTAL DEPTH (m)**	101
PROJECT	FLINDERS PI0P	**PROJECTION**	GDA94 MGA Zone 50	**SCREEN (mBGL)**	41-101
DATE DRILLED	27-29 AUG 2011	**EASTING**	551237.26	**ELEVATION (mAHD)**	543.24
LOGGED BY	S BEAR	**NORTHING**	7552861.77	**WATER LEVEL (mBGL)**	40.61

Contractor	AUSTRAL	**Drill Bit**	5.5"	**Airlift (L/s)**	7	**Salinity (mS/cm)**	0.44
Rig Type	SCHRAMM T64	**Drill Fluid**	AirCore/RC Hammer	**Temperature (°C)**	30.4	**pH**	8.25

Depth (m)	Geological Unit	Graphic Log	Lithology	Field Notes	Bore Construction
48–55				tried airlift at 48m - no yield I 8.33min/m; tried airlift at 54m - no yield I 2.5min/m	
55–62	Cla		CLAY: red brown, minor pisoliths, medium, stiff. From 60m yellow brown with pisoliths, stiff, minor gravels >50mm diameter, consolidated in places	0.46mS I 0.22ppt I pH8.09 I 28.7°C I 2.5min/m I 1L/s	
62–66	CID		SANDY CLAY: yellow brown, cemented in zones, vuggy, weathered. From 63m fine to coarse grained, yellow brown consolidated in places, clay matrix 5-10%		Collapse (22-101)
66–68			SANDY GRAVEL: dark brown grey, porous, vuggy cemented fragments, vitreous goethite and hematite, fine grained	0.45mS I 0.22ppt I pH8.07 I 30.6°C I 9.0min/m I 2.5L/s	
68–70			CLAYEY SAND: yellow brown, coarse grained, cemented zones, vuggy		
70–72			CLAY: grey with yellow mottling, becoming stiff at 68m with pisoliths 5-10mm diameter, yellow brown	0.46mS I 0.23ppt I pH8.43 I 30.4°C I 3.33min/m I 4L/s	50mm PVC Screen (41-103)
72–80			CLAYEY GRAVEL: yellow brown, fine grained with clay lenses between 74 and 75m, consolidated fragments at 75m with ooids and peloids. Dark yellow brown clayey sand, coarse grained, with consolidated fragments. Increased clay content between 78 and 79m	0.46mS I 0.23ppt I pH8.36 I 30.3°C I 5L/s	
80–83			SANDY GRAVEL: dark red brown, some clay, consolidated fragments with fibrous woody pieces, ooids, hematite rich		
83–85			CLAYEY GRAVEL: brown white, gravels up to 10mm diameter	0.46mS I 0.23ppt I pH8.24 I 30.2°C I 5.77min/m I 5L/s	
85–89			SANDY GRAVEL: grey red brown, fine to coarse grained, 2-10mm consolidated fragments. From 86m light red brown, fine grained 1-3mm clay 5%		
89–90			GRAVELLY SAND: dark red brown, coarse grained, clay 5%	0.43mS I 0.23ppt I pH8.22 I 31.4°C I 4.17min/m I 6.7L/s	
90–93			SANDY GRAVEL: yellow brown, fine to medium grained, minor clay 5%. From 91m red brown, fine grained 1-3mm		
93–95			GRAVELLY SAND: dark brown, consolidated zones, ooids, coarse grained, clay 5%		





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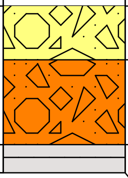
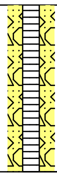
BOREHOLE:
DELTA OBS 2

CLIENT	FMS	**LOCATION**	DELTA	**TOTAL DEPTH (m)**	101
PROJECT	FLINDERS PI0P	**PROJECTION**	GDA94 MGA Zone 50	**SCREEN (mBGL)**	41-101
DATE DRILLED	27-29 AUG 2011	**EASTING**	551237.26	**ELEVATION (mAHD)**	543.24
LOGGED BY	S BEAR	**NORTHING**	7552861.77	**WATER LEVEL (mBGL)**	40.61

Contractor	AUSTRAL	**Drill Bit**	5.5"	**Airlift (L/s)**	7	**Salinity (mS/cm)**	0.44
Rig Type	SCHRAMM T64	**Drill Fluid**	AirCore/RC Hammer	**Temperature (°C)**	30.4	**pH**	8.25

Depth (m)	Geological Unit	Graphic Log	Lithology	Field Notes	Bore Construction
				0.45mS I 0.22ppt I pH8.29 I 30.6°C I 2.5min/m I 6.7L/s	
			SANDY GRAVEL: yellow brown, fine grained 2-5mm, some larger fragments >10mm From 99m dark red brown, clay 5-10%, fine grained		
100	BIF		BIF: fresh, angular	100 0.47mS I 0.23ppt I pH8.35 I 30.2°C I 2min/m I 6.7L/s	Collapse (101-103)

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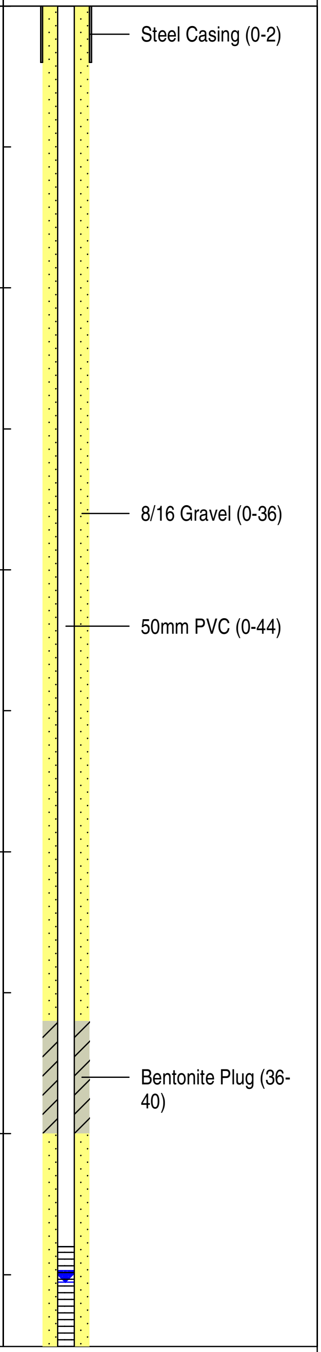
BOREHOLE:
DELTA-OBS-1

CLIENT	FMS	**LOCATION**	DELTA	**TOTAL DEPTH (m)**	95
PROJECT	PIOP	**PROJECTION**	GDA94 MGA Zone 50	**SCREEN (mBGL)**	44-95
DATE DRILLED	25-27 AUG 2011	**EASTING**	550922.65	**ELEVATION (mAHD)**	548.40
LOGGED BY	S BEAR	**NORTHING**	7552536.89	**WATER LEVEL (mBGL)**	45.27

Contractor	AUSTRAL	**Drill Bit**	5.5"	**Airlift (L/s)**	5	**Salinity (mS/cm)**	0.41
Rig Type	SCHRAMM T64	**Drill Fluid**	AirCore/RC Hammer	**Temperature (°C)**	29.6	**pH**	7.91

Depth (m)	Geological Unit	Graphic Log	Lithology	Field Notes
0–20	Alluvium		SANDY GRAVEL: dark red, with gravels of shale, chert and BIF up to 100mm diameter, increasing clay content with depth.	Foam added at 16m 6.67min/m
20–(46+)	DIDh		CLAYEY GRAVEL: dark red brown (30% clay), gravels of shale, chert and BIF up to 10mm diameter, subangular to subrounded, pisoliths 2mm diameter From 29-31m, gravels coarse >20mm diameter Predominantly pisoliths in clay matrix (30-40% clay) Gravels becoming coarse >20mm diameter, with less clay (15-20%) from 36m Gravels coarse from 41m >30mm diameter, increasing clay content with depth	Hammer blocked at 46m cleaned and continued with air core I 3.33min/m

Bore Construction



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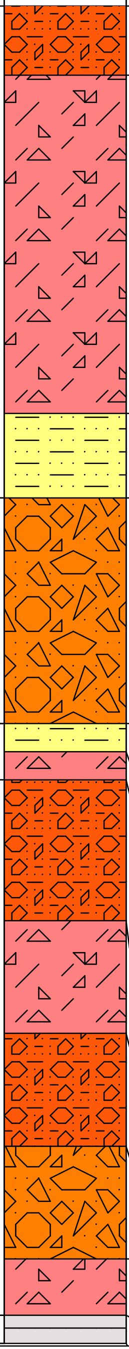
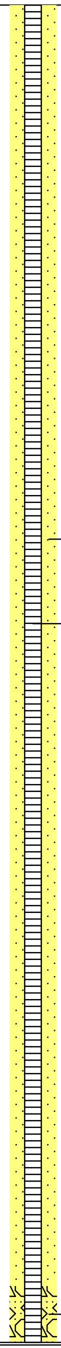
BOREHOLE: *DELTA-OBS-1*

CLIENT	FMS	**LOCATION**	DELTA	**TOTAL DEPTH (m)**	95
PROJECT	PIOP	**PROJECTION**	GDA94 MGA Zone 50	**SCREEN (mBGL)**	44-95
DATE DRILLED	25-27 AUG 2011	**EASTING**	550922.65	**ELEVATION (mAHD)**	548.40
LOGGED BY	S BEAR	**NORTHING**	7552536.89	**WATER LEVEL (mBGL)**	45.27

Contractor	AUSTRAL	**Drill Bit**	5.5"	**Airlift (L/s)**	5	**Salinity (mS/cm)**	0.41
Rig Type	SCHRAMM T64	**Drill Fluid**	AirCore/RC Hammer	**Temperature (℃)**	29.6	**pH**	7.91

Depth (m)	Geological Unit	Graphic Log	Lithology	Field Notes	Bore Construction
50			GRAVELLY CLAY: red brown, predomintly pisoliths 2-5 mm diameter, 40% gravel, 60% clay 20% gravels/pisoliths, 80% clay at 54m Clasts of yellow brown clay at 58m Cemented pisoliths within deposit between 59-62m.	tried airlift at 54m - not enough water/yield 0.42mS I 0.21ppt I pH7.86 I 30.6°C I 1.4L/s	
60			CLAYEY SAND: dark grey brown, contains cemented pisoliths	0.42mS I 0.21ppt I pH8.04 I 31.1°C I 2L/s	
70	DIDg		SANDY GRAVEL: dark grey brown, containing vitreous goethite fragments >60mm, some vuggy/brecciated, gravel is predominantly fine grained.	0.42mS I 0.21ppt I pH7.95 I 30.3°C I 2.86L/s	8/16 Gravel (40-93) 50mm PVC Screen (44-95)
	Clay		SANDY CLAY: yellow brown, goethite rich, gneiss of cemented clay and vitreous goethite.	0.42mS I 0.21ppt I pH8.04 I 30.7°C I 3.3L/s	
	CID		GRAVELLY CLAY: yellow brown, goethite rich		
80			CLAYEY GRAVEL: yellow brown, clay 20-30% becoming a gravelly clay at 77-78m with cemented clay nodules sandy gravel at 78-79m red clayey gravel at 79-80m	0.44mS I 0.21ppt I pH8.80 I 30.8°C I 4L/s	
			GRAVELLY CLAY: red yellow brown, with partially cemented nodules of clay up to 60mm diameter.		
			CLAYEY GRAVEL: red brown, 20% clay, containing cemented clay and cemented ooids, peloids and fossilised wood. Increasing clay at 85-86m to 50%	0.41mS I 0.21ppt I pH8.10 I 30.8°C I 5L/s	
90			SANDY GRAVEL: brown, fine to coarse grained, contains cemented ooids and peloids/fossilised wood.		
			GRAVELLY CLAY: yellow brown, 10% gravel, gravels of chert and BIF.	0.42mS I 0.21ppt I pH8.09 I 30.7°C I4L/s	Collapse (93-95)
	BIF		BIF: fresh, angular		

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BOREHOLE: *DELTA-OBS-1*

CLIENT	FMS	**LOCATION**	DELTA	**TOTAL DEPTH (m)**	95
PROJECT	PI0P	**PROJECTION**	GDA94 MGA Zone 50	**SCREEN (mBGL)**	44-95
DATE DRILLED	25-27 AUG 2011	**EASTING**	550922.65	**ELEVATION (mAHD)**	548.40
LOGGED BY	S BEAR	**NORTHING**	7552536.89	**WATER LEVEL (mBGL)**	45.27

Contractor	AUSTRAL	**Drill Bit**	5.5"	**Airlift (L/s)**	5	**Salinity (mS/cm)**	0.41
Rig Type	SCHRAMM T64	**Drill Fluid**	AirCore/RC Hammer	**Temperature (℃)**	29.6	**pH**	7.91

Depth (m)	Geological Unit	Graphic Log	Lithology	Field Notes	Bore Construction

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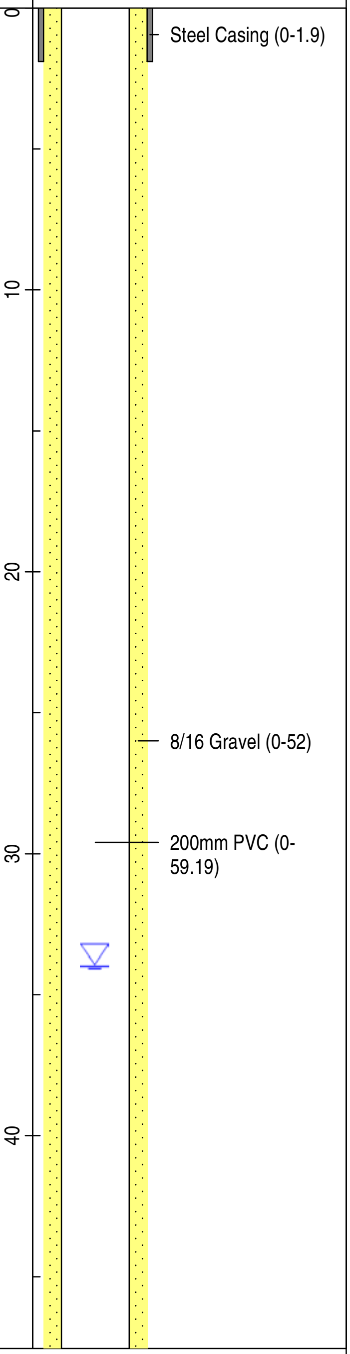
BOREHOLE:
CHAMP-PROD-01

CLIENT	FMS	**LOCATION**	CHAMPION	**TOTAL DEPTH (m)**	110
PROJECT	PIOP	**PROJECTION**	GDA94 MGA Zone 50	**SCREEN (mBGL)**	59.19-99.9
DATE DRILLED	12-18 NOV 2011	**EASTING**	546976.97	**ELEVATION (mAHD)**	548.51
LOGGED BY	R BAIRD	**NORTHING**	7556127.72	**WATER LEVEL (mBGL)**	33.63

Contractor	AUSTRAL	**Drill Bit**	12.25" Tricone	**Airlift (L/s)**	22.5	**Salinity (mS/cm)**	0.31
Rig Type	SCHRAMM T64	**Drill Fluid**	Mud Rotary	**Temperature (°C)**	30.0	**pH**	9.35

Depth (m)	Geological Unit	Lithology	Field Notes
0-20	Colluvium	SILTY GRAVEL: red brown, gravels of BIF, chert and shale 30mm diameter, silt 10%, minor clay	
20-27	Colluvium	SILTY GRAVEL: red brown, gravels of BIF, pisoliths, metallic lustre, 20mm fragments, silt 5%, minor clay	
27-30	Colluvium	SILTY GRAVEL: red brown, increased percentage of BIF fragments and pisoliths	2.5min/m
30-34	DID	GRAVELLY CLAY: as above, clay increasing	3.33min/m
34-45	DID	CLAY: red, medium to high plasticity, sticky, minor lenses of BIF and chert gravels	
45-	DID	GRAVELLY CLAY: red brown, medium to high plasticity, gravel of BIF & chert up to 30%	5min/m

Bore Construction



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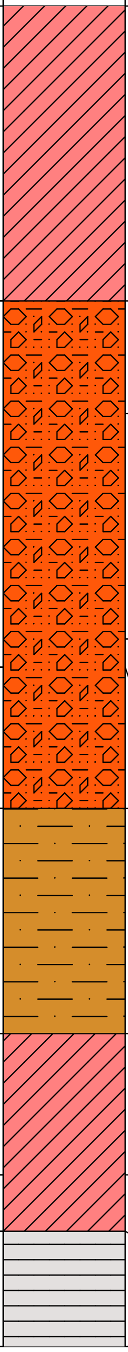
BOREHOLE: *CHAMP-PROD-01*

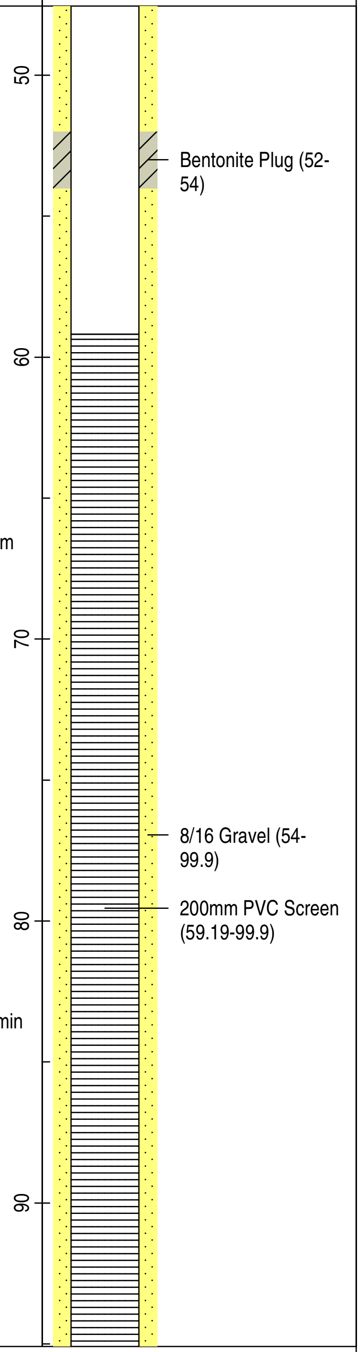
CLIENT	FMS	**LOCATION**	CHAMPION	**TOTAL DEPTH (m)**	110
PROJECT	PIOP	**PROJECTION**	GDA94 MGA Zone 50	**SCREEN (mBGL)**	59.19-99.9
DATE DRILLED	12-18 NOV 2011	**EASTING**	546976.97	**ELEVATION (mAHD)**	548.51
LOGGED BY	R BAIRD	**NORTHING**	7556127.72	**WATER LEVEL (mBGL)**	33.63

Contractor	AUSTRAL	**Drill Bit**	12.25" Tricone	**Airlift (L/s)**	22.5	**Salinity (mS/cm)**	0.31
Rig Type	SCHRAMM T64	**Drill Fluid**	Mud Rotary	**Temperature (°C)**	30.0	**pH**	9.35

Depth (m)	Geological Unit	Graphic Log	Lithology	Field Notes
48–60			Clay: red, medium to high plasticity, sticky, minor lenses of BIF and chert gravels	5min/m; 5min/m
60–64	CID		CLAYEY GRAVEL: red brown yellow, gravels of BIF with abundant pisoliths, gravels up to 10mm diameter, poorly sorted, minor cementation	
64–72	CID		CLAYEY GRAVEL: yellow light grey, gravels of BIF & chert up to 10mm diameter, low plasticity clay	5.83min/m; Centralisers on screens 1, 3, 5, 7; 1m from top of screen; 5.83min/m
72–74	CID		CLAYEY GRAVEL: increase in ooids and peloids in structure	
74–78	BID		CLAYEY GRAVEL: yellow brown red, goethite and hematite weathering, crystalline BIF, minor vugs & cavities, no ooids or peloids in structure therefore interpreted as BID	4.17min/m
78–86	BIDg		BID: banded iron formation altered to goethite ore, alternating layers of BIF and yellow claywith shale and chert, vuggy, porous	4.17min/m; Very hard at 84m; BIF sampling ~30min delay
86–91	BIDh		CLAY: red, hematite rich, weakly to moderately banded BIF and alternating hematite bands	11.67min/m
91–93	BIDg		CLAY: red, hematite rich, weakly to moderately banded BIF and alternating goethite bands	
93–96			BIF: light grey, weathered, chert, shale with thin bands of light grey to grey clay	7.5min/m



Bore Construction



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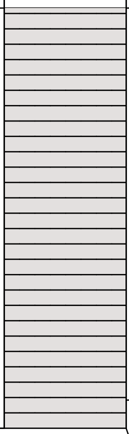
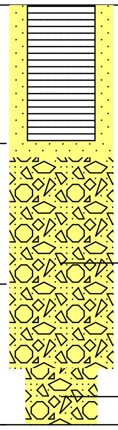
BOREHOLE:
CHAMP-PROD-01

CLIENT	FMS	**LOCATION**	CHAMPION	**TOTAL DEPTH (m)**	110
PROJECT	PI0P	**PROJECTION**	GDA94 MGA Zone 50	**SCREEN (mBGL)**	59.19-99.9
DATE DRILLED	12-18 NOV 2011	**EASTING**	546976.97	**ELEVATION (mAHD)**	548.51
LOGGED BY	R BAIRD	**NORTHING**	7556127.72	**WATER LEVEL (mBGL)**	33.63

Contractor	AUSTRAL	**Drill Bit**	12.25" Tricone	**Airlift (L/s)**	22.5	**Salinity (mS/cm)**	0.31
Rig Type	SCHRAMM T64	**Drill Fluid**	Mud Rotary	**Temperature (℃)**	30.0	**pH**	9.35

Depth (m)	Geological Unit	Graphic Log	Lithology	Field Notes	Bore Construction
100	BIF			5.83min/m	
				Collapsed back to 100.5m I 5min/m	Collapse (100.5-108)
110			BIF: weakly altered/mineralised to fresh BIF, chert and shale	Reamed to 108m very hard, slow penetration I 10min/m	Collapse (108-110)

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Perth WA 6000
ABN 61001 279 812

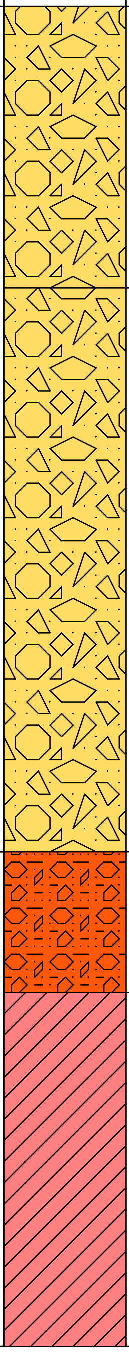
BOREHOLE: *CHAMP-OBS-4-NESTED*

CLIENT	FMS	**LOCATION**	CHAMPION	**TOTAL DEPTH (m)**	106
PROJECT	PI0P	**PROJECTION**	GDA94 MGA Zone 50	**SCREEN (mBGL)**	see field notes
DATE DRILLED	18-20 OCT 2011	**EASTING**	546969.66	**ELEVATION (mAHD)**	548.31
LOGGED BY	S BEAR	**NORTHING**	7556139.73	**WATER LEVEL (mBGL)**	see field notes

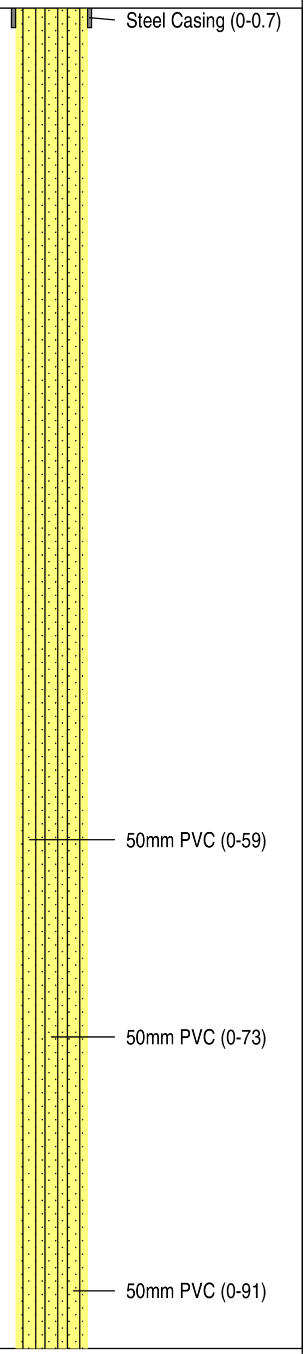
Contractor	AUSTRAL	**Drill Bit**	8.5" Tricone	**Airlift (L/s)**	see field notes	**Salinity (mS/cm)**	see field notes
Rig Type	SCHRAMM T64	**Drill Fluid**	Mud Rotary	**Temperature (°C)**	see field notes	**pH**	see field notes

Depth (m)	Geological Unit	Lithology	Field Notes
0	Colluvium	SILTY GRAVEL: red brown, gravels of BIF, shale and chert, some quartz, angular, subrounded	Bore A: Screened 59.69, WL 33.98 mAHD, 0.27 mS/cm,148 mg/L, 30.1 oC Bore B: Screened 73-80, WL 33.98 mAHD, 0.34 mS/cm, 186 mg/L, 30.4 oC Bore C: Screened 91-100, WL 33.98 mAHD, 0.48 mS/cm, 365 mg/L, 30.9 oC
10	Colluvium	SILTY GRAVEL: red brown, minor rounded hematite gravels at 10m, ooids becoming more predominant with depth	2min/m 2.33min/m 2.83min/m
30	Colluvium	CLAYEY GRAVEL: red brown, gravels of BIF, shale and chert, increasing clay content up to 20%	2.5min/m
35	DIDh	CLAY: red brown with ooids up to 1mm	2.3min/m 3.67min/m

Graphic Log



Bore Construction



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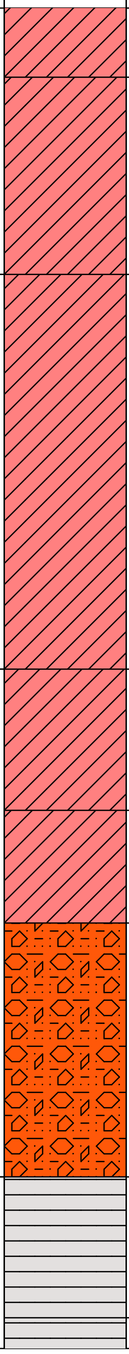
250 St George's Terrace
Perth WA 6000
ABN 61001 279 812

BOREHOLE:
CHAMP-OBS-4-NESTED

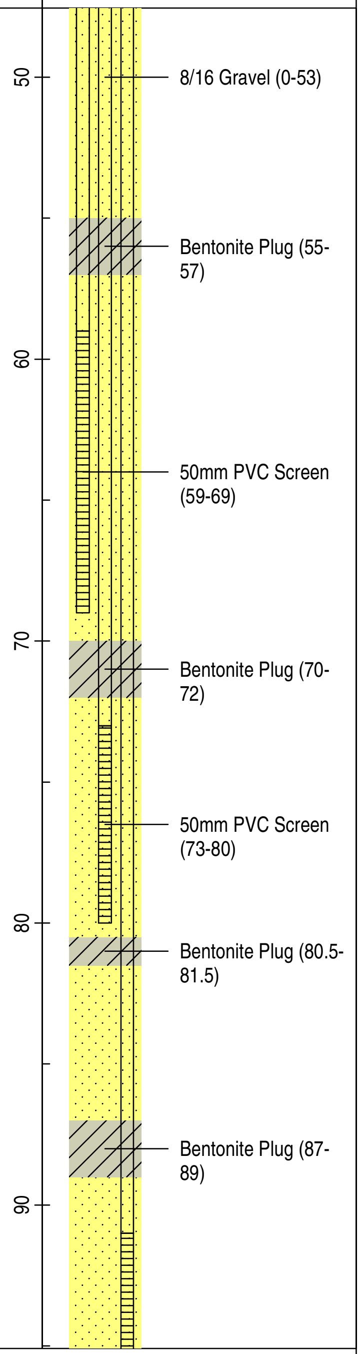
CLIENT	FMS	**LOCATION**	CHAMPION	**TOTAL DEPTH (m)**	106
PROJECT	PI0P	**PROJECTION**	GDA94 MGA Zone 50	**SCREEN (mBGL)**	see field notes
DATE DRILLED	18-20 OCT 2011	**EASTING**	546969.66	**ELEVATION (mAHD)**	548.31
LOGGED BY	S BEAR	**NORTHING**	7556139.73	**WATER LEVEL (mBGL)**	see field notes

Contractor	AUSTRAL	**Drill Bit**	8.5" Tricone	**Airlift (L/s)**	see field notes	**Salinity (mS/cm)**	see field notes
Rig Type	SCHRAMM T64	**Drill Fluid**	Mud Rotary	**Temperature (℃)**	see field notes	**pH**	see field notes

Depth (m)	Geological Unit	Graphic Log	Lithology	Field Notes
50				2.83min/m
			CLAY: red brown	
60	CID		CLAY: yellow, cemented ooids with minor goethitic clay	10.0min/m; 7.33min/m
70			CLAY: yellow, with vitrious goethite, BID, minor vugs and cavities	6.67min/m
			CLAY: yellow brown with minor gravels of BIF and shale	4.67min/m
80	BIDg		CLAYEY GRAVEL: yellow brown, weathered BIDg, 10-20% goethitic clay in matrix, hematite & vitrious goethite, banding visible	2.33min/m; 9.67min/m
90			BIF: weathered BIF, increasing silica, some white clay present within BIF, shale and chert	8.5min/m
			BIF: weathered BIF, increasing silica, some white clay	



Bore Construction



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BOREHOLE:
CHAMP-OBS-4-NESTED

CLIENT	FMS	**LOCATION**	CHAMPION	**TOTAL DEPTH (m)**	106
PROJECT	PI0P	**PROJECTION**	GDA94 MGA Zone 50	**SCREEN (mBGL)**	see field notes
DATE DRILLED	18-20 OCT 2011	**EASTING**	546969.66	**ELEVATION (mAHD)**	548.31
LOGGED BY	S BEAR	**NORTHING**	7556139.73	**WATER LEVEL (mBGL)**	see field notes

Contractor	AUSTRAL	**Drill Bit**	8.5" Tricone	**Airlift (L/s)**	see field notes	**Salinity (mS/cm)**	see field notes
Rig Type	SCHRAMM T64	**Drill Fluid**	Mud Rotary	**Temperature (°C)**	see field notes	**pH**	see field notes

Depth (m)	Geological Unit	Graphic Log	Lithology	Field Notes	Bore Construction
	BIF		present within BIF, shale and chert, red/yellow brown clay 20%		50mm PVC Screen (91-100)
	BIF		BIF: light grey, weathered BIF, clay 30%		
100	BIF		BIF: light grey, weathered BIF, clay 20%	100	Collapse (100-106)

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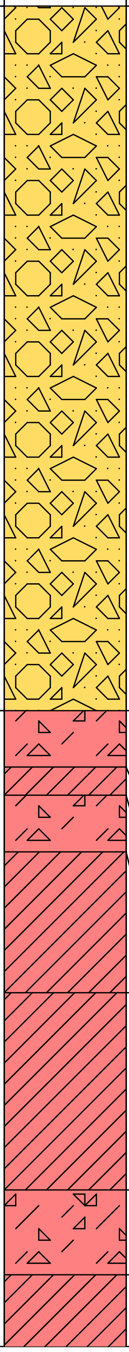
BOREHOLE:
CHAMP-OBS-3

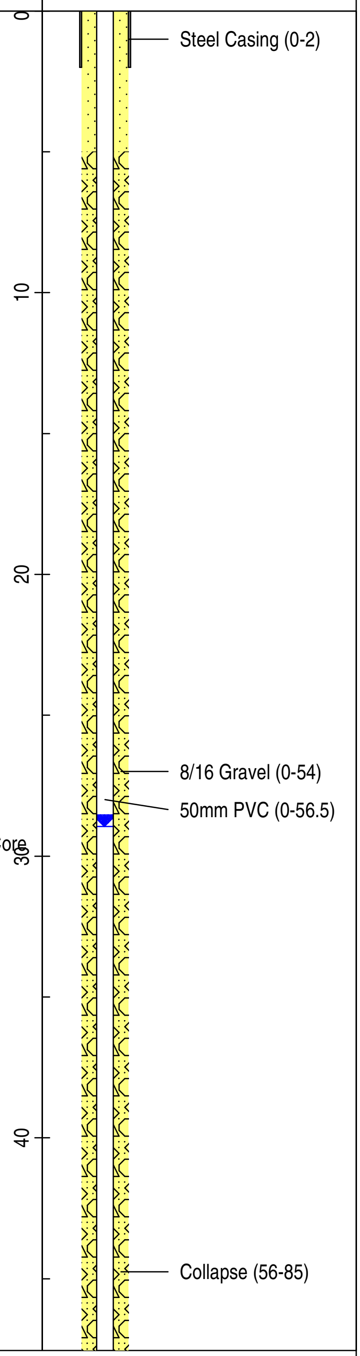
CLIENT	FMS	**LOCATION**	CHAMPION	**TOTAL DEPTH (m)**	84.5
PROJECT	FLINDERS PI0P	**PROJECTION**	GDA94 MGA Zone 50	**SCREEN (mBGL)**	56.5-84.5
DATE DRILLED	5 SEP 2011	**EASTING**	547145.74	**ELEVATION (mAHD)**	543.86
LOGGED BY	S BEAR	**NORTHING**	7556023.68	**WATER LEVEL (mBGL)**	28.95

Contractor	AUSTRAL	**Drill Bit**	5.5"	**Airlift (L/s)**	5	**Salinity (mS/cm)**	0.30
Rig Type	SCHRAMM T64	**Drill Fluid**	AirCore/RC Hammer	**Temperature (°C)**	29.3	**pH**	8.06

Depth (m)	Geological Unit	Graphic Log	Lithology	Field Notes
0	Alluvium		SILTY GRAVEL: red brown, poorly sorted gravels of BIF and Chert, angular to subrounded, silt 20 - 30%, gravels becoming more rounded with depth Dry and loose	RC Hammer to 24m | 7.5min/m
10				1.5min/m
20				1.17min/m 1.67min/m
	DID		GRAVELLY CLAY: dark red brown with gravels of BIF, subrounded to rounded, ooids and pisoliths, 50/50 gravels/clay, moist and cohesive	
			CLAY: dark red brown	
30			GRAVELLY CLAY: red brown, pisoliths and ooids, gravels of BIF, subrounded to rounded, clay 80%	Moisture encountered, switch to Air Core | 1.67min/m
			CLAY: dark red brown, cohesive, soft with pisoliths and gravels of BIF, subangular to subrounded	
			CLAY: dark red brown, rich in pisoliths, wet at 36m less ooids at 38m with some gravels 10% of angular to subrounded BIF and Chert ooids and pisoliths increasing at 40m, cohesive and moist	Wet | 0.83min/m
40				Moist | 0.66min/m | 0L/s
			GRAVELLY CLAY: orange red brown, ooids, pisoliths, gravels of BIF, subangular to subrounded, dry, loose	
			CLAY: dark red brown, pisoliths, moist with minor gravels, cohesive nodules of hard opaline silica clay at 48m green white	



Bore Construction



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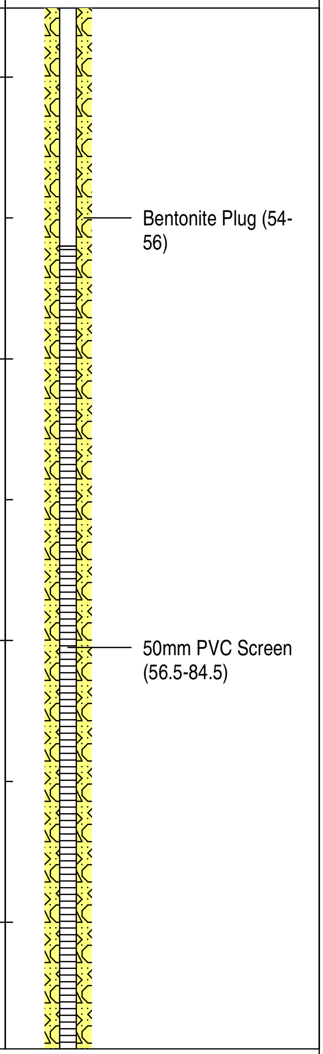
BOREHOLE: *CHAMP-OBS-3*

CLIENT	FMS	**LOCATION**	CHAMPION	**TOTAL DEPTH (m)**	84.5
PROJECT	FLINDERS PI0P	**PROJECTION**	GDA94 MGA Zone 50	**SCREEN (mBGL)**	56.5-84.5
DATE DRILLED	5 SEP 2011	**EASTING**	547145.74	**ELEVATION (mAHD)**	543.86
LOGGED BY	S BEAR	**NORTHING**	7556023.68	**WATER LEVEL (mBGL)**	28.95

Contractor	AUSTRAL	**Drill Bit**	5.5"	**Airlift (L/s)**	5	**Salinity (mS/cm)**	0.30
Rig Type	SCHRAMM T64	**Drill Fluid**	AirCore/RC Hammer	**Temperature (°C)**	29.3	**pH**	8.06

Depth (m)	Geological Unit	Graphic Log	Lithology	Field Notes
50			hard nodules of red brown clay from 49m, >6mm diameter nodules of hard yellow brown clay >15mm	Dry to Moist at 45m I 1.67min/m I 0L/s 2.5min/m I 0L/s
	CID		GOETHITE MATRIX: yellow brown with cemented ooids in vitreous goethite matrix	
	CID		CLAY: yellow brown, cemented with ooids & vitreous goethite in clay matrix	
60	CID		CLAY: white yellow, cemented hard with CID, intermixed 5%	Foam added at 54m I 8.33min/m
	CID		CLAY: yellow brown, weathered/altered with some vugs/cavities but still containing cemented hard white clay cemented ooids, hematite, goethitic clay at 64m yellow brown vugs/cavities increasing with depth very dense and hard, red brown/grey cemented ooids and woody fragments at 66m	0.07mS I 0.14ppt I pH8.99 I 31.1°C I 21.67min/m I 0.06L/s
70	CID		CLAY: weathered shale chert, yellow brown with gravels becomes white yellow brown at 71m	0.11mS I 0.22ppt I pH8.09 I 29.4°C I 3.33min/m I 0.9L/s
	BIF		BIF: red gravels yellow brown from 74m weathered BIF in clay matrix from 76m, white orange-brown.	0.14mS I 0.28ppt I pH7.95 I 31.9°C I 1.00min/m I 5.0L/s
80	BIF		BIF: grey brown, weathered	0.15mS I 0.24ppt I pH8.09 I 31.9°C I 3.33min/m I 4.0L/s

Bore Construction



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250 St George's Terrace
Perth WA 6000
ABN 61001 279 812

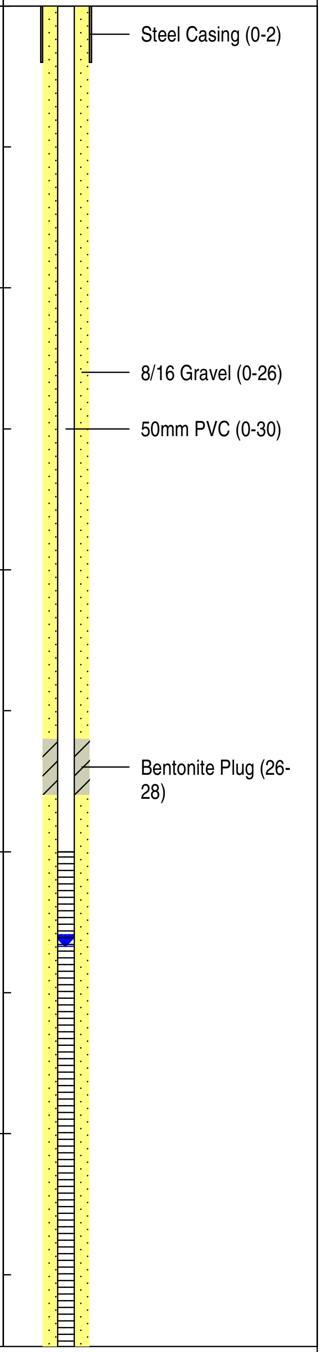
BOREHOLE: *CHAMP-OBS-2*

CLIENT	FMS	**LOCATION**	CHAMPION	**TOTAL DEPTH (m)**	96
PROJECT	FLINDERS PIOP	**PROJECTION**	GDA94 MGA Zone 50	**SCREEN (mBGL)**	30-96
DATE DRILLED	3-5 SEP 2011	**EASTING**	546965.25	**ELEVATION (mAHD)**	548.05
LOGGED BY	S BEAR	**NORTHING**	7556117.32	**WATER LEVEL (mBGL)**	33.32

Contractor	AUSTRAL	**Drill Bit**	5.5"	**Airlift (L/s)**	7	**Salinity (mS/cm)**	0.32
Rig Type	SCHRAMM T64	**Drill Fluid**	543.24	**Temperature (°C)**	29.0	**pH**	8.22

Depth (m)	Geological Unit	Graphic Log	Lithology	Field Notes
0	Colluvium		CLAYEY GRAVEL: red brown, 30% clay, poorly sorted gravels of BIF, chert, quartz, shale, angular to subrounded, minor ooids and peloids	
	Colluvium		GRAVELLY CLAY: red brown, gravel up to 20mm diameter, angular to subrounded	
10	Colluvium		CLAYEY GRAVEL: red brown, clay 20-30%, gravels of BIF and chert, angular to subrounded, poorly sorted, >30mm diameter, some rounded hematite	Air Core RC |4.17min/m 4.17min/m
20	DIDh		CLAYEY GRAVEL: red brown with ooids and pisoliths, gravels angular to subrounded, poorly sorted, colour changes to brown at 24m, clay 10-15%, piece of cemented DIDh at 29m	4.17min/m 5min/m
30	DIDh		CLAY: red brown, some pisoliths, gravels approximately 20% >50mm diameter at 31m, and semi cemented friable clay gravels becoming moist at 32m	2.5min/m
	DIDh		CLAY: dark red brown, cohesive, ooid rich at 38m 1-2mm diameter, rounded gravels of hematite	Water added at 36m | 1.2min/m
40	DIDh		CLAYEY GRAVEL: red borwn, ooids rich, 1-2mm diameter, well rounded and sorted, clay 20%	
	DIDh		CLAY: dark red brown	Foam added at 41m | 1.83min/m
	DIDh		GRAVELLY CLAY: red brown, 5mm diameter cemented gravels and clay becoming more cemented between 49m and 50m contains ooids and pisoliths	

Bore Construction



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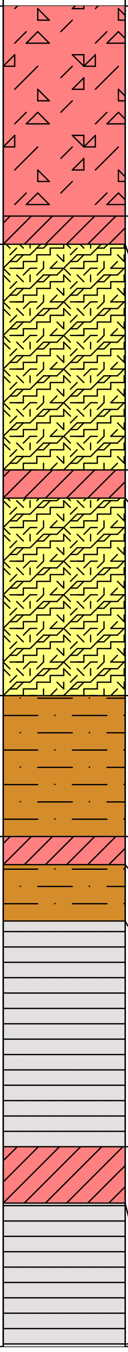
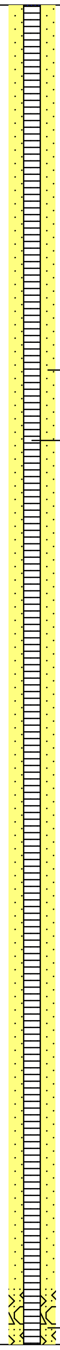
BOREHOLE: *CHAMP-OBS-2*

CLIENT	FMS	**LOCATION**	CHAMPION	**TOTAL DEPTH (m)**	96
PROJECT	FLINDERS PI0P	**PROJECTION**	GDA94 MGA Zone 50	**SCREEN (mBGL)**	30-96
DATE DRILLED	3-5 SEP 2011	**EASTING**	546965.25	**ELEVATION (mAHD)**	548.05
LOGGED BY	S BEAR	**NORTHING**	7556117.32	**WATER LEVEL (mBGL)**	33.32

Contractor	AUSTRAL	**Drill Bit**	5.5"	**Airlift (L/s)**	7	**Salinity (mS/cm)**	0.32
Rig Type	SCHRAMM T64	**Drill Fluid**	543.24	**Temperature (°C)**	29.0	**pH**	8.22

Depth (m)	Geological Unit	Graphic Log	Lithology	Field Notes	Bore Construction
50			fragments of cemented CID	1.83min/m 0.16mS I 0.08ppt I pH8.04 I 30.2°C I 1min/m I 0.07L/s	
60	CIDg		CLAY: red brown with hard cemented nodules of yellow brown green and grey clay		
			GOETHITE MATRIX: dark grey with red and yellow brown mottling, cemented ooids, rounded hematite in gothite matrix, very dense, hard and non porous, fine grained minor vugs and pore spaces in fragments at 60m becoming coarser grained at 62m, pisoliths >5mm and woody fragments with nodules of yellow brown clay	Air core sample at 57m I 0.23mS I 0.11ppt I pH8.19 I 31.0°C I 21.67min/m I 0.9L/s	8/16 Gravel (28-93) 50mm PVC Screen (30-96)
			CLAY: white with yellow and red mottling, hard		
70			GOETHITE MATRIX: cemented ooids, woody fragments and hematite in vitreous goethite matrix, vugs and cavities present, dark grey mottled yellow brown and red gravels of angular hematite in matrix at 71, basal conglomerate	Air core sample at 64m I 0.23mS I 0.12ppt I pH8.22 I 29.5°C I 8.33min/m I 1.7L/s Air core samples at 66m & 71m I 0.23mS I 0.11ppt I pH8.04 I 29.8°C I 6.67min/m I 1.7L/s	
	BIDg		BID: metallic grey with yellow brown goethite clay, vitreous goethite, hard with minor vugs and cavities, weathering quartz in matrix at 74m becoming more weathered at 76m		
			CLAY: yellow brown, minor BID gravels	Air core sample at 72m I 0.32mS I 0.16ppt I pH8.07 I 29.6°C I 2.67min/m I 5.0L/s	
80	BIF		BID: grey brown, weathered with abundant quartz, hematite, chert in yellow brown clayey sand matrix		
			BIF: grey, weathered with shale & chert	0.30mS I 0.15ppt I pH8.11 I 29.2°C I 1min/m I 4.0L/s	
90			CLAY: reddish yellow brown, weathered shale, gravels of shale and chert weathered BIF to clay with gravels, can see bedding in clay	0.44mS I 0.22ppt I pH8.09 I 21.4°C I 0.83min/m I 4.0L/s	
			BIF: grey, weathered with some clay in matrix ~10%	1min/m 0.31mS I 0.15ppt I pH8.20 I 29.5°C I	Collapse (93-96)

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BOREHOLE:
CHAMP-OBS-2

CLIENT	FMS	**LOCATION**	CHAMPION	**TOTAL DEPTH (m)**	96
PROJECT	FLINDERS PI0P	**PROJECTION**	GDA94 MGA Zone 50	**SCREEN (mBGL)**	30-96
DATE DRILLED	3-5 SEP 2011	**EASTING**	546965.25	**ELEVATION (mAHD)**	548.05
LOGGED BY	S BEAR	**NORTHING**	7556117.32	**WATER LEVEL (mBGL)**	33.32

Contractor	AUSTRAL	**Drill Bit**	5.5"	**Airlift (L/s)**	7	**Salinity (mS/cm)**	0.32
Rig Type	SCHRAMM T64	**Drill Fluid**	543.24	**Temperature (℃)**	29.0	**pH**	8.22

Depth (m)	Geological Unit	Graphic Log	Lithology	Field Notes	Bore Construction
			BIF: grey, bands of hematite and chert		

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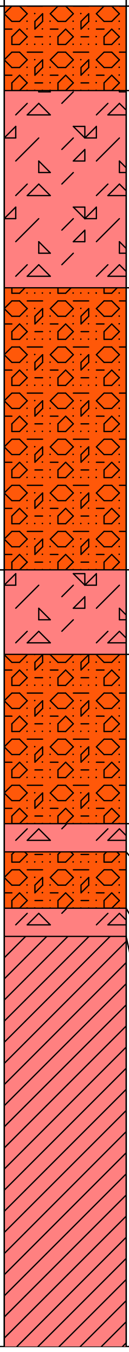
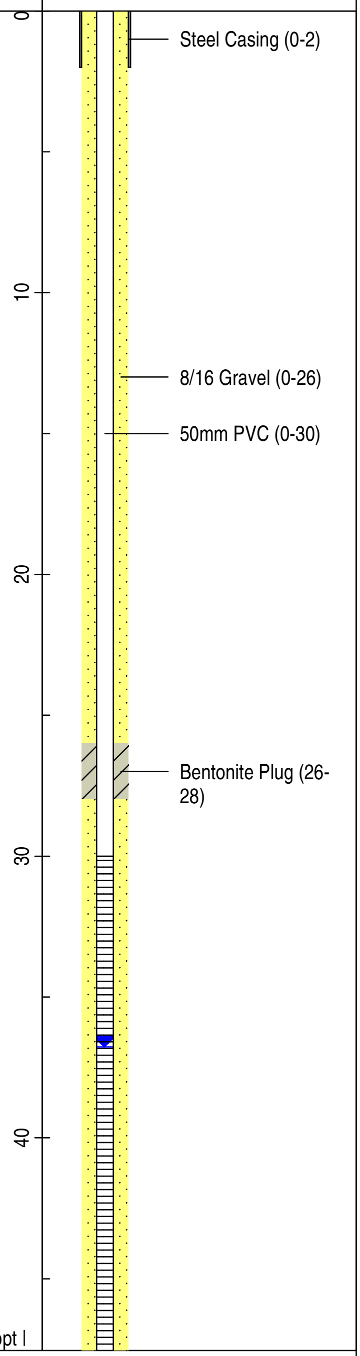
BOREHOLE: *CHAMP-OBS-1*

CLIENT	FMS	**LOCATION**	CHAMPION	**TOTAL DEPTH (m)**	90
PROJECT	FLINDERS PI0P	**PROJECTION**	GDA94 MGA Zone 50	**SCREEN (mBGL)**	30-90
DATE DRILLED	31 AUG - 02 SEP 2011	**EASTING**	546889.99	**ELEVATION (mAHD)**	551.65
LOGGED BY	S BEAR	**NORTHING**	7555876.47	**WATER LEVEL (mBGL)**	36.77

Contractor	AUSTRAL	**Drill Bit**	5.5"	**Airlift (L/s)**	6	**Salinity (mS/cm)**	0.31
Rig Type	SCHRAMM T64	**Drill Fluid**	AirCore/RC Hammer	**Temperature (℃)**	29.2	**pH**	8.55

Depth (m)	Geological Unit	Graphic Log	Lithology	Field Notes	Bore Construction
0	Colluvium		CLAYEY GRAVEL: red brown, poorly sorted, angular to sub-rounded, BIF & chert, clay 20-30%		Steel Casing (0-2)
			GRAVELLY CLAY: red brown, clay 70%		
10			CLAYEY GRAVEL: red brown, poorly sorted, angular to sub-rounded, BIF & chert, clay 20%		8/16 Gravel (0-26); 50mm PVC (0-30)
20			GRAVELLY CLAY: red brown, ooids up to 2mm, poorly sorted BIF & chert		
			CLAYEY GRAVEL: red brown, ooids > 5mm, BIF & chert angular to sub-rounded >10mm, gravels > 60mm		Bentonite Plug (26-28)
30			GRAVELLY CLAY: red brown		
			CLAYEY GRAVEL: dark red brown, ooids up to 2mm, gravels > 20mm, poorly sorted, dry and loose		
			GRAVELLY CLAY: dark red brown, 10% gravels, poorly sorted, sub angular to sub rounded, ooids 2-5mm		
40	DID		CLAY: red brown, moist, 5% gravels, cohesive at 35m with hard cemented clay >10mm, rounded, ooids 10% at 44m, 20% at 48m, and 40% at 50m	Moisture encountered; Water added at 42m l 0.15mS l 0.08ppt l	





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BOREHOLE: *CHAMP-OBS-1*

CLIENT	FMS	**LOCATION**	CHAMPION	**TOTAL DEPTH (m)**	90
PROJECT	FLINDERS PI0P	**PROJECTION**	GDA94 MGA Zone 50	**SCREEN (mBGL)**	30-90
DATE DRILLED	31 AUG - 02 SEP 2011	**EASTING**	546889.99	**ELEVATION (mAHD)**	551.65
LOGGED BY	S BEAR	**NORTHING**	7555876.47	**WATER LEVEL (mBGL)**	36.77

Contractor	AUSTRAL	**Drill Bit**	5.5"	**Airlift (L/s)**	6	**Salinity (mS/cm)**	0.31
Rig Type	SCHRAMM T64	**Drill Fluid**	AirCore/RC Hammer	**Temperature (°C)**	29.2	**pH**	8.55

Depth (m)	Geological Unit	Lithology	Field Notes
48–55			pH8.52 I 29.4°C I 0.83min/m I 0.1L/s
55–56	CID	GRAVEL: dark red brown, well sorted, BIF >10mm, ooids 2mm, 5%, sub-rounded to rounded	0.27mS I 0.13ppt I pH7.72 I 28.3°C I 0.66min/m I 1.8L/s
56–60	CID	CLAYEY GRAVEL: dark red brown, clay 15%, ooids 2-5mm, cemented pisoliths and ooids at 57m with vitrious goethite	
60–79	CID	GOETHITE MATRIX: dark grey with red yellow brown mottling, cemented by a matrix of vitrious goethite appearing breciatted with vugs and small cavities becoming brown at 73m with woody fragments present crumbles to sandy gravel at 77m	0.27mS I 0.13ppt I pH7.93 I 29.7°C I 4.17min/m I 2.8L/s; 0.26mS I 0.13ppt I pH7.97 I 29.5°CI 3.33min/m I 1.7L/s; Foam added at 67m I 0.26mS I 0.13ppt I pH8.20 I 29.8°C I 9.17min/m I 3.3L/s; 0.28mS I 0.14ppt I pH7.90 I 29.9°C I 1.67min/m I 7L/s
79–80	CID	CLAY: yellow, brown	
80–85	CID	CLAY: red yellow brown at 80m, brown at 81m, vugs and cavities increase with depth dark grey red at 84m	0.29mS I 0.14ppt I pH7.92 I 30.0°C I 1.17min/m I 5L/s
85–90	BID	BID: dark brown with yellow mottling, weathered bands of iron and shale, some vugs and cavities grading into BIF, shale chert and quartz	0.29mS I 0.14ppt I pH7.88 I 30.3°C I 1.67min/m I 5L/s

Bore Construction

8/16 Gravel (29-90)

50mm PVC Screen (30-90)

Collapse (90-92)

I:\Projects\201012-00322 FMS VIP\10.0 Engineering\Hydrogeology\Phase 3 DFS Investigations\Borehole logs\Production&Obser

Job Number 201012-00322

WorleyParsons
resources & energy

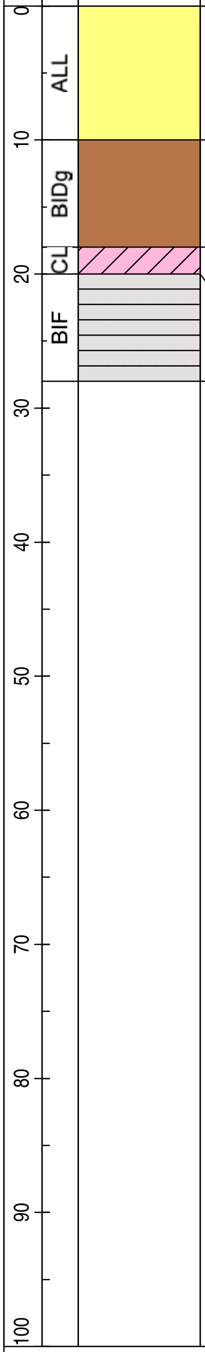
Level 7 | QV1 Building
250 St George's Terrace
Perth WA 6000
ABN 61001 279 812

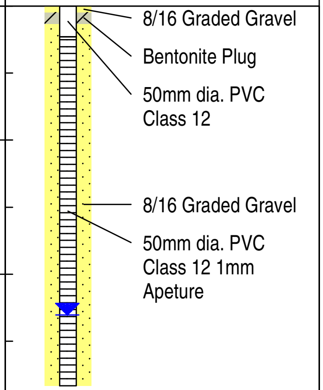
BOREHOLE: *HPRC5359*

CLIENT	FMS	**LOCATION**	DELTA	**DRILLED DEPTH (m)**	28.3
PROJECT	PIOP	**PROJECTION**		**SCREEN (mBGL)**	2.30-28.30
DATE DRILLED	29OCT2011	**EASTING**	552705.171	**ELEVATION (mAHD)**	580.805
LOGGED BY		**NORTHING**	7551089.499	**WATER LEVEL (mBGL)**	23.03

Contractor		**Drill Bit**	5.5"	**Airlift (L/s)**		**Salinity (mS/cm)**	
Rig Type	AIR CORE RC	**Drill Fluid**	A/W	**Temperature (°C)**		**pH**	

Depth (m)	Geological Unit	Graphic Log	Lithology	Field Notes	Bore Construction
0–10	ALL		ALL: Recent Alluvium	""	
10–18	BIDg		BIDg: Bedded Iron Deposit - goethite dominant		
18–20	CL		CLY: Clay		
20–28.3	BIF		BIF: Banded Iron Formation		





Job Number 201012-00322

WorleyParsons
resources & energy

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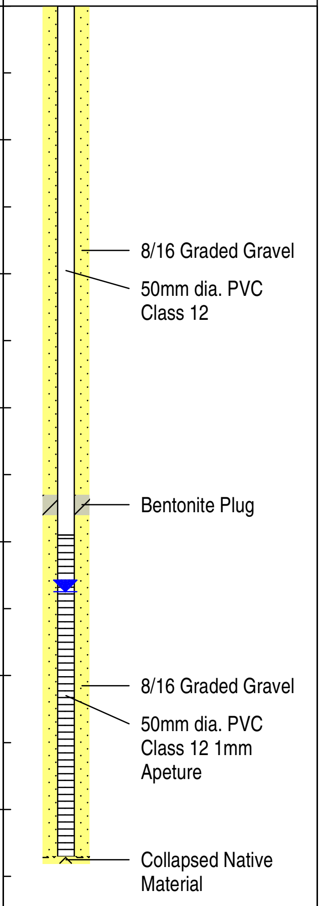
BOREHOLE: *HPRC5275*

CLIENT	FMS	**LOCATION**	DELTA	**DRILLED DEPTH (m)**	64
PROJECT	PIOP	**PROJECTION**		**SCREEN (mBGL)**	39.50-63.50
DATE DRILLED	30OCT2011	**EASTING**	551040.25	**ELEVATION (mAHD)**	546.289
LOGGED BY		**NORTHING**	7552890.839	**WATER LEVEL (mBGL)**	43.74

Contractor		**Drill Bit**	5.5"	**Airlift (L/s)**	0.003	**Salinity (mS/cm)**
Rig Type	AIR CORE RC	**Drill Fluid**	A/W	**Temperature (°C)**		**pH**

Depth (m)	Geological Unit	Graphic Log	Lithology	Field Notes	Bore Construction
0–12	ALL		ALL: Recent Alluvium	"Development Duration 10min; TDS-255ppm"	
12–38	DIDh		DIDh: Detrital Iron Deposit - hematite dominant		
38–60	BIDh		BIDh: Bedded Iron Deposit - goethite with hematite		
60–64	BIF		BIF: Banded Iron Formation		



Job Number 201012-00322

WorleyParsons
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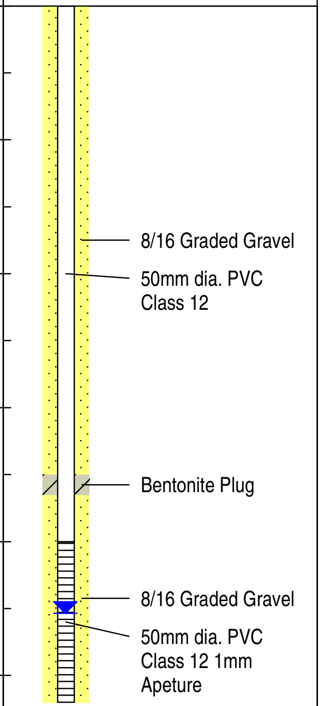
BOREHOLE: *HPRC5210*

CLIENT	FMS	**LOCATION**	DELTA	**DRILLED DEPTH (m)**	52
PROJECT	PIOP	**PROJECTION**		**SCREEN (mBGL)**	40.00-52.00
DATE DRILLED	30OCT2011	**EASTING**	551257.286	**ELEVATION (mAHD)**	549.785
LOGGED BY		**NORTHING**	7552281.918	**WATER LEVEL (mBGL)**	45.37

Contractor		**Drill Bit**	5.5"	**Airlift (L/s)**	0.01	**Salinity (mS/cm)**	
Rig Type	AIR CORE RC	**Drill Fluid**	A/W	**Temperature (℃)**		**pH**	

Depth (m)	Geological Unit	Graphic Log	Lithology	Field Notes
0	ALL		ALL: Recent Alluvium	"Development Duration 10min; TDS-231ppm"
10	DIDh		DIDh: Detrital Iron Deposit - hematite dominant	
48	CI		CIDh: Channel Iron Deposit - hematite dominant	
50	BI		BIDh: Bedded Iron Deposit - goethite with hematite	

Bore Construction



SHEET:1 OF 1

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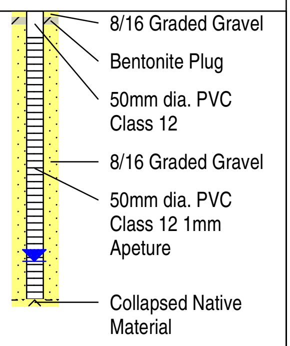
BOREHOLE:
HPRC5034

CLIENT	FMS	**LOCATION**	DELTA	**DRILLED DEPTH (m)**	22
PROJECT	PIOP	**PROJECTION**		**SCREEN (mBGL)**	2.00-21.50
DATE DRILLED	31OCT2011	**EASTING**	551307.608	**ELEVATION (mAHD)**	576.863
LOGGED BY		**NORTHING**	7550982.172	**WATER LEVEL (mBGL)**	18.68

Contractor		**Drill Bit**	5.5"	**Airlift (L/s)**	0	**Salinity (mS/cm)**	
Rig Type	AIR CORE RC	**Drill Fluid**	A/W	**Temperature (°C)**		**pH**	

Depth (m)	Geological Unit	Graphic Log	Lithology	Field Notes	Bore Construction
0	DIDh		DIDh: Detrital Iron Deposit - hematite dominant	"Not enough water to airlift"	
	BIDg		BIDg: Bedded Iron Deposit - goethite dominant		
	BID		BIDh: Bedded Iron Deposit - goethite with hematite		
20	BIF		BIF: Banded Iron Formation		



Depth scale (m): 0, 10, 20, 30, 40, 50, 60, 70, 80, 90, 100

Job Number 201012-00322

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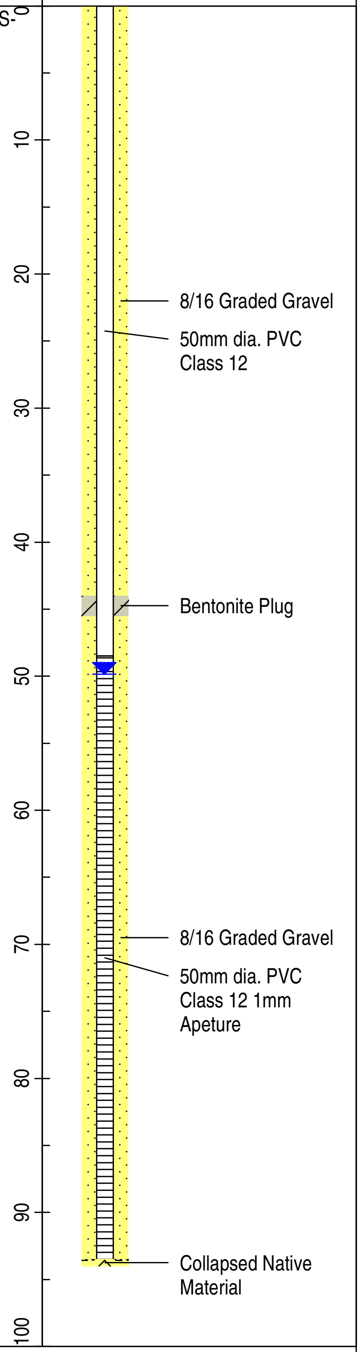
BOREHOLE: *HPRC4257*

CLIENT	FMS	**LOCATION**	EAGLE	**DRILLED DEPTH (m)**	94
PROJECT	PIOP	**PROJECTION**		**SCREEN (mBGL)**	48.50-93.50
DATE DRILLED	27SEP2011	**EASTING**	550653.6	**ELEVATION (mAHD)**	591.405
LOGGED BY		**NORTHING**	7546813.049	**WATER LEVEL (mBGL)**	49.85

Contractor		**Drill Bit**	5.5"	**Airlift (L/s)**	0.2	**Salinity (mS/cm)**	
Rig Type	AIR CORE RC	**Drill Fluid**	A/W	**Temperature (°C)**		**pH**	

Depth (m)	Geological Unit	Lithology	Field Notes
0–22	ALL	ALL: Recent Alluvium	"Development Duration - 30min; TDS-167ppm"
22–46	DIDh	DIDh: Detrital Iron Deposit - hematite dominant	
46–62	CIDg	CIDg: Channel Iron Deposit - goethite dominant	
62–76	CIDh	CIDh: Channel Iron Deposit - hematite dominant	
76–78	SH	SHL: Shale	
78–92	BIF	BIF: Banded Iron Formation	
92–94	CH	CHT: Chert	

Bore Construction



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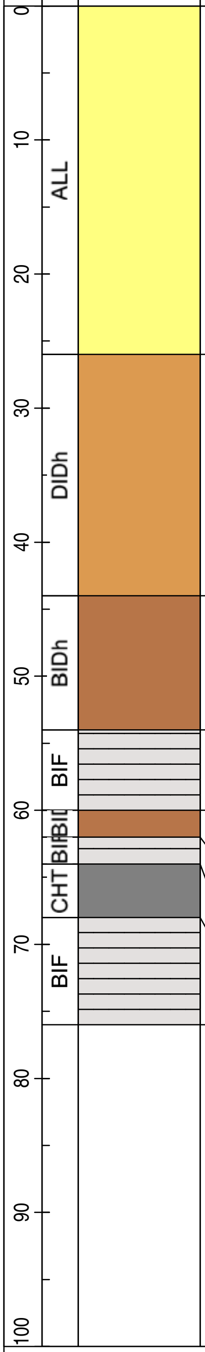
BOREHOLE: *HPRC4180*

CLIENT	FMS	**LOCATION**	EAGLE	**DRILLED DEPTH (m)**	76
PROJECT	PIOP	**PROJECTION**		**SCREEN (mBGL)**	55.74-73.83
DATE DRILLED	17AUG2011	**EASTING**	549402.006	**ELEVATION (mAHD)**	603.024
LOGGED BY		**NORTHING**	7547290.758	**WATER LEVEL (mBGL)**	59.8

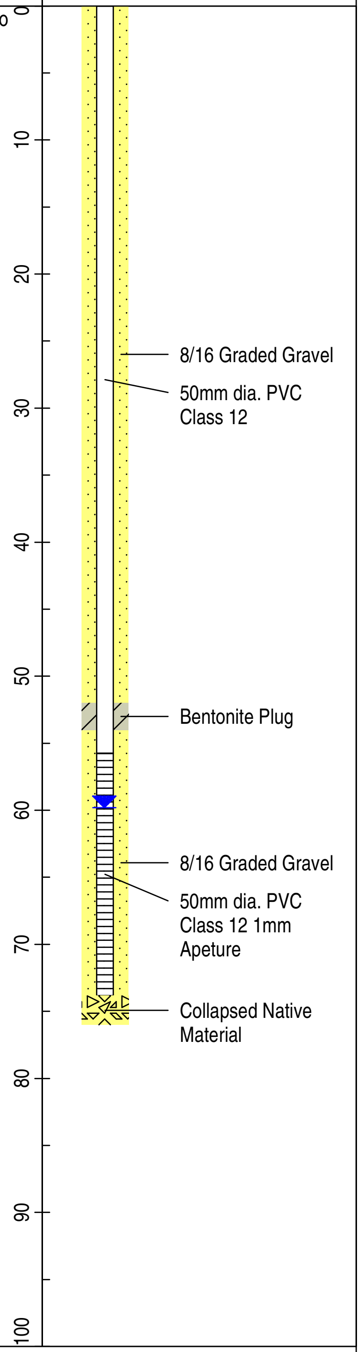
Contractor		**Drill Bit**	5.5"	**Airlift (L/s)**	~0	**Salinity (mS/cm)**	
Rig Type	AIR CORE RC	**Drill Fluid**	A/W	**Temperature (℃)**		**pH**	

Depth (m)	Geological Unit	Lithology	Field Notes
0–26	ALL	ALL: Recent Alluvium	"Development Duration - 20min - no airlift; TDS- 149.0ppm
26–44	DIDh	DIDh: Detrital Iron Deposit - hematite dominant	
44–54	BIDh	BIDh: Bedded Iron Deposit - goethite with hematite	
54–60	BIF	BIF: Banded Iron Formation	
60–62	BID	BIDg: Bedded Iron Deposit - goethite dominant	
62–64	BIF	BIF: Banded Iron Formation	
64–68	CHT	CHT: Chert	
68–76	BIF	BIF: Banded Iron Formation	

Graphic Log



Bore Construction



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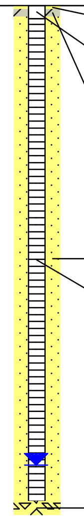
BOREHOLE: *HPRC4122*

CLIENT	FMS	**LOCATION**	EAGLE	**DRILLED DEPTH (m)**	38
PROJECT	PIOP	**PROJECTION**		**SCREEN (mBGL)**	1.00-37.00
DATE DRILLED	01NOV2011	**EASTING**	544946.124	**ELEVATION (mAHD)**	673.697
LOGGED BY		**NORTHING**	7549663.393	**WATER LEVEL (mBGL)**	34.3

Contractor		**Drill Bit**	5.5"	**Airlift (L/s)**		**Salinity (mS/cm)**	
Rig Type	AIR CORE RC	**Drill Fluid**	A/W	**Temperature (°C)**		**pH**	

Depth (m)	Geological Unit	Graphic Log	Lithology	Field Notes
0–2	DID		DIDh: Detrital Iron Deposit - hematite dominant	"Bailed 3L"
2–30	BIDg		BIDg: Bedded Iron Deposit - goethite dominant	
30–34	SHL		SHL: Shale	
34–36	BIF		BIF: Banded Iron Formation	
36–38	DOL		DOL: Dolerite	

Bore Construction



SHEET:1 OF 1

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BOREHOLE: *HPRC4118*

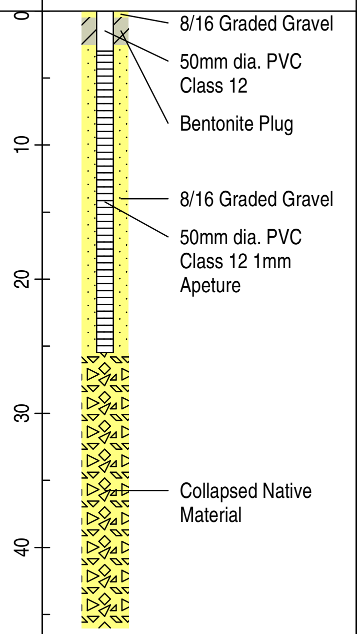
CLIENT	FMS	**LOCATION**	EAGLE	**DRILLED DEPTH (m)**	46
PROJECT	PIOP	**PROJECTION**		**SCREEN (mBGL)**	3.00-25.50
DATE DRILLED	01NOV2011	**EASTING**	545177.968	**ELEVATION (mAHD)**	660.885
LOGGED BY		**NORTHING**	7549533.175	**WATER LEVEL (mBGL)**	Dry

Contractor		**Drill Bit**	5.5"	**Airlift (L/s)**	Dry	**Salinity (mS/cm)**	
Rig Type	AIR CORE RC	**Drill Fluid**	A/W	**Temperature (℃)**		**pH**	

Depth (m)	Geological Unit	Graphic Log	Lithology	Field Notes
0	COL		COL: Recent Colluvium	"Dry Bore"
	DIDh		DIDh: Detrital Iron Deposit - hematite dominant	
	BIDg		BIDg: Bedded Iron Deposit - goethite dominant	
30	SHL		SHL: Shale	
40	BIF		BIF: Banded Iron Formation	

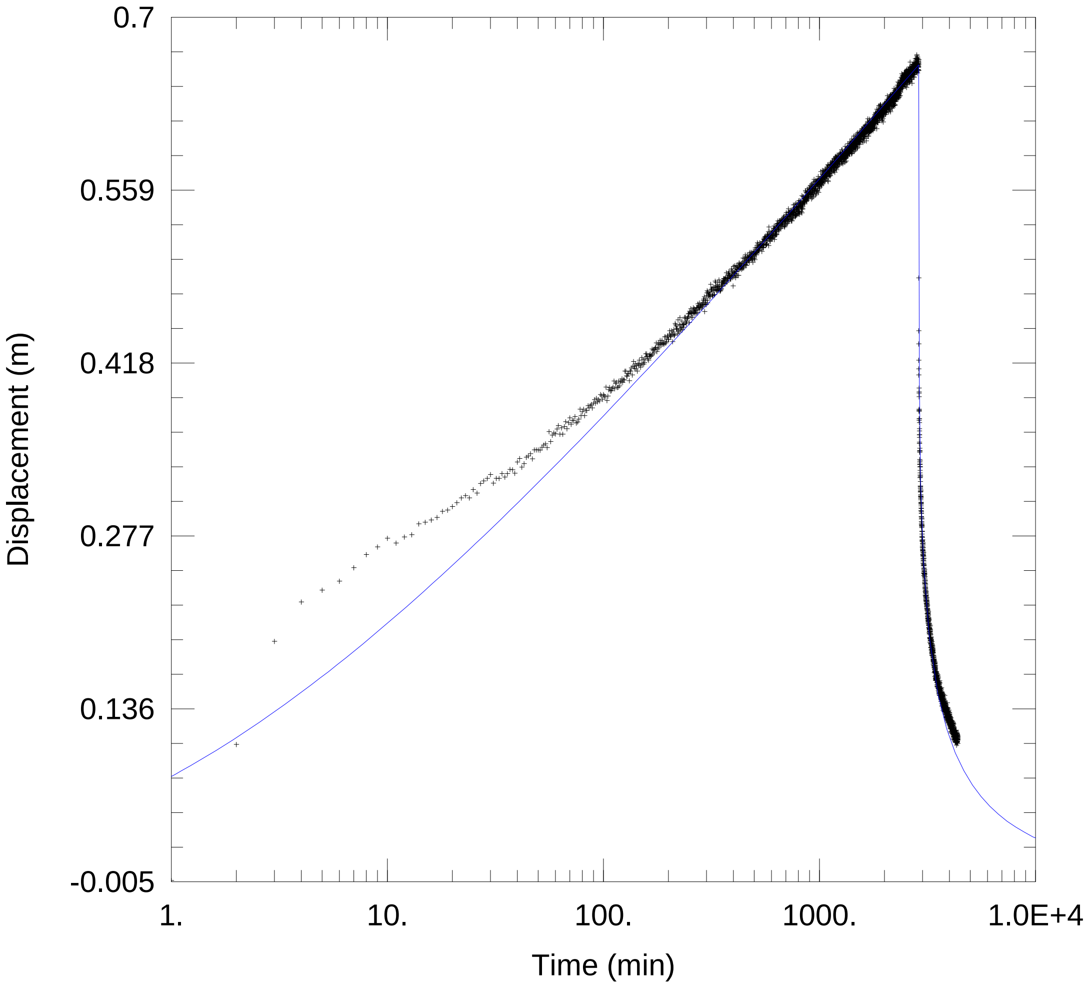
Depth scale (m): 0, 10, 20, 30, 40, 50, 60, 70, 80, 90, 100

Bore Construction



Job Number 201012-00322

Appendix 4: Pump Test Results



WELL TEST ANALYSIS

Data Set: I:\...\Eagle04m.aqt
Date: 02/20/12 Time: 16:46:51

PROJECT INFORMATION

Company: WP
Client: FMS
Project: 201012-00322
Location: EAGLE
Test Well: EAGLE
Test Date: 28NOV2011

AQUIFER DATA

Saturated Thickness: 58. m
Anisotropy Ratio (Kz/Kr): 1.
Aquitard Thickness (b'): 1. m
Aquitard Thickness (b"): 1. m

WELL DATA

Pumping Wells

Well Name	X (m)	Y (m)
Eagle Production	0	0

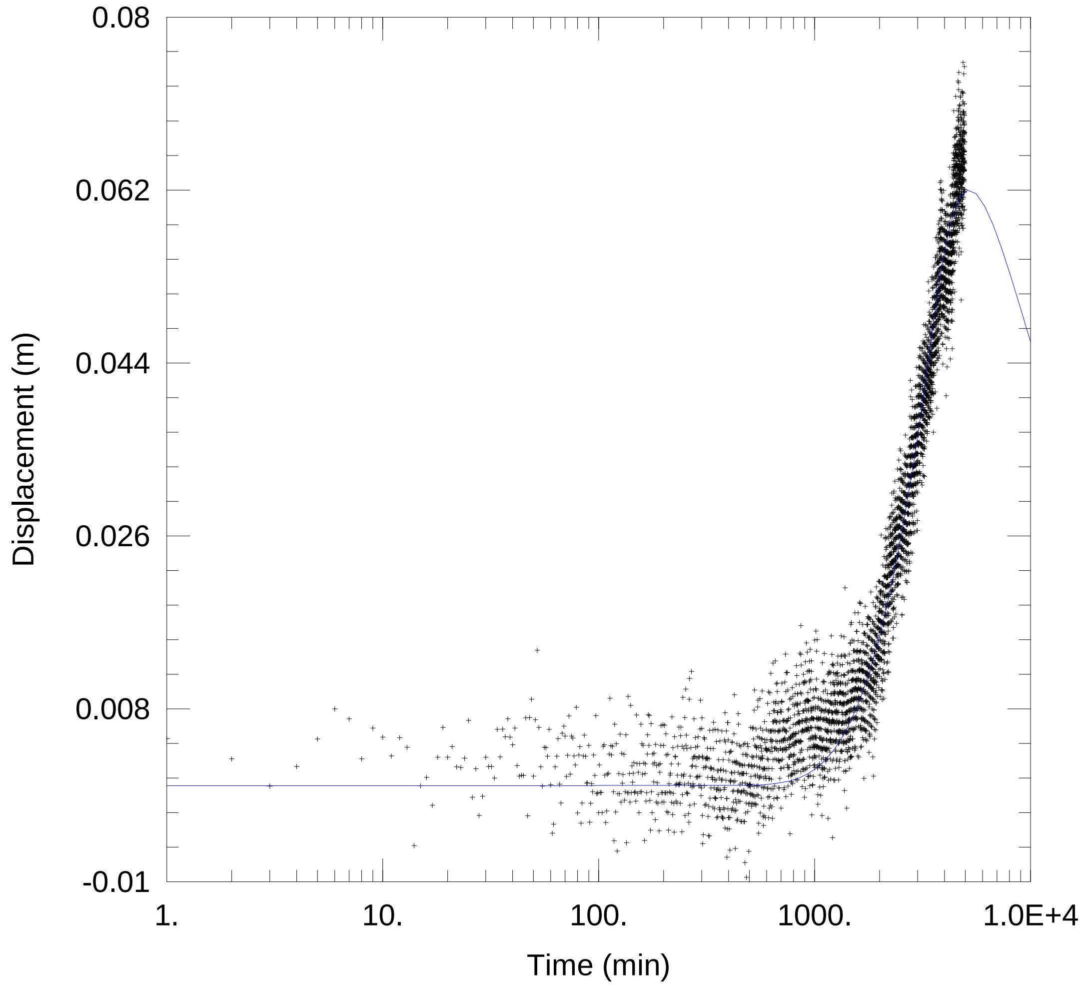
Observation Wells

Well Name	X (m)	Y (m)
O4m	13.9	0

SOLUTION

Aquifer Model: Leaky
Solution Method: Hantush

T = 1120.4 m^2/day
S = 2.568E-5
r/B' = 1.0E-5
ß' = 8.144
r/B" = 0.
ß" = 0.



WELL TEST ANALYSIS

Data Set: I:\...\Eagle03.aqt
Date: 02/20/12 Time: 16:38:55

PROJECT INFORMATION

Company: WP
Client: FMS
Project: 201012-00322
Location: EAGLE
Test Well: EAGLE
Test Date: 28NOV2011

WELL DATA

Pumping Wells

Well Name	X (m)	Y (m)
Eagle Production	0	0

Observation Wells

Well Name	X (m)	Y (m)
O3	807.93	0

SOLUTION

Aquifer Model: Confined

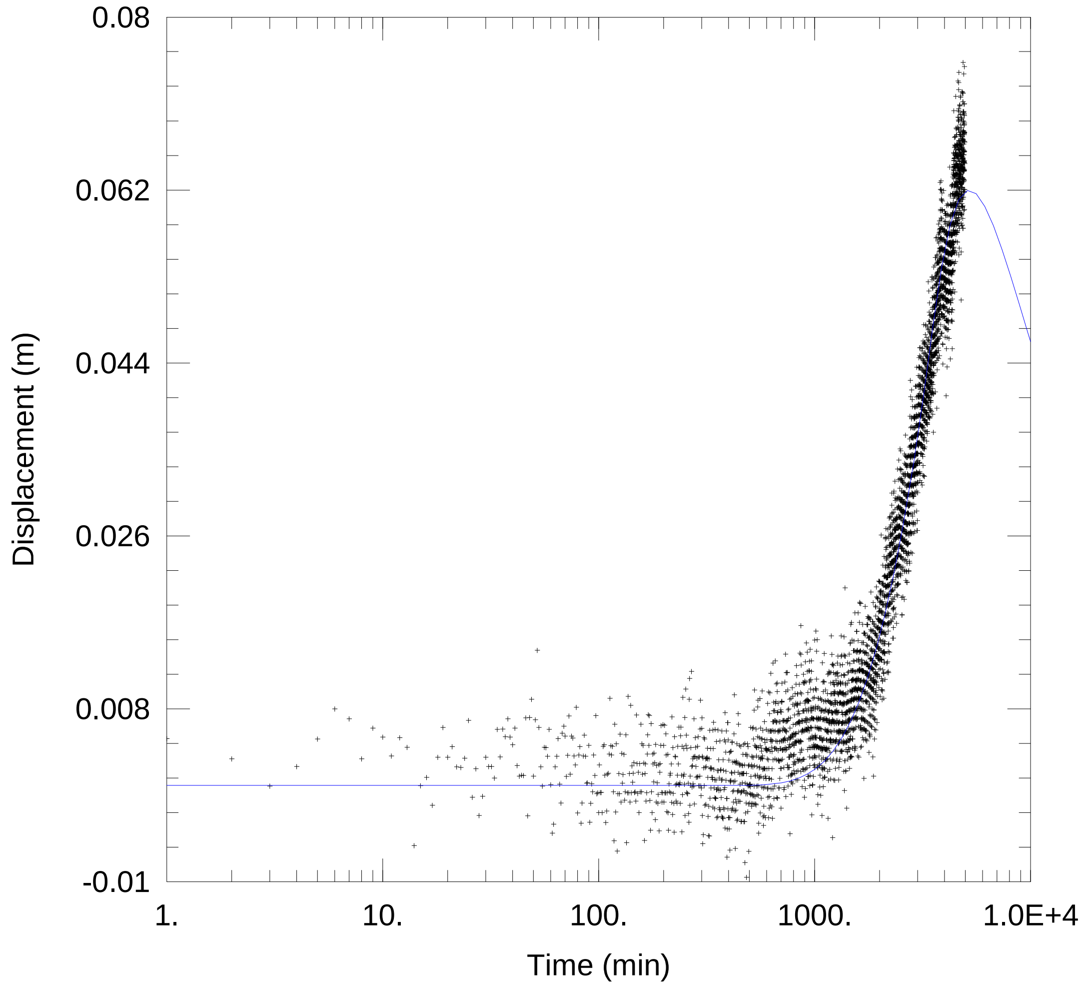
Solution Method: Theis

T = 1015.3 m^2/day

S = 0.01459

Kz/Kr = 1.

b = 58. m



WELL TEST ANALYSIS

Data Set: I:\...\Eagle03.aqt
Date: 02/20/12 Time: 16:48:00

PROJECT INFORMATION

Company: WP
Client: FMS
Project: 201012-00322
Location: EAGLE
Test Well: EAGLE
Test Date: 28NOV2011

AQUIFER DATA

Saturated Thickness: 58. m
Anisotropy Ratio (Kz/Kr): 1.
Aquitard Thickness (b'): 1. m
Aquitard Thickness (b"): 1. m

WELL DATA

Pumping Wells

Well Name	X (m)	Y (m)
Eagle Production	0	0

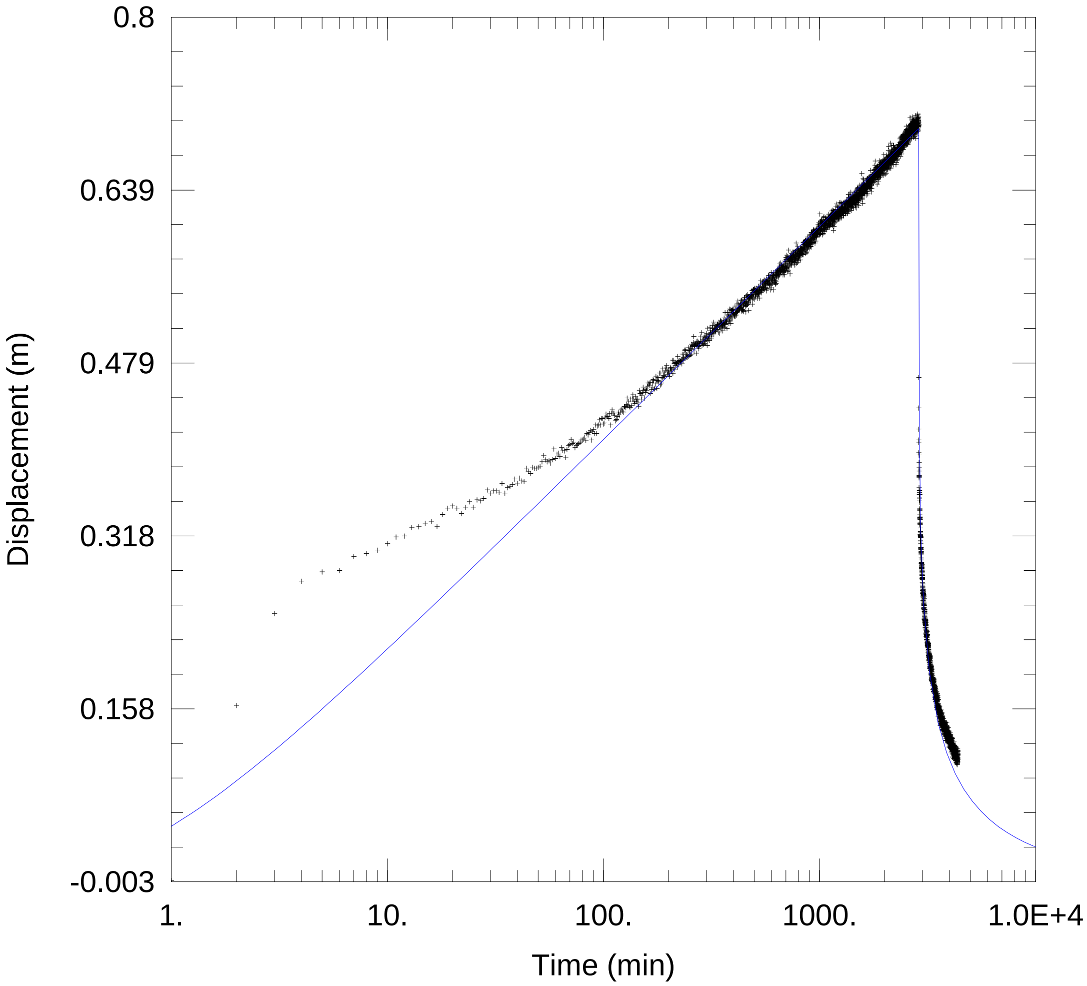
Observation Wells

Well Name	X (m)	Y (m)
O3	807.93	0

SOLUTION

Aquifer Model: Leaky
Solution Method: Hantush

T = 1015.3 m^2/day
r/B' = 1.0E-5
r/B" = 0.
S = 0.01459
ß' = 1.0E-5
ß" = 0.



WELL TEST ANALYSIS

Data Set: I:\...\Eagle02.aqt
Date: 02/20/12 Time: 16:40:20

PROJECT INFORMATION

Company: WP
Client: FMS
Project: 201012-00322
Location: EAGLE
Test Well: EAGLE
Test Date: 28NOV2011

WELL DATA

Pumping Wells

Well Name	X (m)	Y (m)
Eagle Production	0	0

Observation Wells

Well Name	X (m)	Y (m)
O2	18.35	0

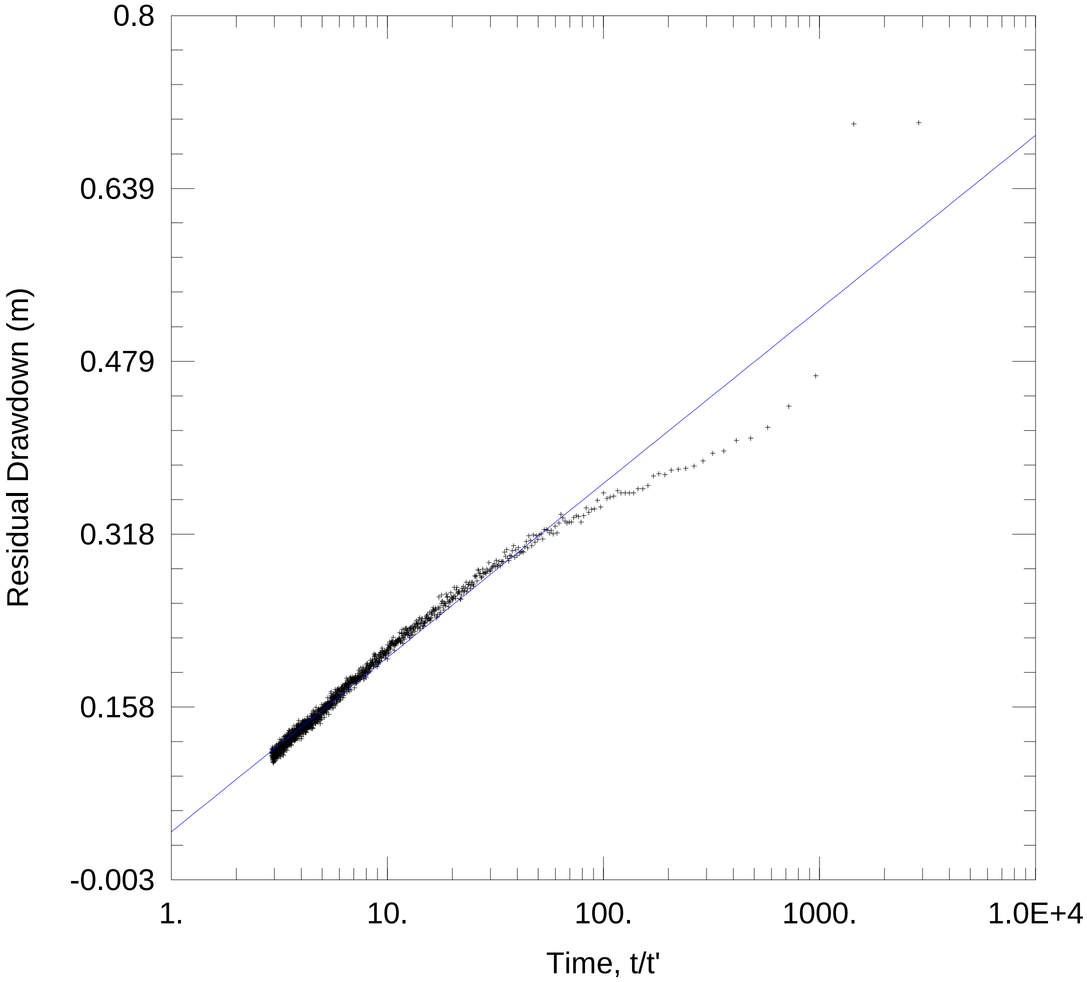
SOLUTION

Aquifer Model: Confined

Solution Method: Theis

T = 2395.4 m^2/day
Kz/Kr = 1.

S = 0.009837
b = 58. m



WELL TEST ANALYSIS

Data Set: I:\...\Eagle02.aqt
Date: 02/20/12 Time: 16:42:58

PROJECT INFORMATION

Company: WP
Client: FMS
Project: 201012-00322
Location: EAGLE
Test Well: EAGLE
Test Date: 28NOV2011

AQUIFER DATA

Saturated Thickness: 58. m Anisotropy Ratio (Kz/Kr): 1.

WELL DATA

Pumping Wells

Well Name	X (m)	Y (m)
Eagle Production	0	0

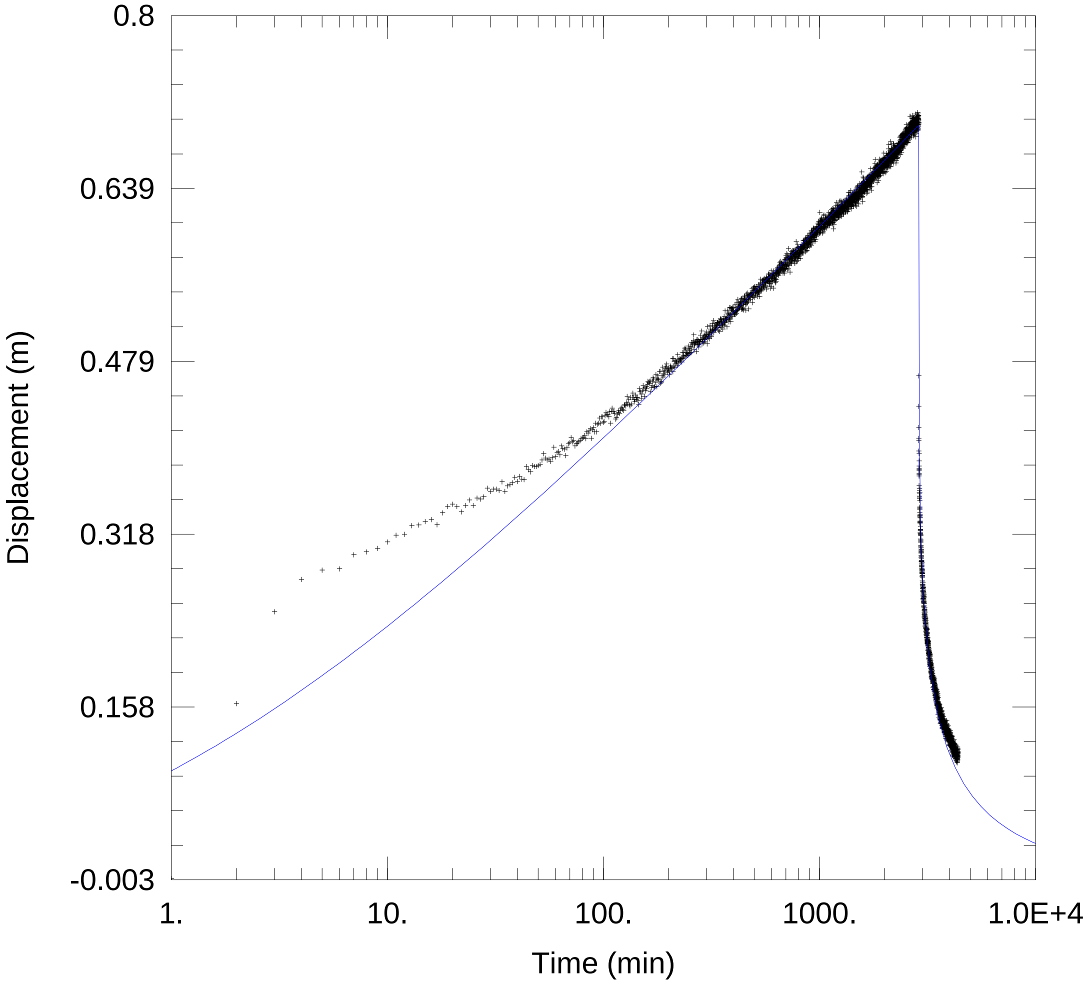
Observation Wells

Well Name	X (m)	Y (m)
+ O2	18.35	0

SOLUTION

Aquifer Model: Confined Solution Method: Theis (Recovery)

T = 2935.4 m^2/day S/S' = 0.5553



WELL TEST ANALYSIS

Data Set: I:\...\Eagle02.aqt
Date: 02/20/12 Time: 16:49:20

PROJECT INFORMATION

Company: WP
Client: FMS
Project: 201012-00322
Location: EAGLE
Test Well: EAGLE
Test Date: 28NOV2011

AQUIFER DATA

Saturated Thickness: 58. m
Anisotropy Ratio (Kz/Kr): 1.
Aquitard Thickness (b'): 1. m
Aquitard Thickness (b"): 1. m

WELL DATA

Pumping Wells

Well Name	X (m)	Y (m)
Eagle Production	0	0

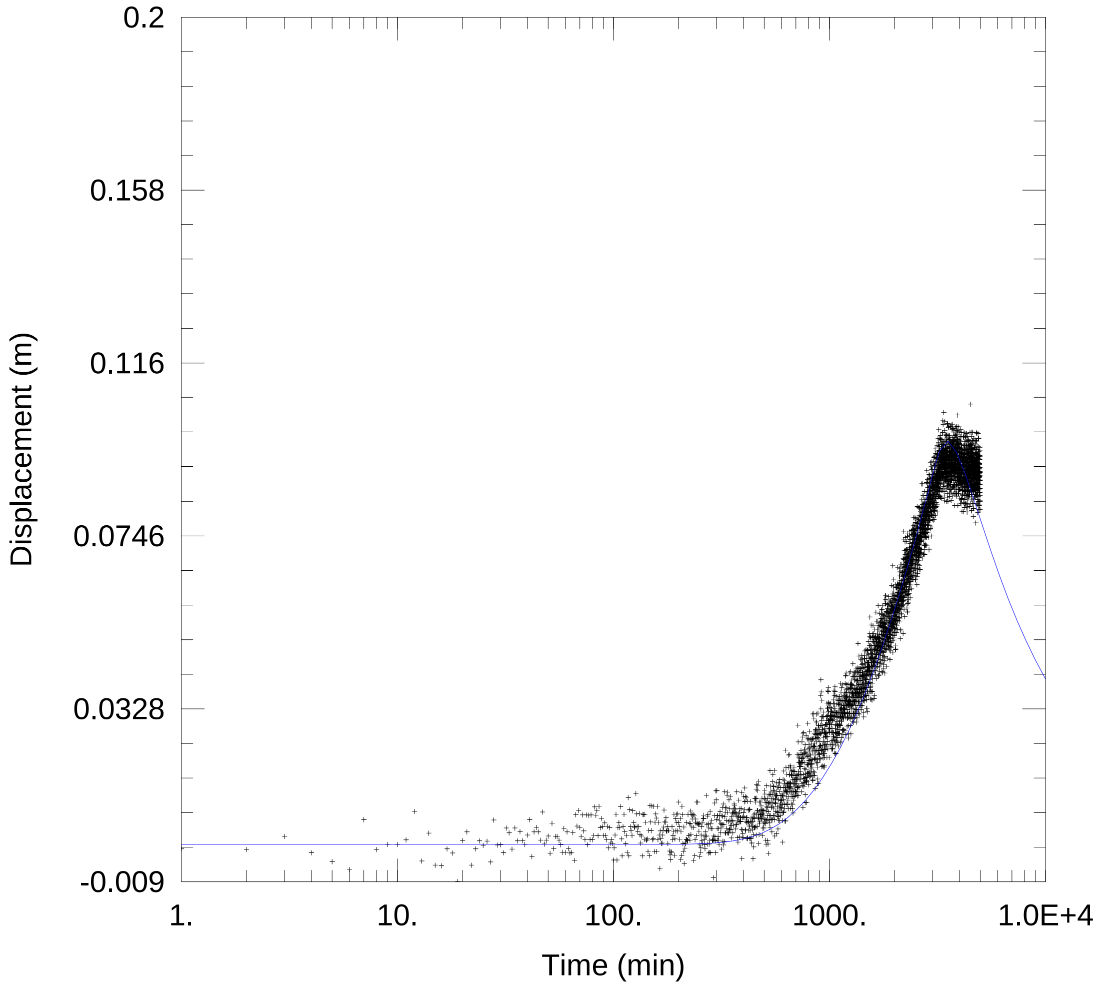
Observation Wells

Well Name	X (m)	Y (m)
+ O2	18.35	0

SOLUTION

Aquifer Model: Leaky
Solution Method: Hantush

T = 1117. m^2/day
S = 1.893E-5
r/B' = 1.0E-5
ß' = 5.899
r/B" = 0.
ß" = 0.



WELL TEST ANALYSIS

Data Set: I:\...\Eagle01.aqt
Date: 02/20/12 Time: 16:40:44

PROJECT INFORMATION

Company: WP
Client: FMS
Project: 201012-00322
Location: EAGLE
Test Well: EAGLE
Test Date: 28NOV2011

WELL DATA

Pumping Wells

Well Name	X (m)	Y (m)
Eagle Production	0	0

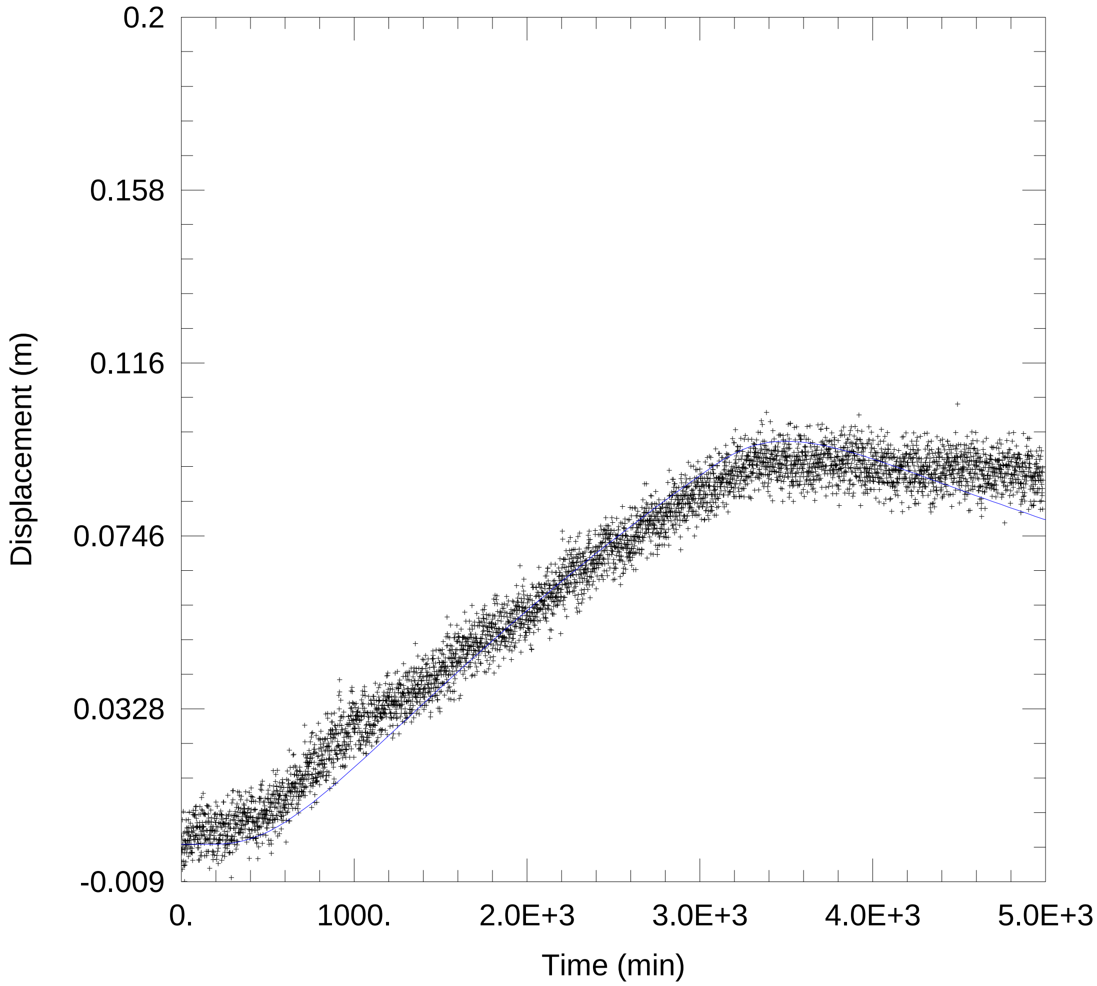
Observation Wells

Well Name	X (m)	Y (m)
O1	1152.75	0

SOLUTION

Aquifer Model: Confined
Solution Method: Theis

T = 1500.9 m^2/day
S = 0.004083
Kz/Kr = 1.
b = 58. m



WELL TEST ANALYSIS

Data Set: I:\...\Eagle01.aqt
Date: 02/20/12 Time: 16:50:01

PROJECT INFORMATION

Company: WP
Client: FMS
Project: 201012-00322
Location: EAGLE
Test Well: EAGLE
Test Date: 28NOV2011

AQUIFER DATA

Saturated Thickness: 58. m
Anisotropy Ratio (Kz/Kr): 1.
Aquitard Thickness (b'): 1. m
Aquitard Thickness (b"): 1. m

WELL DATA

Pumping Wells

Well Name	X (m)	Y (m)
Eagle Production	0	0

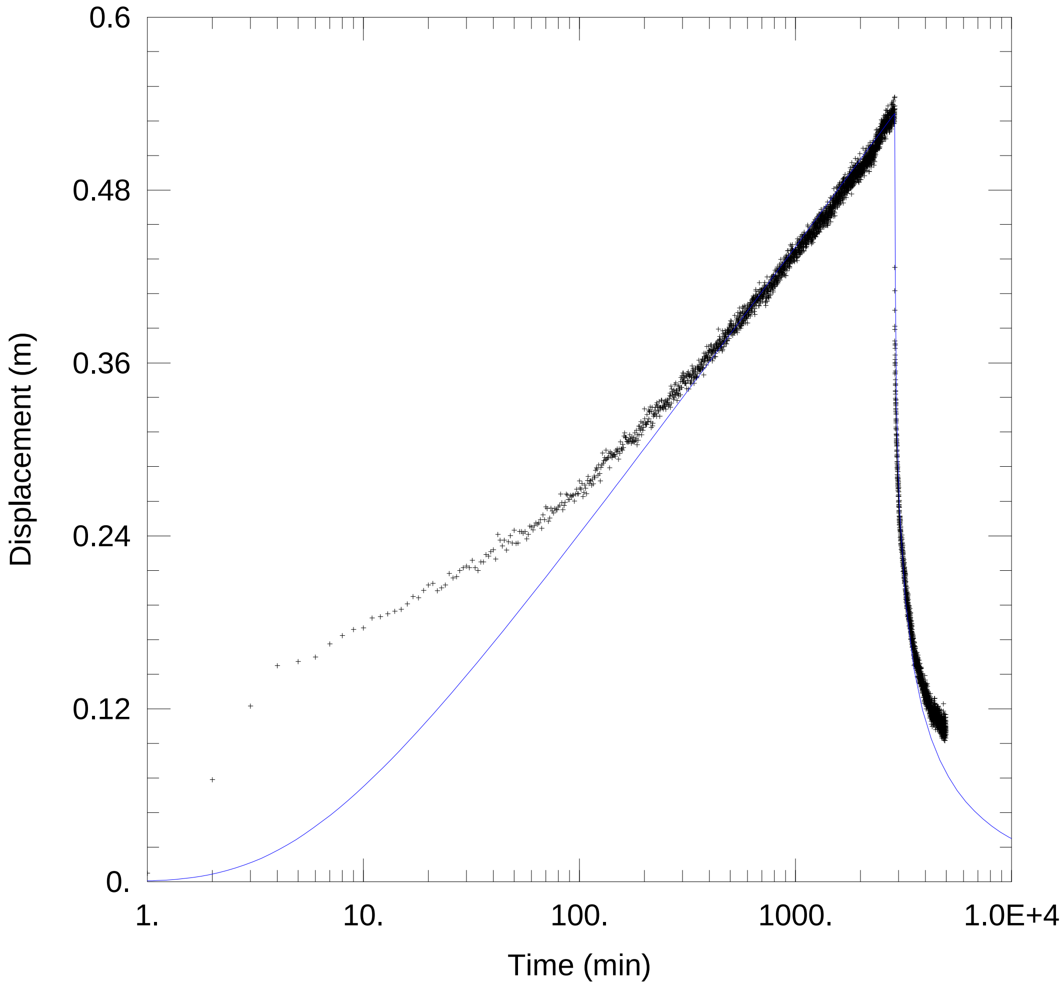
Observation Wells

Well Name	X (m)	Y (m)
O1	1152.75	0

SOLUTION

Aquifer Model: Leaky
Solution Method: Hantush

T = 1500.7 m^2/day
S = 0.004083
r/B' = 1.0E-5
ß' = 1.0E-5
r/B" = 0.
ß" = 0.



WELL TEST ANALYSIS

Data Set: I:\...\Eag04d.aqt
Date: 02/20/12 Time: 16:41:05

PROJECT INFORMATION

Company: WP
Client: FMS
Project: 201012-00322
Location: EAGLE
Test Well: EAGLE
Test Date: 28NOV2011

WELL DATA

Pumping Wells

Well Name	X (m)	Y (m)
Eagle Production	0	0

Observation Wells

Well Name	X (m)	Y (m)
O4d	13.9	0

SOLUTION

Aquifer Model: Confined

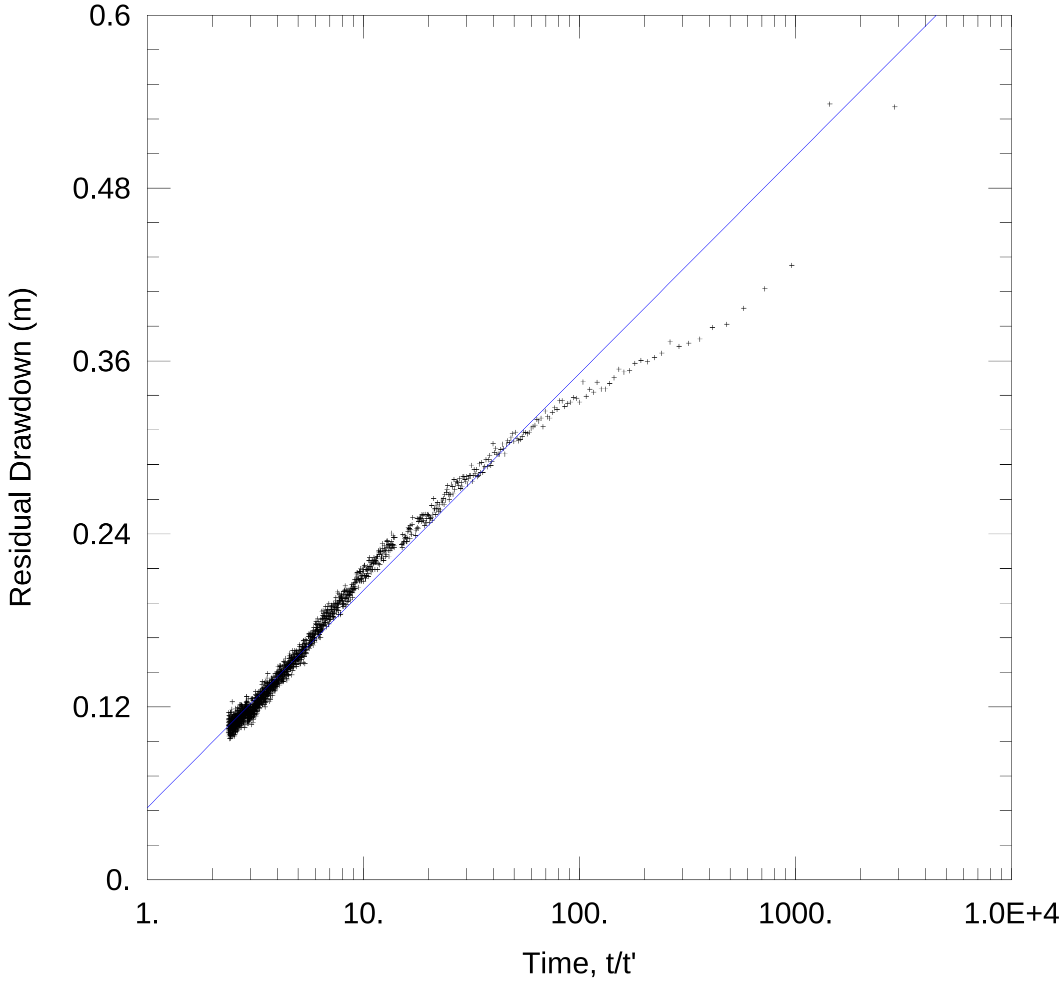
Solution Method: Theis

T = 2349.8 m^2/day

S = 0.1261

Kz/Kr = 1.

b = 58. m



WELL TEST ANALYSIS

Data Set: I:\...\Eag04d.aqt
Date: 02/20/12 Time: 16:43:17

PROJECT INFORMATION

Company: WP
Client: FMS
Project: 201012-00322
Location: EAGLE
Test Well: EAGLE
Test Date: 28NOV2011

AQUIFER DATA

Saturated Thickness: 58. m Anisotropy Ratio (Kz/Kr): 1.

WELL DATA

Pumping Wells

Well Name	X (m)	Y (m)
Eagle Production	0	0

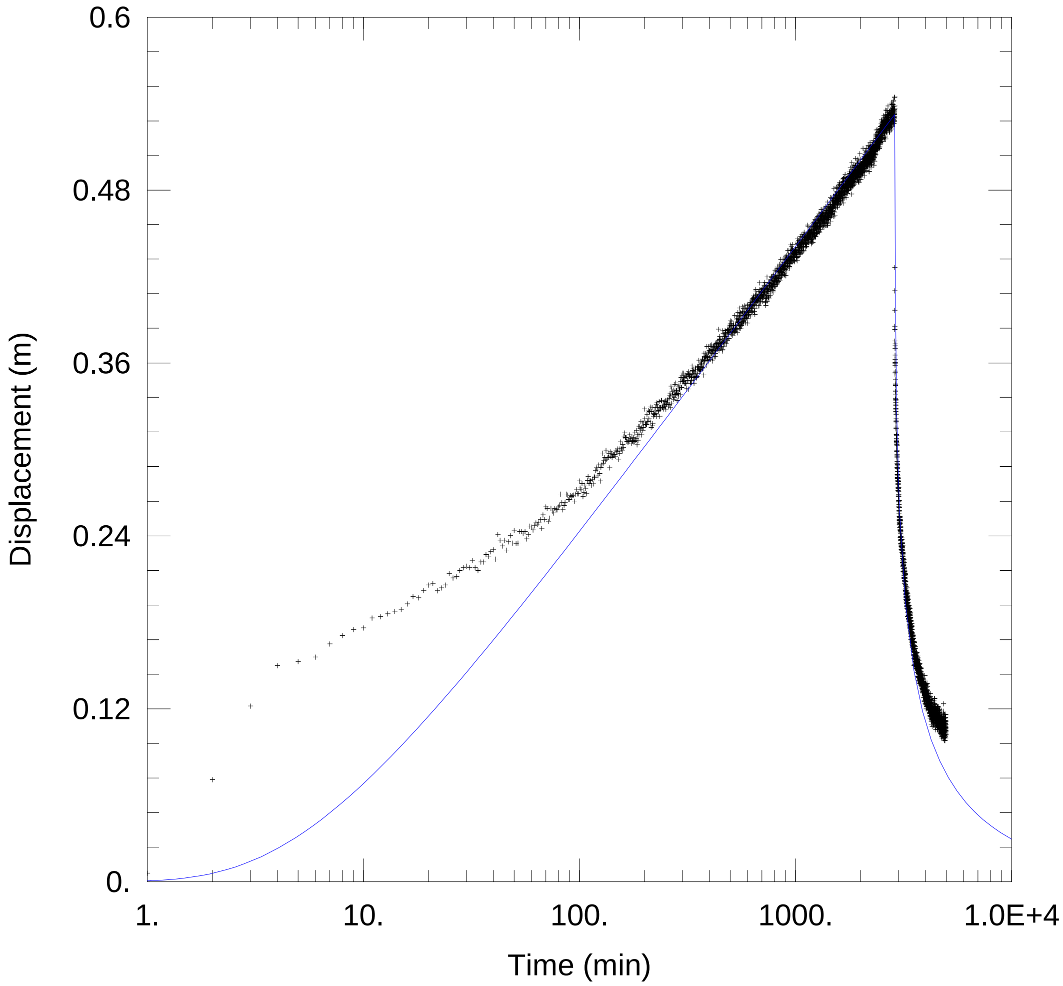
Observation Wells

Well Name	X (m)	Y (m)
O4d	13.9	0

SOLUTION

Aquifer Model: Confined Solution Method: Theis (Recovery)

T = 3153.7 m^2/day S/S' = 0.4668



WELL TEST ANALYSIS

Data Set: I:\...\Eag04d.aqt
Date: 02/20/12
Time: 16:51:04

PROJECT INFORMATION

Company: WP
Client: FMS
Project: 201012-00322
Location: EAGLE
Test Well: EAGLE
Test Date: 28NOV2011

AQUIFER DATA

Saturated Thickness: 58. m
Anisotropy Ratio (Kz/Kr): 1.
Aquitard Thickness (b'): 1. m
Aquitard Thickness (b"): 1. m

WELL DATA

Pumping Wells

Well Name	X (m)	Y (m)
Eagle Production	0	0

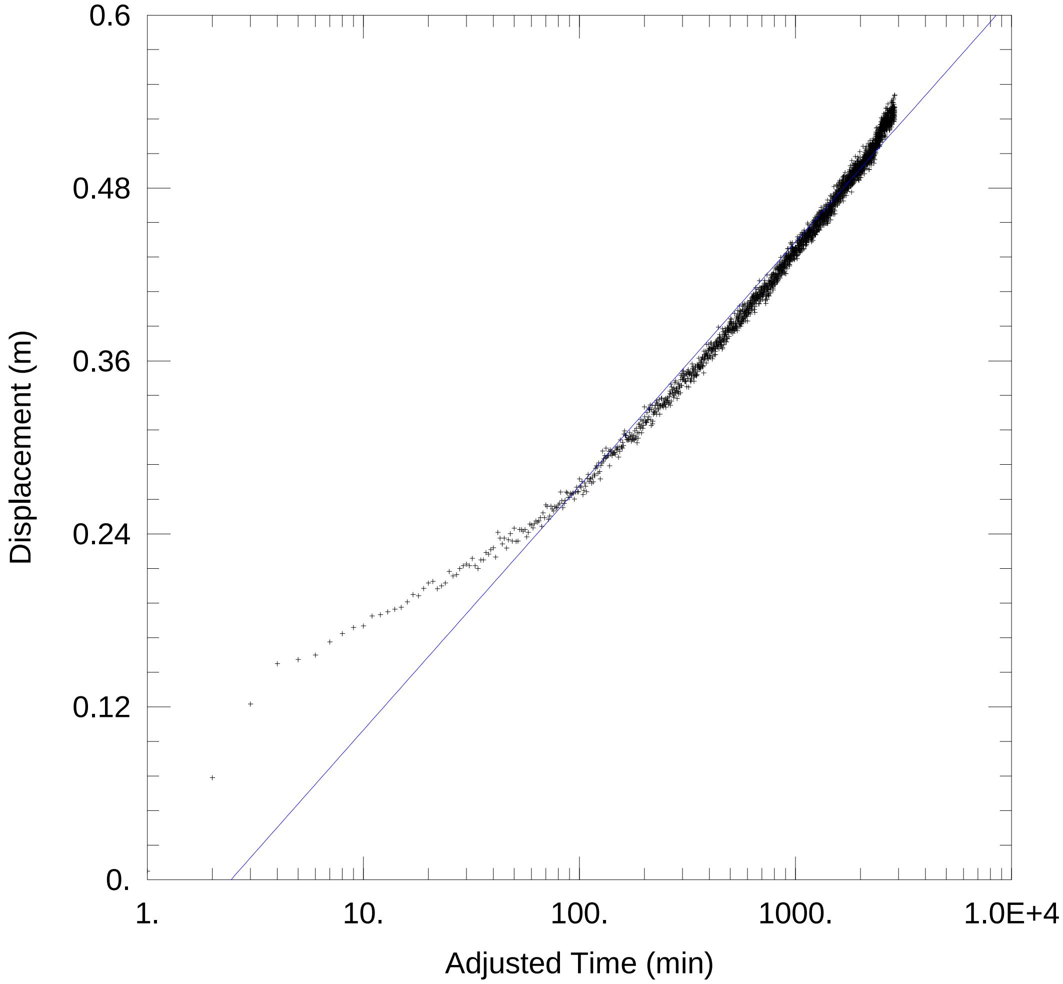
Observation Wells

Well Name	X (m)	Y (m)
O4d	13.9	0

SOLUTION

Aquifer Model: Leaky
Solution Method: Hantush

T = 2369.2 m^2/day
S = 0.1218
r/B' = 1.0E-5
ß' = 1.0E-5
r/B" = 0.
ß" = 0.



WELL TEST ANALYSIS

Data Set: I:\...\Eag04d.aqt
Date: 02/20/12 Time: 16:51:38

PROJECT INFORMATION

Company: WP
Client: FMS
Project: 201012-00322
Location: EAGLE
Test Well: EAGLE
Test Date: 28NOV2011

AQUIFER DATA

Saturated Thickness: 58. m Anisotropy Ratio (Kz/Kr): 1.

WELL DATA

Pumping Wells

Well Name	X (m)	Y (m)
Eagle Production	0	0

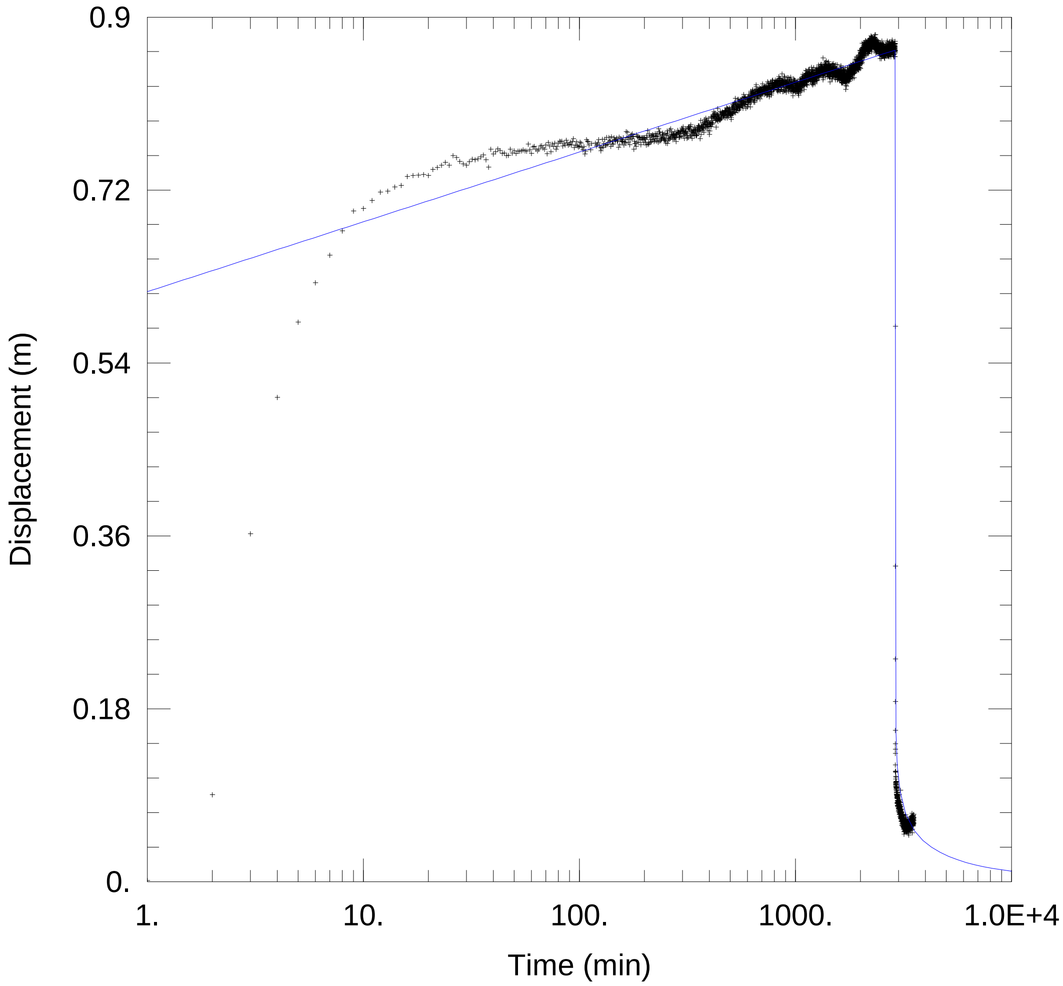
Observation Wells

Well Name	X (m)	Y (m)
O4d	13.9	0

SOLUTION

Aquifer Model: Confined Solution Method: Cooper-Jacob

T = 2803. m^2/day S = 0.05541



WELL TEST ANALYSIS

Data Set: I:\...\Delta04s.aqt
Date: 02/20/12 Time: 16:06:20

PROJECT INFORMATION

Company: WP
Client: FMS
Location: Delta
Test Well: Delta Production

WELL DATA

Pumping Wells

Well Name	X (m)	Y (m)
Dlt-Prod	0	0

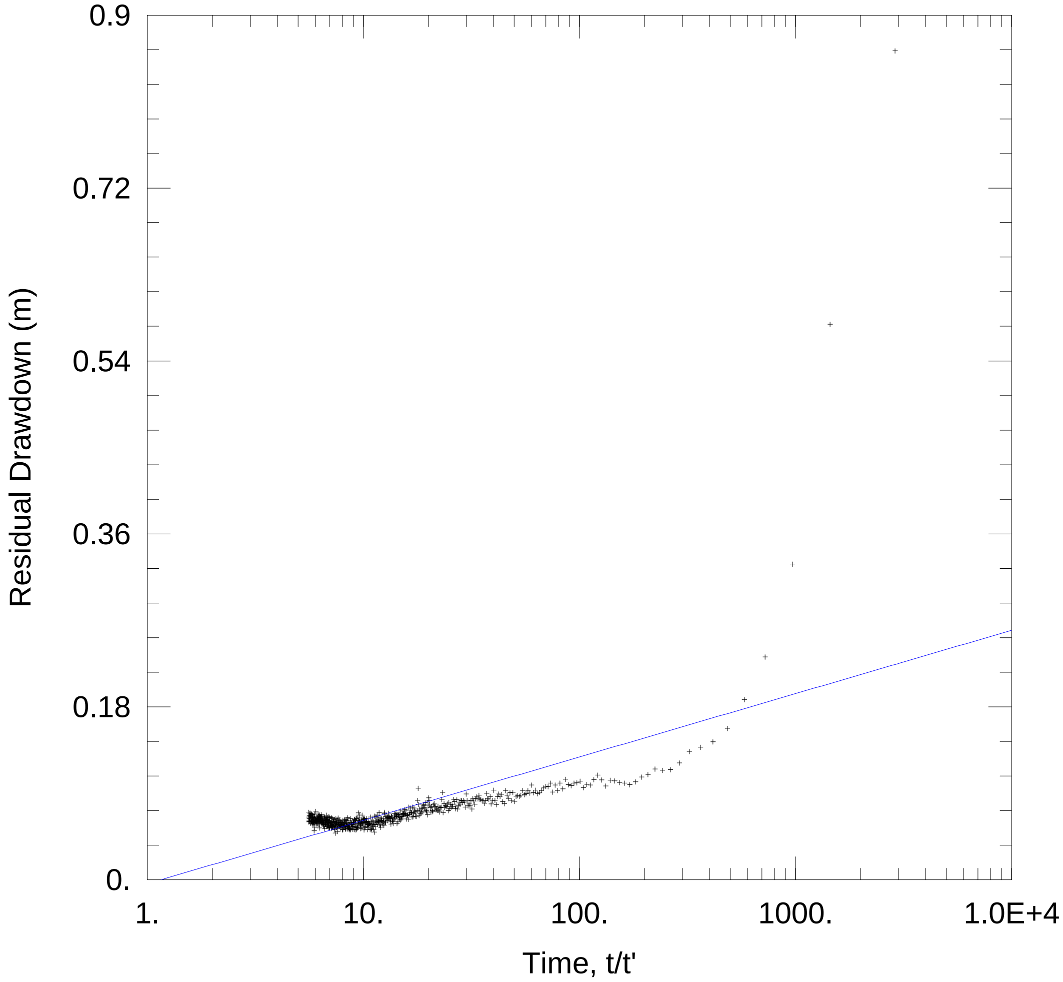
Observation Wells

Well Name	X (m)	Y (m)
Dlt-Obs-04-shl	15.46	0

SOLUTION

Aquifer Model: Confined
Solution Method: Theis

T = 4358.8 m^2/day
S = 1.0E-10
Kz/Kr = 1.
b = 40. m



WELL TEST ANALYSIS

Data Set: I:\...\Delta04s.aqt
Date: 02/20/12 Time: 16:08:39

PROJECT INFORMATION

Company: WP
Client: FMS
Location: Delta
Test Well: Delta Production

AQUIFER DATA

Saturated Thickness: 40. m Anisotropy Ratio (Kz/Kr): 1.

WELL DATA

Pumping Wells

Well Name	X (m)	Y (m)
Dlt-Prod	0	0

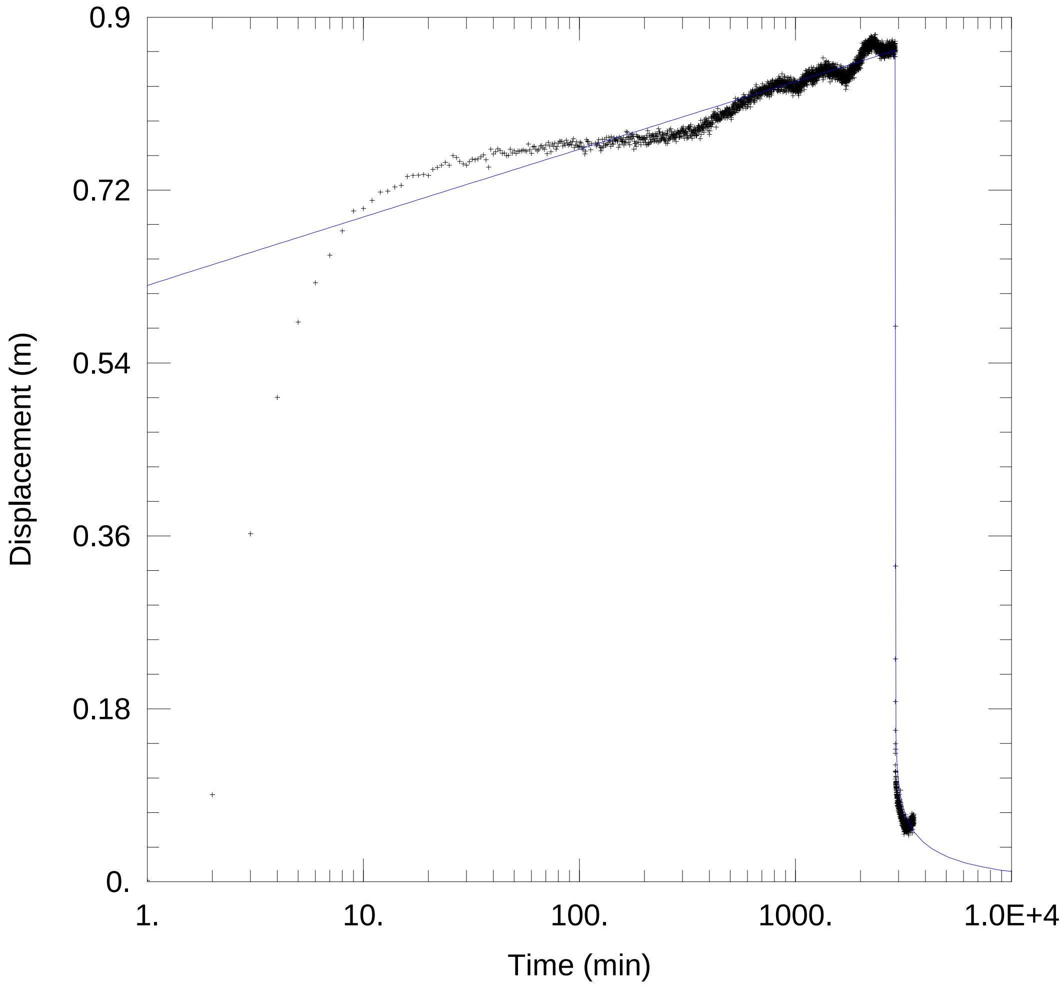
Observation Wells

Well Name	X (m)	Y (m)
+ Dlt-Obs-04-shl	15.46	0

SOLUTION

Aquifer Model: Confined Solution Method: Theis (Recovery)

T = 4801.6 m^2/day S/S' = 1.165



WELL TEST ANALYSIS

Data Set: I:\...\Delta04s.aqt
Date: 02/20/12 Time: 16:53:28

PROJECT INFORMATION

Company: WP
Client: FMS
Location: Delta
Test Well: Delta Production

AQUIFER DATA

Saturated Thickness: 40. m
Aquitard Thickness (b'): 30. m
Anisotropy Ratio (Kz/Kr): 1.
Aquitard Thickness (b"): 30. m

WELL DATA

Pumping Wells

Well Name	X (m)	Y (m)
Dlt-Prod	0	0

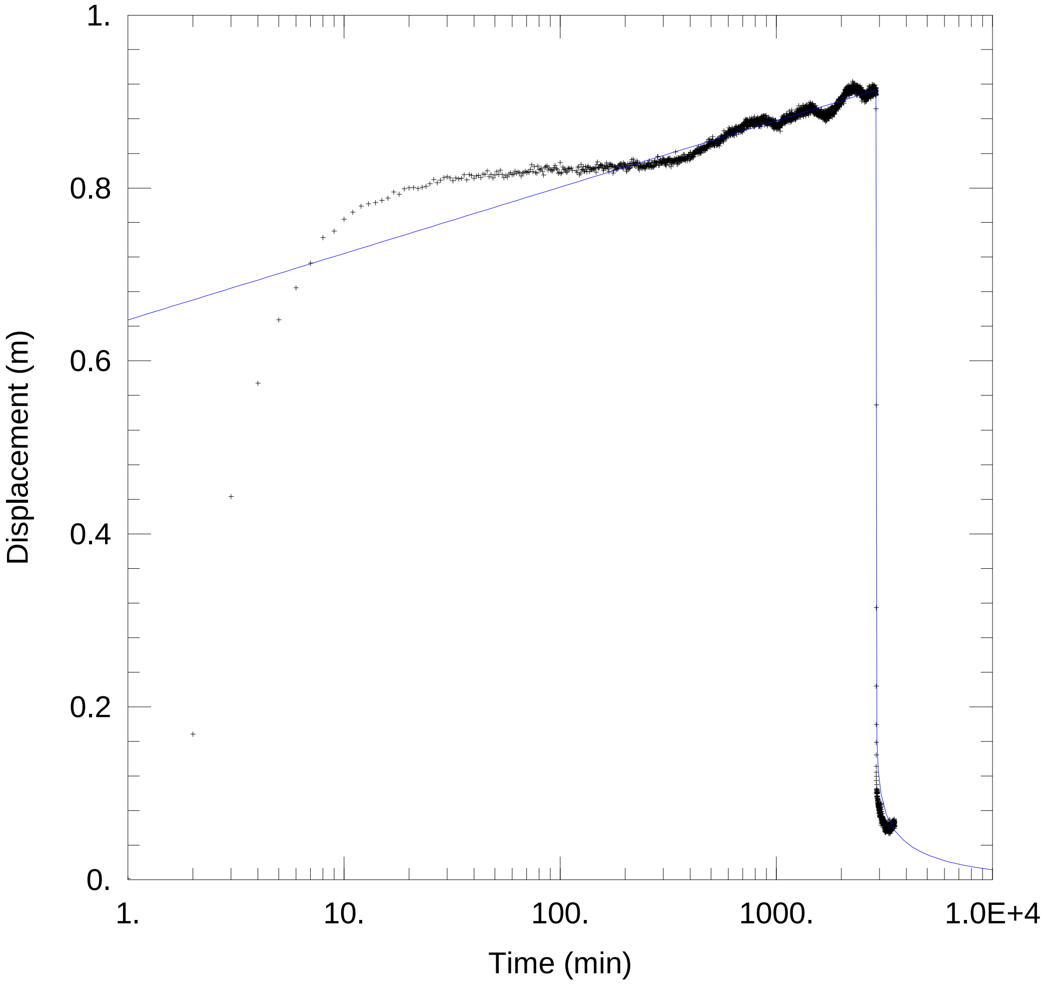
Observation Wells

Well Name	X (m)	Y (m)
Dlt-Obs-04-shl	15.46	0

SOLUTION

Aquifer Model: Leaky
Solution Method: Hantush

T = 2255.6 m^2/day
r/B' = 1.0E-5
r/B" = 0.
S = 1.839E-8
ß' = 0.009288
ß" = 0.



WELL TEST ANALYSIS

Data Set: I:\...\Delta04d.aqt
Date: 02/20/12 Time: 16:06:47

PROJECT INFORMATION

Company: WP
Client: FMS
Location: Delta
Test Well: Delta Production

WELL DATA

Pumping Wells

Well Name	X (m)	Y (m)
Dlt-Prod	0	0

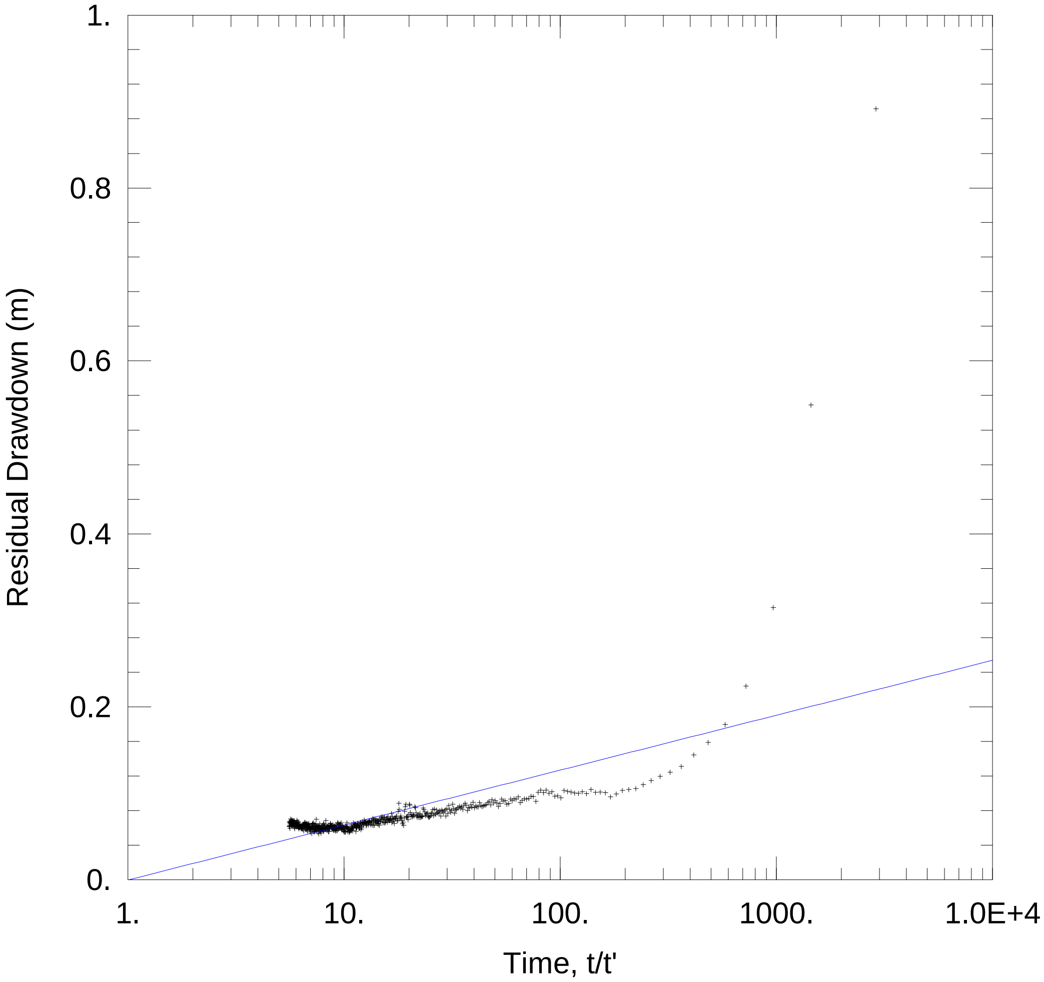
Observation Wells

Well Name	X (m)	Y (m)
+ Dlt-Obs-04-dp	15.46	0

SOLUTION

Aquifer Model: Confined Solution Method: Theis

T = 4123.4 m^2/day S = 1.0E-10
Kz/Kr = 1. b = 40. m



WELL TEST ANALYSIS

Data Set: I:\...\Delta04d.aqt
Date: 02/20/12
Time: 16:09:09

PROJECT INFORMATION

Company: WP
Client: FMS
Location: Delta
Test Well: Delta Production

AQUIFER DATA

Saturated Thickness: 40. m
Anisotropy Ratio (Kz/Kr): 1.

WELL DATA

Pumping Wells

Well Name	X (m)	Y (m)
Dlt-Prod	0	0

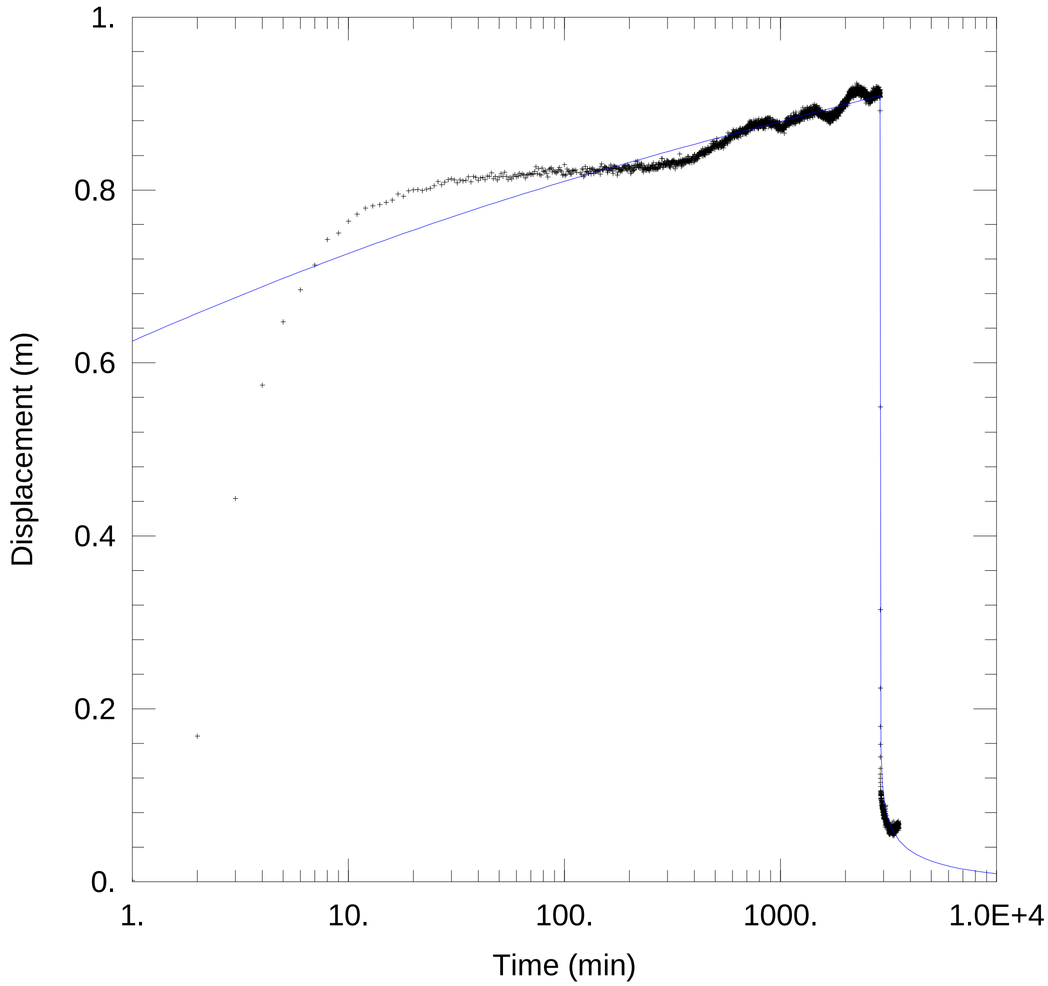
Observation Wells

Well Name	X (m)	Y (m)
+ Dlt-Obs-04-dp	15.46	0

SOLUTION

Aquifer Model: Confined
Solution Method: Theis (Recovery)

T = 4984.9 m^2/day
S/S' = 1.019



WELL TEST ANALYSIS

Data Set: I:\...\Delta04d.aqt
Date: 02/20/12 Time: 16:54:02

PROJECT INFORMATION

Company: WP
Client: FMS
Location: Delta
Test Well: Delta Production

AQUIFER DATA

Saturated Thickness: 40. m Anisotropy Ratio (Kz/Kr): 1.
Aquitard Thickness (b'): 30. m Aquitard Thickness (b"): 30. m

WELL DATA

Pumping Wells

Well Name	X (m)	Y (m)
Dlt-Prod	0	0

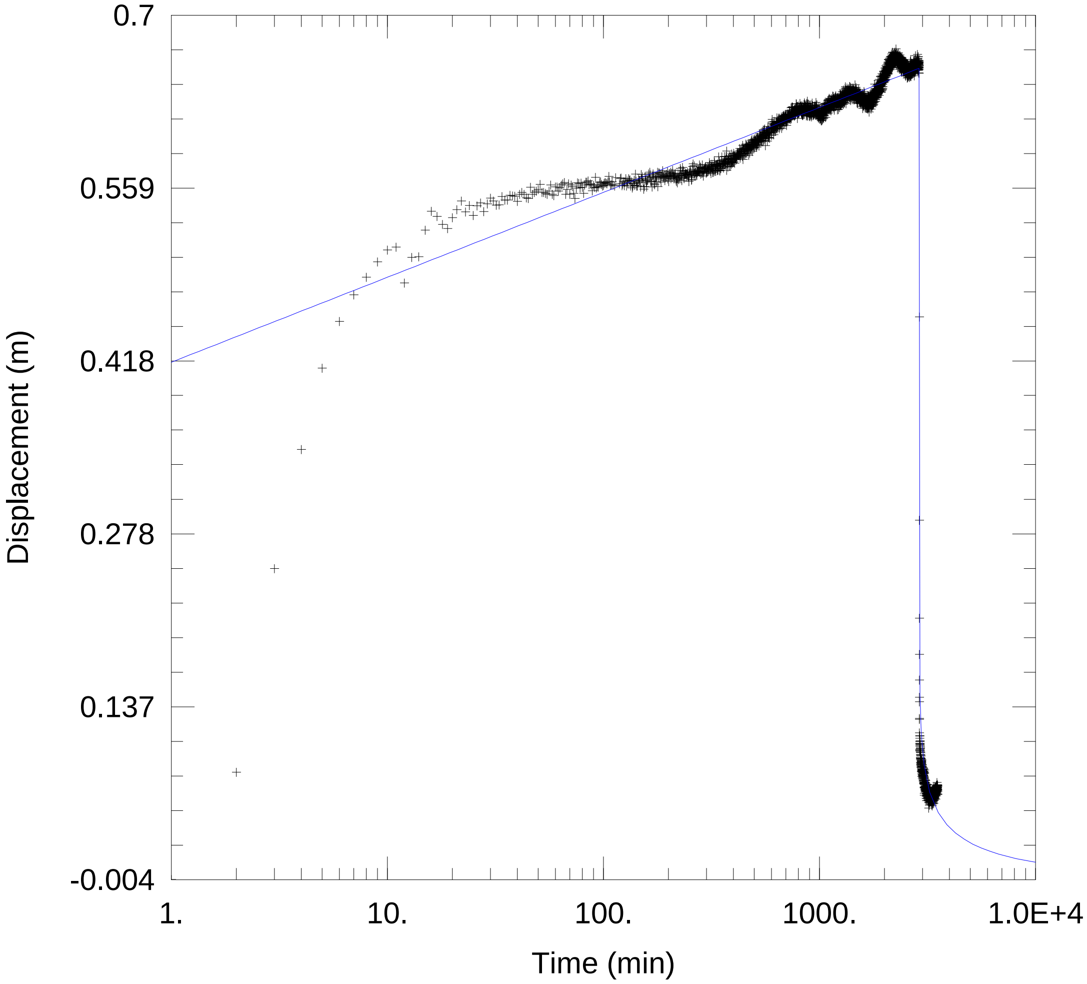
Observation Wells

Well Name	X (m)	Y (m)
+ Dlt-Obs-04-dp	15.46	0

SOLUTION

Aquifer Model: Leaky Solution Method: Hantush

T = 2628.6 m^2/day S = 8.905E-8
r/B' = 1.0E-5 ß' = 0.0001796
r/B" = 0. ß" = 0.



WELL TEST ANALYSIS

Data Set: I:\...\Delta03.aqt
Date: 02/20/12 Time: 16:07:26

PROJECT INFORMATION

Company: WP
Client: FMS
Location: Delta
Test Well: Delta Production

WELL DATA

Pumping Wells

Well Name	X (m)	Y (m)
Dlt-Prod	0	0

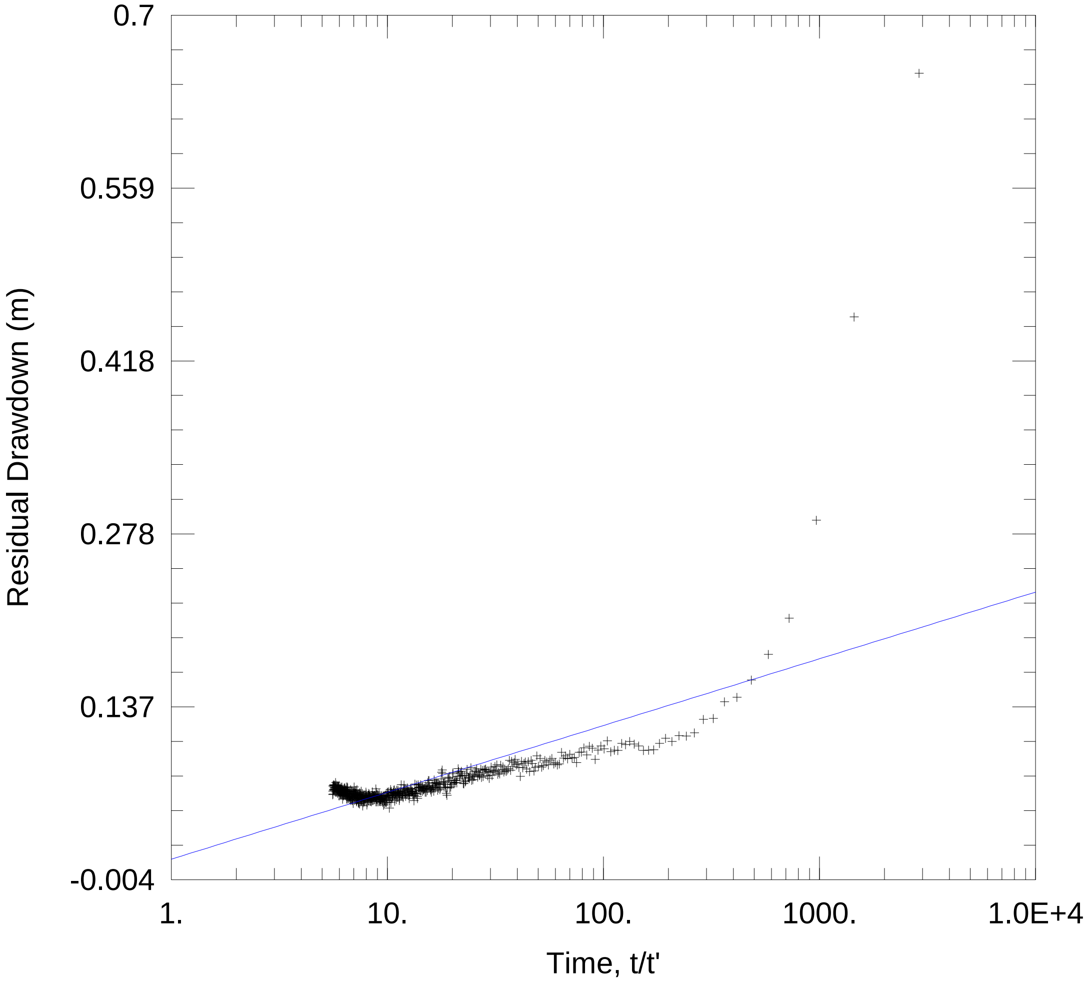
Observation Wells

Well Name	X (m)	Y (m)
+ Dlt-Obs-03-cor	16.7	0

SOLUTION

Aquifer Model: Confined
Solution Method: Theis

T = 4579.5 m^2/day
S = 2.363E-8
Kz/Kr = 1.
b = 40. m



WELL TEST ANALYSIS

Data Set: I:\...\Delta03.aqt
Date: 02/20/12 Time: 16:09:25

PROJECT INFORMATION

Company: WP
Client: FMS
Location: Delta
Test Well: Delta Production

AQUIFER DATA

Saturated Thickness: 40. m Anisotropy Ratio (Kz/Kr): 1.

WELL DATA

Pumping Wells

Well Name	X (m)	Y (m)
Dlt-Prod	0	0

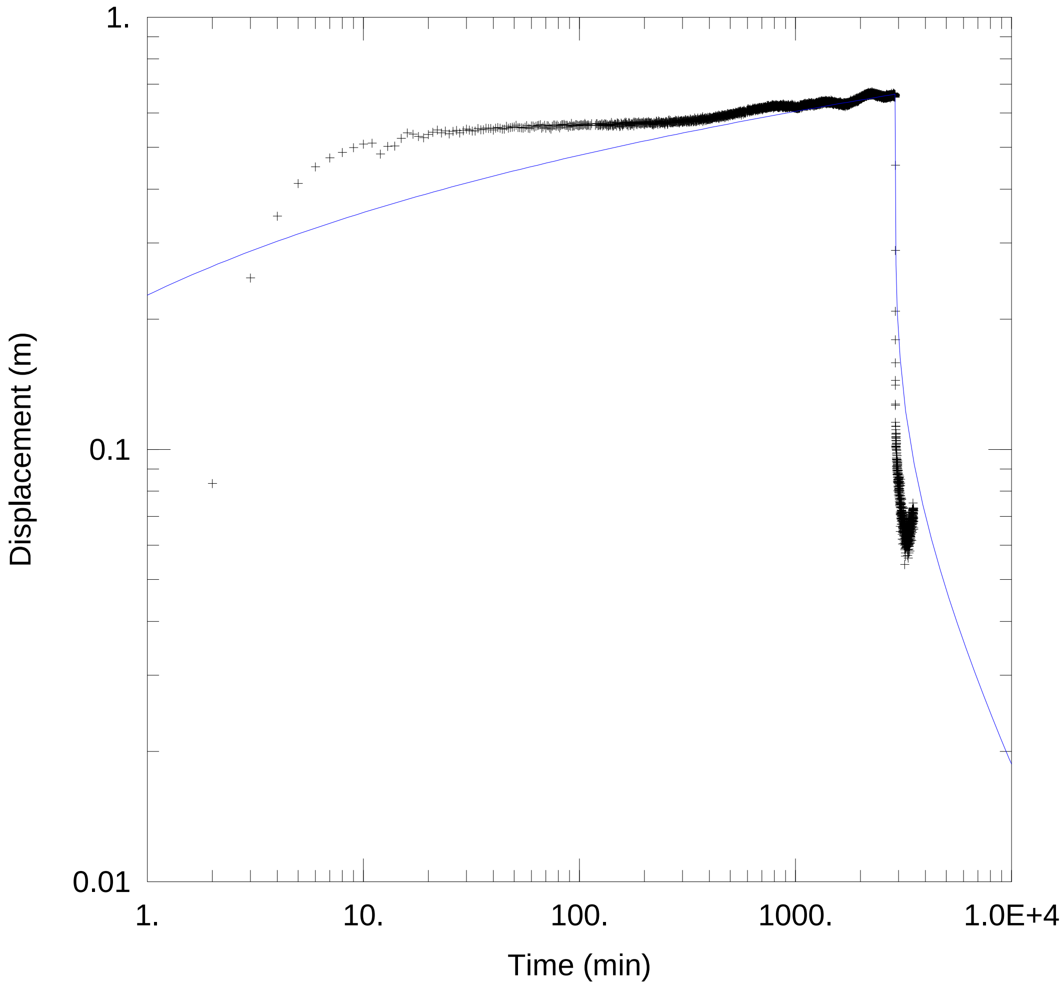
Observation Wells

Well Name	X (m)	Y (m)
+ Dlt-Obs-03-cor	16.7	0

SOLUTION

Aquifer Model: Confined Solution Method: Theis (Recovery)

T = 5824.8 m^2/day S/S' = 0.5857



WELL TEST ANALYSIS

Data Set: I:\...\Delta03.aqt
Date: 02/20/12 Time: 16:55:48

PROJECT INFORMATION

Company: WP
Client: FMS
Location: Delta
Test Well: Delta Production

WELL DATA

Pumping Wells

Well Name	X (m)	Y (m)
Dlt-Prod	0	0

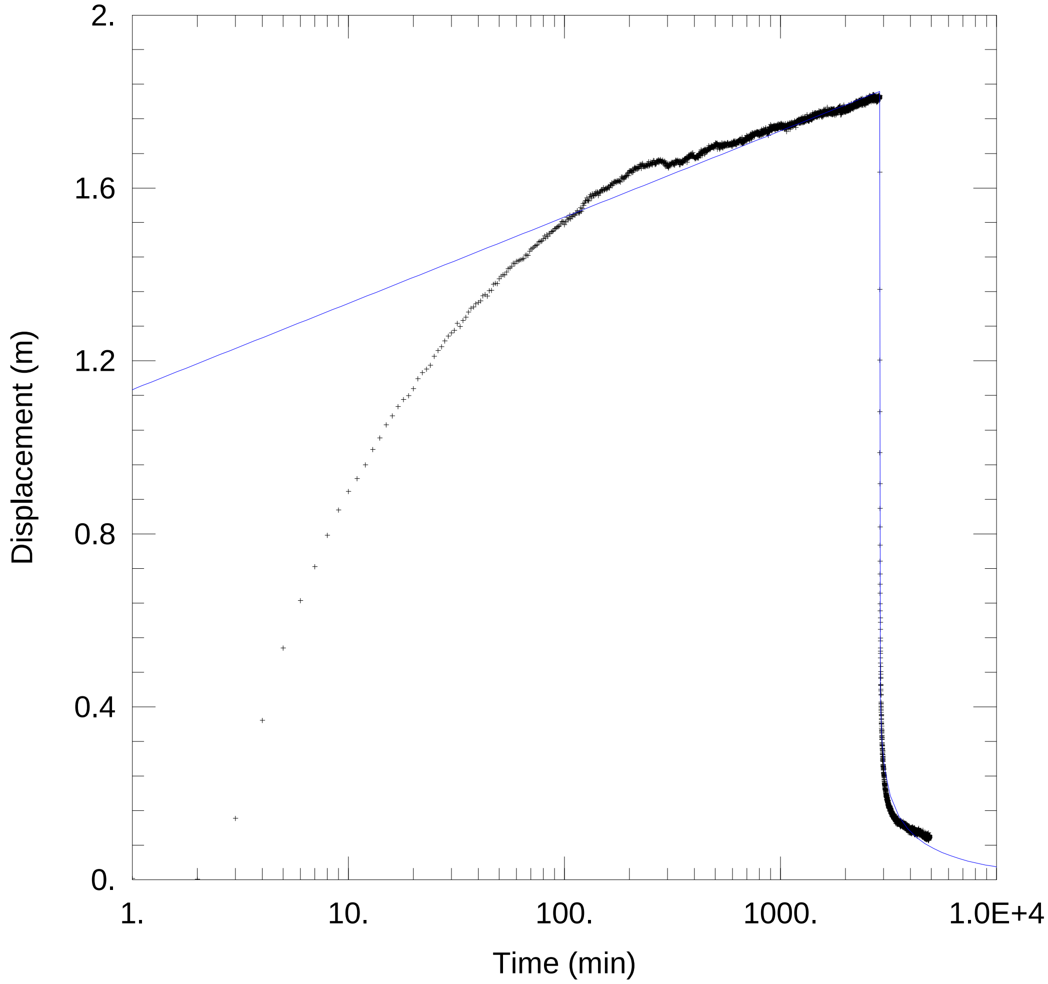
Observation Wells

Well Name	X (m)	Y (m)
+ Dlt-Obs-03-cor	16.7	0

SOLUTION

Aquifer Model: Confined
Solution Method: Theis

T = 2513.2 m^2/day
S = 0.0002226
Kz/Kr = 1.
b = 40. m



WELL TEST ANALYSIS

Data Set: I:\...\Chp04s.aqt
Date: 02/20/12 Time: 16:00:39

PROJECT INFORMATION

Company: WP
Client: FMS
Project: 201012-00322
Location: Champion
Test Well: Champion Production
Test Date: 28/11/2011

WELL DATA

Pumping Wells

Well Name	X (m)	Y (m)
Champion Production	0	0

Observation Wells

Well Name	X (m)	Y (m)
Chp-04s	14.06	0

SOLUTION

Aquifer Model: Confined

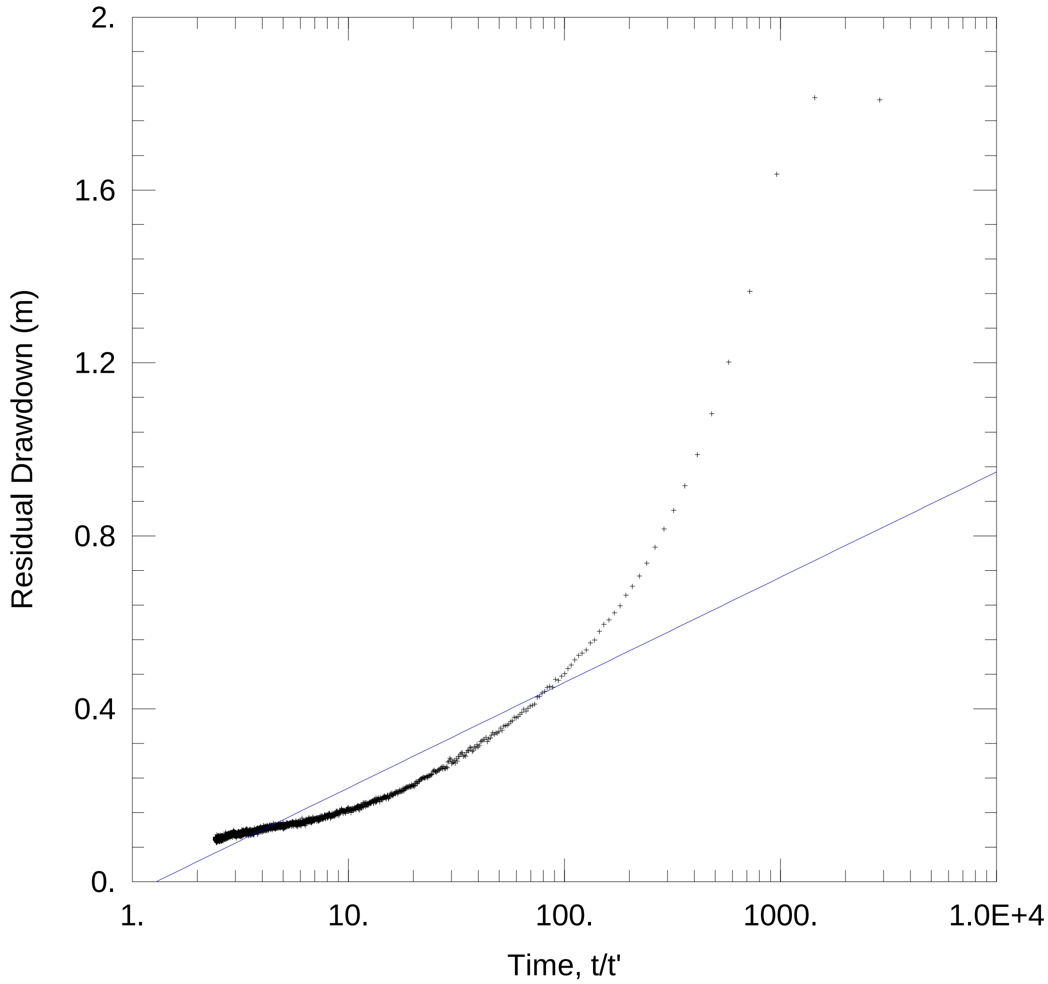
Solution Method: Theis

T = 2221.7 m^2/day

S = 3.662E-8

Kz/Kr = 1.

b = 52. m



WELL TEST ANALYSIS

Data Set: I:\...\Chp04s.aqt
Date: 02/20/12 Time: 16:03:24

PROJECT INFORMATION

Company: WP
Client: FMS
Project: 201012-00322
Location: Champion
Test Well: Champion Production
Test Date: 28/11/2011

AQUIFER DATA

Saturated Thickness: 52. m Anisotropy Ratio (Kz/Kr): 1.

WELL DATA

Pumping Wells

Well Name	X (m)	Y (m)
Champion Production	0	0

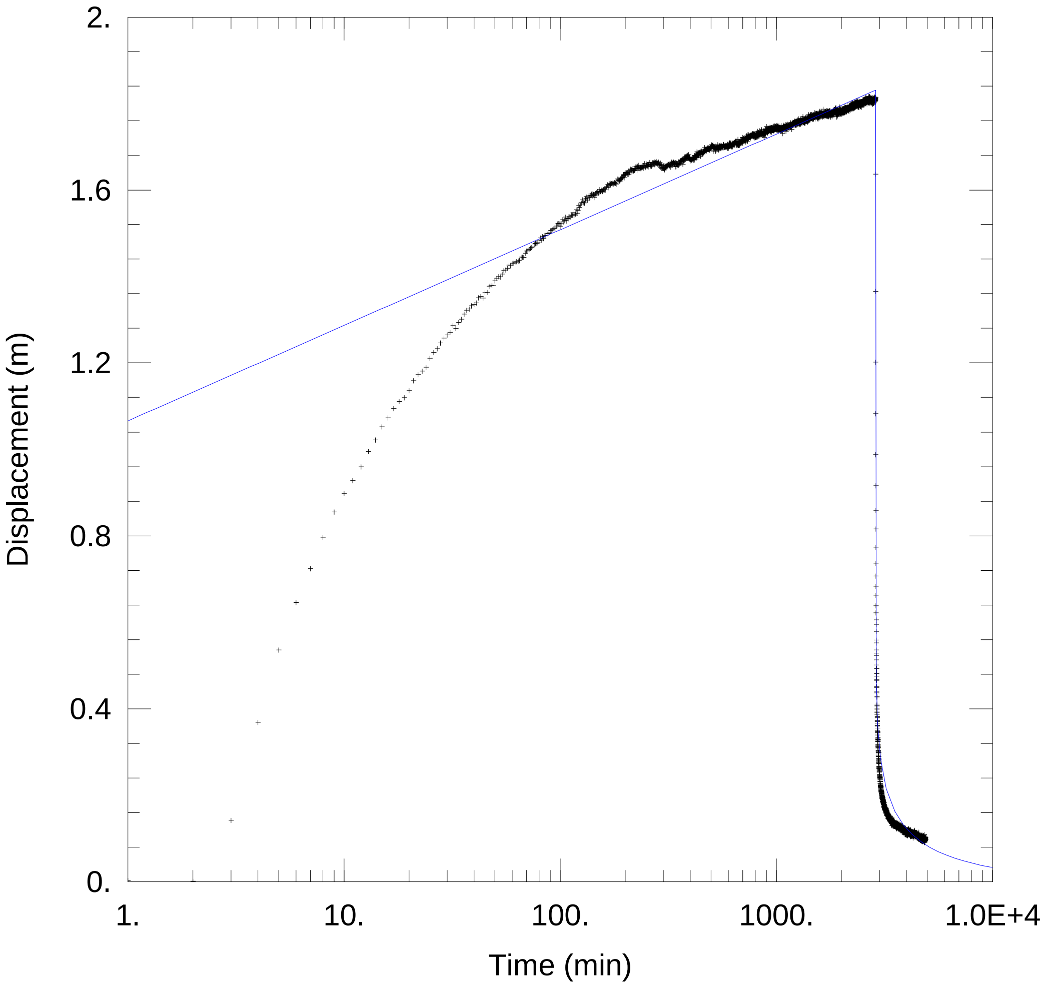
Observation Wells

Well Name	X (m)	Y (m)
+ Chp-04s	14.06	0

SOLUTION

Aquifer Model: Confined Solution Method: Theis (Recovery)

T = 1818.9 m^2/day S/S' = 1.295



WELL TEST ANALYSIS

Data Set: I:\...\Chp04s.aqt
Date: 02/20/12 Time: 16:57:29

PROJECT INFORMATION

Company: WP
Client: FMS
Project: 201012-00322
Location: Champion
Test Well: Champion Production
Test Date: 28/11/2011

AQUIFER DATA

Saturated Thickness: 52. m
Anisotropy Ratio (Kz/Kr): 1.
Aquitard Thickness (b'): 30. m
Aquitard Thickness (b"): 1. m

WELL DATA

Pumping Wells

Well Name	X (m)	Y (m)
Champion Production	0	0

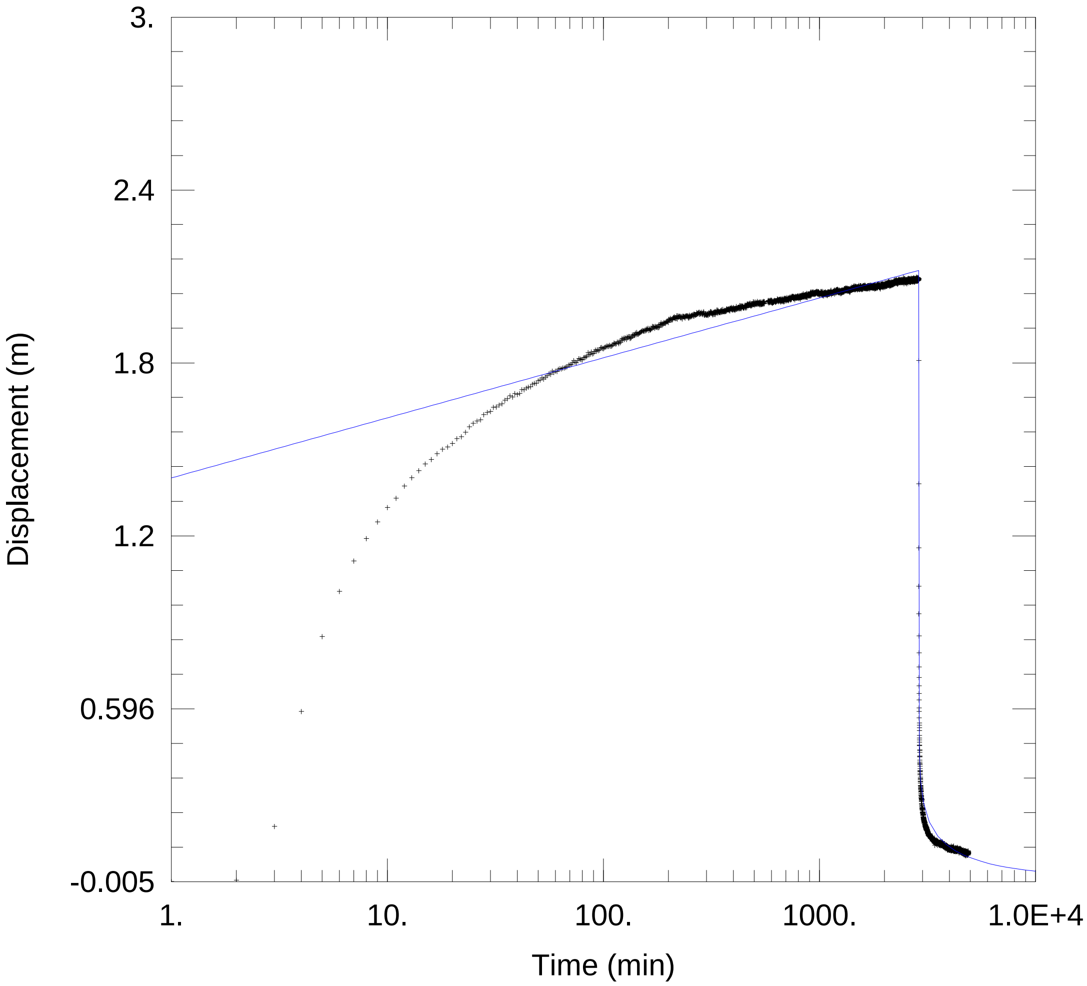
Observation Wells

Well Name	X (m)	Y (m)
Chp-04s	14.06	0

SOLUTION

Aquifer Model: Leaky
Solution Method: Hantush

T = 1000.4 m^2/day
S = 3.662E-8
r/B' = 0.0005644
ß' = 0.5166
r/B" = 0.
ß" = 0.



WELL TEST ANALYSIS

Data Set: I:\...\Chp04m.aqt
Date: 02/20/12 Time: 16:01:04

PROJECT INFORMATION

Company: WP
Client: FMS
Project: 201012-00322
Location: Champion
Test Well: Champion Production
Test Date: 28/11/2011

WELL DATA

Pumping Wells

Well Name	X (m)	Y (m)
Champion Production	0	0

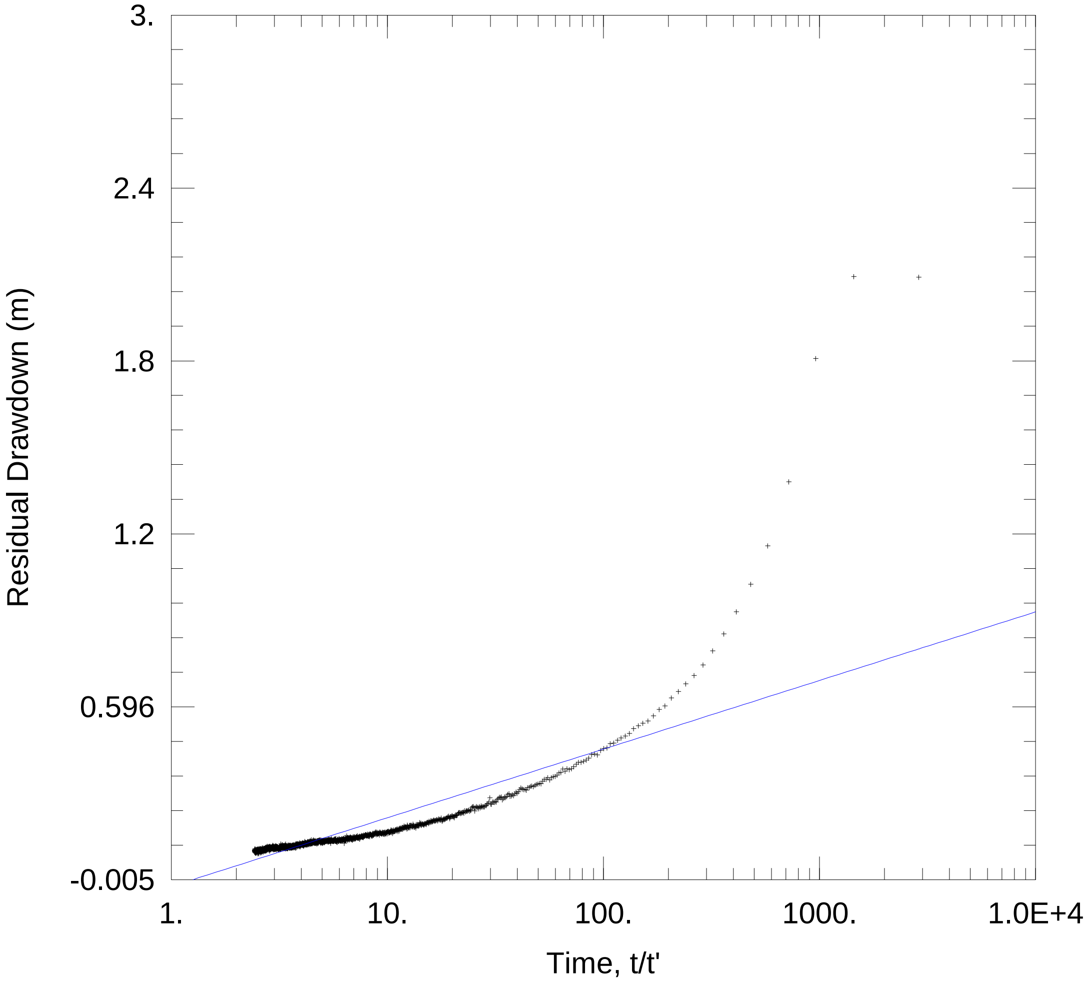
Observation Wells

Well Name	X (m)	Y (m)
Chp-04m	14.06	0

SOLUTION

Aquifer Model: Confined
Solution Method: Theis

T = 2125.5 m^2/day
S = 3.318E-9
Kz/Kr = 1.
b = 52. m



WELL TEST ANALYSIS

Data Set: I:\...\Chp04m.aqt
Date: 02/20/12 Time: 16:03:49

PROJECT INFORMATION

Company: WP
Client: FMS
Project: 201012-00322
Location: Champion
Test Well: Champion Production
Test Date: 28/11/2011

AQUIFER DATA

Saturated Thickness: 52. m Anisotropy Ratio (Kz/Kr): 1.

WELL DATA

Pumping Wells

Well Name	X (m)	Y (m)
Champion Production	0	0

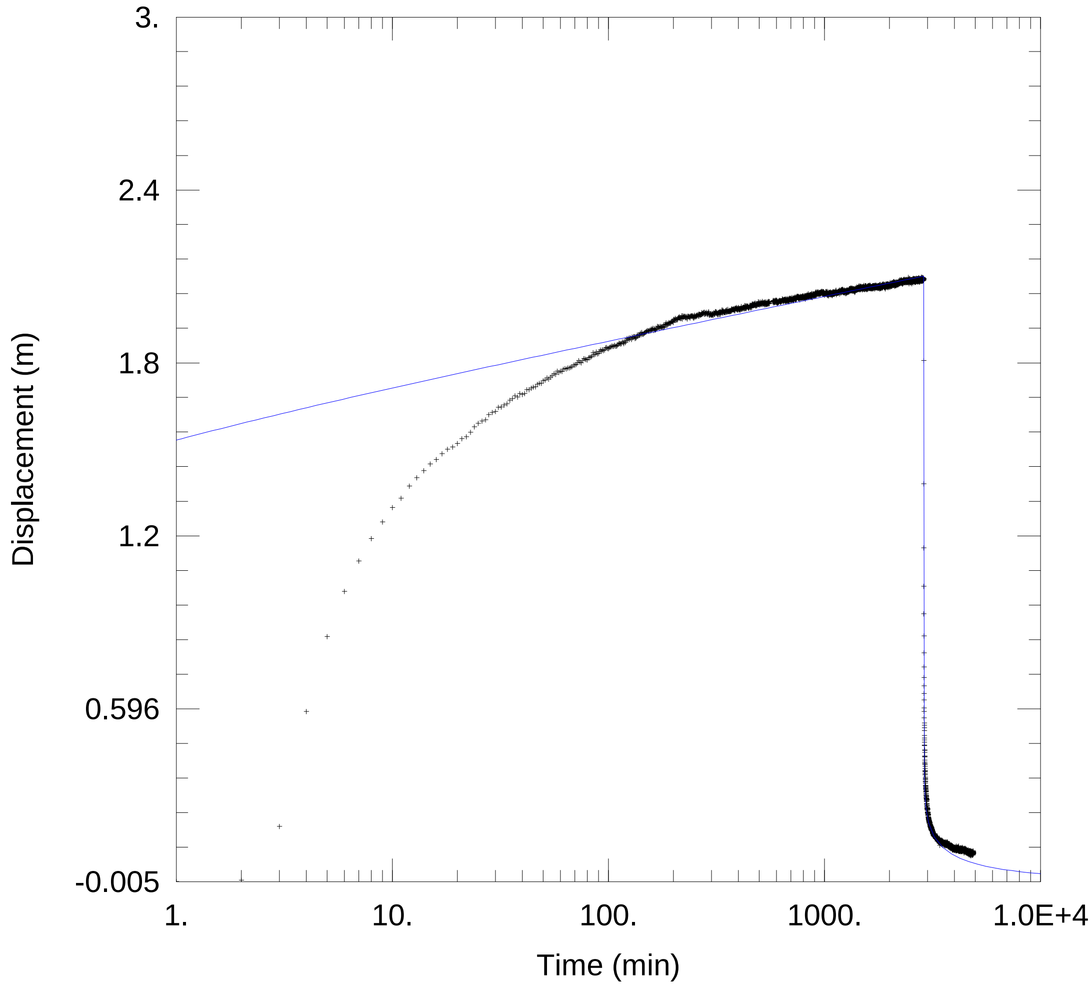
Observation Wells

Well Name	X (m)	Y (m)
Chp-04m	14.06	0

SOLUTION

Aquifer Model: Confined Solution Method: Theis (Recovery)

T = 1858. m^2/day S/S' = 1.323



WELL TEST ANALYSIS

Data Set: I:\...\Chp04m.aqt
Date: 02/20/12 Time: 16:58:33

PROJECT INFORMATION

Company: WP
Client: FMS
Project: 201012-00322
Location: Champion
Test Well: Champion Production
Test Date: 28/11/2011

AQUIFER DATA

Saturated Thickness: 52. m
Aquitard Thickness (b'): 30. m
Anisotropy Ratio (Kz/Kr): 1.
Aquitard Thickness (b"): 1. m

WELL DATA

Pumping Wells

Well Name	X (m)	Y (m)
Champion Production	0	0

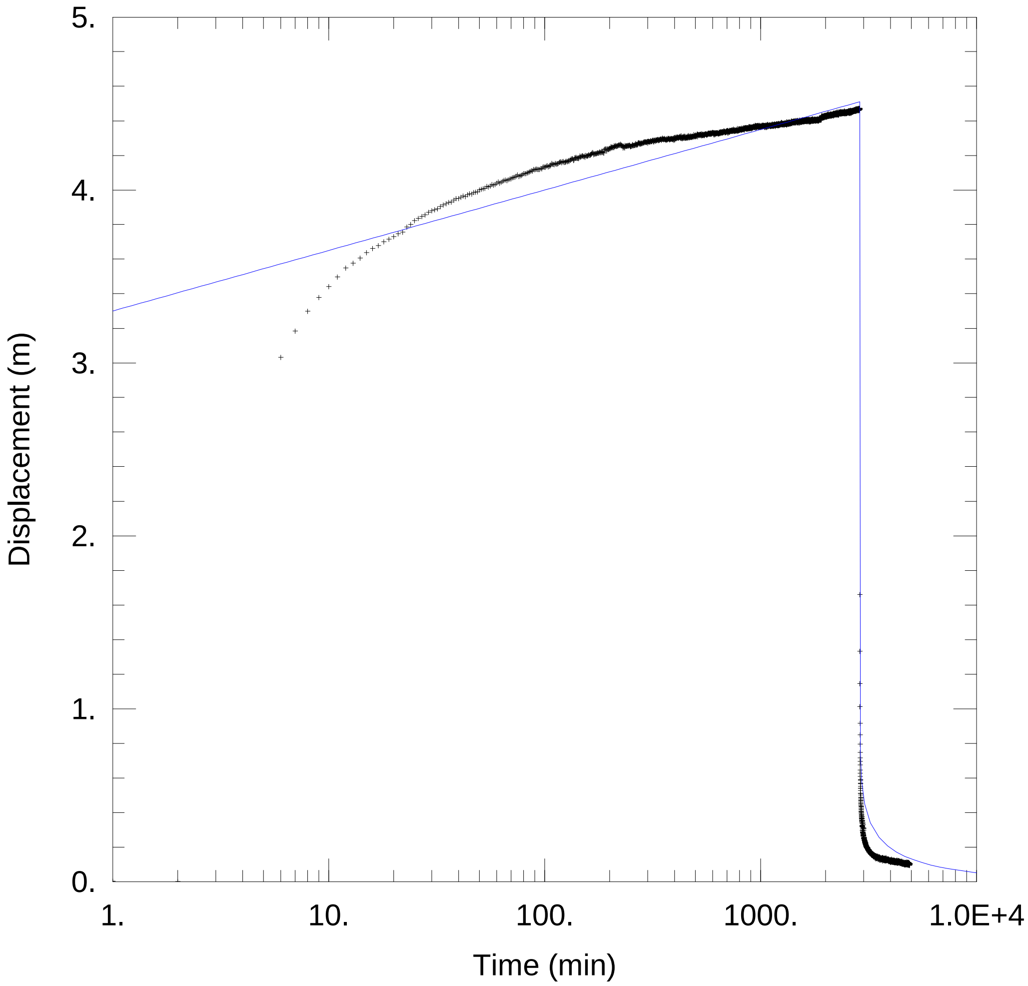
Observation Wells

Well Name	X (m)	Y (m)
Chp-04m	14.06	0

SOLUTION

Aquifer Model: Leaky
Solution Method: Hantush

T = 1449.9 m^2/day
r/B' = 1.0E-5
r/B" = 0.
S = 3.662E-8
ß' = 0.001136
ß" = 0.



WELL TEST ANALYSIS

Data Set: I:\...\Chp04d.aqt
Date: 02/20/12 Time: 16:01:21

PROJECT INFORMATION

Company: WP
Client: FMS
Project: 201012-00322
Location: Champion
Test Well: Champion Production
Test Date: 28/11/2011

WELL DATA

Pumping Wells

Well Name	X (m)	Y (m)
Champion Production	0	0

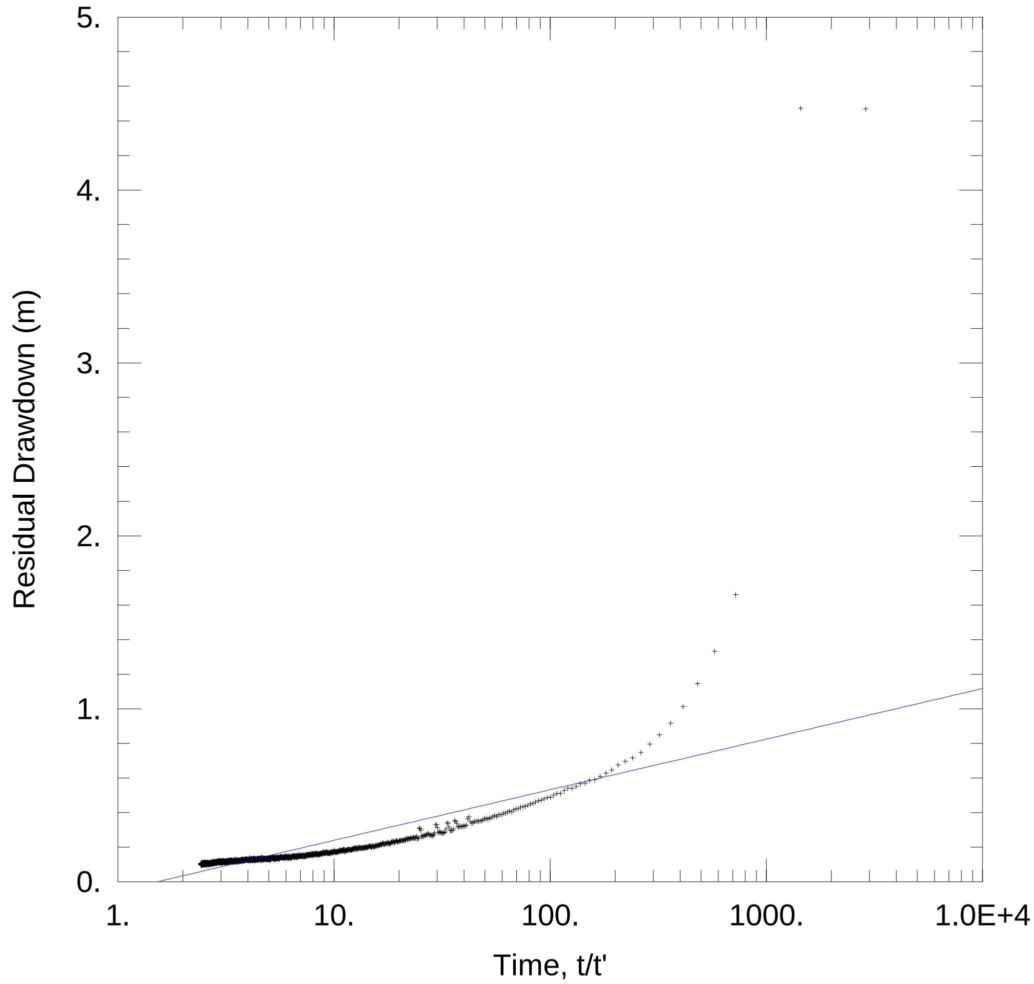
Observation Wells

Well Name	X (m)	Y (m)
Chp-04d	14.06	0

SOLUTION

Aquifer Model: Confined
Solution Method: Theis

T = 1267.6 m^2/day
S = 3.662E-12
Kz/Kr = 1.
b = 52. m



WELL TEST ANALYSIS

Data Set: I:\...\Chp04d.aqt
Date: 02/20/12 Time: 16:04:03

PROJECT INFORMATION

Company: WP
Client: FMS
Project: 201012-00322
Location: Champion
Test Well: Champion Production
Test Date: 28/11/2011

AQUIFER DATA

Saturated Thickness: 52. m Anisotropy Ratio (Kz/Kr): 1.

WELL DATA

Pumping Wells

Well Name	X (m)	Y (m)
Champion Production	0	0

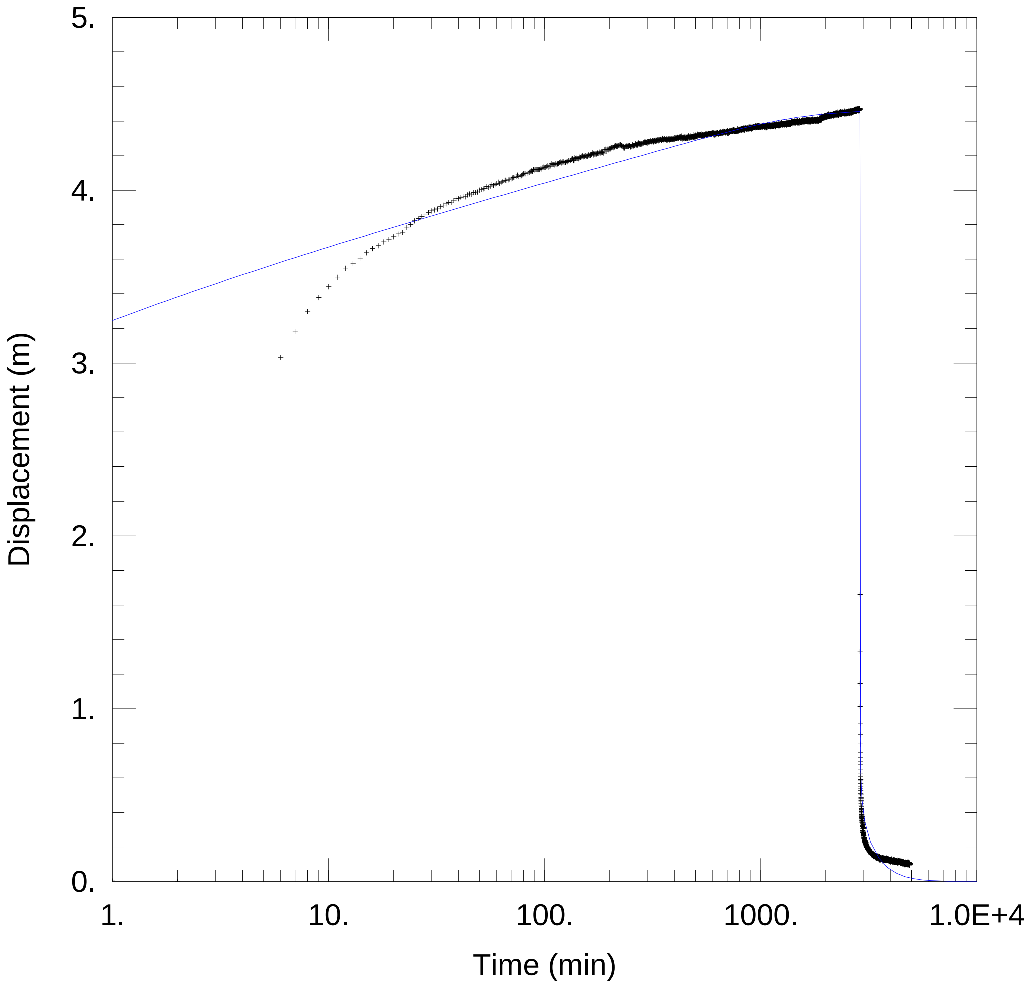
Observation Wells

Well Name	X (m)	Y (m)
+ Chp-04d	14.06	0

SOLUTION

Aquifer Model: Confined Solution Method: Theis (Recovery)

T = 1514.8 m^2/day S/S' = 1.534



WELL TEST ANALYSIS

Data Set: I:\...\Chp04d.aqt
Date: 02/20/12 Time: 16:59:46

PROJECT INFORMATION

Company: WP
Client: FMS
Project: 201012-00322
Location: Champion
Test Well: Champion Production
Test Date: 28/11/2011

AQUIFER DATA

Saturated Thickness: 52. m
Anisotropy Ratio (Kz/Kr): 1.
Aquitard Thickness (b'): 30. m
Aquitard Thickness (b"): 1. m

WELL DATA

Pumping Wells

Well Name	X (m)	Y (m)
Champion Production	0	0

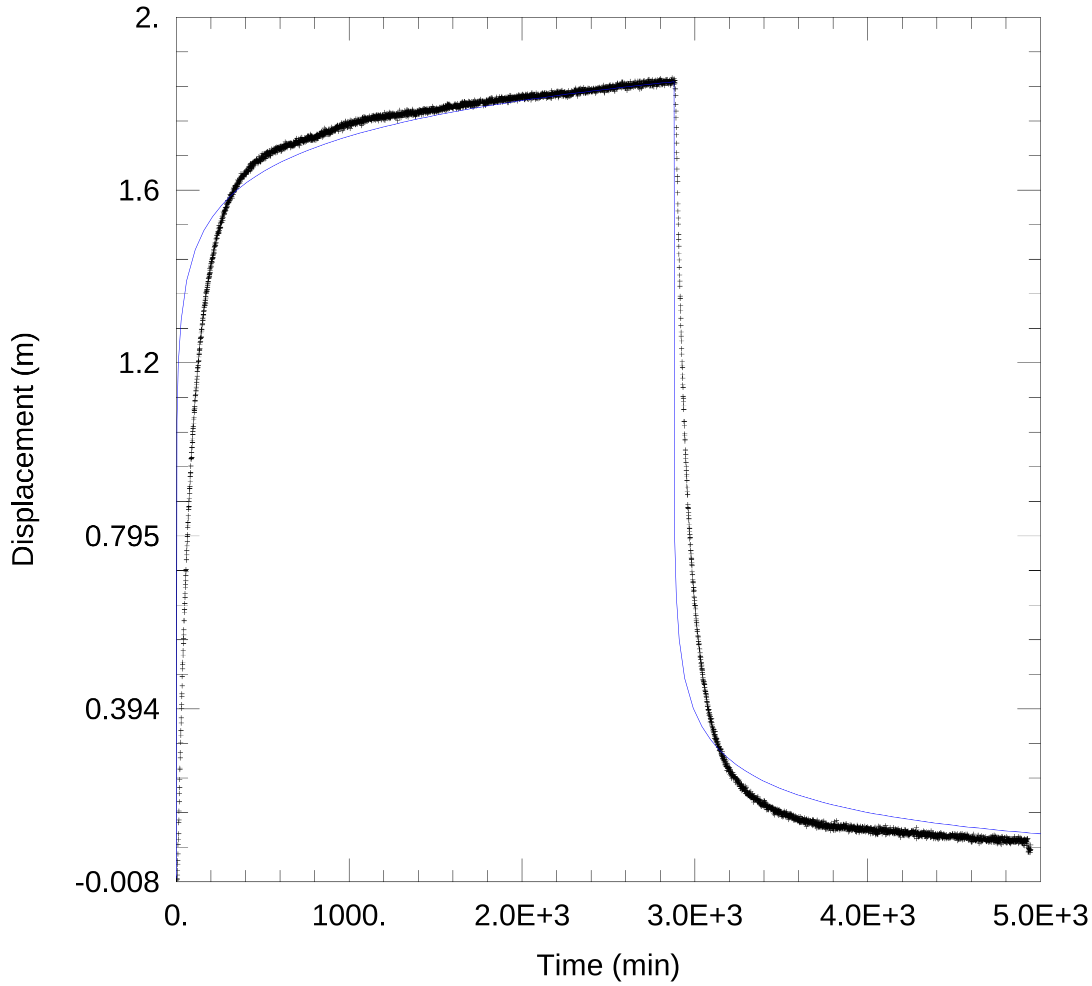
Observation Wells

Well Name	X (m)	Y (m)
Chp-04d	14.06	0

SOLUTION

Aquifer Model: Leaky
Solution Method: Hantush

T = 647.6 m^2/day
r/B' = 0.0006181
r/B" = 0.
S = 3.662E-8
ß' = 0.001253
ß" = 0.



WELL TEST ANALYSIS

Data Set: I:\...\Chp03.aqt
Date: 02/20/12 Time: 16:01:34

PROJECT INFORMATION

Company: WP
Client: FMS
Project: 201012-00322
Location: Champion
Test Well: Champion Production
Test Date: 28/11/2011

WELL DATA

Pumping Wells

Well Name	X (m)	Y (m)
Champion Production	0	0

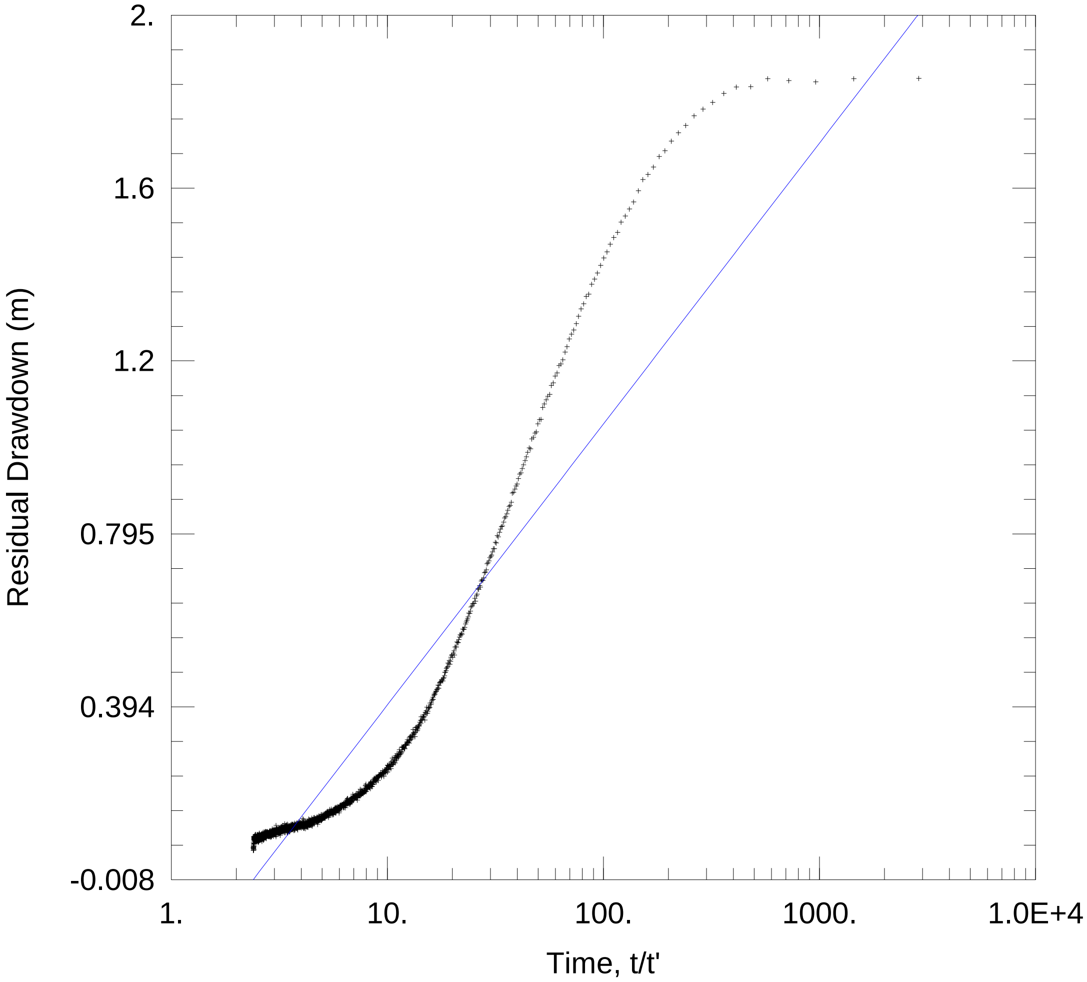
Observation Wells

Well Name	X (m)	Y (m)
Chp-03	198.26	0

SOLUTION

Aquifer Model: Confined
Solution Method: Theis

T = 1605.5 m^2/day
S = 3.662E-8
Kz/Kr = 1.
b = 52. m



WELL TEST ANALYSIS

Data Set: I:\...\Chp03.aqt
Date: 02/20/12
Time: 16:04:19

PROJECT INFORMATION

Company: WP
Client: FMS
Project: 201012-00322
Location: Champion
Test Well: Champion Production
Test Date: 28/11/2011

AQUIFER DATA

Saturated Thickness: 52. m
Anisotropy Ratio (Kz/Kr): 1.

WELL DATA

Pumping Wells

Well Name	X (m)	Y (m)
Champion Production	0	0

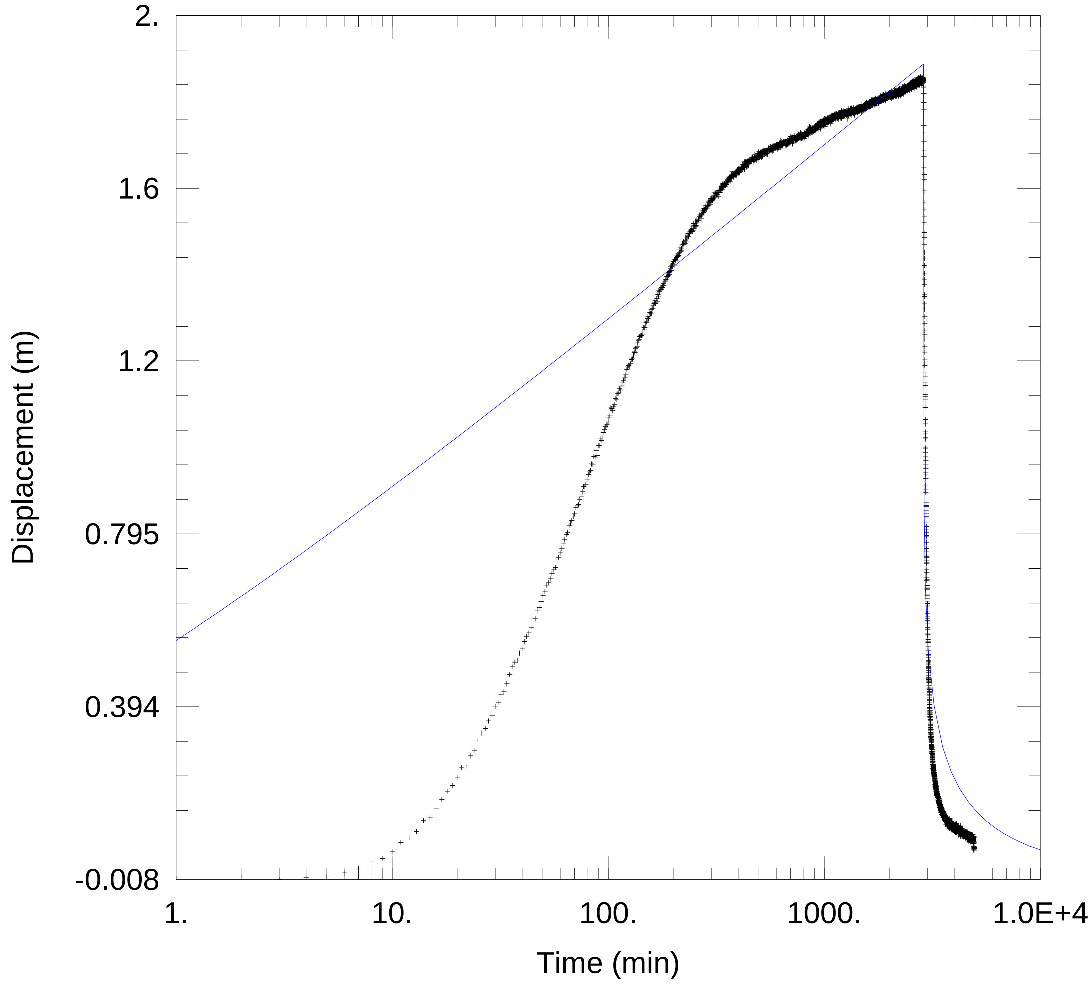
Observation Wells

Well Name	X (m)	Y (m)
+ Chp-03	198.26	0

SOLUTION

Aquifer Model: Confined
Solution Method: Theis (Recovery)

T = 679.4 m^2/day
S/S' = 2.466



WELL TEST ANALYSIS

Data Set: I:\...\Chp03.aqt
Date: 02/20/12 Time: 17:00:39

PROJECT INFORMATION

Company: WP
Client: FMS
Project: 201012-00322
Location: Champion
Test Well: Champion Production
Test Date: 28/11/2011

AQUIFER DATA

Saturated Thickness: 52. m
Anisotropy Ratio (Kz/Kr): 1.
Aquitard Thickness (b'): 30. m
Aquitard Thickness (b"): 1. m

WELL DATA

Pumping Wells

Well Name	X (m)	Y (m)
Champion Production	0	0

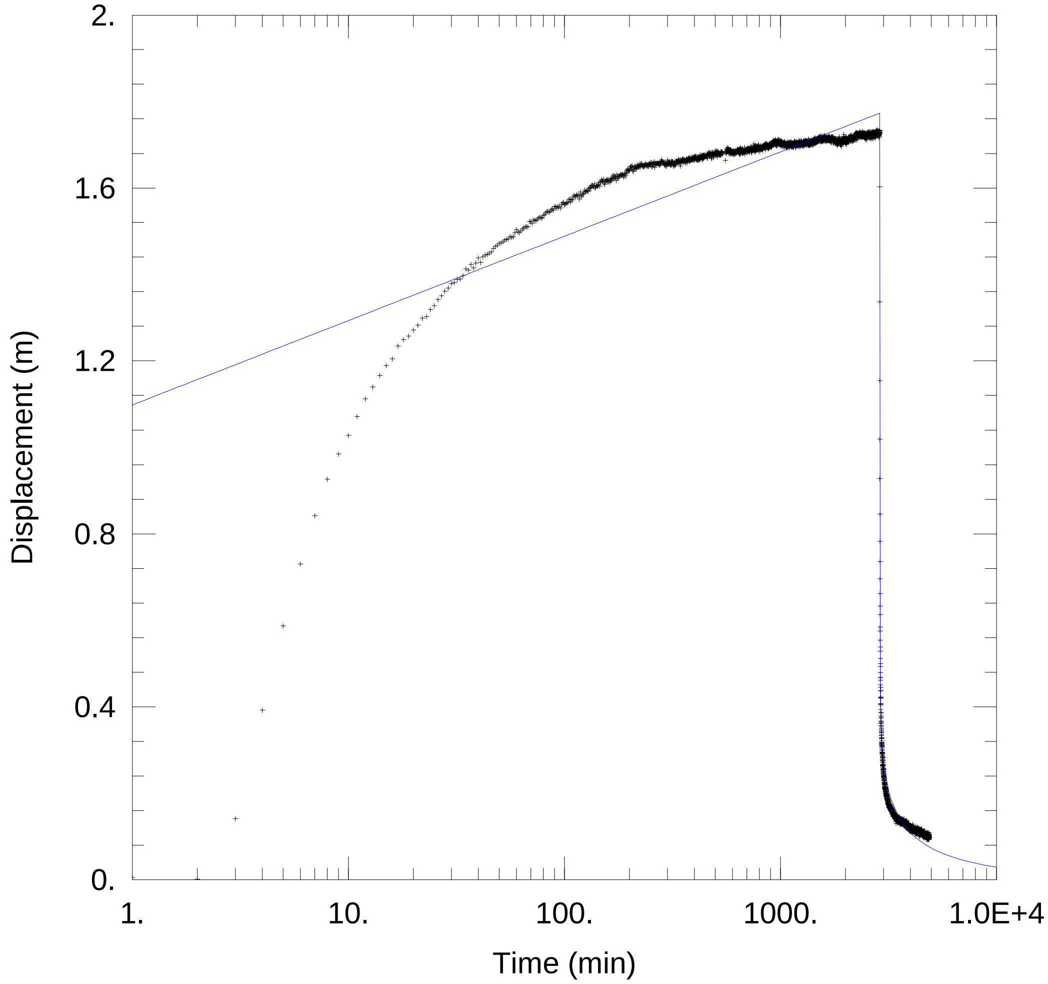
Observation Wells

Well Name	X (m)	Y (m)
Chp-03	198.26	0

SOLUTION

Aquifer Model: Leaky
Solution Method: Hantush

T = 535.8 m^2/day
S = 3.662E-8
r/B' = 1.0E-5
ß' = 1.923
r/B" = 0.
ß" = 0.



WELL TEST ANALYSIS

Data Set: I:\...\Chp02.aqt
Date: 02/20/12 Time: 16:01:48

PROJECT INFORMATION

Company: WP
Client: FMS
Project: 201012-00322
Location: Champion
Test Well: Champion Production
Test Date: 28/11/2011

WELL DATA

Pumping Wells

Well Name	X (m)	Y (m)
Champion Production	0	0

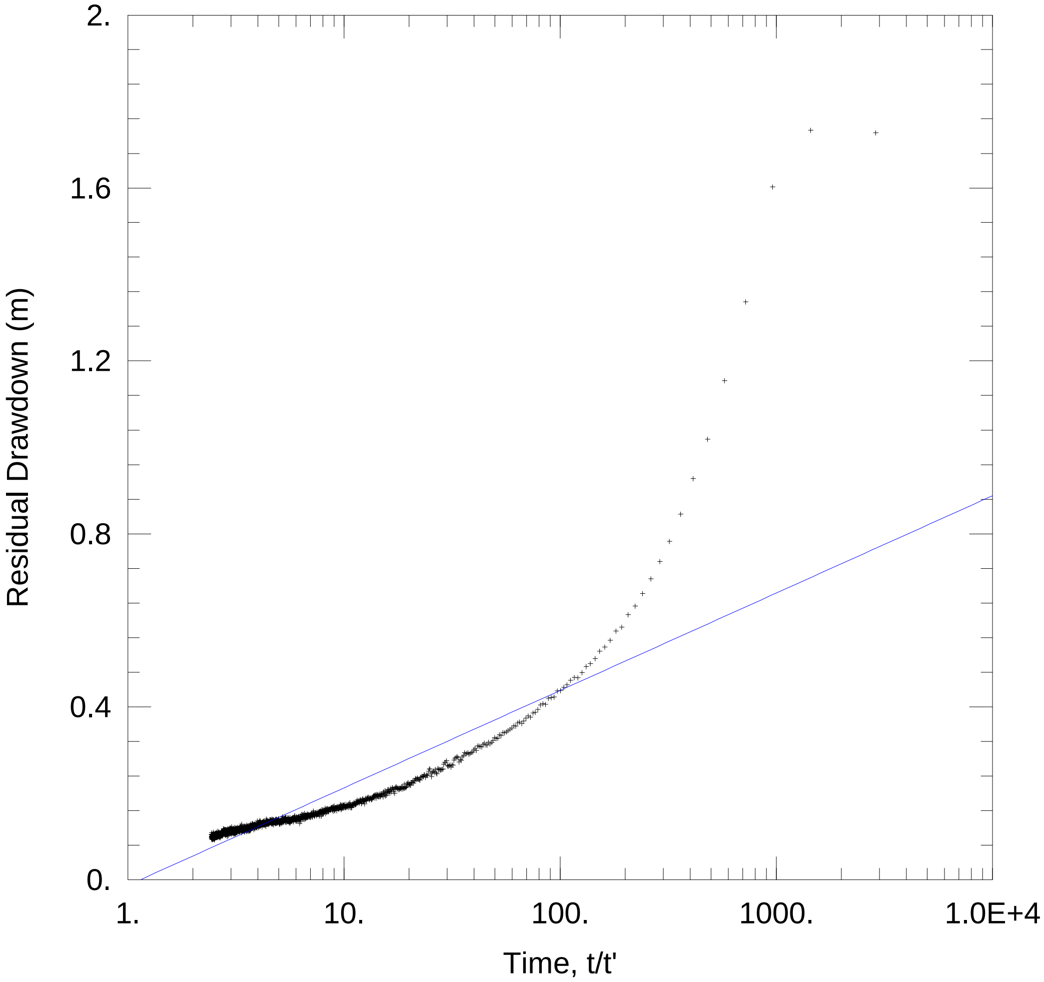
Observation Wells

Well Name	X (m)	Y (m)
Chp-02	15.67	0

SOLUTION

Aquifer Model: Confined
Solution Method: Theis

T = 2271.1 m^2/day
S = 3.424E-8
Kz/Kr = 1.
b = 52. m



WELL TEST ANALYSIS

Data Set: I:\...\Chp02.aqt
Date: 02/20/12 Time: 16:04:34

PROJECT INFORMATION

Company: WP
Client: FMS
Project: 201012-00322
Location: Champion
Test Well: Champion Production
Test Date: 28/11/2011

AQUIFER DATA

Saturated Thickness: 52. m Anisotropy Ratio (Kz/Kr): 1.

WELL DATA

Pumping Wells

Well Name	X (m)	Y (m)
Champion Production	0	0

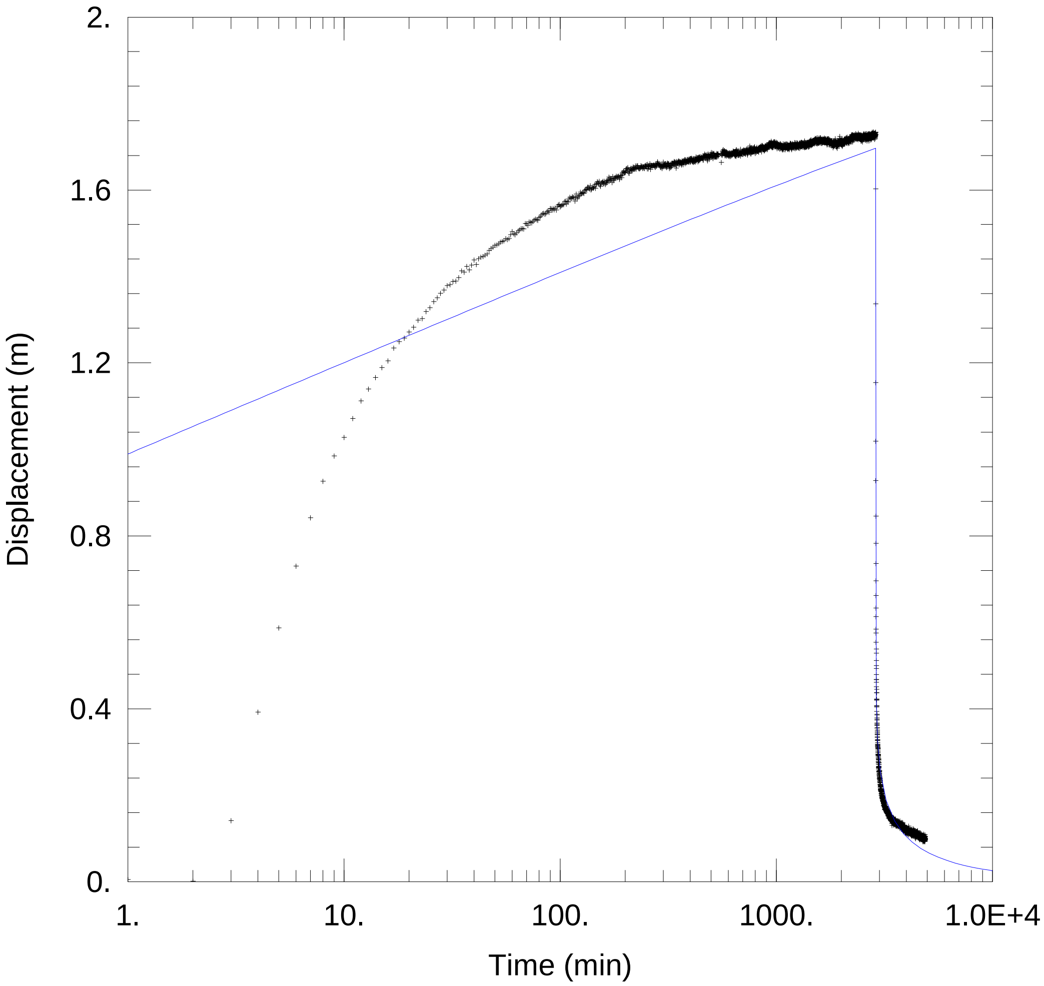
Observation Wells

Well Name	X (m)	Y (m)
+ Chp-02	15.67	0

SOLUTION

Aquifer Model: Confined Solution Method: Theis (Recovery)

T = 1967.5 m^2/day S/S' = 1.147



WELL TEST ANALYSIS

Data Set: I:\...\Chp02.aqt
Date: 02/20/12 Time: 17:04:34

PROJECT INFORMATION

Company: WP
Client: FMS
Project: 201012-00322
Location: Champion
Test Well: Champion Production
Test Date: 28/11/2011

AQUIFER DATA

Saturated Thickness: 52. m
Aquitard Thickness (b'): 30. m
Anisotropy Ratio (Kz/Kr): 1.
Aquitard Thickness (b"): 1. m

WELL DATA

Pumping Wells

Well Name	X (m)	Y (m)
Champion Production	0	0

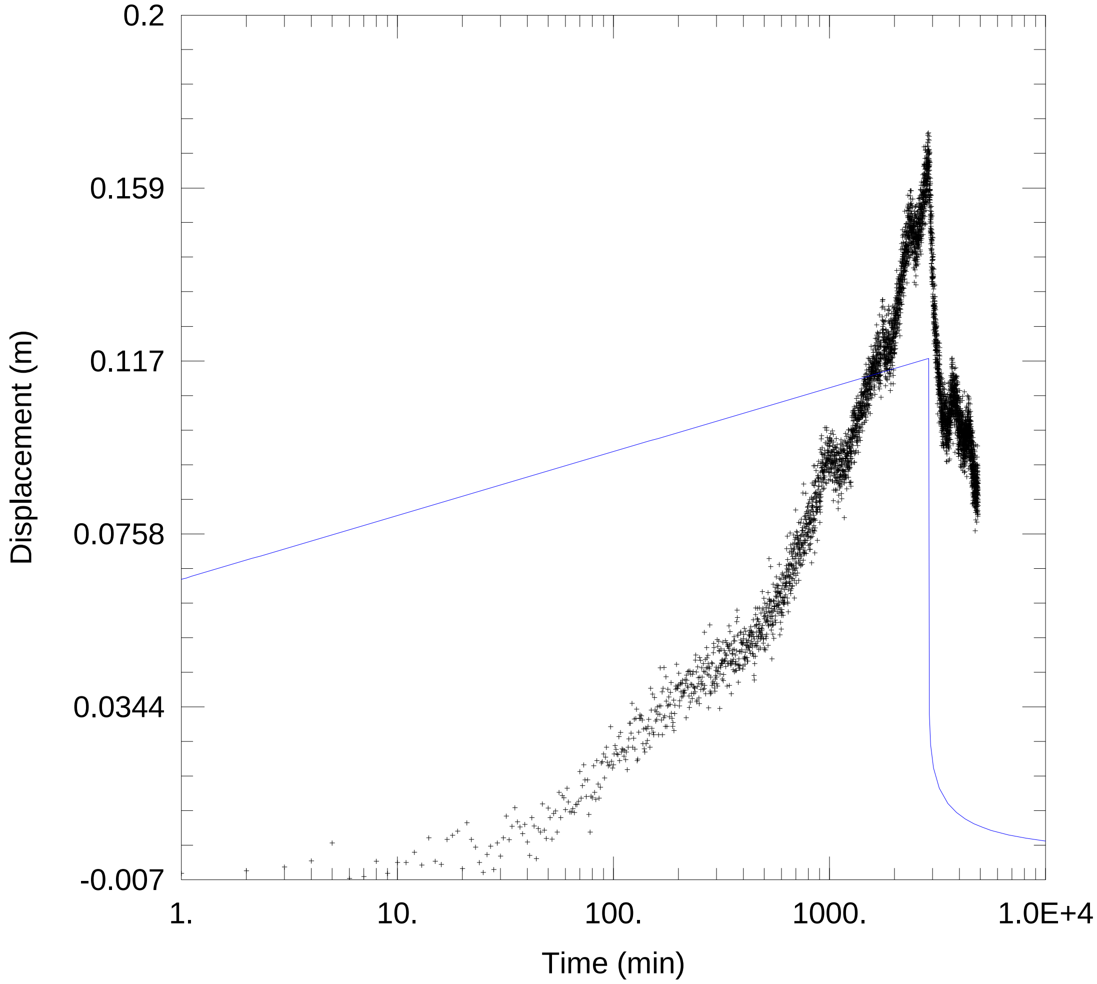
Observation Wells

Well Name	X (m)	Y (m)
Chp-02	15.67	0

SOLUTION

Aquifer Model: Leaky
Solution Method: Hantush

T = 2085.8 m^2/day
r/B' = 1.18E-5
r/B" = 0.
S = 2.924E-7
ß' = 1.0E-5
ß" = 0.



WELL TEST ANALYSIS

Data Set: I:\...\Chp01.aqt
Date: 02/20/12 Time: 16:02:12

PROJECT INFORMATION

Company: WP
Client: FMS
Project: 201012-00322
Location: Champion
Test Well: Champion Production
Test Date: 28/11/2011

WELL DATA

Pumping Wells

Well Name	X (m)	Y (m)
Champion Production	0	0

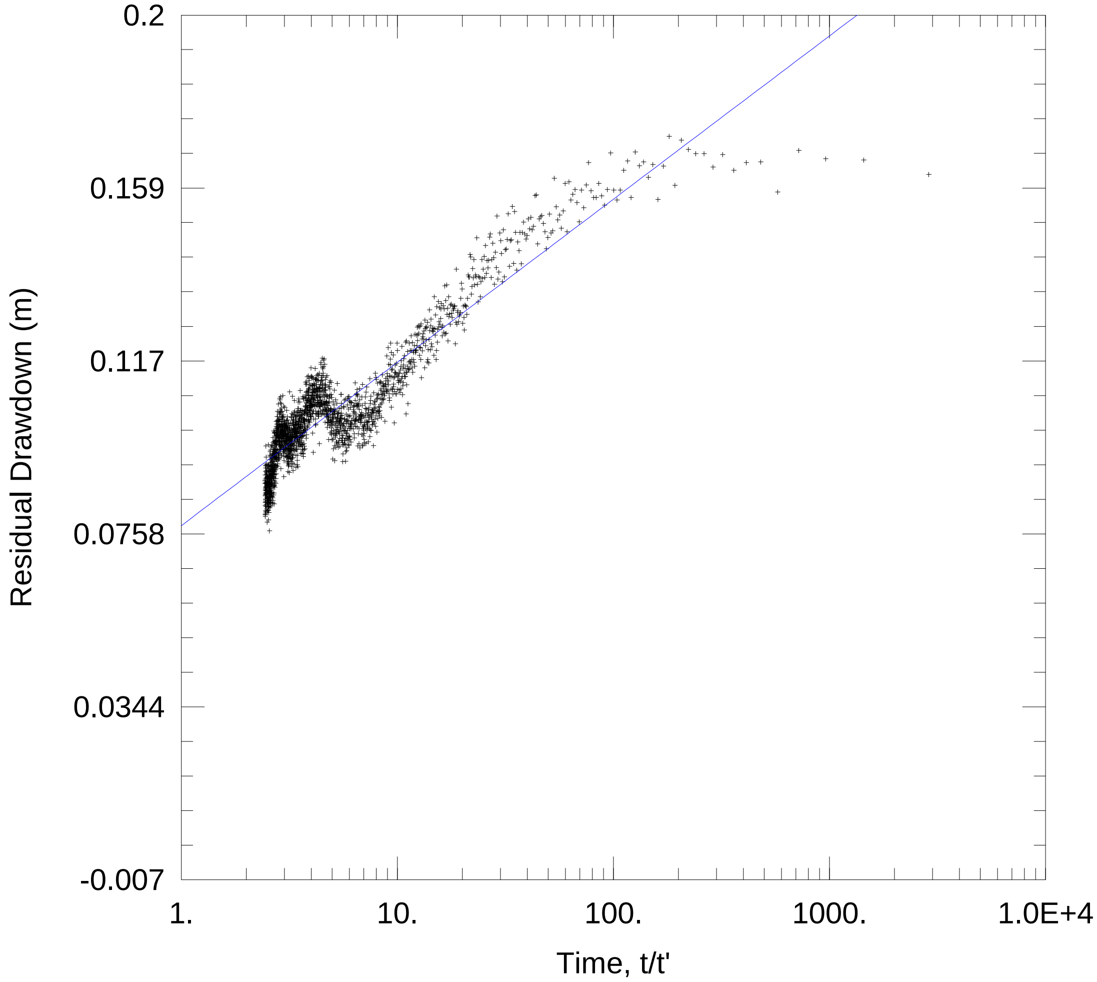
Observation Wells

Well Name	X (m)	Y (m)
Chp-01	265.88	0

SOLUTION

Aquifer Model: Confined
Solution Method: Theis

T = 2.899E+4 m^2/day
S = 3.662E-8
Kz/Kr = 1.
b = 52. m



WELL TEST ANALYSIS

Data Set: I:\...\Chp01.aqt
Date: 02/20/12 Time: 16:04:55

PROJECT INFORMATION

Company: WP
Client: FMS
Project: 201012-00322
Location: Champion
Test Well: Champion Production
Test Date: 28/11/2011

AQUIFER DATA

Saturated Thickness: 52. m Anisotropy Ratio (Kz/Kr): 1.

WELL DATA

Pumping Wells

Well Name	X (m)	Y (m)
Champion Production	0	0

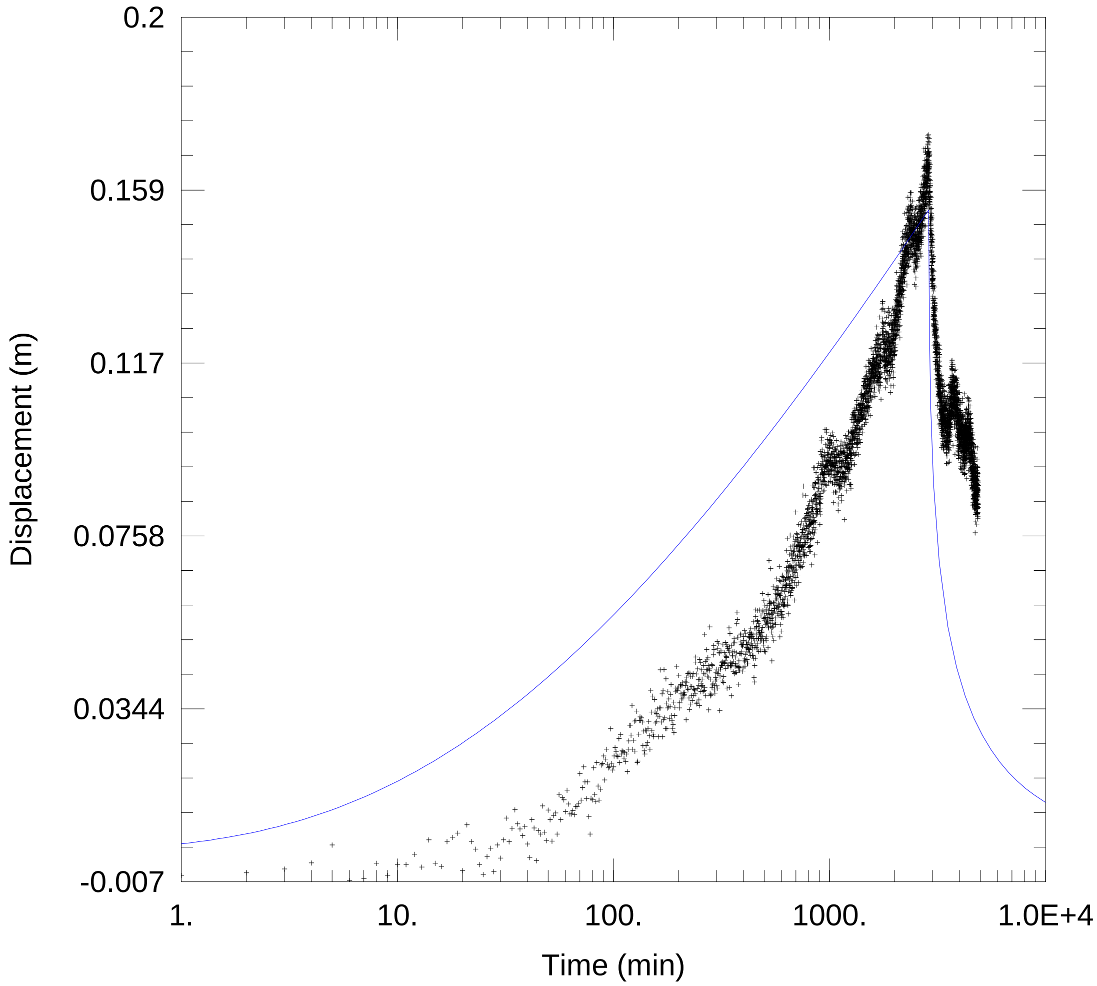
Observation Wells

Well Name	X (m)	Y (m)
Chp-01	265.88	0

SOLUTION

Aquifer Model: Confined Solution Method: Theis (Recovery)

T = 1.135E+4 m^2/day S/S' = 0.01026



WELL TEST ANALYSIS

Data Set: I:\...\Chp01.aqt
Date: 02/20/12
Time: 17:07:55

PROJECT INFORMATION

Company: WP
Client: FMS
Project: 201012-00322
Location: Champion
Test Well: Champion Production
Test Date: 28/11/2011

AQUIFER DATA

Saturated Thickness: 52. m
Anisotropy Ratio (Kz/Kr): 1.
Aquitard Thickness (b'): 30. m
Aquitard Thickness (b"): 1. m

WELL DATA

Pumping Wells

Well Name	X (m)	Y (m)
Champion Production	0	0

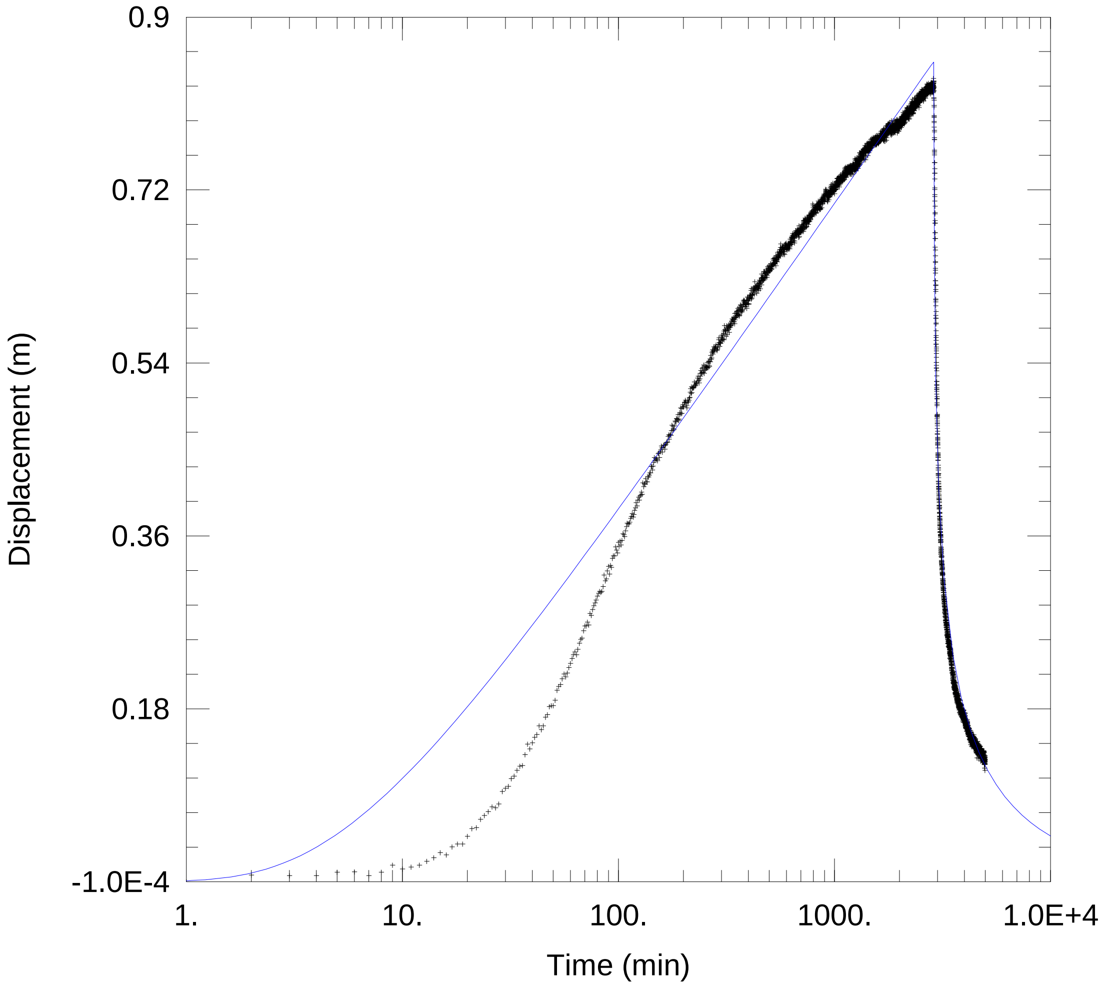
Observation Wells

Well Name	X (m)	Y (m)
Chp-01	265.88	0

SOLUTION

Aquifer Model: Leaky
Solution Method: Hantush

T = 2483.2 m^2/day
S = 3.346E-6
r/B' = 1.0E-5
ß' = 10.
r/B" = 0.
ß" = 0.



WELL TEST ANALYSIS

Data Set: I:\...\Eagle04s.aqt
Date: 02/20/12 Time: 16:38:14

PROJECT INFORMATION

Company: WP
Client: FMS
Project: 201012-00322
Location: EAGLE
Test Well: EAGLE
Test Date: 28NOV2011

WELL DATA

Pumping Wells

Well Name	X (m)	Y (m)
Eagle Production	0	0

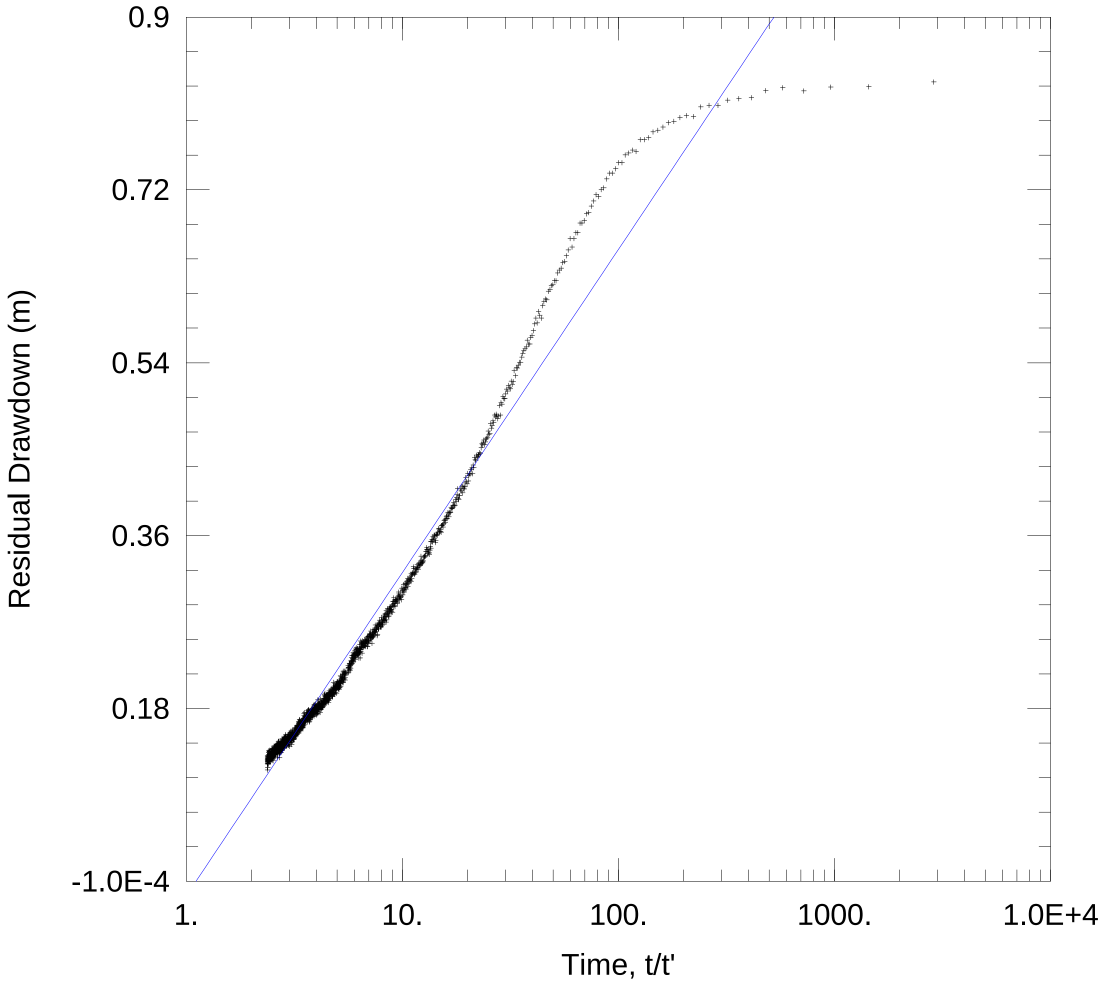
Observation Wells

Well Name	X (m)	Y (m)
O4s	13.9	0

SOLUTION

Aquifer Model: Confined
Solution Method: Theis

T = 1472.9 m^2/day
S = 0.07742
Kz/Kr = 1.
b = 58. m



WELL TEST ANALYSIS

Data Set: I:\...\Eagle04s.aqt
Date: 02/20/12 Time: 16:42:09

PROJECT INFORMATION

Company: WP
Client: FMS
Project: 201012-00322
Location: EAGLE
Test Well: EAGLE
Test Date: 28NOV2011

AQUIFER DATA

Saturated Thickness: 58. m Anisotropy Ratio (Kz/Kr): 1.

WELL DATA

Pumping Wells

Well Name	X (m)	Y (m)
Eagle Production	0	0

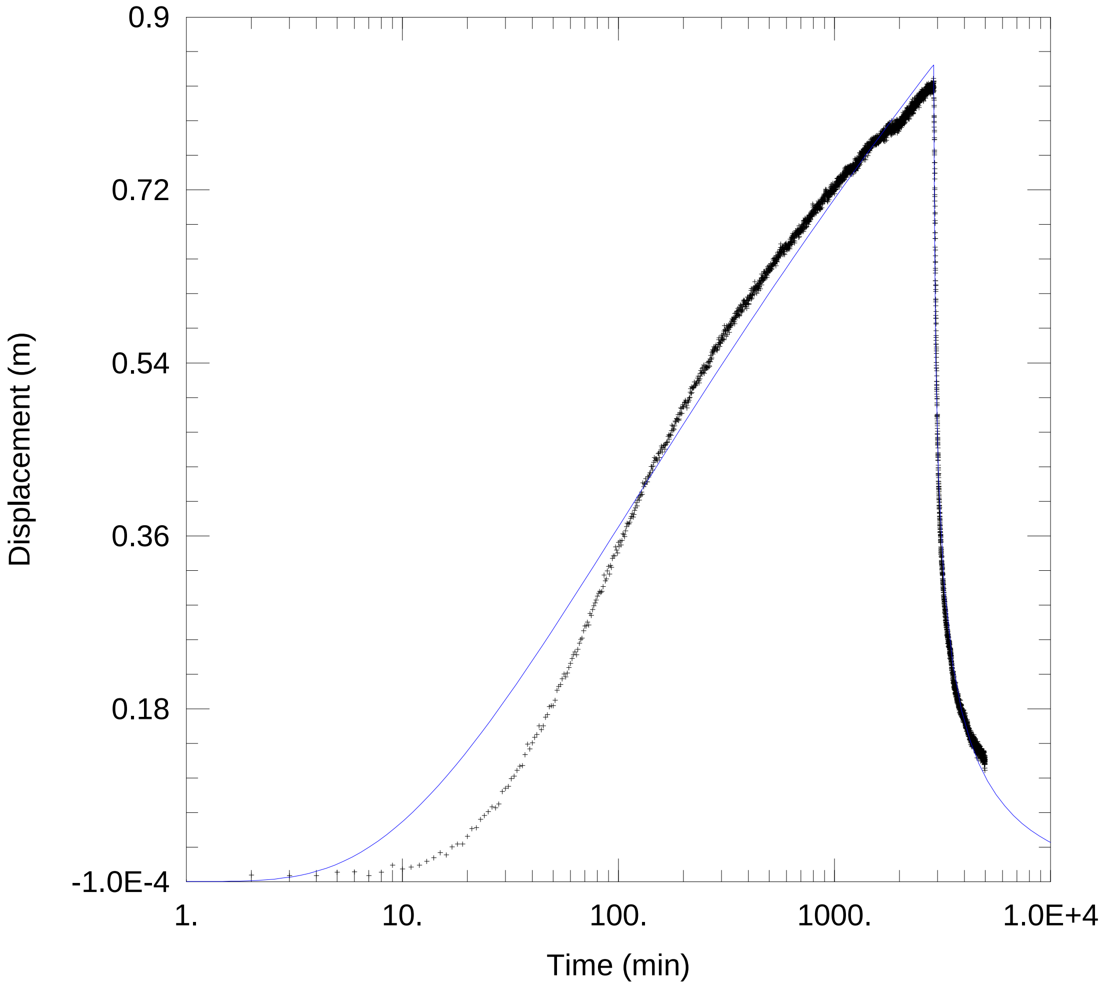
Observation Wells

Well Name	X (m)	Y (m)
O4s	13.9	0

SOLUTION

Aquifer Model: Confined Solution Method: Theis (Recovery)

T = 1411.3 m^2/day S/S' = 1.113



WELL TEST ANALYSIS

Data Set: I:\...\Eagle04s.aqt
Date: 02/20/12 Time: 16:45:35

PROJECT INFORMATION

Company: WP
Client: FMS
Project: 201012-00322
Location: EAGLE
Test Well: EAGLE
Test Date: 28NOV2011

AQUIFER DATA

Saturated Thickness: 58. m
Anisotropy Ratio (Kz/Kr): 1.
Aquitard Thickness (b'): 1. m
Aquitard Thickness (b"): 1. m

WELL DATA

Pumping Wells

Well Name	X (m)	Y (m)
Eagle Production	0	0

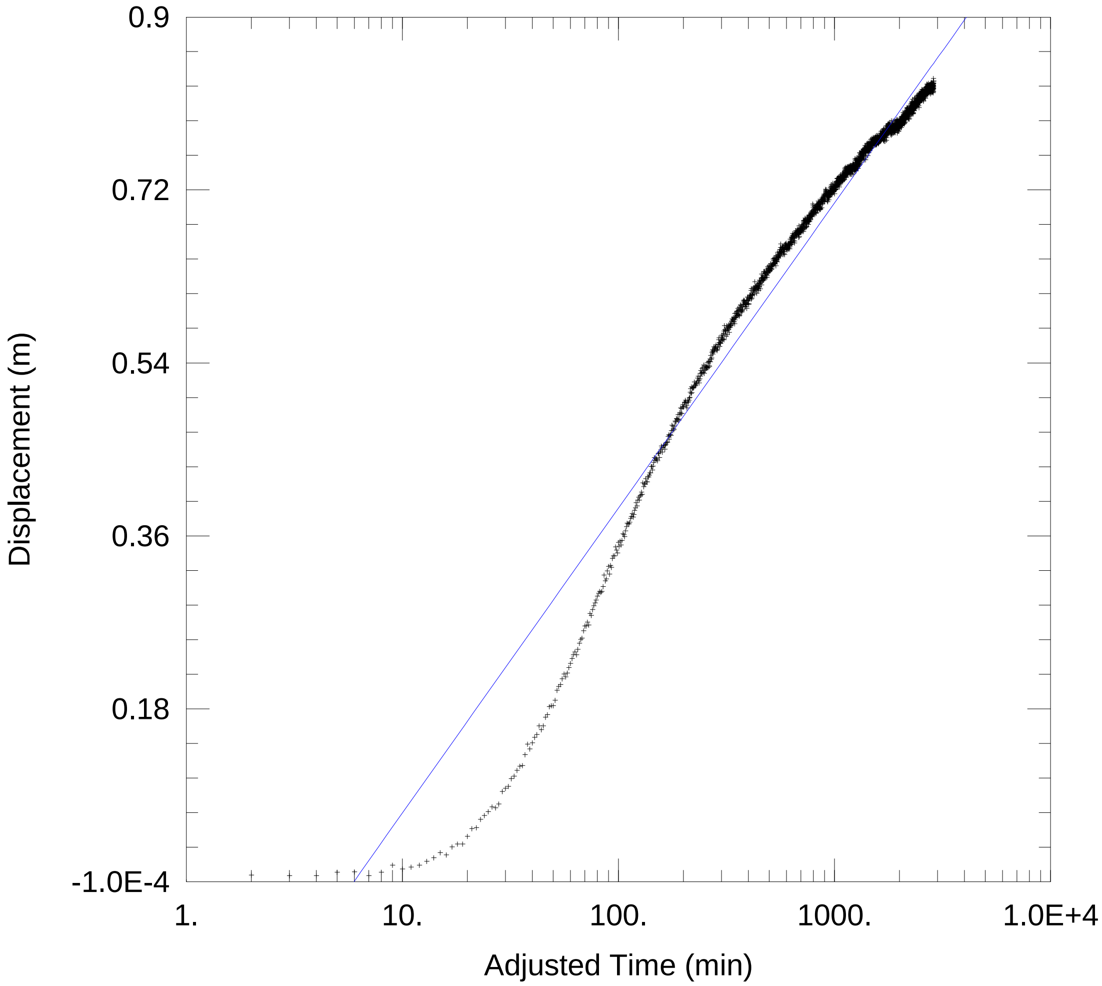
Observation Wells

Well Name	X (m)	Y (m)
O4s	13.9	0

SOLUTION

Aquifer Model: Leaky
Solution Method: Hantush

T = 948.3 m^2/day
S = 0.1038
r/B' = 1.0E-5
ß' = 0.06866
r/B" = 0.
ß" = 0.



WELL TEST ANALYSIS

Data Set: I:\...\Eagle04s.aqt
Date: 02/20/12 Time: 16:44:42

PROJECT INFORMATION

Company: WP
Client: FMS
Project: 201012-00322
Location: EAGLE
Test Well: EAGLE
Test Date: 28NOV2011

AQUIFER DATA

Saturated Thickness: 58. m Anisotropy Ratio (Kz/Kr): 1.

WELL DATA

Pumping Wells

Well Name	X (m)	Y (m)
Eagle Production	0	0

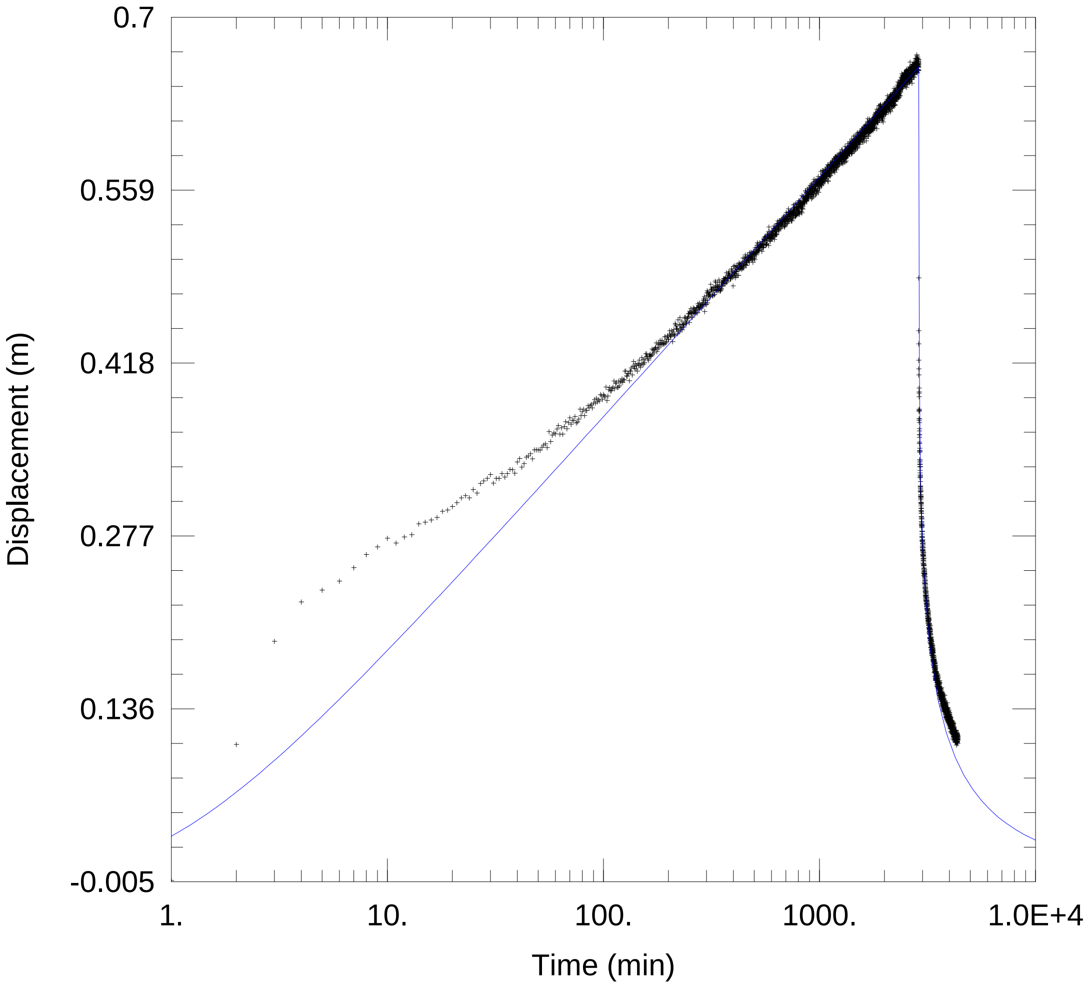
Observation Wells

Well Name	X (m)	Y (m)
+ O4s	13.9	0

SOLUTION

Aquifer Model: Confined Solution Method: Cooper-Jacob

T = 1495.8 m^2/day S = 0.07223



WELL TEST ANALYSIS

Data Set: I:\...\Eagle04m.aqt
Date: 02/20/12 Time: 16:38:33

PROJECT INFORMATION

Company: WP
Client: FMS
Project: 201012-00322
Location: EAGLE
Test Well: EAGLE
Test Date: 28NOV2011

WELL DATA

Pumping Wells

Well Name	X (m)	Y (m)
Eagle Production	0	0

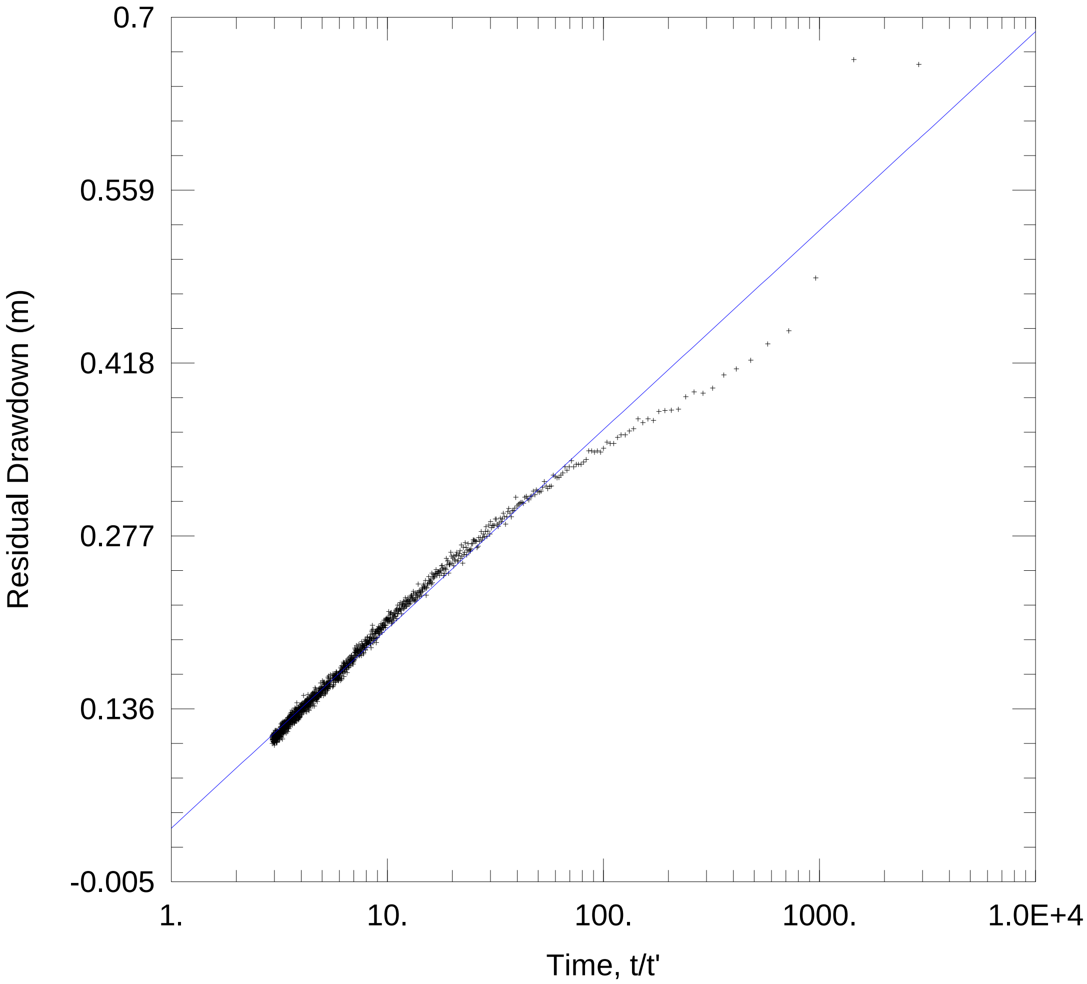
Observation Wells

Well Name	X (m)	Y (m)
O4m	13.9	0

SOLUTION

Aquifer Model: Confined
Solution Method: Theis

T = 2424.3 m^2/day
S = 0.02433
Kz/Kr = 1.
b = 58. m



WELL TEST ANALYSIS

Data Set: I:\...\Eagle04m.aqt
Date: 02/20/12 Time: 16:42:29

PROJECT INFORMATION

Company: WP
Client: FMS
Project: 201012-00322
Location: EAGLE
Test Well: EAGLE
Test Date: 28NOV2011

AQUIFER DATA

Saturated Thickness: 58. m Anisotropy Ratio (Kz/Kr): 1.

WELL DATA

Pumping Wells

Well Name	X (m)	Y (m)
Eagle Production	0	0

Observation Wells

Well Name	X (m)	Y (m)
O4m	13.9	0

SOLUTION

Aquifer Model: Confined Solution Method: Theis (Recovery)

T = 2924.5 m^2/day S/S' = 0.5797

Appendix 5: Water Levels

Measured Water Levels

Deposit	Hole-ID	Northing	Easting	Date	RL (Height of GL)/ToC	SWL (mbgl)	RWL	EOH
DELTA	HPRC0203	7551864.5	551737.1	8/9/2008	556.1	50.00	506.14	
DELTA	HPRC0204	7552035.5	551624.2	11/9/2008	554.3	52.00	502.33	
DELTA	HPRC0205	7552199.1	551515.2	13/9/2008	551.0	30.00	520.96	
DELTA	HPRC0206	7552360.1	551403.7	13/9/2008	548.3	30.00	518.26	
DELTA	HPRC0208	7552693.1	551184.1	14/9/2008	545.4	40.00	505.41	
DELTA	HPRC0240	7551476.5	550185.3	10/10/2008	575.3	46.00	529.26	
DELTA	HPRC0216	7552257.5	550278.3	5/12/2008	557.0	32.00	525.03	
DELTA	HPRC0209	7552865.5	551070.9	7/12/2008	544.9	48.00	496.85	
DELTA	HPDD0007	7552862.6	551073.2	7/9/2009	544.8	40.40	504.44	
DELTA	HPDD0008	7553436.7	550669.7	7/9/2009	561.4	52.80	508.64	
DELTA	HPRC0205	7552199.1	551515.2	Jul-09	551.0	44.97	505.99	
DELTA	HPRC0208	7552693.1	551184.1	Jul-09	545.4	38.70	506.71	
DELTA	HPRC0208A	7552695.4	551169.5	Jul-09	545.4	43.70	501.68	
DELTA	HPRC0209	7552865.5	551070.9	Jul-09	544.9	42.00	502.85	
DELTA	HPRC0211	7553184.7	550842.8	Jul-09	557.4	54.94	502.50	
DELTA	HPRC0216	7552257.5	550278.3	Jul-09	557.0	50.24	506.79	
DELTA	HPRC0219	7550656.7	550147.7	Jul-09	581.4	39.51	541.93	
DELTA	HPRC0222	7551856.0	549342.1	Jul-09	572.1	53.64	518.45	
DELTA	HPRC0224	7551534.9	551422.2	Jul-09	565.0	46.91	518.05	
DELTA	HPRC0226	7552191.1	550979.4	Jul-09	554.4	49.58	504.84	
DELTA	HPRC0227	7552517.5	550746.3	Jul-09	551.0	47.70	503.33	
DELTA	HPRC0232	7552051.3	549777.7	Jul-09	564.7	51.24	513.43	
DELTA	HPRC0234	7551703.7	548842.3	Jul-09	580.9	40.59	540.36	
DELTA	HPRC0238	7551151.9	550391.8	Jul-09	571.2	38.57	532.61	
DELTA	HPRC0240	7551476.5	550185.3	Jul-09	575.3	44.69	530.57	
DELTA	HPRC0242	7550311.3	549806.0	Jul-09	592.3	17.87	574.41	
DELTA	HPRC0243	7550490.4	549698.6	Jul-09	588.1	21.46	566.66	
DELTA	HPRC0247	7551930.5	551138.7	Jul-09	555.0	49.32	505.73	
DELTA	HPRC0248	7552030.8	551093.6	Jul-09	554.2	49.04	505.19	
DELTA	HPRC0249A	7552089.5	551045.8	Jul-09	554.0	26.57	527.41	
DELTA	HPRC0250	7552322.2	550848.1	Jul-09	551.3	47.12	504.15	
DELTA	HPRC0251	7552667.6	550639.3	Jul-09	551.1	47.94	503.16	
DELTA	HPRC0252	7550410.7	549757.8	Jul-09	589.1	22.42	566.73	
DELTA	HPRC0254	7551085.1	550446.7	Jul-09	571.9	34.09	537.79	
DELTA	HPRC0255	7551249.0	550354.6	Jul-09	570.5	32.94	537.60	
DELTA	HPRC0256	7551638.9	550738.4	Jul-09	561.9	42.69	519.18	
DELTA	HPRC0258	7551627.6	548913.2	Jul-09	580.9	39.81	541.08	
DELTA	HPRC0264	7551974.9	549831.3	Jul-09	564.3	41.56	522.74	
DELTA	HPRC0266	7552367.7	550244.9	Jul-09	558.9	52.74	506.18	
DELTA	HPRC0267	7552501.9	550120.0	Jul-09	561.4	56.98	504.42	
Delta	HPRC0257	7551785.8	550626.0	14/04/2011	560.9	36.01	524.88	
Delta	HPRC2050	7552578.4	550349.8	14/04/2011	556.6	57.82	498.75	
DELTA	HPRC2054	7553025.0	550651.9	14/04/2011	557.8	14.39	543.43	
Delta	HPRC2151	7552609.4	550795.4	14/04/2011	549.7	47.39	502.32	
Delta	HPRC2174	7553294.2	551060.2	14/04/2011	549.1	47.44	501.68	
DELTA	HPRC2183	7552558.7	551566.5	14/04/2011	547.5	45.24	502.25	
DELTA	HPRC2184	7552635.0	551533.0	14/04/2011	545.7	43.74	501.99	
Delta	HPRC2186	7552797.8	551419.7	14/04/2011	543.6	34.65	508.95	
DELTA	HPRC2187	7552894.1	551350.9	14/04/2011	542.1	40.00	502.10	
Delta	HPRC2194	7552884.2	551181.2	14/04/2011	542.6	41.09	501.51	
Delta	HPRC2238	7552444.6	551053.6	15/04/2011	548.4	46.18	502.26	
DELTA	HPRC3039	7551538.1	551687.6	15/04/2011	565.6	35.45	530.14	
Delta	HPRC0216	550278.2	7552257.5	Nov-11	557.0	29.70	527.34	
Delta	HPRC0269	551507.9	7553095.9	Nov-11	539.6	Dry	Dry	
Delta	HPRC0285	550088.9	7550744.5	Nov-11	579.9	40.22	539.69	
Delta	HPRC2084	548542.3	7551893.9	Nov-11	591.8	64.79	526.99	
Delta	HPRC2094	7552214.0	550764.0	Nov-11	552.3	Dry	Dry	39
Delta	HPRC2118	549487.2	7551828.3	Nov-11	569.9	51.18	518.67	
Delta	HPRC2119	7551888.9	549449.4	Nov-11	570.2	Dry	Dry	54
Delta	HPRC2144	550103.0	7552277.0	Nov-11	559.4	46.82	512.55	
Delta	HPRC2174	551059.2	7553294.1	Nov-11	549.1	47.12	502.00	
Delta	HPRC2240	7552278.5	551168.8	Nov-11	550.8	44.14	506.62	48
Delta	HPRC2242	7552117.4	551280.7	Nov-11	552.4	Dry	Dry	45
Delta	HPRC2249	550720.2	7551836.5	Nov-11	558.0	43.61	514.39	
Delta	HPRC2267	7551540.5	550467.9	Nov-11	564.9	Dry	Dry	14
Delta	HPRC2276	7551390.9	550411.6	Nov-11	567.9	Dry	Dry	15.8
Delta	HPRC2302	550189.6	7550852.4	Nov-11	577.5	23.46	554.00	
Delta	HPRC3019	552339.7	7551490.4	Nov-11	568.5	57.99	510.51	77.5
Delta	HPRC3029	551731.5	7551693.9	Nov-11	561.5	51.99	509.53	
Delta	HPRC3128	7551793.0	549454.0	Nov-11	570.5	Dry	Dry	52
Delta	HPRC3129	7551833.0	549428.0	Nov-11	570.8	Dry	Dry	50

Delta	HPRC3442	7551314.7	550386.6	Nov-11	569.2	Dry	Dry	35
Delta	HPRC3442A	7551309.0	550379.0	Nov-11	569.2	Dry	Dry	38
Delta	HPRC5034	551307.6	7550982.2	Nov-11	577.0	18.68	558.29	
Delta	HPRC5069	7552174.9	550784.7	Nov-11	553.6	Dry	Dry	46
Delta	HPRC5070	7552250.5	550723.1	Nov-11	551.3	57.70	493.64	47.165
Delta	HPRC5203A	7551697.0	551648.0	Nov-11	551.3	Dry	Dry	51
Delta	HPRC5210	551257.3	7552281.9	Nov-11	549.8	45.37	504.40	
Delta	HPRC5225	7551731.7	551706.7	Nov-11	560.2	Dry	Dry	32.4
Delta	HPRC5275	551040.3	7552890.8	Nov-11	546.4	43.74	502.62	
Delta	HPRC5320A	7551638.0	552085.0	Nov-11		Dry	Dry	46
Delta	HPRC5359	552705.3	7551089.4	Nov-11	590.0	23.03	566.97	
Delta	HPRC5366	7551383.0	552494.0	Nov-11	580.0	Dry	Dry	40
Delta	HPRC5376	7551127.0	552753.0	Nov-11	580.0	Dry	Dry	26
Delta	HPRC5377	7551206.0	552696.0	Nov-11	589.0	Dry	Dry	40
Delta	HPRC5384	7551235.0	552747.0	Nov-11	589.0	Dry	Dry	40
Delta	HPRC5386	7551331.0	552685.0	Nov-11	581.0	43.35	537.65	46
Delta	HPRC5387	7551363.0	552661.0	Nov-11	579.0	Dry	Dry	52
Delta	HPRC5394	7551270.0	552786.0	Nov-11	587.0	27.20	559.80	28
Delta	HPRC5395	7551357.0	552729.0	Nov-11	577.0	Dry	Dry	40
Delta	HPRC5396	7551440.0	552678.0	Nov-11	576.0	Dry	Dry	52
Delta	HPRC5397	7551537.0	552619.0	Nov-11	580.0	Dry	Dry	34
Delta	HPRC5398	7551603.0	552558.0	Nov-11	573.0	Dry	Dry	28
Delta	DELTA PROD 1	551424.9	7553228.2	17/11/2011	540.5	39.23	501.30	
Delta	HPRC2118	549487.2	7551828.3	17/11/2011	569.9	51.99	517.86	
Delta	HPRC3019	552339.7	7551490.4	17/11/2011	568.5	58.80	509.70	
Delta	HPRC5034	551307.6	7550982.2	17/11/2011	577.0	52.75	524.22	
Delta	DELTA OBS 1	550922.6	7552536.9	23/11/2011	548.4	45.90	502.49	
Delta	DELTA OBS 2	551237.3	7552861.8	23/11/2011	543.2	41.43	501.81	
Delta	DELTA OBS 3	551411.9	7553238.6	23/11/2011	540.8	39.83	500.99	
Delta	Delta-Obs-4-Deep	551418.4	7553214.2	23/11/2011	540.7	39.34	501.31	
Delta	Delta-Obs-4-Shallow	551418.4	7553214.2	23/11/2011	540.7	39.34	501.31	
Delta	HPRC0216	550278.2	7552257.5	23/11/2011	557.0	Dry	Dry	
Delta	HPRC0269	551507.9	7553095.9	23/11/2011	539.6	27.92	511.66	
Delta	HPRC0284	7551415.2	550227.1	23/11/2011	575.0	65.34	509.71	
Delta	HPRC0285	550088.9	7550744.5	23/11/2011	579.9	41.16	538.76	
Delta	HPRC2144	550103.0	7552277.0	23/11/2011	559.4	48.37	511.00	
Delta	HPRC2174	551059.2	7553294.1	23/11/2011	549.1	48.02	501.10	
Delta	HPRC2249	550720.2	7551836.5	23/11/2011	558.0	44.35	513.64	
Delta	HPRC2302	550189.6	7550852.4	23/11/2011	577.5	26.38	551.08	
Delta	HPRC3029	551731.5	7551693.9	23/11/2011	561.5	52.80	508.72	
Delta	HPRC5210	551257.3	7552281.9	23/11/2011	549.8	20.66	529.11	
Delta	HPRC5275	551040.3	7552890.8	23/11/2011	546.4	46.09	500.27	
Delta	HPRC5359	552705.3	7551089.4	23/11/2011	590.0	44.59	545.42	
Eagle	HPWB0001	39641.0	7548807.6	551499.173	599.9290161	34.00	565.93	37
Eagle	HPRC0004	39650.0	7548198.6	551380.136	588.3519897	39.80	548.55	25.5
Eagle	HPRC0002	39658.0	7547397.6	551391.889	584.6049805	44.90	539.70	71.4
Eagle	HPRC0003	39659.0	7547804.0	551393.828	584.5499878	41.50	543.05	60.5
Eagle	HPRC0008	39661.0	7547403.9	550928.821	589.0689697	48.10	540.97	51.5
Eagle	HPRC0001	39663.0	7546995.3	551396.071	584.1359863	44.00	540.14	83.2
Eagle	HPRC0011	39679.0	7547800.7	550395.621	592.802002	47.00	545.80	74.4
Eagle	HPRC0012	39680.0	7547626.4	550426.547	593.6190186	52.80	540.82	62.5
Eagle	HPRC0013	39683.0	7547396.7	550388.981	593.7589722	57.00	536.76	93.5
Eagle	HPRC0014	39684.0	7547227.8	550426.398	593.4290161	60.00	533.43	74.8
Eagle	HPRC0025	39689.0	7546999.2	548396.201	613.3469849	39.04	574.30	43.5
Eagle	HPRC0026	39690.0	7547185.4	548382.775	613.6309814	37.54	576.09	44.3
Eagle	HPRC0036	39936.0	7548868.1	546781.578	634.960022	47.00	587.96	61.2
Eagle	HPRC0037	39936.0	7549071.2	546858.693	637.0819702	39.70	597.38	98
Eagle	HPRC0040	39936.0	7549368.2	545897.155	648.6450195	28.88	619.77	108
Eagle	HPRC0072	39936.0	7548868.0	547334.655	633.9780273	46.65	587.33	26
Eagle	HPRC0079	39936.0	7549697.2	546591.747	659.8779907	23.20	636.68	106
Eagle	HPRC0080	39936.0	7549320.6	545335.522	659.3270264	52.20	607.13	120
Eagle	HPRC0081	39936.0	7549406.1	545386.982	656.8480225	45.25	611.60	108
Eagle	HPRC0084	39936.0	7549059.7	546317.889	641.940979	43.63	598.31	113
Eagle	HPRC0090	39936.0	7549199.1	545830.373	650.2069702	48.30	601.91	126
Eagle	HPRC0091	39936.0	7549277.7	545880.8	648.5430298	40.55	607.99	54
Eagle	HPRC0095	39936.0	7549333.2	546994.789	644.9229736	35.80	609.12	66
Eagle	HPRC0096	39936.0	7549514.6	547086.79	650.4550171	31.40	619.06	54
Eagle	HPRC0098	39936.0	7548718.1	547225.253	630.9180298	60.55	570.37	66
Eagle	HPRC0019	39937.0	7547212.1	549378.116	602.9110107	56.70	546.21	120
Eagle	HPRC0020	39937.0	7547395.1	549386.672	603.1699829	59.95	543.22	72
Eagle	HPRC0021	39937.0	7547599.4	549399.538	602.3359985	59.85	542.49	48
Eagle	HPRC0025	39937.0	7546999.2	548396.201	613.3469849	40.00	573.35	36
Eagle	HPRC0026	39937.0	7547185.4	548382.775	613.6309814	38.45	575.18	24
Eagle	HPRC0029	39937.0	7547797.8	548399.47	613.1710205	41.00	572.17	66
Eagle	HPRC0035	39937.0	7548996.2	548398.993	647.0629883	48.85	598.21	66

Eagle	HPRC0059	39937.0	7546996.4	549897.343	598.1110229	54.70	543.41	42
Eagle	HPRC0060	39937.0	7547199.4	549891.478	598.3640137	56.05	542.31	90
Eagle	HPRC0061	39937.0	7547399.9	549895.985	598.4689941	56.80	541.67	90
Eagle	HPRC0062	39937.0	7547605.5	549892.76	597.5900269	56.40	541.19	24
Eagle	HPRC0063	39937.0	7547795.4	549907.13	600.8029785	59.70	541.10	30
Eagle	HPRC0064	39937.0	7547997.0	549893.821	605.1409912	64.05	541.09	48
Eagle	HPRC0066	39937.0	7547004.2	548886.944	607.8759766	46.85	561.03	42
Eagle	HPRC0068	39937.0	7547396.1	548901.969	607.7180176	59.50	548.22	54
Eagle	HPRC0069	39937.0	7547599.6	548890.72	608.0629883	63.20	544.86	48
Eagle	HPRC0105	39937.0	7547683.4	548392.24	612.6339722	40.40	572.23	54
Eagle	HPRC0107	39937.0	7547998.2	548385.949	617.8959961	42.05	575.85	42
Eagle	HPRC0108	39937.0	7548102.5	548395.584	620.0159912	54.55	565.47	36
Eagle	HPRC0112	39937.0	7548681.2	548395.453	634.6309814	41.25	593.38	30
Eagle	HPRC0011	39938.0	7547800.7	550395.621	592.802002	51.95	540.85	18
Eagle	HPRC0012	39938.0	7547626.4	550426.547	593.6190186	52.65	540.97	102
Eagle	HPRC0013	39938.0	7547396.7	550388.981	593.7589722	51.10	542.66	96
Eagle	HPRC0014	39938.0	7547227.8	550426.398	593.4290161	52.95	540.48	60
Eagle	HPRC0015	39938.0	7546999.2	550400.602	592.1640015	50.00	542.16	90
Eagle	HPRC0016	39938.0	7548202.9	550395.498	599.1350098	39.00	560.14	90
Eagle	HPRC0017A	39938.0	7548033.7	550415.344	595.6959839	54.45	541.25	90
Eagle	HPRC0042	39938.0	7546996.2	551400.831	584.1069946	43.45	540.66	54
Eagle	HPRC0043	39938.0	7547234.3	551389.371	584.117981	43.80	540.32	66
Eagle	HPRC0044	39938.0	7547640.7	551390.098	584.0219727	41.90	542.12	76
Eagle	HPRC0045	39938.0	7547798.4	551398.657	584.4869995	42.10	542.39	78
Eagle	HPRC0047	39938.0	7548196.2	551398.124	588.4439697	40.20	548.24	54
Eagle	HPRC0049	39938.0	7548598.2	551395.612	595.0079956	34.90	560.11	36
Eagle	HPRC0050	39938.0	7546999.3	550902.733	588.1610107	45.40	542.76	30
Eagle	HPRC0051	39938.0	7547250.3	550920.039	588.0040283	44.20	543.80	36
Eagle	HPRC0052	39938.0	7547398.3	550929.667	589.065979	48.30	540.77	20
Eagle	HPRC0053	39938.0	7547647.7	550881.958	589.0180054	48.35	540.67	76
Eagle	HPRC0056	39938.0	7548200.2	550896.744	597.5200195	35.50	562.02	66
Eagle	HPRC0058	39938.0	7548604.3	550907.704	600.7880249	41.85	558.94	96
Eagle	HPRC0102	39938.0	7547093.2	548377.355	613.2349854	36.50	576.73	72
Eagle	HPRC0103	39938.0	7547293.1	548414.819	612.8770142	42.00	570.88	
Eagle	HPRC0113	39938.0	7547102.9	550389.789	593.5130005	52.30	541.21	78
Eagle	HPRC0011	39996.0	7547800.7	550395.621	592.802002	56.66	536.14	
Eagle	HPRC0012	39996.0	7547626.4	550426.547	593.6190186	54.43	539.19	
Eagle	HPRC0013	39996.0	7547396.7	550388.981	593.7589722	53.07	540.69	
Eagle	HPRC0014	39996.0	7547227.8	550426.398	593.4290161	51.75	541.68	
Eagle	HPRC0015	39996.0	7546999.2	550400.602	592.1640015	48.50	543.66	
Eagle	HPRC0018	39996.0	7547002.7	549401.81	602.6339722	44.60	558.03	
Eagle	HPRC0019	39996.0	7547212.1	549378.116	602.9110107	55.89	547.02	
Eagle	HPRC0020	39996.0	7547395.1	549386.672	603.1699829	59.49	543.68	
Eagle	HPRC0021	39996.0	7547599.4	549399.538	602.3359985	59.54	542.80	
Eagle	HPRC0023	39996.0	7548196.1	549396.816	612.9550171	35.62	577.34	
Eagle	HPRC0025	39996.0	7546999.2	548396.201	613.3469849	39.26	574.08	
Eagle	HPRC0026	39996.0	7547185.4	548382.775	613.6309814	37.56	576.08	
Eagle	HPRC0028	39996.0	7547590.0	548392.269	611.8140259	43.35	568.46	
Eagle	HPRC0029	39996.0	7547797.8	548399.47	613.1710205	39.88	573.29	
Eagle	HPRC0034	39996.0	7548792.1	548415.884	638.3380127	42.61	595.73	
Eagle	HPRC0035	39996.0	7548996.2	548398.993	647.0629883	48.56	598.50	
Eagle	HPRC0036	39996.0	7548868.1	546781.578	634.960022	45.90	589.06	
Eagle	HPRC0037	39996.0	7549071.2	546858.693	637.0819702	51.08	586.00	
Eagle	HPRC0040	39996.0	7549368.2	545897.155	648.6450195	28.49	620.16	
Eagle	HPRC0042	39996.0	7546996.2	551400.831	584.1069946	43.22	540.89	
Eagle	HPRC0043	39996.0	7547234.3	551389.371	584.117981	43.81	540.31	
Eagle	HPRC0044	39996.0	7547640.7	551390.098	584.0219727	37.84	546.18	
Eagle	HPRC0045	39996.0	7547798.4	551398.657	584.4869995	41.49	543.00	
Eagle	HPRC0047	39996.0	7548196.2	551398.124	588.4439697	39.42	549.03	
Eagle	HPRC0048	39996.0	7548428.1	551378.093	591.3599854	35.84	555.52	
Eagle	HPRC0049	39996.0	7548598.2	551395.612	595.0079956	34.14	560.87	
Eagle	HPRC0050	39996.0	7546999.3	550902.733	588.1610107	45.35	542.81	
Eagle	HPRC0051	39996.0	7547250.3	550920.039	588.0040283	53.35	534.66	
Eagle	HPRC0052	39996.0	7547398.3	550929.667	589.065979	48.13	540.94	
Eagle	HPRC0053	39996.0	7547647.7	550881.958	589.0180054	48.20	540.82	
Eagle	HPRC0056	39996.0	7548200.2	550896.744	597.5200195	35.52	562.00	
Eagle	HPRC0058	39996.0	7548604.3	550907.704	600.7880249	35.42	565.36	
Eagle	HPRC0059	39996.0	7546996.4	549897.343	598.1110229	54.11	544.00	
Eagle	HPRC0060	39996.0	7547199.4	549891.478	598.3640137	55.70	542.66	
Eagle	HPRC0061	39996.0	7547399.9	549895.985	598.4689941	56.45	542.02	
Eagle	HPRC0062	39996.0	7547605.5	549892.76	597.5900269	56.09	541.50	
Eagle	HPRC0063	39996.0	7547795.4	549907.13	600.8029785	59.47	541.33	
Eagle	HPRC0064	39996.0	7547997.0	549893.821	605.1409912	63.89	541.25	
Eagle	HPRC0066	39996.0	7547004.2	548886.944	607.8759766	45.55	562.33	
Eagle	HPRC0067	39996.0	7547200.5	548887.048	608.40802	34.27	574.14	
Eagle	HPRC0068	39996.0	7547396.1	548901.969	607.7180176	51.72	556.00	

Eagle	HPRC0069	39996.0	7547599.6	548890.72	608.0629883	61.83	546.23	
Eagle	HPRC0072	39996.0	7548868.0	547334.655	633.9780273	46.17	587.81	
Eagle	HPRC0079	39996.0	7549697.2	546591.747	659.8779907	25.18	634.70	
Eagle	HPRC0080	39996.0	7549320.6	545335.522	659.3270264	51.81	607.52	
Eagle	HPRC0084	39996.0	7549059.7	546317.889	641.940979	42.84	599.10	
Eagle	HPRC0090	39996.0	7549199.1	545830.373	650.2069702	47.29	602.92	
Eagle	HPRC0091	39996.0	7549277.7	545880.8	648.5430298	40.13	608.41	
Eagle	HPRC0094	39996.0	7549160.2	546905.643	639.5629883	48.47	591.09	
Eagle	HPRC0095	39996.0	7549333.2	546994.789	644.9229736	38.50	606.42	
Eagle	HPRC0096	39996.0	7549514.6	547086.79	650.4550171	30.92	619.54	
Eagle	HPRC0099	39996.0	7548789.9	547281.046	632.3499756	53.96	578.39	
Eagle	HPRC0102	39996.0	7547093.2	548377.355	613.2349854	24.15	589.08	
Eagle	HPRC0103	39996.0	7547293.1	548414.819	612.8770142	41.50	571.38	
Eagle	HPRC0104	39996.0	7547498.0	548398.86	612.1820068	41.50	570.68	
Eagle	HPRC0105	39996.0	7547683.4	548392.24	612.6339722	37.10	575.53	
Eagle	HPRC0106	39996.0	7547894.1	548397.022	615.3280029	44.20	571.13	
Eagle	HPRC0107	39996.0	7547998.2	548385.949	617.8959961	19.50	598.40	
Eagle	HPRC0108	39996.0	7548102.5	548395.584	620.0159912	59.80	560.22	
Eagle	HPRC0113	39996.0	7547102.9	550389.789	593.5130005	52.14	541.37	
Eagle	HPRC4222	40647.0	7546997.0	551405.00	623.00	42.8	580.20	74
Eagle	HPRC0008	40648.0	7547403.9	550928.82	589.07	48.52	540.55	30
Eagle	HPRC0018	40648.0	7547002.7	549401.81	602.63	48.33	554.30	66
Eagle	HPRC0028	40648.0	7547590.0	548392.27	611.81	53.28	558.53	60
Eagle	HPRC0046	40648.0	7548031.1	551386.75	586.00	39.51	546.49	72
Eagle	HPRC0102	40648.0	7547093.2	548377.36	613.23	24.49	588.74	70
Eagle	HPRC4006	40648.0	7548674.3	551391.70	596.50	33.80	562.70	24
Eagle	HPRC4185	40648.0	7547385.0	549279.00	606.00	61.56	544.44	48
Eagle	HPRC4122	40848.0	544946.1	7549663.393	673.86	34.395	639.462	30
Eagle	HPRC4118	40848.0	545178.0	7549533.175	661.01	Dry	-	12
Eagle	HPRC0098	40848.0	547225.3	7548717.863	630.92	61.6	569.31803	36
Eagle	HPRC0108	40848.0	548395.6	7548102.472	620.02	54.5	565.515991	48
Eagle	HPRC0035	40848.0	548399.0	7548996.028	647.06	47.406	599.656988	42
Eagle	HPRC0068	40848.0	548902.0	7547396.143	607.72	61.2	546.518018	24
Eagle	HPRC4180	40848.0	549402.0	7547290.758	602.95	59.8	543.15	26
Eagle	HPRC4029	40848.0	550653.1	7548792.622	610.97	49.8	561.165	54
Eagle	HPRC4257	40848.0	550653.6	7546813.049	-	49.85	-	48
Eagle	HPRC0052	40848.0	550929.5	7547398.306	589.07	48.4	540.665979	30
Eagle	HPRC4052	40848.0	551272.7	7548503.04	592.82	Dry	-	18
Eagle	HPRC4053	40848.0	551286.0	7548613.494	594.42	32.6	561.821	54
Eagle	HPRC0004	40848.0	551380.3	7548198.296	588.35	38.3	550.05199	48
Eagle	HPRC0002	40848.0	7547397.6	551391.889	584.60	blocked	-	24
Eagle	HPRC0008	40848.0	7547403.9	550928.821	589.07	48.4	540.66897	18
Eagle	HPRC0010	40848.0	7548196.6	550901.341	597.32	dry	-	24
Eagle	HPRC0011	40848.0	7547800.7	550395.621	592.80	51.95	540.852002	30
Eagle	HPRC0012	40848.0	7547626.4	550426.547	593.62	52.65	540.969019	54
Eagle	HPRC0013	40848.0	7547396.7	550388.981	593.76	51.1	542.658972	42
Eagle	HPRC0014	40848.0	7547227.8	550426.398	593.43	52.95	540.479016	24
Eagle	HPRC0015	40848.0	7546999.2	550400.602	592.16	50	542.164001	57
Eagle	HPRC0016	40848.0	7548202.9	550395.498	599.14	39	560.13501	54
Eagle	HPRC0017A	40848.0	7548033.7	550415.344	595.70	54.45	541.245984	42
Eagle	HPRC0018	40848.0	7547002.7	549401.81	602.63	46.1	556.533972	42
Eagle	HPRC0019	40848.0	7547212.1	549378.116	602.91	56.7	546.211011	24
Eagle	HPRC0020	40848.0	7547395.1	549386.672	603.17	59.95	543.219983	56
Eagle	HPRC0021	40848.0	7547599.4	549399.538	602.34	59.85	542.485999	26
Eagle	HPRC0022	40848.0	7547793.8	549402.227	606.34	dry	-	18
Eagle	HPRC0023	40848.0	7548196.1	549396.816	612.96	dry	-	60
Eagle	HPRC0024	40848.0	7548385.4	549397.481	622.75	dry	-	48
Eagle	HPRC0025	40848.0	7546999.2	548396.201	613.35	40	573.346985	42
Eagle	HPRC0026	40848.0	7547185.4	548382.775	613.63	38.5	575.130981	54
Eagle	HPRC0027	40848.0	7547400.7	548401.042	612.39	42.35	570.03501	78
Eagle	HPRC0028	40848.0	7547590.0	548392.269	611.81	46.7	565.114026	78
Eagle	HPRC0029	40848.0	7547797.8	548399.47	613.17	41	572.171021	56
Eagle	HPRC0030	40848.0	7547996.8	548392.923	618.07	dry	-	36
Eagle	HPRC0031	40848.0	7548198.8	548395.46	622.10	dry	-	30
Eagle	HPRC0032A	40848.0	7548391.1	548384.667		dry	-	42
Eagle	HPRC0033	40848.0	7548599.3	548400.753	631.88	dry	-	90
Eagle	HPRC0034	40848.0	7548792.1	548415.884	638.34	dry	-	18
Eagle	HPRC0036	40848.0	7548868.1	546781.578	634.96	47	587.960022	
Eagle	HPRC0037	40848.0	7549071.2	546858.693	637.08	39.7	597.38197	
Eagle	HPRC0038	40848.0	7549245.7	546952.41	642.34	dry	-	
Eagle	HPRC0039	40848.0	7549426.5	547022.964	647.63	dry	-	
Eagle	HPRC0040	40848.0	7549368.2	545897.155	648.65	28.88	619.76502	
Eagle	HPRC0041	40848.0	7549559.5	545978.546	657.04	dry	-	
Eagle	HPRC0042	40848.0	7546996.2	551400.831	584.11	43.45	540.656995	
Eagle	HPRC0043	40848.0	7547234.3	551389.371	584.12	43.8	540.317981	
Eagle	HPRC0044	40848.0	7547640.7	551390.098	584.02	41.9	542.121973	

Eagle	HPRC0045	40848.0	7547798.4	551398.657	584.49	42.1	542.387		
Eagle	HPRC0046	40848.0	7548031.1	551386.751	586.00	blocked	-		
Eagle	HPRC0047	40848.0	7548196.2	551398.124	588.44	40.2	548.24397		
Eagle	HPRC0048	40848.0	7548428.1	551378.093	591.36	blocked	-		
Eagle	HPRC0049	40848.0	7548598.2	551395.612	595.01	34.9	560.107996		
Eagle	HPRC0050	40848.0	7546999.3	550902.733	588.16	45.4	542.761011		
Eagle	HPRC0051	40848.0	7547250.3	550920.039	588.00	44.2	543.804028		
Eagle	HPRC0053	40848.0	7547647.7	550881.958	589.02	48.35	540.668005		
Eagle	HPRC0054	40848.0	7547802.5	550907.083	588.67	dry	-		
Eagle	HPRC0055	40848.0	7548040.5	550916.018	593.36	dry	-		
Eagle	HPRC0056	40848.0	7548200.2	550896.744	597.52	35.5	562.02002		
Eagle	HPRC0057	40848.0	7548523.3	550910.303	599.63	dry	-		
Eagle	HPRC0058	40848.0	7548604.3	550907.704	600.79	41.85	558.938025		
Eagle	HPRC0059	40848.0	7546996.4	549897.343	598.11	54.7	543.411023		
Eagle	HPRC0060	40848.0	7547199.4	549891.478	598.36	56.05	542.314014		
Eagle	HPRC0061	40848.0	7547399.9	549895.985	598.47	56.8	541.668994		
Eagle	HPRC0062	40848.0	7547605.5	549892.76	597.59	56.4	541.190027		
Eagle	HPRC0063	40848.0	7547795.4	549907.13	600.80	59.7	541.102979		
Eagle	HPRC0064	40848.0	7547997.0	549893.821	605.14	64.05	541.090991		
Eagle	HPRC0065	40848.0	7548197.4	549898.265	608.72	dry	-		
Eagle	HPRC0066	40848.0	7547004.2	548886.944	607.88	46.85	561.025977		
Eagle	HPRC0067	40848.0	7547200.5	548887.048	608.41	blocked	-		
Eagle	HPRC0069	40848.0	7547599.6	548890.72	608.06	63.2	544.862988		
Eagle	HPRC0070	40848.0	7547801.9	548908.578	610.10	dry	-		
Eagle	HPRC0071	40848.0	7547979.7	548883.022	616.09	dry	-		
Eagle	HPRC0072	40848.0	7548868.0	547334.655	633.98	46.65	587.328027		
Eagle	HPRC0073	40848.0	7549050.9	547426.974	637.34	dry	-		
Eagle	HPRC0074	40848.0	7549229.4	547507.01	642.09	dry	-		
Eagle	HPRC0075	40848.0	7548970.2	546255.846	646.21	dry	-		
Eagle	HPRC0076	40848.0	7549149.6	546338.119	641.76	dry	-		
Eagle	HPRC0077	40848.0	7549334.9	546414.088	644.34	dry	-		
Eagle	HPRC0078	40848.0	7549507.7	546514.188	652.34	dry	-		
Eagle	HPRC0079	40848.0	7549697.2	546591.747	659.88	23.2	636.677991		
Eagle	HPRC0080	40848.0	7549320.6	545335.522	659.33	52.2	607.127026		
Eagle	HPRC0081	40848.0	7549406.1	545386.982	656.85	45.25	611.598022		
Eagle	HPRC0082	40848.0	7549497.7	545434.658	658.50	dry	-		
Eagle	HPRC0083	40848.0	7549654.8	545490.821	670.65	dry	-		
Eagle	HPRC0084	40848.0	7549059.7	546317.889	641.94	43.63	598.310979		
Eagle	HPRC0085	40848.0	7549246.3	546367.191	641.76	dry	-		
Eagle	HPRC0086	40848.0	7549430.7	546443.574	647.76	dry	-		
Eagle	HPRC0087	40848.0	7549612.0	546571.08	657.71	dry	-		
Eagle	HPRC0088	40848.0	7549003.5	545727.267	656.91	blocked	-		
Eagle	HPRC0089	40848.0	7549108.7	545793.131	653.27	dry	-		
Eagle	HPRC0090	40848.0	7549199.1	545830.373	650.21	48.3	601.90697		
Eagle	HPRC0091	40848.0	7549277.7	545880.8	648.54	40.55	607.99303		
Eagle	HPRC0092	40848.0	7549448.4	545926.596	651.47	dry	-		
Eagle	HPRC0093	40848.0	7548972.7	546821.937	634.79	dry	-		
Eagle	HPRC0094	40848.0	7549160.2	546905.643	639.56	dry	-		
Eagle	HPRC0095	40848.0	7549333.2	546994.789	644.92	35.8	609.122974		
Eagle	HPRC0096	40848.0	7549514.6	547086.79	650.46	31.4	619.055017		
Eagle	HPRC0097	40848.0	7549609.0	547123.709	653.99	dry	-		
Eagle	HPRC0099	40848.0	7548789.9	547281.046	632.35	66.65	565.699976		
Eagle	HPRC0100	40848.0	7548971.0	547382.326	637.03	dry	-		
Eagle	HPRC0101	40848.0	7549165.4	547472.615	639.68	dry	-		
Eagle	HPRC0102	40848.0	7547093.2	548377.355	613.23	36.5	576.734985		
Eagle	HPRC0103	40848.0	7547293.1	548414.819	612.88	42	570.877014		
Eagle	HPRC0104	40848.0	7547498.0	548398.86	612.18	dry	-		
Eagle	HPRC0105	40848.0	7547683.4	548392.24	612.63	40.4	572.233972		
Eagle	HPRC0106	40848.0	7547894.1	548397.022	615.33	blocked	-		
Eagle	HPRC0107	40848.0	7547998.2	548385.949	617.90	42.65	575.245996		
Eagle	HPRC0109	40848.0	7548196.3	548391.018	622.02	dry	-		
Eagle	HPRC0110	40848.0	7548293.9	548391.941	624.43	dry	-		
Eagle	HPRC0111	40848.0	7548507.3	548396.629	629.61	dry	-		
Eagle	HPRC0112	40848.0	7548681.2	548395.453	634.63	41.25	593.380981		
Eagle	HPRC0113	40848.0	7547102.9	550389.789	593.51	52.3	541.213		
Eagle	HPRC0114	40848.0	7548069.7	549387.009	611.36	dry	dry		
Eagle	EAGLE OBS 4 s	40874.0	551407.0	7547011.000	**584.733**	44.01	540.723		
Eagle	EAGLE OBS 4 m	40874.0	551407.0	7547011.000	**584.733**	44.029	540.704		
Eagle	EAGLE OBS 4 d	40874.0	551407.0	7547011.000	**584.733**	43.96	540.773		
Eagle	EAGLE PROD 1	40874.0	551396.2	7547002.153	**584.554**	43.72	540.834		
Eagle	HPRC0004	40874.0	551380.3	7548198.296	**589.141**	39.245	549.896		
Eagle	HPRC0052	40874.0	550929.5	7547398.306	**589.815**	49.092	540.723		
Eagle	HPRC0121	40874.0	549899.4	7547696.095	**600.765**	59.7	541.065		
Eagle	HPRC4257	40874.0	550653.6	7546813.049	**592.180**	50.387	541.793		
Eagle	EAGLE OBS 2	40875.0	551403.5	7546985.324	**584.531**	43.79	540.741		
Eagle	EAGLE OBS 3	40875.0	551373.0	7547809.750	**585.331**	44.385	540.946		

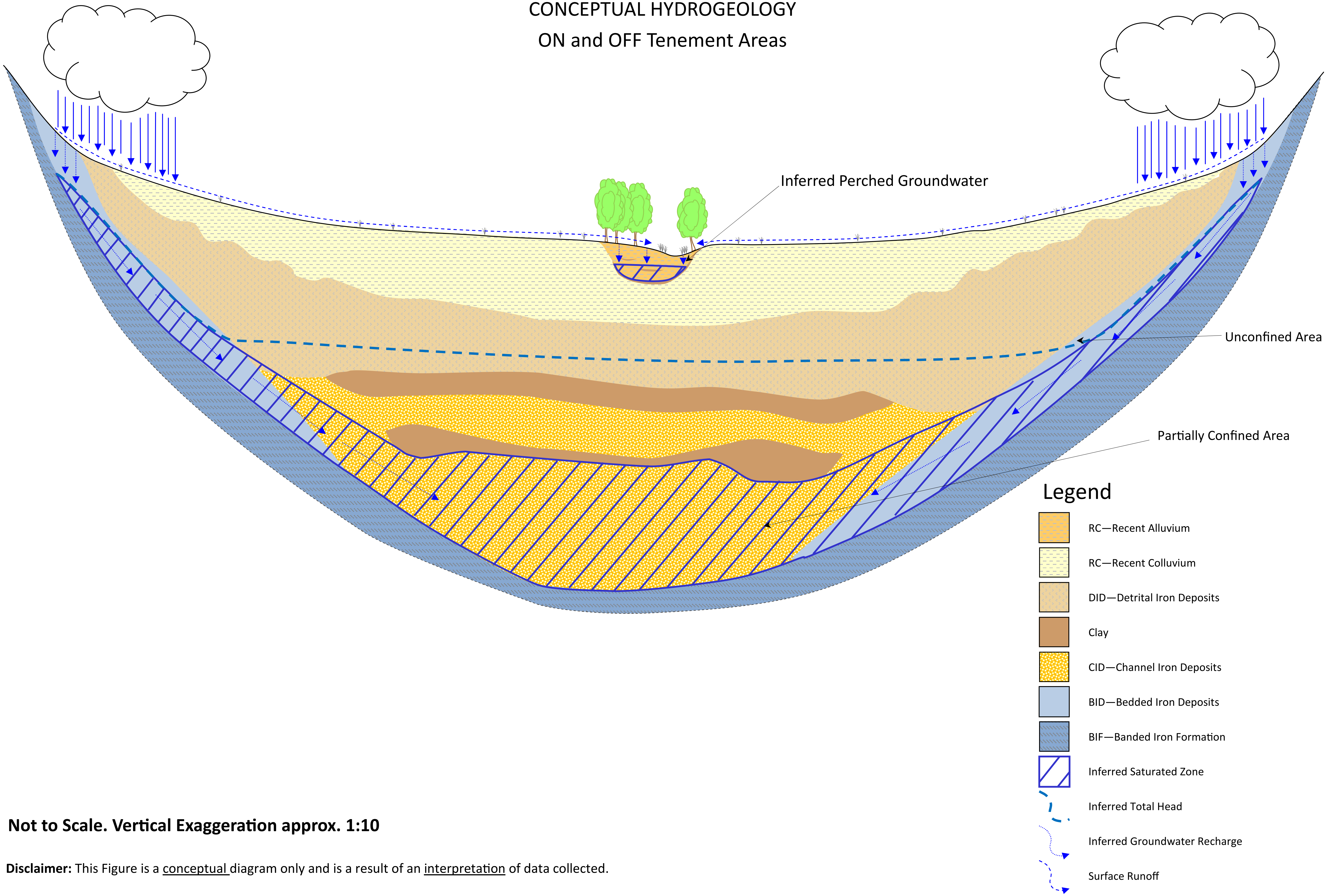
Eagle	HPRC0068	40875.0	548902.0	7547396.143	**608.381**	49.055	559.326	
Eagle	HPRC0098	40875.0	547225.3	7548717.863	**631.616**		631.616	
Eagle	HPRC4029	40875.0	550653.1	7548792.622	**611.735**	50.935	560.800	
Eagle	HPRC4052	40875.0	551272.7	7548503.040	**593.558**	35.55	558.008	
Eagle	HPRC4053	40875.0	551286.0	7548613.494	**595.048**	33.762	561.286	
Eagle	HPRC4118	40875.0	545178.0	7549533.175	**661.670**		661.670	
Eagle	HPRC4122	40875.0	544946.1	7549663.393	**674.512**		674.512	
Eagle	EAGLE OBS 1	40876.0	550278.4	7547283.521	**595.353**	54.29	541.063	
Eagle	HPRC0035	40876.0	548399.0	7548996.028	**647.744**	48.225	599.519	
Eagle	HPRC0108	40876.0	548395.6	7548102.472	**620.782**	55.782	565.000	
Eagle	HPRC4180	40876.0	549402.0	7547290.758	**603.814**	60.557	543.257	
Champion	HPRC0689	Nov-11	544663.444	7554588.262	592.522	25.4	567.132	32
Champion	HPRC0531	Nov-11	545490.472	7553341.661	577.1619873	36.1	541.026987	41.8
Champion	HPRC0352	Nov-11	545564.959	7553282.635	577.210022	Dry	-	30
Champion	HPRC0766	Nov-11	545920.967	7554368.005	568.5	39.9	528.63	56.5
Champion	HPRC0919	Nov-11	546259.945	7553639.857	568.58	38.1	530.45	59
Champion	HPRC0641	Nov-11	546441.869	7554919.119	567.028	49.6	517.403	70.7
Champion	HPRC0321	Nov-11	546581.314	7554467.782	559.2509766	31.0	528.275977	34.64
Champion	HPRC0395	Nov-11	546661.13	7555504.01	555.1970215	39.8	515.397021	52
Champion	HPRC0631	Nov-11	546893.535	7555104.519	552.87	35.5	517.33	48.5
Champion	HPRC0792	Nov-11	546895.888	7553541.338	574.91	Dry	-	38
Champion	HPRC0672	Nov-11	547008.045	7553444.277	577.446	47.2	530.276	55.75
Champion	HPRC0549	Nov-11	547642.192	7555493.228	554.019	30.5	523.564	60
Champion	HPRC1026	Nov-11	547882.973	7553186.708	598	16.5	581.545	24
Champion	HPRC0973	Nov-11	548034.734	7555166.046	570	22.9	547.07	52
Champion	HPRC0581	Nov-11	547234.092	7555967.636	545.135	28.4	516.735	54.9
Champion	HPRC0615	Nov-11	547089.013	7555464.768	548.838	31.3	517.538	58
Champion	HPRC0614	Nov-11	547022.506	7555503.721	548.918	31.4	517.478	40.7
Champion	HPRC0399	Nov-11	546481.564	7553933.501	565.2420044	36.0	529.242004	40
Champion	HPRC0787	Nov-11	546462.01	7553778	565.74	36.4	529.375	64
Champion	HPRC0786	Nov-11	546382.54	7553824.92	565.96	36.4	529.54	39.8
Champion	HPRC0905	Nov-11	546482.65	7553637.1	567.65	38.1	529.55	46
Champion	HPRC0788	Nov-11	546553.95	7553729	567.67	38.3	529.41	49.7
Champion	HPRC0920	Nov-11	546346.07	7553588.92	569.57	39.1	530.5	50.5
Champion	HPRC0345	Nov-11	545410.727	7553985.441	575.7000122	42.8	532.950012	53.5
Champion	HPRC0329	Nov-11	546226.945	7554081.688	564.9719849	Dry	-	24.5
Champion	HPRC0530	Nov-11	545668.687	7553255.864	576.2230225	Dry	-	31
Champion	HPRC0685	Nov-11	544584.093	7554851.044	597.776	Dry	-	31
Champion	HPRC0707	Nov-11	545408.974	7554290.976	575.548	Dry	-	34.55
Champion	HPRC0768	Nov-11	546094	7554278	565.13	Dry	-	36
Champion	HPRC0904	Nov-11	546390.88	7553676.43	567.17	dry	-	52.6
Champion	HPRC0906	Nov-11	546561.67	7553582.8	568.43	dry	-	40
Champion	HPRC0918	Nov-11	546172.41	7553678.21	569.2	Dry	-	40.2
Champion	CHAMP OBS 1	1/12/2001	546889.991	7555876.47	**552.433**	37.3	515.128	
Champion	CHAMP OBS 2	2/12/2001	546965.249	7556117.324	**548.85**	34.0	514.823	
Champion	CHAMP OBS 3	2/12/2001	547145.737	7556023.679	**544.574**	31.2	513.329	
Champion	CHAMP OBS 4shallow	2/12/2001	546969.662	7556139.732	**548.997**	34.1	514.887	
Champion	CHAMP OBS4 m	2/12/2001	546969.662	7556139.732	**548.997**	34.1	514.902	
Champion	CHAMP OBS 4d	2/12/2001	546969.662	7556139.732	**548.997**	34.0	514.985	
Champion	CHAMP PROD 01	2/12/2001	546976.97	7556127.717	**548.937**			
Champion	HPRC0321	1/12/2001	546581.314	7554467.782	**560.01**	31.8	528.25	
Champion	HPRC0352	1/12/2001	545564.959	7553282.635	**577.954**	dry	dry	
Champion	HPRC0395	1/12/2001	546661.13	7555504.01	**555.915**	40.7	515.185	
Champion	HPRC0531	1/12/2001	545490.472	7553341.661	**577.857**	36.9	540.997	
Champion	HPRC0549	1/12/2001	547642.192	7555493.228	**554.684**	31.2	523.439	
Champion	HPRC0631	1/12/2001	546893.535	7555104.519	**553.578**	36.4	517.198	
Champion	HPRC0641	1/12/2001	546441.869	7554919.119	**567.759**	50.5	517.274	
Champion	HPRC0672	1/12/2001	547008.045	7553444.277	**578.162**	48.0	530.192	
Champion	HPRC0689	1/12/2001	544663.444	7554588.262	**593.17**	26.5	566.66	
Champion	HPRC0766	1/12/2001	545920.967	7554368.005	**569.156**			
Champion	HPRC0792	1/12/2001	546895.888	7553541.338	**575.687**	dry	dry	38
Champion	HPRC0919	1/12/2001	546259.945	7553639.857	**569.387**	39.0	530.387	
Champion	HPRC0973	1/12/2001	548034.734	7555166.046	**563.608**	23.8	539.828	
Champion	HPRC1026	1/12/2001	547882.973	7553186.708	**596.526**	17.3	579.196	
Champion	HPRC0301	Jul-09	7555821.594	547246.719	546.80	24.5	522.34	
Champion	HPRC0302	Jul-09	7555412.502	546940.08	549.52	25.6	523.90	
Champion	HPRC0303	Jul-09	7555275.988	547140.621	550.43	27.8	522.66	
Champion	HPRC0304	Jul-09	7555354.173	547032.984	549.66	28.0	521.71	
Champion	HPRC0306	Jul-09	7555504.04	546774.172	551.28	31.7	519.55	
Champion	HPRC0307	Jul-09	7555579.244	546580.695	552.61	30.2	522.44	
Champion	HPRC0308	Jul-09	7554897.654	546743.386	554.59	33.2	521.35	
Champion	HPRC0309	Jul-09	7554878.184	546833.513	554.51	32.7	521.85	
Champion	HPRC0310	Jul-09	7554826.952	546918.623	555.64	32.3	523.38	
Champion	HPRC0311	Jul-09	7555656.226	547605.096	551.64	26.4	525.29	
Champion	HPRC0312	Jul-09	7555730.022	547421.641	549.38	17.8	531.60	

Champion	HPRC0314	Jul-09	7556005.687	546883.697	545.98	26.6	519.35	
Champion	HPRC0315	Jul-09	7556098.455	546715.041	546.72	27.5	519.21	
Champion	HPRC0316	Jul-09	7555270.834	547225.639	553.26	29.5	523.73	
Champion	HPRC0318	Jul-09	7554992.794	546547.732	567.35	46.1	521.27	
Champion	HPRC0319	Jul-09	7555089.677	546381.416	567.46	46.9	520.56	
Champion	HPRC0321	Jul-09	7554467.722	546581.464	559.25	29.4	529.83	
Champion	HPRC0322	Jul-09	7554573.518	546383.069	560.41	20.7	539.74	
Champion	HPRC0323	Jul-09	7554633.138	546204.821	562.02	33.3	528.75	
Champion	HPRC0324	Jul-09	7553587.162	547102.021	578.39	42.0	536.39	
Champion	HPRC0326	Jul-09	7553791.7	546752	570.20	39.0	531.17	
Champion	HPRC0327	Jul-09	7553889.672	546580.82	567.14	36.2	530.99	
Champion	HPRC0328	Jul-09	7553984.613	546392.458	564.61	33.9	530.74	
Champion	HPRC0329	Jul-09	7554081.688	546226.945	564.97	34.2	530.82	
Champion	HPRC0330	Jul-09	7554140.361	546018.947	565.87	32.2	533.67	
Champion	HPRC0331	Jul-09	7554251.056	545861.95	568.55	46.8	521.72	
Champion	HPRC0332	Jul-09	7554345.81	545678.945	572.45	32.2	540.23	
Champion	HPRC0333	Jul-09	7554460.855	545522.28	575.84	43.8	532.09	
Champion	HPRC0334	Jul-09	7554557.732	545331.676	579.60	38.6	540.99	
Champion	HPRC0336	Jul-09	7554740.213	544988.8	587.53	31.5	556.06	
Champion	HPRC0341	Jul-09	7553584.332	546098.573	570.81	37.8	533.01	
Champion	HPRC0342	Jul-09	7553676.056	545906.258	570.94	37.0	533.92	
Champion	HPRC0343	Jul-09	7553768.769	545744.504	571.12	37.0	534.07	
Champion	HPRC0344	Jul-09	7553861.836	545556.083	571.25	37.1	534.15	
Champion	HPRC0345	Jul-09	7553985.441	545410.727	575.70	19.1	556.60	
Champion	HPRC0346	Jul-09	7554058.903	545212.408	580.68	47.0	533.68	
Champion	HPRC0358	15/04/2011	7552630.83	545793.89	585.60	37.8	547.77	
Champion	HPRC0559	15/04/2011	7555216.53	547948.66	561.04	22.0	539.07	
Champion	HPRC0578	15/04/2011	7556303.00	546702.00	548.33	32.8	515.56	
Champion	HPRC0580	14/04/2011	7556019.00	547129.00	544.20	26.0	518.20	
Champion	HPRC0581	15/04/2011	7555969.00	547238.00	545.14	28.5	516.66	
Champion	HPRC0582	15/04/2011	7555921.95	547319.69	546.74	28.5	518.28	
Champion	HPRC0591	14/04/2011	7555784.00	547047.00	545.84	27.9	517.90	
Champion	HPRC0592	14/04/2011	547134.77	7555731.25	546.60	28.7	517.89	
Champion	HPRC0593	15/04/2011	7555683.13	547221.12	547.01	27.0	520.05	
Champion	HPRC0624	15/04/2011	7555206.56	546945.05	551.81	34.2	517.61	
Champion	HPRC0631	15/04/2011	7555104.45	546893.23	552.87	35.2	517.69	
Champion	HPRC0690	15/04/2011	7554502.57	544635.37	593.47	15.9	577.59	
Champion	HPRC0707	14/04/2011	7554276.00	545333.00	575.55	34.4	541.19	
Champion	HPRC0919	14/04/2011	7553316.00	546261.00	571.00	38.0	532.98	

Appendix 6: Conceptual Cross Sections

CONCEPTUAL HYDROGEOLOGY

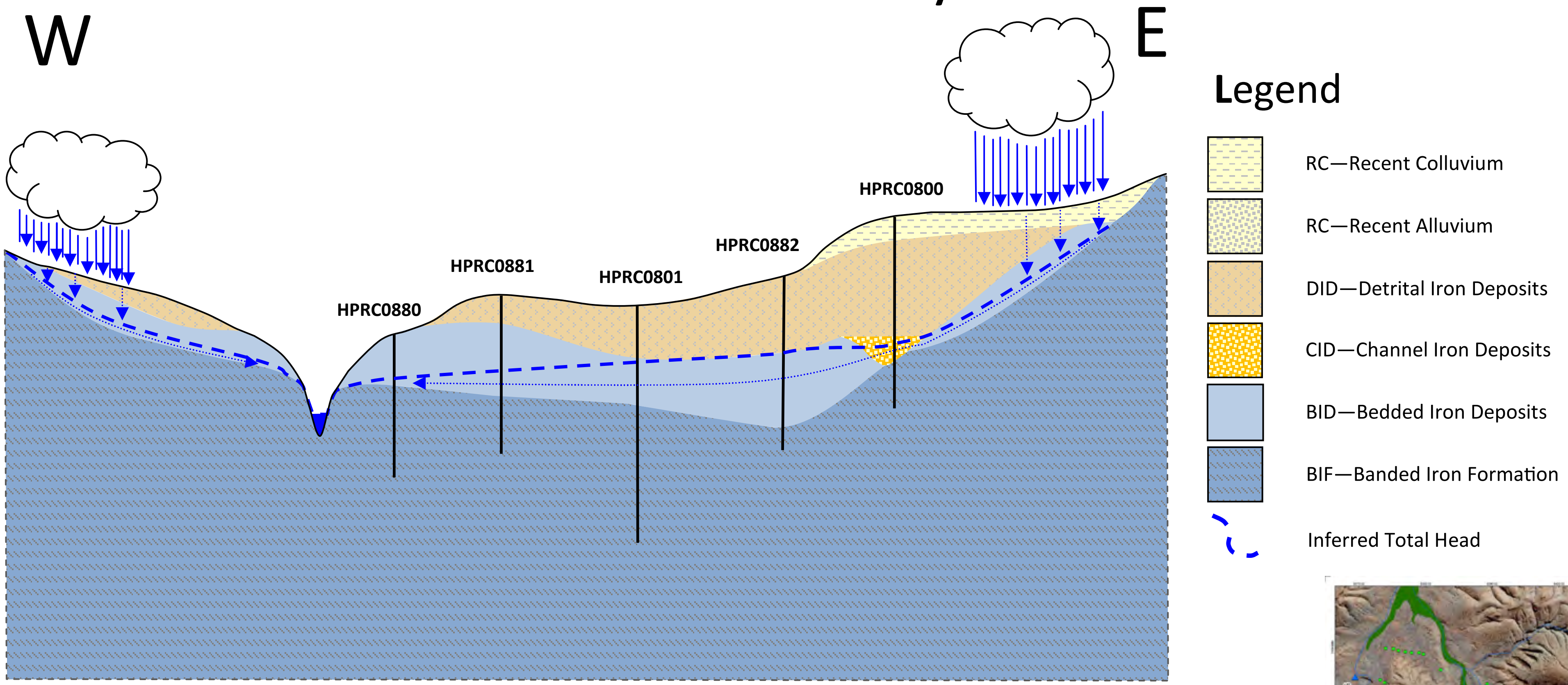
ON and OFF Tenement Areas



Not to Scale. Vertical Exaggeration approx. 1:10

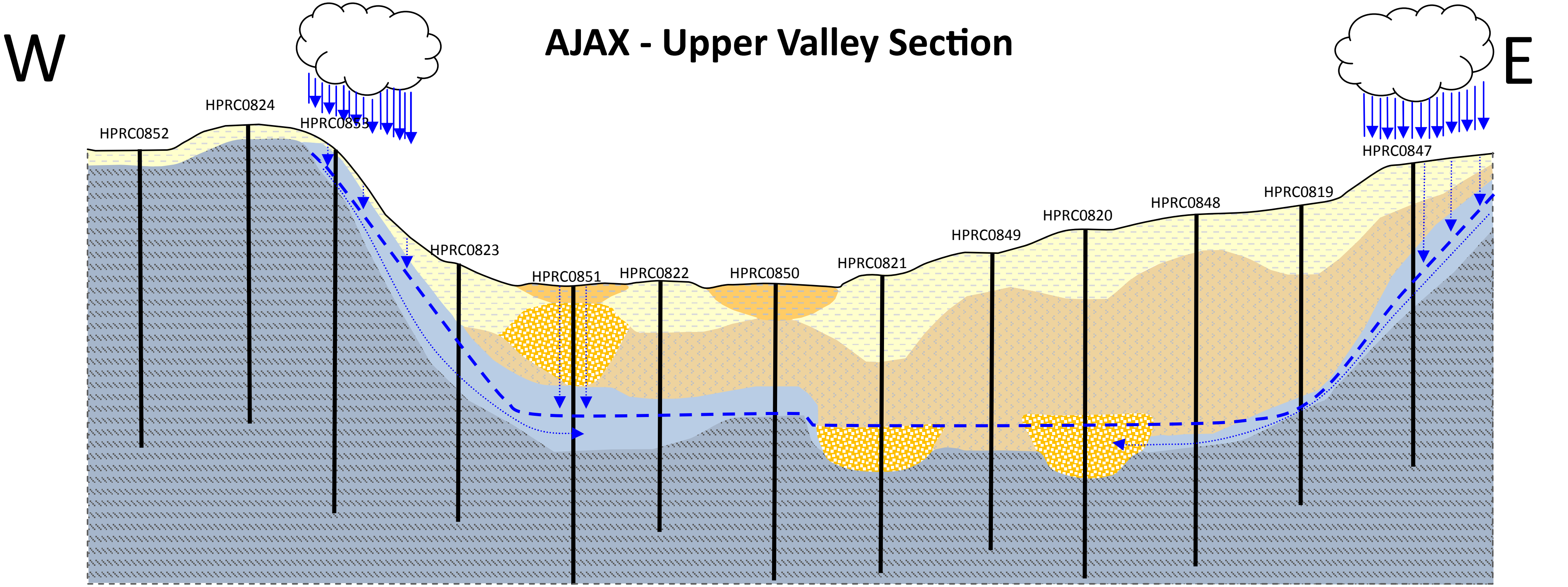
Disclaimer: This Figure is a conceptual diagram only and is a result of an interpretation of data collected.

AJAX - Lower Valley Section



Approximately 10x Vertical exaggeration

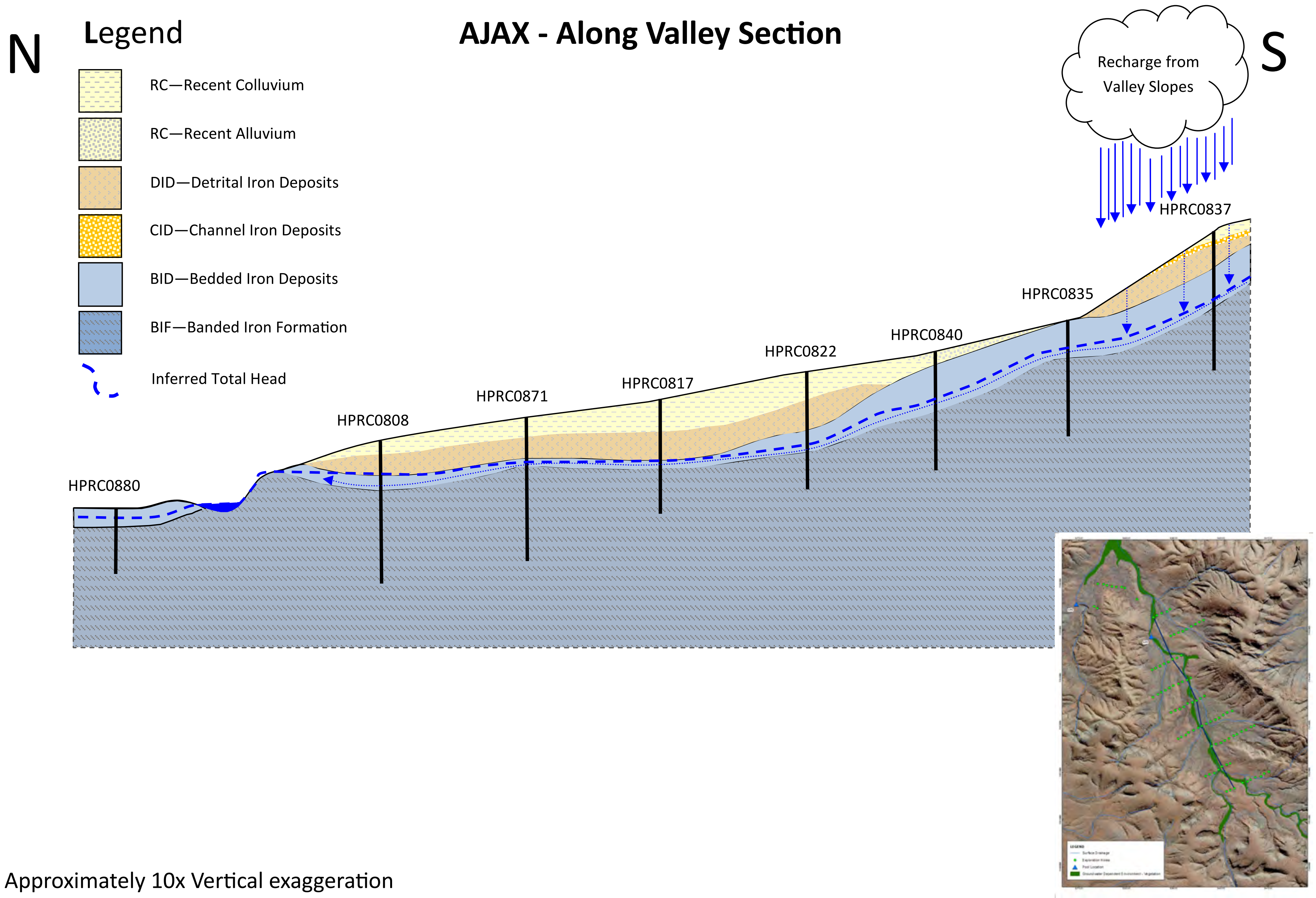
AJAX - Upper Valley Section



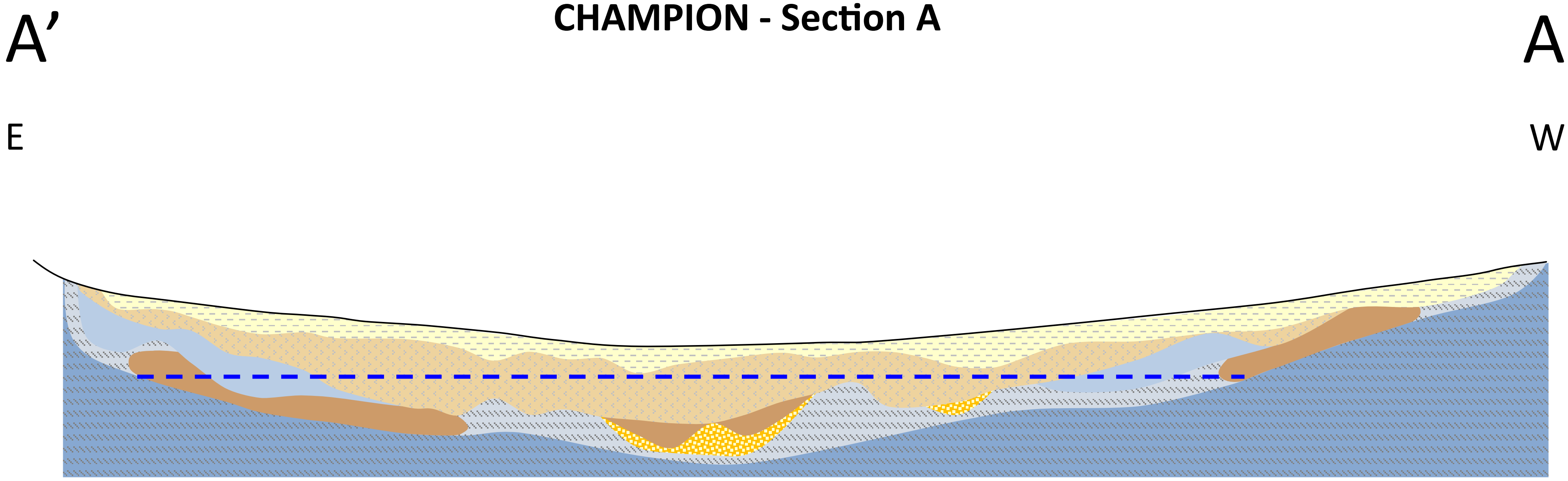
Approximately 9x Vertical exaggeration

Legend

- RC—Recent Alluvium
- RC—Recent Colluvium
- DID—Detrital Iron Deposits
- CID—Channel Iron Deposits
- BID—Bedded Iron Deposits
- BIF—Banded Iron Formation
- Inferred Total Head


N
Legend
AJAX - Along Valley Section
S
Recharge from
Valley Slopes
RC—Recent Colluvium
RC—Recent Alluvium
DID—Detrital Iron Deposits
CID—Channel Iron Deposits
BID—Bedded Iron Deposits
BIF—Banded Iron Formation
Inferred Total Head
HPRC0837
HPRC0835
HPRC0840
HPRC0822
HPRC0817
HPRC0871
HPRC0808
HPRC0880
Approximately 10x Vertical exaggeration

CHAMPION - Section A



Legend

RC—Recent Alluvium/Colluvium

DID—Detrital Iron Deposits

Clay

CID—Channel Iron Deposits

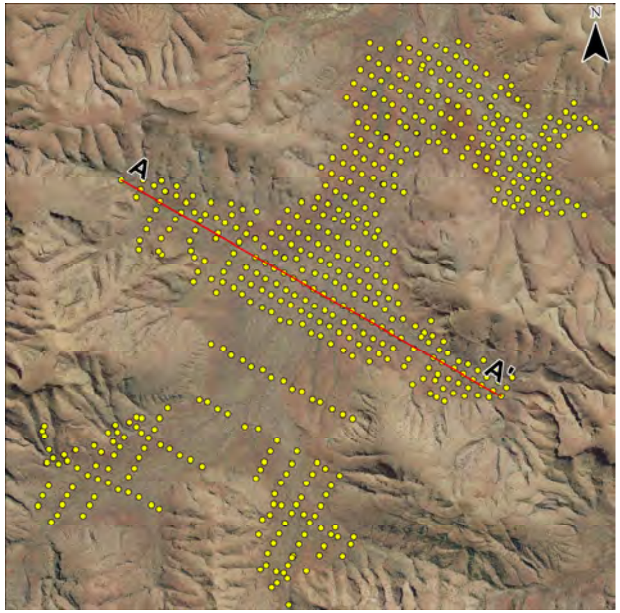
BID—Bedded Iron Deposits

WBIF—Weathered Banded Iron Formation

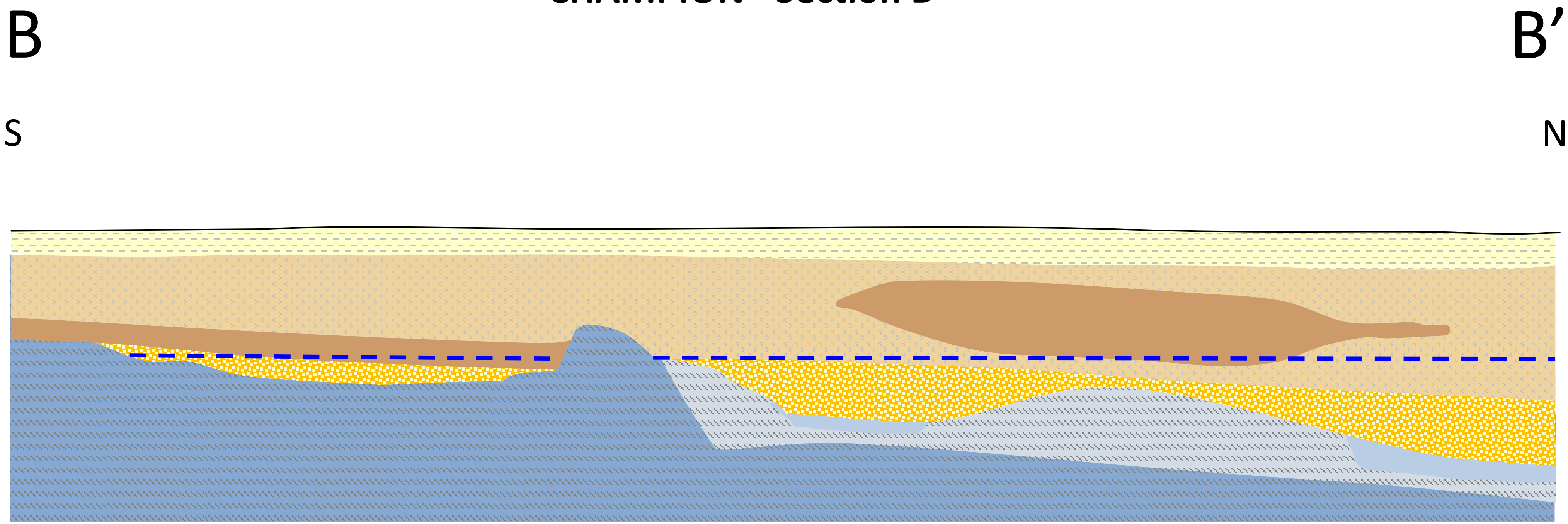
BIF—Banded Iron Formation

Inferred Total Head

3x Vertical exaggeration



CHAMPION - Section B



Legend

RC—Recent Alluvium/Colluvium

DID—Detrital Iron Deposits

Clay

CID—Channel Iron Deposits

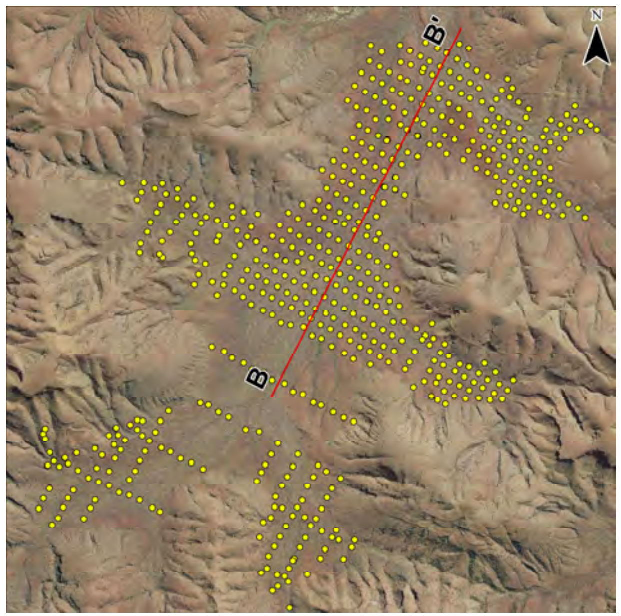
BID—Bedded Iron Deposits

WBIF—Weathered Banded Iron Formation

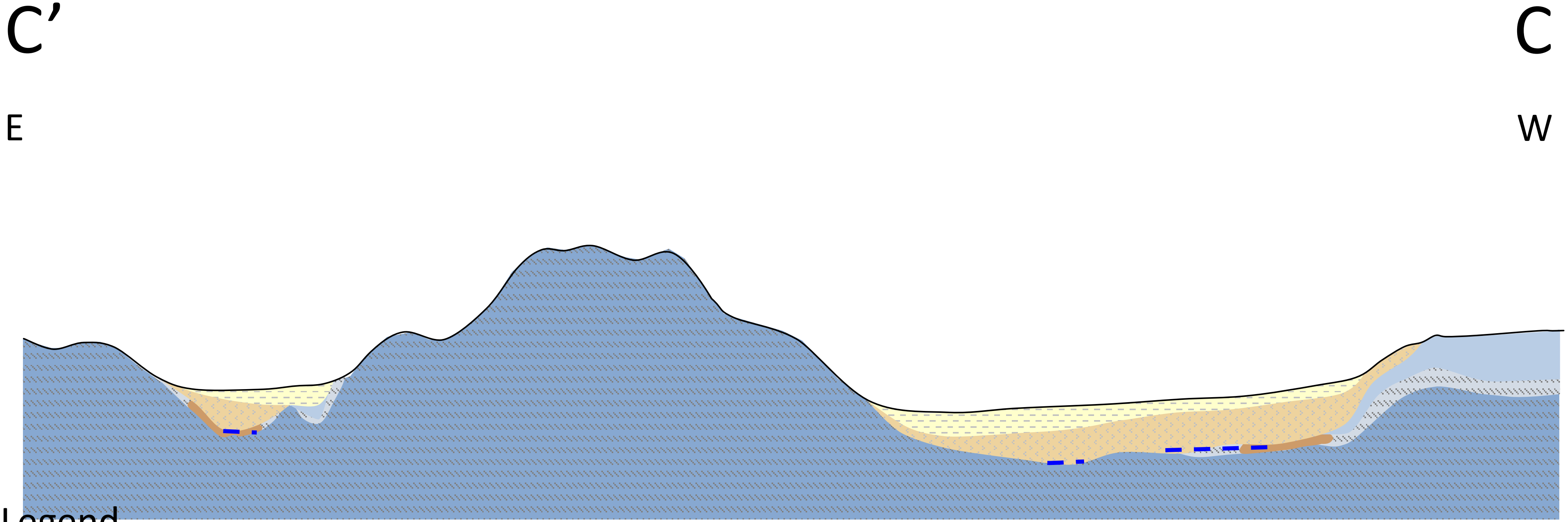
BIF—Banded Iron Formation

Inferred Total Head

Not to Scale



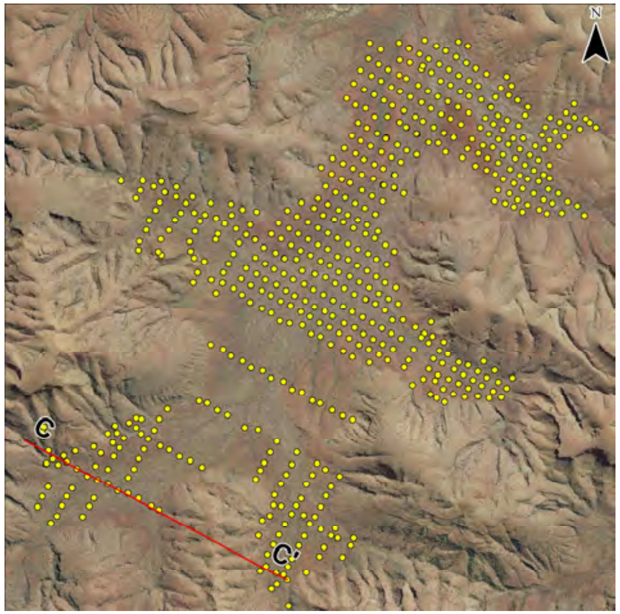
CHAMPION - Section C



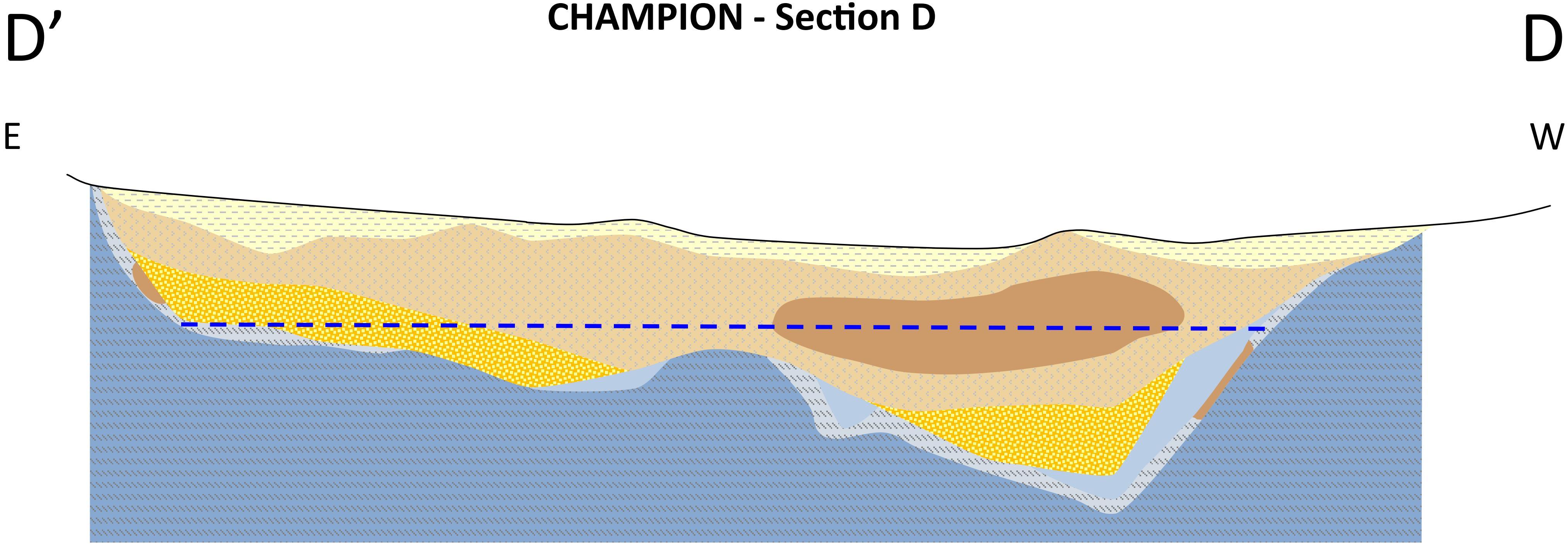
Legend

- RC—Recent Alluvium/Colluvium
- DID—Detrital Iron Deposits
- Clay
- CID—Channel Iron Deposits
- BID—Bedded Iron Deposits
- WBIF—Weathered Banded Iron Formation
- BIF—Banded Iron Formation
- Inferred Total Head

3x Vertical exaggeration



CHAMPION - Section D



Legend

RC—Recent Alluvium/Colluvium

DID—Detrital Iron Deposits

Clay

CID—Channel Iron Deposits

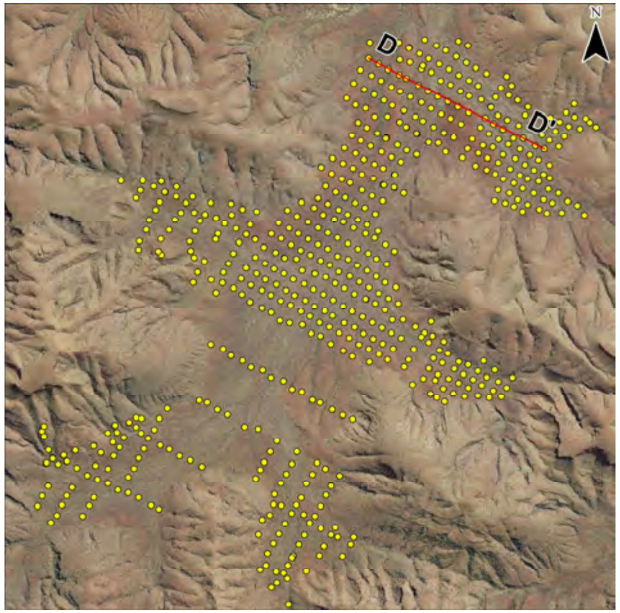
BID—Bedded Iron Deposits

WBIF—Weathered Banded Iron For-

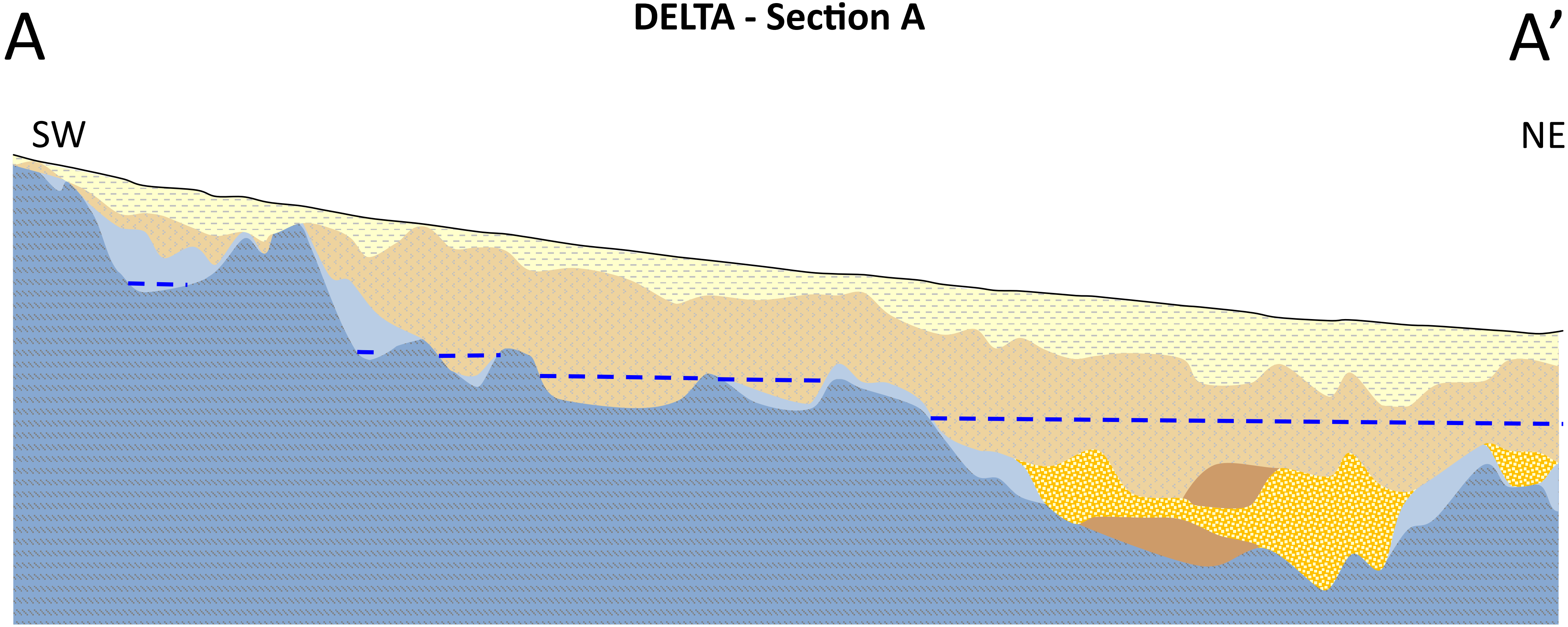
BIF—Banded Iron Formation

Inferred Total Head

3x Vertical exaggeration



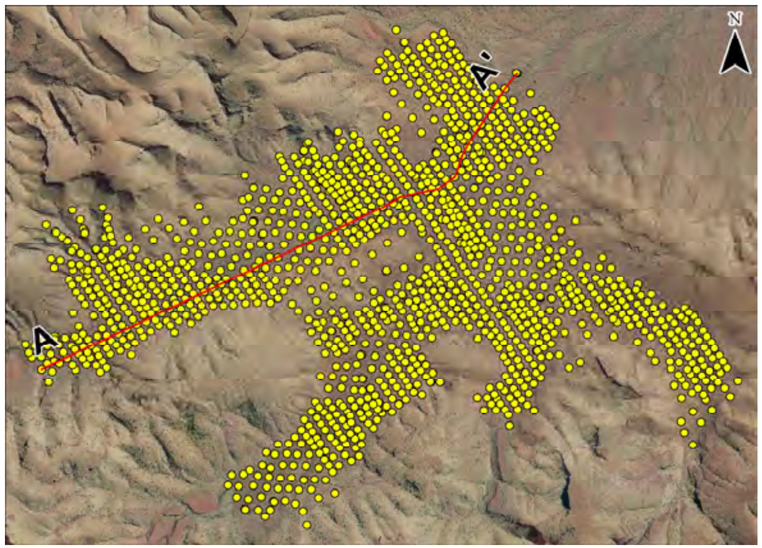
DELTA - Section A



Legend

- RC—Recent Alluvium/Colluvium
- DID—Detrital Iron Deposits
- Clay
- CID—Channel Iron Deposits
- BID—Bedded Iron Deposits
- BIF—Banded Iron Formation
- Inferred Total Head

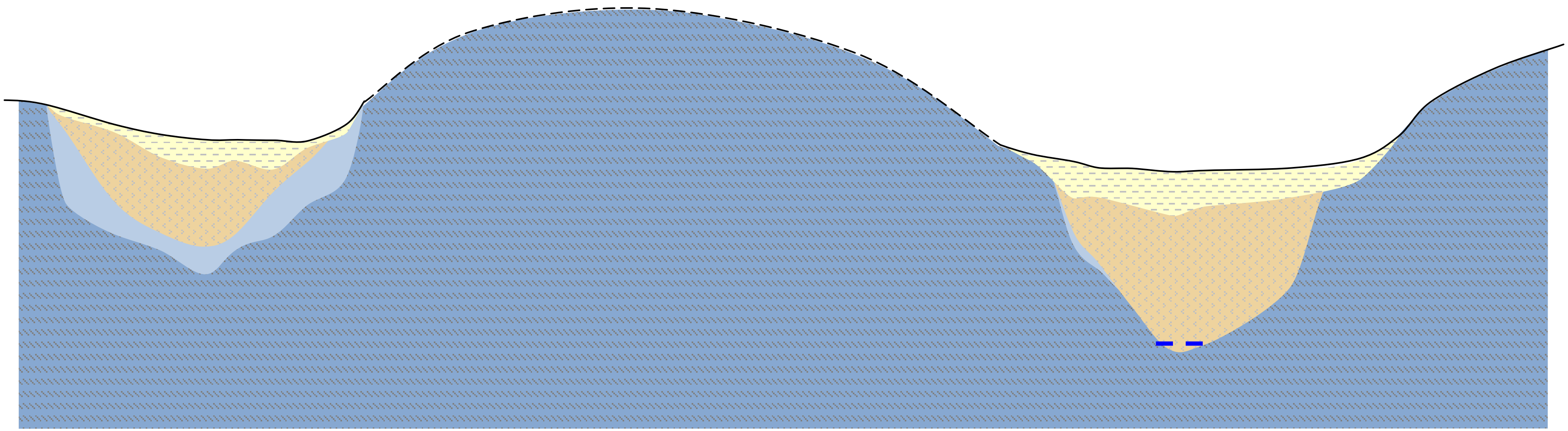
3x Vertical exaggeration



DELTA - Section B

B B’

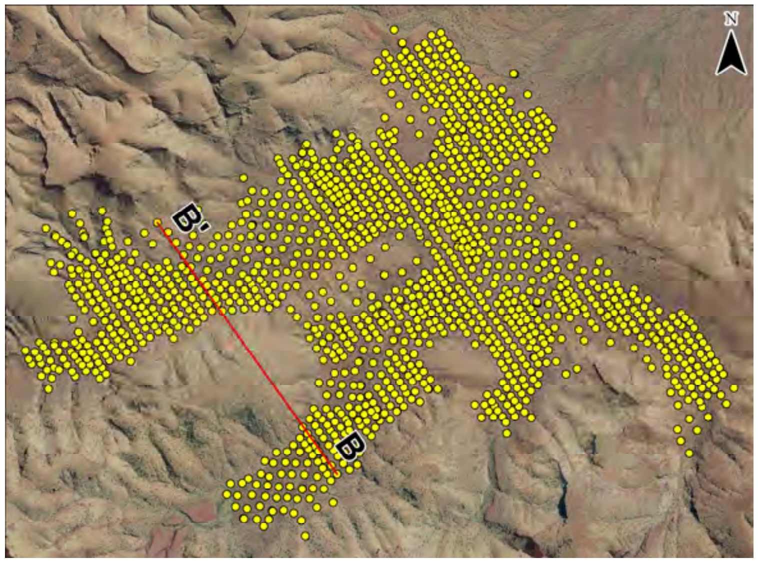
SE NW

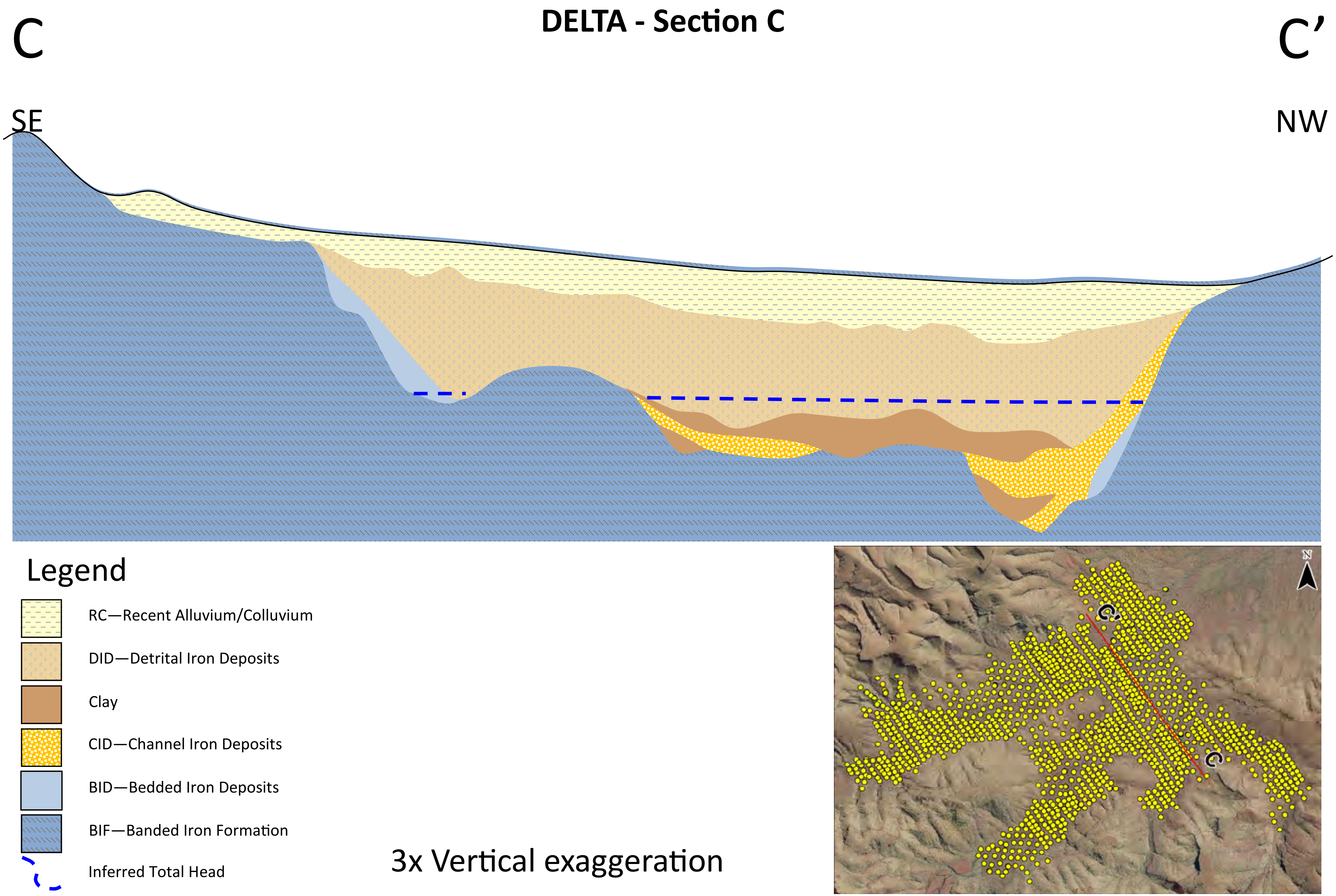


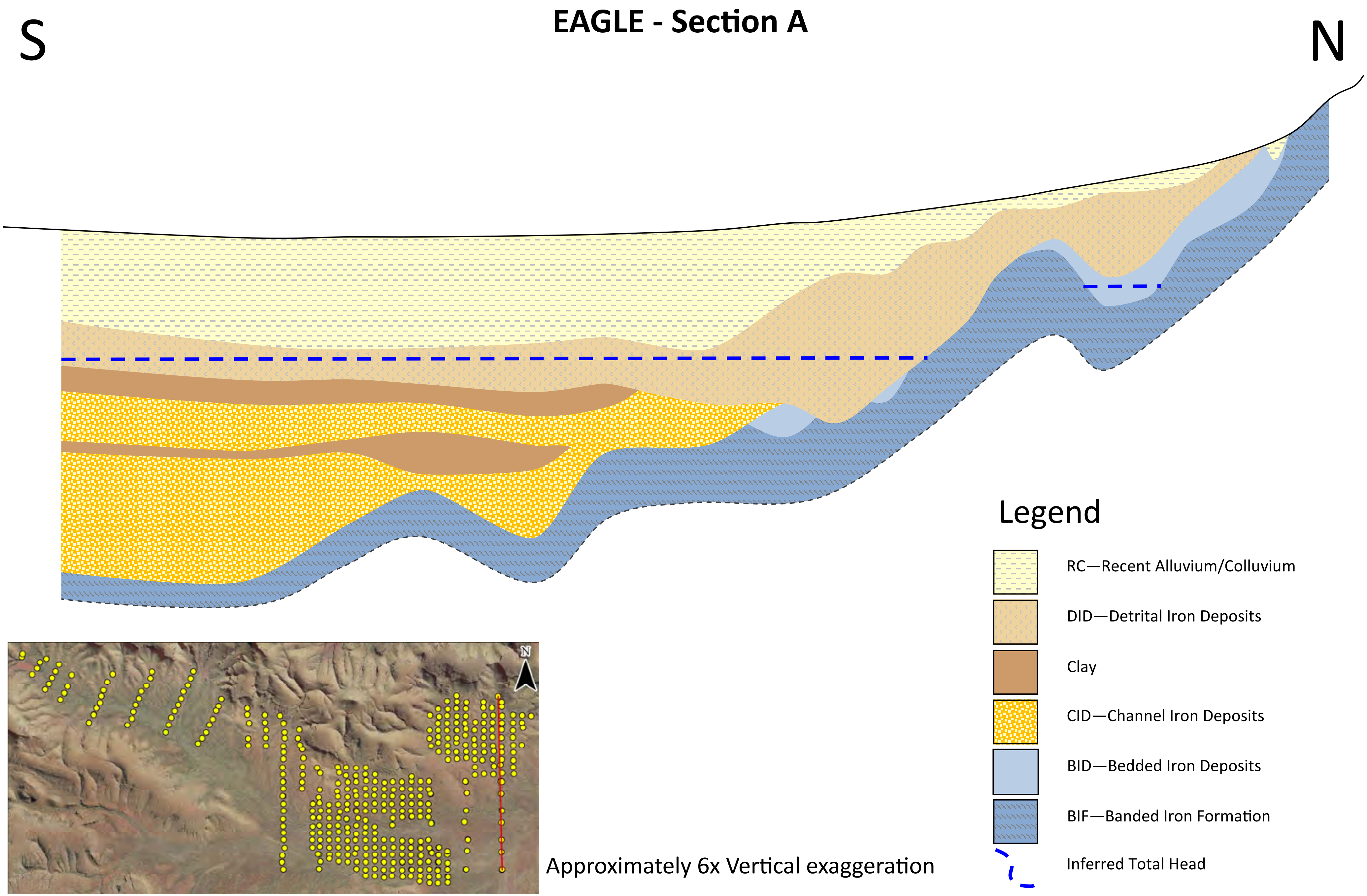
Legend

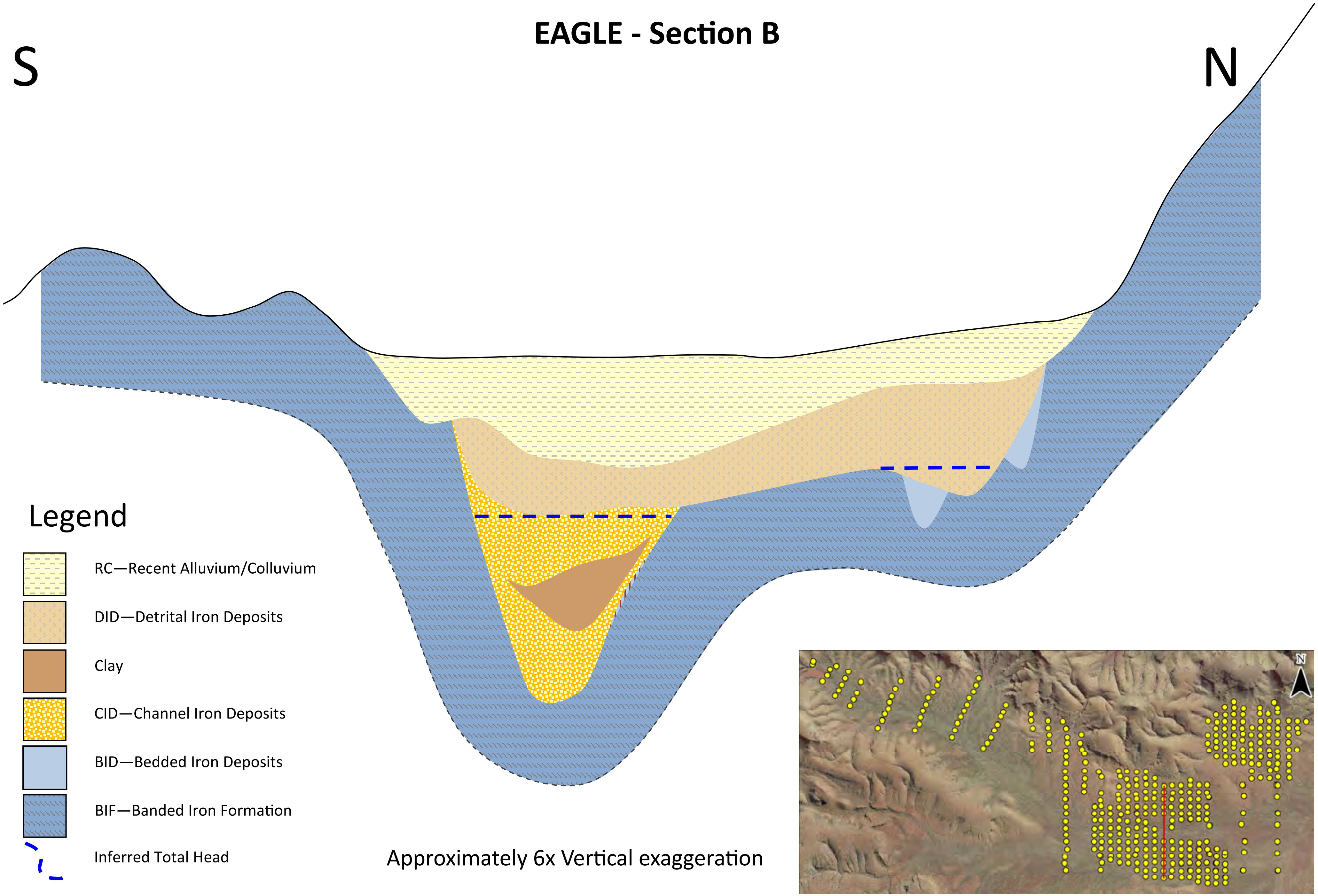
- RC—Recent Alluvium/Colluvium
- DID—Detrital Iron Deposits
- Clay
- CID—Channel Iron Deposits
- BID—Bedded Iron Deposits
- BIF—Banded Iron Formation
- Inferred Total Head

3x Vertical exaggeration

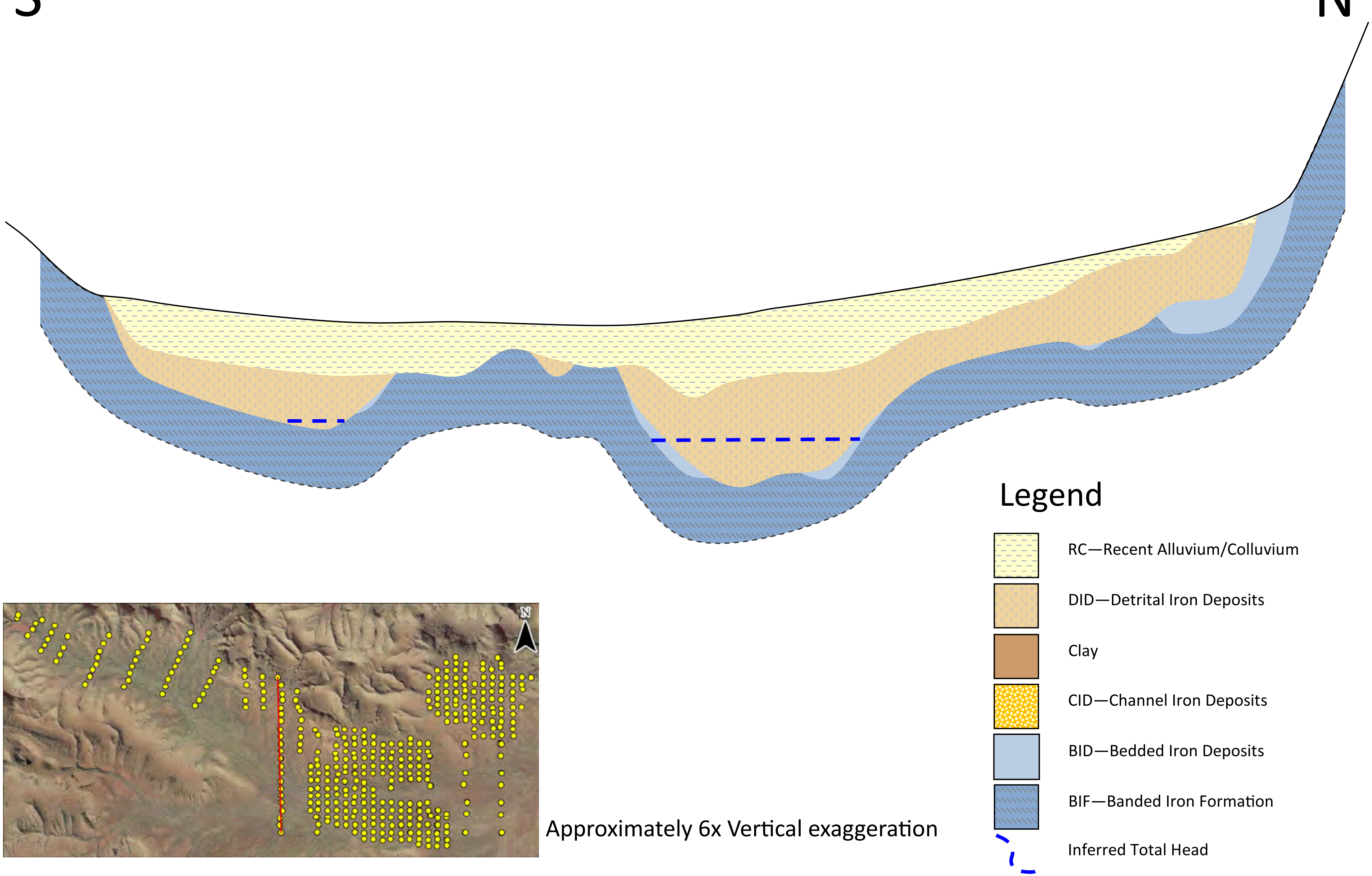


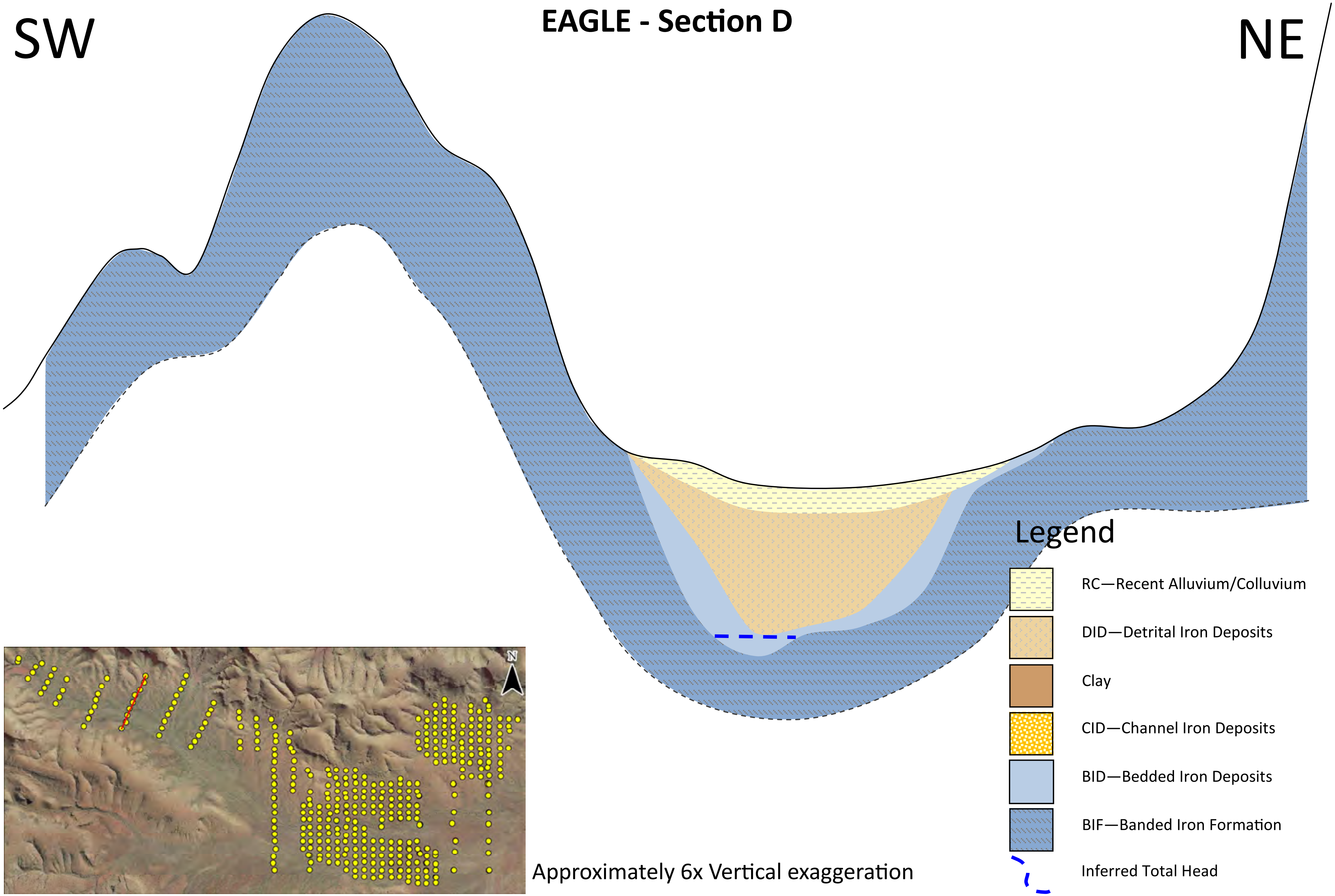

DELTA - Section C
C
C'
SE
NW
Legend
RC—Recent Alluvium/Colluvium
DID—Detrital Iron Deposits
Clay
CID—Channel Iron Deposits
BID—Bedded Iron Deposits
BIF—Banded Iron Formation
Inferred Total Head
3x Vertical exaggeration
N
C'
C


EAGLE - Section A
S
N
Legend
RC—Recent Alluvium/Colluvium
DID—Detrital Iron Deposits
Clay
CID—Channel Iron Deposits
BID—Bedded Iron Deposits
BIF—Banded Iron Formation
Inferred Total Head
Approximately 6x Vertical exaggeration
N


EAGLE - Section B
S
N
Legend
RC—Recent Alluvium/Colluvium
DID—Detrital Iron Deposits
Clay
CID—Channel Iron Deposits
BID—Bedded Iron Deposits
BIF—Banded Iron Formation
Inferred Total Head
Approximately 6x Vertical exaggeration
N

EAGLE - Section C





EAGLE - Section D
SW
NE
Legend
RC—Recent Alluvium/Colluvium
DID—Detrital Iron Deposits
Clay
CID—Channel Iron Deposits
BID—Bedded Iron Deposits
BIF—Banded Iron Formation
Inferred Total Head
N
Approximately 6x Vertical exaggeration

Appendix 7: Recharge Estimates

Flinders PIOP
Recharge Calculations
25th Feb 2012

CATCHMENT NAME	Total Catchment Area (m^2)	Total Catchment Area (km^2)	% of the Millstream area	Estimated Recharge to Millstream based on catchment area (GL/yr)	Estimated Catchment Recharge to Local Aquifers Assuming 5% (GL/yr)
Ajax	35662277	36	0.7%	0.18	0.8
Blackjack	11340884	11	0.2%	0.06	0.3
Champion	30970726	31	0.6%	0.16	0.7
Delta	18790218	19	0.3%	0.09	0.4
Eagle	27400164	27	0.5%	0.14	0.6
Serenity	203329847	203	3.7%	1.03	4.6
Entire Millstream Catchment *	**5480000000**	5480	**100.0%**	**27.7**	**125**

* Based on the 27.7 GL/yr average annual recharge at Millstream presented in:
Source: Barnett and Davidson, 1985. Hydrogeology of the Western Fortescue Valley, Pilbara Region, WA, Geological Survey 1985.

Annual Rainfall at Wittenoom (mm/yr) **457**

Recharge Estimates taken from Barnett and Davidson (1985)

Catchment	Recharge Estimates (m3/a)	% of total
Hamersley Range-Mount Flora	2600000	9.4%
Hamersley Range-Mount Pyrton	1400000	5.1%
Caliwingina Creek	7700000	27.8%
Weelumurra Creek	16000000	57.8%
Total	**27,700,000**	**m3/a**
	27.7	**GL/a**

Appendix 8: Area and Volume Calculations

Flinders PIOP
Approximate aquifer volume and areas
25/02/2012

Location	Volume of Aquifer (m^3)	Porosity	Volume of Water in Aquifer (m^3)	Volume of Water in Aquifer (GL)	Volume of Aquifer Impacted (m3)	Volume of Aquifer Impacted (GL)	% Impacted	Maximum reduction in saturated aquifer thickness (m)	Maximum Drawdown in Total Head (m)
	Approximate Values Derived from Available Data *								
Eagle	54,590,000	0.15	8,188,500	8.2	8,188,500	8.2	100%	60	70
Delta	43,850,000	0.15	6,577,500	6.6	6,577,500	6.6	100%	48	70
Champion	35,750,000	0.15	5,362,500	5.4	5,362,500	5.4	100%	66	66
Blackjack	1,297,500	0.15	194,625	0.2	194,625	0.2	100%	Insufficient data available	Insufficient data available
Ajax	6,376,250	0.15	956,438	1.0	956,438	1.0	100%	Insufficient data available	Insufficient data available
Off-Tenement at Serenity (at Eagle and Delta)	760,995,503	0.15	114,149,326	114.1	-	0.0	0%	0	9.5
Off-Tenement at Champion	72,834,234	0.15	10,925,135	10.9	3,899,647	3.9	36%	40	40
Total	**975,693,487**	**0.15**	**146,354,023**	**146.4**	**25,179,210**	**25.2**	**17%**	**N/A**	**N/A**

Location	Area of Aquifer (m^2)	Area of Aquifer Impacted (m^2)	% Impacted
	Approximate Values Derived from Available Data *		
Eagle	7,939,973	7,939,973	100%
Delta	6,847,489	6,847,489	100%
Champion	7,244,153	7,244,153	100%
Blackjack	1,575,252	1,575,252	100%
Ajax	3,941,913	3,941,913	100%
Off-Tenement at Serenity (at Eagle and Delta)	46,632,552	-	0%
Off-Tenement at Champion	4,310,723	2,305,900	53%
Total	**78,492,055**	**29,854,680**	**38%**
Total considering CID aquifer within Caliwigina Creek and Weelumurra Creek catchments	**165,672,000**	**29,854,680**	**18%**
Total estimated aquifer within Caliwigina Creek and Weelumurra Creek catchments	**292,640,460**	**29,854,680**	**10%**

* The calculations and modelling for off-tenement areas has been based on little or no available off tenement data. The data collected for on tenement areas at Eagle, Champion and Delta has been extrapolated to off-tenement areas, and is assumed to be representative. The estimates for Ajax and Blackjack are also based on limited available groundwater data. Additional data is needed for off-tenement areas as well as at Ajax and Blackjack to confirm these calculated values.

Assumptions:

1) The off tenement impacts at Ajax and Blackjack are assumed to be negligible because it is assumed that all mine dewater will be returned to the aquifer.

2) The results reflect the net impact of pumping 1.33GL/a from Delta, Eagle and Champion to meet the project water demands (4GL/a in total). It has been assumed that all excess mine dewater is returned to the aquifer.

3) The volume of aquifer impacted is defined here as the volume of the aquifer that has been dried out due to dewatering. The area of aquifer impacted is the corresponding extent of the aquifer that has been dried out due to dewatering. This assumes that the saturated thickness must be reduced to dry 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).