HASTINGS
Technology Metals Limited

APPENDIX 4-2

Hydrogeological Assessment

REPORT ON

DFS STUDY – STAGE I HYDROGEOLOGICAL ASSESSMENT

YANGIBANA RARE EARTHS PROJECT

Prepared for

Hastings Technology Metals Limited

c/o Wave International

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Report Distribution

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EXECUTIVE SUMMARY

Hastings Technology Metals Limited is currently undertaking a Definitive Feasibility Study (DFS) an the basis of developing their Yangibana Rare Earths Project, comprising three proposed pits (Fraser's, Bald Hills and Yangibana), with on-site processing, a camp and an airstrip. The Project has a proposed Life of Mine (LoM) of seven years, and an estimated annual water demand of 2.5 GL/annum (79.3 L/sec). Hastings has commissioned Groundwater Resource Management Pty Ltd (GRM) to undertake the hydrogeological components of the DFS, which is being conducted in two stages. The Stage I DFS study comprised a dewatering assessment, including field investigations, a preliminary water supply assessment involving re-use of mine water and a post closure pit lake assessment.

The field testing programme comprised groundwater exploration drilling of 6 drill-holes; hydraulic testing of 12 drill-holes; installation of two test production bores; test pumping of three production bores; and the collection of groundwater samples for laboratory analysis. The results indicate that modest permeability is associated with the extensive ironstone dykes (which also host the mineralisation). The fractured and vuggy ironstone dykes are semi-confined, regionally extensive, and outcrop to the north east of the proposed pits and plunge to the south west. The data suggests generally low permeability conditions within the overlying and underlying granitic sequences. The groundwater is fresh to slightly brackish, ranging from 920 to 1,200 mg/L TDS, and the groundwater flow direction is to the south south-west (towards the Lyons River). Groundwater samples for isotope analysis, for the purpose of age dating, have been collected and submitted to ANSTO for assessment.

The results of the field testing programme were used to develop a 3D groundwater flow model for the proposed pits which indicate dewatering rates of between 6 L/sec during the year 2, when mining extends below the water table, to 51 L/sec during year 7. The drawdown extents at the end of mining are asymmetrical which reflects the geometry of the aquifer, with the predicted 5 m drawdown contour extending up to 1.5 km from the pit perimeter at Fraser's, up to 1.25 km from the pit perimeter at Bald Hills and up to 2 km from the pit perimeter at Yangibana. The simulated drawdown contours suggest that other groundwater users in the area (for stock watering purposes) should not be impacted by mine dewatering. The modelling indicates that dewatering will be best achieved by a combination of ex-pit dewatering bores and sump pumping.

A pit lake model was developed for each pit and run over a 500 year period to estimate pit lake conditions after mine closure. The results indicate that the risk of impact (i.e. discharge of pit lake water) to the groundwater environment post closure is low. However pit catchment areas have not been delineated or characterised for the Project, and consequently the models were based on a nominal catchment size of 20% of the pit area. Considering that the residual drawdown in the pits is a function of the ex-pit catchment parameters, the pit lake modelling will require re-running once the ex-pit catchment parameters are established.

The Project will require additional water supply sources to supplement the dewatering supply and met the Projects total water demand. The ironstone aquifer potentially has limited storage and sufficient water supply contingency will be necessary to accommodate for this. Additional water supply options have been identified which include extended use of dewatering bores and sump pumping; a sacrificial bore at Yangibana; water supply bore/s at Auer North; a water supply borefield in the Western Belt, and a water supply borefield in the Lyons Palaeochannel. It is expected the demand can be met from these sources. However, further field investigations as part of the Stage II DFS study will be necessary to confirm the water supply potential of these sources.

GLOSSARY OF HYDROGEOLOGICAL TERMS

Aquifer	A saturated geological unit that is permeable enough to yield economic quantities of water.
Aquitard	A geological unit that is permeable enough to transmit water but not sufficient to yield economic quantities.
Aquiclude	A geological unit that is impermeable, *i.e.* cannot transmit water.
Confined Aquifer	An aquifer bounded above and below by an aquiclude, where the water level in the aquifer extends above the aquifer top and is represented by a pressure head, *i.e.* the aquifer is completely saturated.
Drawdown	The change in hydraulic head observed at a well in an aquifer, typically due to pumping.
Leaky Aquifer or Semi-Confined Aquifer	An aquifer with upper and/or lower boundaries as an aquitard, where the water level in the aquifer extends above the aquifer top and is represented by a pressure head. Pumping from the aquifer induces leakage from the neighbouring aquitard units.
Unconfined or Watertable Aquifer	An aquifer that is bounded below by an aquiclude, but is not restricted on its upper boundary, which is represented by the water table.
Hydraulic Conductivity (K) ***[Permeability]***	The volume of water that will flow in a unit time under a unit hydraulic gradient through a unit area. Analogous to the permeability with respect to fresh water (units commonly m/d or m/s).
Transmissivity (T)	The product of the hydraulic conductivity and the saturated aquifer thickness (units commonly $m^3/d/m$ or m^2/d)
Specific Storage (S_s)	The volume of water released from a unit volume of aquifer under a unit decline in hydraulic head, assuming confined aquifer conditions. Water is released because of compaction of the aquifer under effective stress and expansion of the water due to decreasing pressure (units commonly m^{-1}).
Storativity (S)	The volume of water released from a unit area of aquifer, i.e the aquifer column, per unit decline in hydraulic head (dimensionless parameter).
Specific Yield (S_y)	The volume of water released from an unconfined aquifer per unit decline in the water table. The release of water is mostly from aquifer draining. Contributions from aquifer compaction are generally small. Analogous with effective porosity (dimensionless parameter).

Terms referenced from Kruseman GP and deRidder NA (1994) 2nd edition, Analysis and Evaluation of Pumping Test Data. ILRI Publication 47 The Netherlands.

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1.0 INTRODUCTION

Hastings Technology Metals Limited (Hastings) owns the Yangibana Rare Earths Project (the Project), located approximately 150 km north east of Gascoyne Junction, in the Upper Gascoyne region of Western Australia (Figure 1).

The Project's tenement package covers approximately 650 km^2, and hosts extensive rare-earths-bearing ferrocarbonatite/ironstone veins containing neodymium, praseodymium and dysprosium in a monazite ore. The elements are of interest to the rare earths magnet market, and the advancing technologies in electric vehicles, wind turbines, robotics and digital services.

Hastings is currently undertaking a Definitive Feasibility Study (DFS) on the basis of developing three proposed pits; Fraser's, Bald Hills and Yangibana (Figure 2), with on-site processing, FIFO / DIDO mine camp and an airstrip.

The pits will be developed using conventional open cut methods to depths of 70 m below ground level at Fraser's and 95 m below ground level at both Bald Hills and Yangibana. The three pits extend well below the ambient groundwater level and will require pit dewatering to maintain dry mining conditions.

On-site processing will produce a rare earth elements (REE) concentrate, via a crushing, grinding and flotation circuit. The plant has a proposed annual throughput of 1 Mtpa, producing approximately 12,000 to 13,000 tpa of REE concentrate. The Project's proposed Life of Mine (LoM) is seven years.

The project has an estimated water demand of up to 2.5 GL/annum (79.3 L/sec), for the purposes of mineral processing, dust suppression and camp / potable supply (via reverse osmosis treatment).

A desktop hydrogeological report for the Project was completed by Global Groundwater in 2016. Hastings has subsequently commissioned Groundwater Resource Management Pty Ltd (GRM) to assist them with the hydrogeological components of the DFS, which includes:

- A dewatering assessment for the proposed pits.
- A water supply options assessment for the project.
- An assessment of pit void conditions post closure.
- A site water balance model.

This report presents the Stage I study results, which includes the dewatering assessment, preliminary post closure pit void assessment, preliminary water supply assessment, and recommendations for the subsequent Stage II study.

2.0 BACKGROUND

2.1 Project Description

The Project is situated approximately 270 east north-east of Carnarvon, and 150 km north east of Gascoyne Junction. The Mount Augustus National Park is approximately 80 km south east of the project and the Kennedy Range National Park is approximately 100 km to the south west.

The Project is located within tenure covering an area of some 650 km^2, with mining activities proposed across six tenements (M09/157to M09/162) and associated infrastructure across ten general purpose and miscellaneous tenements.

The tenements comprising the Project are within the Gifford Creek and Wanna pastoral stations. There are no other mining developments in the local Shire of Upper Gascoyne, with the nearest mining operation being the Useless Loop (in the Shire of Shark Bay) and Lake Macleod (north of Carnarvon) areas.

The topography in the Project area has been influenced by the Lyons River to the south (Figure 2), and a small range of hills to the north of Fraser's and Bald Hills. The remainder of the area is characterised by subdued topography, with rounded granitic hills and open flat areas, cross cut by small dendritic drainages.

The Project is situated within the Lyons River catchment. The Lyons River itself is located about 10 km south of the Project and flows westward, ultimately discharging to the Gascoyne River. Several smaller creeks, including Fraser Creek and Yangibana Creek cross the Project site in a roughly north to south direction, discharging to the Lyons River (Figure 2). The creeks and rivers in the region are ephemeral, only flowing following significant rainfall events.

2.2 Climate

The Gascoyne region is semi-arid to arid, characterised by cool daytime temperatures in winter, and hot daytime temperatures in summer. Rainfall is typically bi-modal, whereby intense summer rainfall can result from the passage of tropical cyclones from the north west, whilst winter rainfall is typically less intense, and associated with cold winter fronts from the south west.

The nearest registered Bureau of Meteorological (BoM) weather station is Wanna (station number 7028), located approximately 12 km south of the Project. The station has a 98% complete data set for the 63 year period between 1 Jan 1946 to 31 October 2009. Minimum, maximum and mean monthly rainfall data is provided in Table 1. The data from Wanna indicates that the average annual rainfall is around 240 mm, with the highest rainfall occurring from January to March, closely followed by May and June.

Evaporation data is recorded at Paraburdoo (station number 7178), located 160 km north east of the Project, and Learmonth Airport (station number 5007), 290 km north west of the Project. The data from Paraburdoo and Learmonth has been scaled, based upon distance, to develop an estimate of average monthly evaporation for Yangibana, as provided in Table 1.

The evaporation data indicates that the pan evaporation exceeds mean monthly rainfall in all months of the year, with the total annual evaporation well over an order of magnitude higher than the annual rainfall.

Table 1: Long Term Average Rainfall and Evaporation Data

Month	Wanna (BoM station 7028)			Yangibana Project*
	Minimum Monthly Rainfall (mm)	Maximum Monthly Rainfall (mm)	Mean Monthly Rainfall (mm)	Mean Monthly Pan Evaporation (mm)
January	0	155.0	32.5	411
February	0	219.4	59.0	365
March	0	258.2	32.3	335
April	0	110.0	18.1	272
May	0	148.5	25.3	187
June	0	170.0	32.0	137
July	0	106.2	18.9	147
August	0	104.1	10.1	191
September	0	28.9	2.7	261
October	0	43.5	3.0	346
November	0	24.1	3.3	396
December	0	49.0	7.7	427
		Annual Total	**240.2**	**3,475**

2.3 Geology

The description of the geological conditions associated with the project are derived from information provided by Hastings and Global Groundwater (2016).

The Project is located within the Gascoyne Province of the Capricorn Orogen, bounded by the Archean Yilgarn Craton to the south, the Archean Pilbara Craton to the north, and the Phanerozoic Carnarvon Basin to the west.

The predominant lithology in the area is the Durlacher Supersuite granites, which comprise the Pimbyana Granite, the Dingo Creek Granite, the Yangibana Granite and several other un-named units. The suite mainly consists of monzogranite and granodiorite, with lesser syenogranite and minor amounts of tonalite and rare gabbro.

Within the Project area, the granites contain rafts of older sedimentary rocks, and intrusive dykes. The primary mineralisation occurs in narrow, regionally extensive ironstone dykes. The ironstone dykes dip to the south west, outcropping to the north east.

The dykes carry anomalous rare earths within the monazite mineralisation. The dykes are understood to be a younger intrusive phase which has cross cut slightly older feroocarbonatite dykes, possibly leaching and upgrading rare earths (and base metals) from them. The carbonatite dykes (which form the Gifford Creek Carbonatite Complex), along with associated fenitic alteration, is considered to be sourced from (an as yet undiscovered) carbonatite intrusion at depth, which could potentially host significant rare earths and base metals.

2.4 Regional Hydrogeology

The description of the regional hydrogeological conditions are derived from publicly available information provided by Hastings, and the desktop study completed by Global Groundwater (2016).

The project is located within the Bangemall/Capricorn Groundwater subarea of the Gascoyne Groundwater area. Groundwater resources within the subarea comprise alluvium, calcrete, palaeochannel and fractured rock aquifers.

The hydrogeology of the area is characterised by a south westerly draining system, coincident with the Lyons River surface water catchment. Alluvial cover is typically thin or absent across the majority of the area, but thickens near the creeks and major drainages.

Groundwater occurrences in the area predominantly occur as fractured bedrock aquifers, whereby permeability in the natural rock is enhanced by fracturing, dissolution and chemical weathering. Away from the fractures permeability in the bedrock is typically low. In the Project are the extensive ironstone dykes form a potentially significant fractured rock aquifer. The ironstone aquifer is discussed in more detail later in this report.

Groundwater occurrences are also known to occur in calcrete aquifers in the area. Thorpe (1990) identified that calcrete extends to depths of 30 m within the Edmund and Lyons Rivers, and likely extends over large areas beneath the alluvial cover.

Small amounts of groundwater can occur in alluvium associated with the larger drainage systems. However away from the larger drainage systems the alluvium is typically absent or of insufficient thickness to extend below the water table.

Groundwater is recharged by direct rainfall infiltration or by stream flow during episodic rainfall events. Recharge is expected to be highest following streamflow events, in locations where the alluvium overlies more permeable units (such as calcrete or fractured basement). Groundwater recharge by direct infiltration of rainfall is likely to be minor.

Groundwater quality in the area is typically fresh to brackish, with salinities ranging from about 900 to 4,000 mg/L Total Dissolved Solids (TDS). The lowest salinity groundwater occurs closest to the areas of recharge, with salinity increasing away from the recharge areas.

2.5 Other Groundwater Users

A search of bore records within a 20 km radius of Bald Hills was carried using the Water Information Reporting (WIR) database, which is managed by the Department of Water (DoW).

The WIR data indicates that there are 15 registered bores within 20 km of the project tenements. A summary of the bore information is provided in Table 2 below, and the bore locations closest to the Project area are shown in Figure 3.

The WIR data indicates that:

- The closest bores to the proposed pits are Yangibana Bore and Fraser Well, located 5 km south of Yangibana and 5 km west of Fraser's deposits, respectively. The bores are listed as being of unknown type and status. However it is believed the bores are operational livestock bores.

- Nine of the 15 bores are listed as livestock bores. The Roadside bore is listed as an investigation bore, and the remaining five bores are of unknown type. However it is presumed that the bores listed as unknown type are also livestock bores, given the land use in the area.

- Pimbiana Bore is registered as being installed into a calcrete aquifer, and is located approximately 10 km east of Fraser's. Pimbiana Bore is not near the Lyons or Edmund Rivers (as shown in Figure 3) and occurrence of calcrete in this location suggests calcrete may not be restricted to the major rivers, and may extend over larger distances beneath the alluvial cover, as suggested by Thorpe (1990).

- Contessis Well is listed as installed into an alluvial aquifer, and is located approximately 9 km north of Yangibana.

- The remainder of the listed bores are of unknown aquifer type. However, based upon the shallow drilled depths and the locations, it is likely the bores are installed into either alluvial, calcrete or shallow bedrock aquifers.

Table 2: WIR Bores Within 20 km

Site Name	Coordinates MGA Zone 50		Purpose	Status	Aquifer Type	Depth (m)
	Easting	Northing				
Hart Bore	435,911	7,343,600	Livestock	Operational		33.2
Star Well	422,154	7,339,440	Livestock	Operational		9.5
Benbageon Well	444,249	7,362,723	Livestock	Operational		25.6
Boogardi Bore	441,689	7,366,535	-	Operational		48.77
Dingo Well	438,838	7,371,621	Livestock	Operational		-
Cardibar Bore	434,984	7,362,312	-	Unknown		26.82
Gap Bore	430,211	7,371,424	Livestock	Unknown		32.92
Pimbiana Bore	439,609	7,350,284	Livestock	Unknown	Calcrete	-
Henderson Bore	437,326	7,353,953	Livestock	Operational		-
Wallaby Bore	440,420	7,354,405	-	Unknown		-
Roadside Bore	444,679	7,349,061	Investigation	Unknown		33.53
Fraser Well	424,549	7,351,619	-	Operational		23.47
E15 Contessis Well	416,352	7,370,553	Livestock	Operational	Alluvium	21.34
E16 Red Hill Bore	419,949	7,368,896	Livestock	Operational		16.76
Yangibana Bore	414,879	7,357,752	-	Operational		32.61

Groundwater level and water quality data was collected by ATC Williams (Hastings geotechnical consultant) as part of the pre-feasibility study (PFS) for the Project from several of the surrounding livestock bores. The sampled bores are shown in Figure 3 and the data collected is provided in Table 3 below. The data indicates that:

- The depth to groundwater ranges from 2.4 m below ground level at Edmund Homestead to 31.0 m at Fraser Well.
- The pH is neutral to slightly alkaline, ranging from 7.2 in the Red Hill 2 Bore to 8.6 in the Edmund Homestead Bore.
- The water quality is fresh to brackish, ranging from 600 mg/L TDS in the Contessis Bore to 2,800 mg/L TDS in the Red Hill 2 Bore.
- The groundwater reports concentrations above detection limits of arsenic, boron, copper, iron, molybdenum, silicon, vanadium, tin, strontium, selenium and uranium.

Table 3: Livestock Bore Data

Parameter	Edmund HST	Minga Well	Contessis Bore	Edmund Well	Fraser Well	Yangibana Bore	Woodsys Bore	Red Hill 2
Easting (MGA z50)	410,186	407,894	416,349	405,351	424,854	414,866	413,896	419,832
Northing(MGA z50)	7,371,981	7,368,128	7,370,735	7,354,106	7,351,570	7,357,878	7,346,769	7,368,605
SWL (June 2015)	2.40	2.60	14.90	9.10	31.90	10.6	7.30	9.20
pH	8.6	8.2	8.5	7.9	8.0	7.5	7.7	7.2
TDS (mg/L)	1,400	920	600	2,200	1,600	1,600	1,800	2,800
TSS (mg/L)	<5	<5	7	17	<5	<5	<5	76
Alkalinity ($mgCaCO_3/L$)	300	520	360	430	410	360	440	440
Acidity($mgCaCO_3/L$)	82	120	77	130	93	120	140	200
Phosphorus (mg/L)	0.09	0.12	0.06	0.07	0.14	0.04	0.12	0.39
Sulphate (mg/L)	330	110	45	320	160	180	250	830
Chloride (mg/L)	270	110	95	810	570	530	590	710
Fluoride (mg/L)	1.4	2.3	2.5	2.9	3	2.2	1.3	4
Nitrate (mg/L)	8.97	6.5	0.05	17	12	18	12.98	-
Hardness ($mgCaCO_3/L$)	535	336	273	609	282	608	728	1,160
Aluminium (mg/L)	<0.1	<0.1	<0.1	0.2	<0.1	<0.1	<0.1	0.9
Total Iron (mg/L)	0.15	0.07	0.03	0.22	0.02	0.02	<0.01	1.5
Sulphur (mg/L)	96	38	17	110	52	60	79	250
Calcium (mg/L)	66	39	30	79	47	120	110	250
Magnesium (mg/L)	90	58	48	100	40	75	110	130
Sodium (mg/L)	280	150	70	610	550	350	380	620
Beryllium (mg/L)	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Boron (mg/L)	1	0.5	0.26	1.4	0.83	0.55	0.8	2.1
Chromium (mg/L	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Cadmium (mg/L)	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Cobalt (mg/L)	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Copper (mg/L)	<0.01	<0.01	0.02	0.04	<0.01	<0.01	<0.01	<0.01
Iron (mg/L)	0.07	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.19
Lead (mg/L)	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Manganese (mg/L)	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.87
Molybdenum(mg/L)	<0.01	0.01	0.01	0.01	0.02	<0.01	<0.01	0.01
Nickel (mg/L)	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Silver (mg/L)	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Strontium (mg/L)	0.76	0.41	0.3	1.1	0.52	0.92	0.82	2.2
Tin (mg/L)	<0.01	<0.01	0.02	<0.01	<0.01	<0.01	<0.01	<0.01
Titanium (mg/L)	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Vanadium (mg/L)	0.04	0.05	<0.01	0.03	<0.01	<0.01	0.01	<0.01
Zinc (mg/L)	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01

Parameter	Edmund HST	Minga Well	Contessis Bore	Edmund Well	Fraser Well	Yangibana Bore	Woodsys Bore	Red Hill 2
Antimony (mg/L)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Arsenic (mg/L)	0.003	0.002	<0.001	<0.001	<0.001	<0.001	<0.001	0.004
Selenium (mg/L)	0.007	0.003	<0.001	0.003	0.005	0.005	0.003	<0.001
Silicon mg/L)	32	36	30	23	24	23	26	31
Thorium (mg/L)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Uranium (mg/L)	0.004	0.004	0.02	0.038	0.025	0.029	0.009	0.079

2.6 Department of Water Register

The DoW online water register was interrogated to identify the presence of existing licensed groundwater users in the vicinity of the Project.

The information shows that there are two current groundwater licences within 30 km of the Project, both of which are held by Mr. James Millar from Cobra Station. Both licences are on the southern side of the Lyons River, approximately 5 km and 10 km south of Fraser's deposit.

One licence allows up to 10,000 kL per annum from the Superficial aquifer and the other allows 41,500 kL per annum from the Combined Fractured Rock West aquifer.

Table 4 below provides details of the existing licensees within 30 km of the Project.

Table 4: Nearby Groundwater Well Licences

GWL Holder	GWL	Allocation (kL/yr)	Aquifer	Tenements	Location from the Project
James Millar, Cobra Station	46673	100,000	Carnarvon - Superficial	M09/63	5km S
James Millar, Cobra Station	64561	415,000	Combined – Fractured Rock West – Fractured Rock	M09/79	10km S

2.7 Groundwater Dependent Ecosystems

A review of the Bureau of Meteorology's (BoM's) GDE Atlas indicates that the Project area is classified as having:

- No to low potential for groundwater interaction with vegetation reliant on subsurface groundwater.
- No identified vegetation GDE's reliant of surface expression of groundwater (rivers, springs, wetlands).
- No identified subterranean GDEs (caves or aquifers).

The nearest significant GDE is along the Lyons River (to the south of the Project) and the Edmund River (to the west of the Project), which both report vegetation GDE's reliant on surface water and groundwater.

A copy of the GDE Atlas report, for an area of 25 km from 428,000 mE and 7,356,000 mN (Bald Hills) is provided as Appendix A.

Ecoscape (Australia) Pty Ltd (2015)[1] completed a flora and vegetation assessment of the broad Project region, including the proposed development envelope. The assessment reported the presence of one vegetation type which represents a GDE (presence of *Eucalyptus camaldulensis)*, and three other vegetation types represent potential GDEs (presence of *Eucalyptus victrix*). General GDE vegetation types are located outside the proposed disturbance footprint, except where linear infrastructure crosses the Lyons River, Fraser Creek and Yangibana Creek.

Hastings has initiated subterranean fauna studies in the Project area, as part of the DFS process, and the outcomes will be discussed further in the Stage II study report.

1 Ecoscape (Australia) Pty Ltd (2015) "Yangibana Project Biological Assessment: Flora and Vegetation" unpublished report prepared for Hastings Technology Metals Limited, December 2015

3.0 SELECTION OF TESTING LOCATIONS

A review was carried out by GRM of the available hydrogeological and geological data collected for the deposits to gain an understanding of likely hydrogeological conditions and confirm suitable testing locations.

The information used for the review included the geological drill-hole database, records of groundwater intersects in resource drill-holes, preliminary testing locations proposed by ATC Williams (geotechnical consultants), and information provided by Hastings geologists.

The available information was qualitative but indicated consistent groundwater inflows associated with the ironstone dykes, and generally low permeability conditions in the footwall and hanging wall granite.

The results of the review were used to revise the preliminary testing locations provided by ATC Williams, to develop a Stage I field testing programme.

The Stage I programme was aimed at providing sufficient data for 3D groundwater flow modelling, and consequently included small scale hydraulic testing and 48 hour test pumping, to provide an indication of hydraulic parameters for input to the groundwater flow model.

The details of the field investigations are discussed in Section 4.0.

4.0 STAGE 1 FIELD INVESTIGATIONS

Field investigations to assess the likely dewatering rates for the three proposed pits comprised the following:

- Groundwater exploration drilling to collect hydrogeological data, and identify potential test bore locations (Fraser's and Bald Hills). Note no exploration drilling was required at Yangibana as an existing drilling supply bore was available for testing purposes.
- Airlift recovery testing of groundwater exploration holes and/or from selected existing mineral exploration drill-holes to provide a range of estimates of hydraulic conductivity within the mining area.
- Install test bores at Fraser's and Bald Hills, and undertake test pumping (all pits) to estimate hydraulic parameters for the fractured rock aquifer and identify any potential boundary conditions.
- Collection of groundwater samples for laboratory analysis from the deposits.

4.1 Exploration Drilling

Hydrogeological data was collected during the drilling of 6 groundwater exploration drill-holes (two at Fraser's and four at Bald Hill), which varied in depth from 70 to 102 m deep. The selected drill-holes targeted the ironstone dyke on the down-dip side of the pit, for the purpose of collecting hydrogeological information as well as locating suitable test bore locations.

The drilling was undertaken by Three Rivers Drilling between 20 October and 13 November 2016, using reverse circulation (RC) methods. The programme was overseen by GRM and Hastings field personnel who were responsible for the collection and field assessment of geological and hydrogeological data.

The exploration holes were drilled under a granted Licence to Construct or Alter a Well CAW183123(1), issued by the DoW on 3 August 2016. The CAW is provided in Appendix B.

A summary of the drilling results is provided in Table 5 and the bore logs are provided in Appendix C.

The exploration drilling results indicate the following:

- Groundwater inflows were associated with the ironstone dykes.
- Away from the ironstone dykes, the granite reported low groundwater inflows.
- There were no reported inflows associated with alluvium or calcrete.
- The two most prospective drill-holes (FRW01 at Fraser's and BHW04 at Bald Hill) reported modest groundwater inflows, with airlift yields of between 1.5 and 2.2 L/sec.

The exploration drilling results support the presence of a discrete fractured rock aquifer associated with the ironstone dykes.

It should be noted that RC drilling generally under-predicts yields, due to the narrow annulus between the drill rod and the drill-hole. Higher yields were reported during airlift recovery testing, as discussed in Section 4.2

Table 5: Exploration Drilling Results

Location	Hole	mE MGA Zn50	mN MGA Zn50	RL (mAHD)	Depth (m)	Max Airlift Yield During Drilling (L/sec)
Fraser's	FRW1	429,941	7,351,211	350.5	110	1.5
	FRW2	429,804	7,351,086	343.0	96	1.2
Bald Hill	BHW1	427,958	7,356,494	355.7	70	<1
	BHW2	428,017	7,356,253	353.6	85	<1
	BHW3	428,064	7,356,105	350.5	100	<1
	BHW4	428,189	7,356,019	346.7	102	2.9

4.2 Hydraulic Testing

Airlift recovery testing of 12 drill-holes, comprising 3 locations at Fraser's, seven locations at Bald Hill and two locations at Yangibana, was conducted between October and December 2016. The locations comprised both existing resource drill-holes and the water exploration drill-holes completed as part of this programme.

The testing was undertaken by a combination of GRM and Hastings personnel, using the services of Three Rivers Drilling.

The testing methodology comprised:

i. A water level measurement was collected prior to testing.

ii. Galvanised pipe (50 mm diameter) was run down the existing drill-hole to about 12 m above the base of the hole.

iii. The drill-hole was airlifted until the flow stabilised (around an hour).

iv. During airlifting yield measurements (using a V Notch weir) and water quality parameters were recorded at regular intervals.

v. At the completion of airlifting the galvanized pipe was un-coupled and groundwater recovery measurements collected through the inner tube using a combination of pressure transducers and manual measurements, until the recovery came to within 90% of the standing water level.

The test data was analysed using a combination of standard analytical methods including Theis (1935) and the Theim steady state method. The resulting transmissivities from the various testing methods were then reviewed and an adopted hydraulic conductivity value was assigned for each test location.

It should be noted, the recovery data for drill-hole BHRC097 was erroneous and consequently a slug test was conducted for this drill-hole. The slug test data was analysed using Hvorslev (1951).

A summary of the test data and results are provided in Tables 6 and 7. The results are presented in Figures 4 to 6, and the analysis is provided as Appendix D.

The test results indicate the following:

- Airlift yields ranged from 0.015 L/sec in FFRC098 to 8 L/sec in YGRC057.
- Three test locations reported hydraulic conductivities below 0.1 m/d. These results are indicative of the expected low permeability conditions of the bedrock away from the ironstone dyke.
- Three test locations reported hydraulic conductivities between 0.1 m/d and 1 m/d. These locations were interpreted to represent minor fractures or thin ironstone dykes within the otherwise low permeability bedrock.
- Six test locations reported conductivities above 1 m/d, which confirm the modest permeability associated with the ironstone dyke, characteristic of a fractured rock aquifer.

Table 6: Hydraulic Testing Data

Location	Hole	mE MGA Zn50	mN MGA Zn50	RL (mAHD)	Depth (m)	SWL (mbtoc)	SWL (m RL)	Final Airlift Rate (L/sec)
Fraser's	FRW2	429,804	7,351,086	343	96	35.6	307.44	1.5
	FFRC082	429,925	7,351,046	338.89	60	35.5	303.36	3.4
	FFRC098	429,770	7,350,825	336.51	48	33.1	303.41	0.015
Bald Hill	BHW1	427,958	7,356,494	355.7	72	35.0	320.70	3.9
	BHW2	428,017	7,356,253	353.6	72	33.6	320.00	1.8
	BHW3	428,064	7,356,105	350.5	119	29.85	320.65	0.14
	BHRC161	428,397	7,355,720	343.6	75	25.87	317.73	3.0
	BHRC082	428,268	7,355,904	346.0	58	23.23	322.77	2.0
	BHRC095	428,206	7,356,149	337.12	58	29.14	307.98	0.33
	BHRC097	428,134	7,356,197	337.28	70	30.26	307.02	0.8
Yangibana	YWRC057	417,189	7,362,389	339.90	24	12.54	322.46	8.0
	YWRC003	417,291	7,362,277	342.38	48	8.38	334.00	3.7

Table 7: Hydraulic Test Results

Hole ID	Aquifer Thickness (m)	Transmissivity (m^2/d)				Adopted Transmissivity (m^2/d)	Adopted Hydraulic Conductivity (m/d)	Comments
		Airlift Recovery (Theis) ET	Airlift Recovery (Theis) LT	Steady State (Theim)	Slug Test (Hvorslev)			
FRW02	60.4	243	34	3.7	-	19	0.3	Aquifer less well defined in this location, results represent general rock mass, average of LT R and SS most representative, and consistent with airlift rate (1.5 L/s)
FFRC082	11	-	223	27	-	27	2.5	The R data is unreliable (minimal residual drawdown). The SS analysis result is consistent with the airlift rate (3.4 L/s)
FRRC098	14.9	0.12	0.25	0.18	-	0.18	0.012	The AR and SS analysis are consistent with the low flow rate during airlifting (<0.1 L/s), indicative of general rock mass
BHW01	20	100	-	26	-	63	3.15	The AR and SS analysis result is consistent with the airlift rate (3.9L/s)
BHW02	20	0.8	32	6.8	-	13	0.66	Aquifer less well defined in this location, results represent general rock mass, average of all tests is consistent with airlift rate (1.8 L/s)
BHW03	87.25	-	-	0.36	-	0.36	0.004	Unreliable results from AR test, SS analysis results and airlift rate (0.14L/s) indicative of general rock mass
BHRC161	5	17	80	15	-	37	7.5	The AR and SS analysis are consistent with airlift yield (3 L/s)
BHRC082	34.77	-	66	49	-	58	1.7	Aquifer less well defined in this location, results represent general rock mass, average of LT R and SS
BHRC095	28.86	0.72	-	3.2	-	1.98	0.07	Aquifer less well defined in this location, results represent general rock mass, average of ET R and SS

Hole ID	Aquifer Thickness (m)	Transmissivity (m^2/d)				Adopted Transmissivity (m^2/d)	Adopted Hydraulic Conductivity (m/d)	Comments
		Airlift Recovery (Theis) ET	Airlift Recovery (Theis) LT	Steady State (Theim)	Slug Test (Hvorslev)			
BHRC097	34.74	-	-	4.8	10	10	0.29	Poor data during R test, ST and SS analysis consistent with airlift rate (0.8 L/s). Results indicative of general rock mass
YWRC057	11.46	-	-	117	-	117	10	Unable to get reliable data during the R phase, SS analysis consistent with airlift rate (8 L/s)
YWRC003	4	-	28	20	-	24	6.0	Reasonable fit to Theis, results consistent with airlift rate (3.7 L/s)

Notes: CH constant head; LT late time; ET early time; R recovery; SS steady state; HC hydraulic conductivity; AR airlift recovery; ST slug test; T transmissivity

4.3 Test Bore Installation

Two test production bores, FRW03 and BHW05, were installed adjacent to the two highest yielding exploration drill-holes (FRW01 and BHW04). Please note that FRW03 was referred to as FRW01 during the field investigations, but has subsequently been re-named to maintain consistent nomenclature and differentiate it from the original FRW01 drill-hole.

Drill-holes FRW01 and BHW04 were constructed as temporary monitoring bores for the purposes of test pumping, with the installation of 50 mm uPVC casing.

The test production bores were drilled and constructed by Three Rivers Drilling and overseen by GRM and Hastings personnel. The bores were installed under a granted Licence to Construct or Alter a Well CAW183123(1), issued by the DoW on 3 August 2016. The CAW is provided as Appendix B.

The production bore installation methodology comprised:

- Collaring to 3 m, using 15.5 inch diameter air rotary methods.
- Installation of 10 inch diameter steel surface casing to 2 to 3 m depth, cement grouted.
- Drilling a pilot hole and then reaming out to 10 inch diameter hole to depth using air rotary methods.
- Installation of 155 mm class 9 uPVC casing, slotted over the aquifer sequence, as identified from drill-cuttings and from geological logs from the original exploration hole, and capped at its base using an external uPVC end-cap.
- Installation of +3.2 to 6.4 mm graded gravel pack in the annulus from the base of the bore to just below surface.
- Placement of an annular bentonite seal from the top of the gravel packed interval to surface to prevent surface water ingress.
- Airlift development of the bore for a period of at least 2 hours, to remove fine sediment from within the gravel pack and adjacent formation.
- Completion of the bore with a concrete plinth, and uPVC end-cap.

The details of the installed test bores are provided in Table 8, and bore logs are provided in Appendix C.

Table 8: Test Production Bore Schedule

Parameter	Units	Test Production Bores	
		FRW03	**BHW05**
Exploration Drill Hole		FRW01	BHW04
Collar Location MGA Zn 50	(mE)	429,941	428,289
	(mN)	7,351,211	7,356,019
RL	(mAHD)	350.5	346.7
Depth Drilled/Reamed	(mbgl)	110	106
Surface Casing Depth	(mbgl)	3.2	4
Cased Depth	(mbgl)	95.2	104
Casing Type		155 mm Class 9 uPVC	155 mm Class 9 uPVC
Slotted Interval	(mbgl)	71.2 to 95.2	80 to 104
Slot Type		1 mm	1 mm
Gravel Pack Grade	mm	3.2 to 6.4	3.2 to 6.4
Gravel Pack Interval		+0.1 to 95.5	+0.1 to 104
Annual Bentonite Seal		0.1 to +0.1	0.1 to +0.1
Stick-up	(magl)	0.1	0.1
SWL	(mbtoc)	33.8	26.52
SWL Date		4 Nov 2016	14 Nov 2016

Note: mbgl = metres below ground level; magl = metres above ground level; mbtoc = metres below top of casing

4.4 Test Pumping

Test pumping of FRW03, BHW05 and an existing drilling water supply bore at Yangibana (YGWB03) was carried out by Three Rivers Drilling between October and December 2016, and overseen by GRM and Hastings personnel.

Bore YGWB03, an existing bore, was installed for a temporary drilling supply and constructed of 155 mm Class 9 uPVC casing to a depth of 58.6 m, slotted between 34.6 and 58.6 m. The bore was gravel packed and completed with an annular bentonite seal.

The three production bores were tested using a 6 inch Grundfos SP46-12 electrical submersible pump with a maximum capacity of about 15 L/sec at 70 m head.

Testing of FRW01, BHW05 and YGWB03 comprised a three to four hour step test, followed after recovery by 48-hour constant rate and recovery tests. The results from the step test was used to identify a suitable rate for the constant rate test. The pumping and drawdown data for the constant rate and subsequent recovery tests were used to:

- estimate the transmissivity and storativity of the aquifer using standard analytical methods;
- identify boundaries to the fractured rock aquifer;
- characterise the aquifer type (i.e. unconfined, confined or leaky);

- provide an indication of likely long term sustainable yields for the bores.

Over the period of the 48-hour constant rate test, pumping rates were measured and recorded at hourly intervals in the bore, and water levels monitored periodically in the pumping bore and adjacent monitoring bore. Groundwater quality field parameters were measured from the pumping bore periodically throughout the constant rate tests.

The details of the step and constant rate tests are presented in Table 9.

Table 9: Test Pumping Summary

Production Bore ID	Step Test Pumping Rates (L/sec)				48-Hour Pumping Rate (L/sec)	Maximum Drawdown after 48 Hrs (L/sec)	Distance Between Production & Monitor Bore
	Step 1	Step 2	Step 3	Step 4			
FRW03	4	5	8	10	8	4.5	6.0
BHW05	5	6	11	18	16	10.8	7.4
YGWB03	5	8	11*	-	3.15	9.7	7.87

Notes: *drawdown exceeded pumping depth

The test data was analysed using a combination of standard analytical methods including Cooper Jacob (1946), Neuman (1974) and Theis (1935). The resulting transmissivities from the various testing methods were then reviewed and an adopted hydraulic conductivity value was assigned for each test location.

The test analysis is provided in Appendix D and a summary of the analyses is presented in Table 10.

Table 10: Test Pumping Analysis Results

Hole ID	Aquifer Thickness (m)	Transmissivity (m^2/d)					Adopted Transmissivity (m^2/d)	Adopted Hydraulic Conductivity (m/d)	Storativity (S)	Comments
		Constant Rate ET (Cooper Jacob)	Constant Rate LT (Cooper Jacob)	Constant Rate (Neuman)	Recovery ET (Theis)	Recovery LT (Theis)				
FRW03	11	-	28	-	329	197	28	2.5	-	CRT indicates boundary condition at about 1000 mins, LT data for CRT most representative
FRW01	11	-	28	-	-	-	28	2.5	-	Results consistent with pumping bore, CRT LT data most representative
BHW05	20	236	75	-	207	217	75	3.75	1.0 E-04	CRT indicated boundary condition at about 1000 mins, LT data for CRT most representative
BHW04	20	214	75	-	232	-	75	3.75	4.0 E-04	Results consistent with pumping bore
YGWB03	10	-	55	-	30	83	56	5.6	1.0 E-06	Poor curve fitting, average of all test data
YGWB03obs	10	-	36	10	23	78	37	3.7	-	Good curve fit with Neuman, results consistent with pumping bore

Notes: CRT constant rate test; ET Early time; LT late time

The test pumping results show the following:

- Barrier boundary conditions were observed in both FRW03 and BHW05 at around 1,000 minutes, indicative of a fractured rock environment whereby smaller fractures are drained during the testing.
- Drawdown patterns are consistent with a semi-confined aquifer.
- The results indicate the hydraulic conductivity ranged between 2.5 to 5.6 m/d for the fractured rock aquifer, and a bulk storativity value adopted of about 0.0001.
- Groundwater quality parameters remained stable during both constant rate tests, with FRW03 reporting an Electrical Conductivity (EC) of 2.39 mS/cm and pH of 7.45, BHW05 reporting an EC of 2.11 mS/cm and pH of 6.88, and YGWB03 reporting an EC of 1.83 mS/cm and pH of 7.15.
- Total drawdown during the 48 hour constant rate test from FRW03 was 4.5 m, at a test rate of 8 L/sec. The data suggests a maximum duty rate of 7 L/sec as a sustainable short term supply for construction, and 6 L/sec as a long term operational rate is suitable for this bore.
- Total drawdown during the 48 hour constant rate test from BHW05 was 10.8 m, at a test rate of 16 L/sec. The data suggests a maximum duty rate of 10 L/sec as a short term supply for construction, and 8 L/sec as a long term operational rate is suitable for this bore.
- Total drawdown during the 48 hour constant rate test from YGWB03 was 9.7 m, at a test rate of 3.15 L/sec. The data suggests a maximum duty rate of about 1 L/sec, and indicates the bore is unsuitable as a longer term water supply bore.

It must be noted, fractured rock aquifers have limited storativity and given that the drawdown response during testing of FRW03 and BHW05 indicated boundary conditions early in the test, the bores may experience yield reduction at any stage.

Production bore details and recommended pumping rates are provided in Table 11 below.

Table 11: Bore Details and Pumping Rates

Bore ID	Location (MGA zone 50)		Bore Depth (m bgl)	SWL (m btoc)	Peak (Construction) Pumping Rate (L/sec)	Long Term Operational Pumping Rate (L/sec)	Pump Inlet Setting (m btoc)
	(mE)	(mN)					
FRW03	429,941	7,351,211	95.2	33.80	7	6	72
BHW05	428,189	7,356,019	104.0	26.52	10	8	82
YGWB03	417,265	7,362,211	58.6	18.03	<1	<1	36

4.5 Groundwater Quality

Groundwater samples were collected from Fraser's, Bald Hill and Yangibana for standard laboratory analysis and isotope analysis to provide an indication of groundwater quality and for age dating. The various analyses are discussed in more detail below.

4.5.1 Laboratory Analysis

Groundwater samples for laboratory analysis were collected from FRW03, BHW05 and YGWB03 at the completion of test pumping.

The results of the analysis are provided in Table 12 and laboratory certificates provided as Appendix E. The results indicate:

- The groundwater is slightly alkaline, reporting a pH of 7.8 to 8.5.
- The groundwater is fresh to slightly brackish, with TDS ranging from 920 to 1,200 mg/L TDS.
- The groundwater is of sodium chloride type.

Table 12: Groundwater Quality

Analyte	Unit	FRW03	BHW05	YGWB03
pH		8.5	8.0	7.8
Electrical Conductivity	µS/cm	2,100	1,900	1,500
Total Dissolved Solids	mg/L	1,200	1,000	920
Total Alkalinity	mg/L	-	-	270
Carbonate Alkalinity	mg/L	11	<1	<1
Bicarbonate Alkalinity	mg/L	280	<5	330
Chloride	mg/L	380	330	250
Sulphate	mg/L	160	100	89
Nitrite	mg/L	<0.2	<0.05	<0.2
Nitrate	mg/L	9.1	65	63
Calcium	mg/L	72	81	85
Magnesium	mg/L	67	51	44
Potassium	mg/L	9.5	9.0	7.5
Silica, soluble	mg/L	52	72	91
Silicon	mg/L	-	34	43
Sodium	mg/L	230	240	180
Total Hardness	mg/L	460	410	390
Aluminium	mg/L	<5	<5	<5
Iron	mg/L	73	9	5
Manganese	mg/L	<1	<1	<1
Selenium	mg/L	4	7	6

4.5.2 Groundwater Isotope Analysis

Groundwater isotope analysis is being undertaken as part of the investigation to provide an assessment of groundwater age, which in turn will provide an indication of the degree to which the ironstone aquifer is recharged.

GRM approached Ms. Karina Meredith[1] (ANSTO Hydrogeologist) for advice regarding isotope analysis and was advised that given the construction of the bores (i.e. the ironstone aquifer is not physically isolated from the overlying granite), the groundwater in the bore will likely be a mix of different aged groundwater, and consequently age dating using radiocarbon methods will likely give misleading results.

GRM was advised that the most appropriate method of groundwater dating in this situation would be to use tritium detection dating, whereby positive detection of tritium indicates that the groundwater is less than 50 years old. Ms. Meredith suggested collecting a sample at the commencement of test pumping to assess the groundwater close to the bore (which may be a mix of groundwater from the ironstone and overlying granite) and a second sample at the end of test pumping which should represent groundwater drawn from the ironstone aquifer (given the low permeability of the granite).

A positive detection of tritium in both samples would indicate that the groundwater in the ironstone aquifer is less than 50 years old, which would suggest recent recharge.

Samples were collected during test pumping and have been submitted to the ANSTO laboratory for tritium detection. It is anticipated the results will be available by April 2017, and will be discussed in the Stage II report.

4.6 Groundwater Levels

Groundwater level measurements were collected during testing. The data is provided in Table 13, and presented in Figures 4 to 6.

The data indicates the groundwater level across the deposits range from about 309 mRL at Fraser's, 316 mRL at Bald Hill and 323 mRL at Yangibana. The recorded groundwater levels are consistent with a regional groundwater flow direction towards the south south-west (i.e. towards the Lyons River).

[1] Co-author of "Evolution of chemical and isotope composition of inorganic carbon in a complex semi-arid zone environment: Consequences for groundwater dating using radiocarbon" K.T. Meredith, L.F. Han, S.E. Hollins, D.I. Cendon, G.E. Jacobsen, A. Baker.

Table 13: Groundwater Level Data

Location	Easting (MGA Zn50)	Northing (MGA Zn50)	RL	SWL (m)	SWL (mRL)
FRW01	429,941	7,351,211	350.5	33.80	316.70
FRW02	429,804	7,351,086	343.0	35.56	307.44
FRRC082	429,925	7,351,046	338.89	35.53	303.36
FRRC098	429,770	7,350,825	336.51	33.10	303.41
BHW01	427,958	7,356,494	355.7	35.00	320.70
BHW02	428,017	7,356,253	353.6	33.60	320.00
BHW03	428,064	7,356,105	350.5	29.85	320.65
BHW04	428,189	7,356,019	346.7	26.52	320.18
BHRC082	428,268	7,355,904	346.0	23.23	322.77
BHRC161	428,397	7,355,720	343.6	25.87	317.73
BHRC097	428,134	7,356,197	337.28	30.26	307.02
BHRC095	428,206	7,356,149	337.12	29.14	307.98
YWRC003	416,930	7,362,444	319.02	8.38	310.64
YWRC057	416,212	7,362,817	323.0	12.54	310.46
YGWB03	417,265	7,362,211	341.29	18.03	323.26

5.0 CONCEPTUAL MODEL

The conceptual model for the Project deposits is derived from information collected during the desktop study and the field investigations.

The conceptual model for the area recognises three hydrogeological units, which are shown schematically in Figure 7, and described below:

- Hydrogeological Unit (HU) 1 comprises the alluvium and calcrete units. This unit is discontinuous within the Project area, with alluvium typically occupying low lying areas in creeks and drainage channels. Alluvium is typically absent or less than a few metres thick across the remainder of the Project area. In locations where the alluvium is sufficiently thick to extend below the water table (i.e. in the larger creeks), permeability in this unit can be modest, depending upon the composition of the alluvium, as evidenced by several stock watering bores installed into this unit. It is likely this unit could fluctuate between saturated and unsaturated seasonally, in response to streamflow. Calcrete is known to occur adjacent to the major drainages (Lyons and Edmund Rivers) and may extend over large areas beneath the alluvial cover. The calcrete is known to extend to depths of up to 30 m and permeability in this unit is likely to be modest to high. Groundwater quality within the HU1 is expected to be fresh, and there is likely to be some degree of hydraulic connection between the HU1 and HU2. The HU1 is thin to absent in the immediate area of the proposed pits, and is not shown in the schematic model provided as Figure 7.

- HU2 comprises discrete ironstone units within the fresh bedrock. The ironstone units are narrow, but regionally extensive, and pinch and swell along strike as well as at depth. The ironstone thickness varies from about 1m to 20m, with an average thickness of about 4 to 5m. The ironstone outcrops to the north east, plunging to the south west, and is highly fractured and vuggy. Groundwater inflows from the HU2 are generally modest. However storage characteristics can be low, given the discrete nature of the feature. Groundwater quality in the HU2 is typically fresh to brackish, with salinity increasing away from recharge areas. Recharge to the HU2 will primarily occur where the HU2 is in contact with saturated HU1. Direct rainfall recharge (where the HU2 outcrops) and recharge from the HU3 is expected to be minimal. The HU2 is a semi-confined aquifer, somewhat confined by the overlying low permeability HU3.

- HU3 comprises the intact fresh bedrock sequences (excluding the HU2 feature). The HU3 comprises granites, granodiorite and monzanites, which form the hangingwall and footwall units to the HU2. Permeability within this unit is very low, with low storage characteristics. The depth of weathering in the HU3 is quite shallow (i.e. typically less than 10 m) and whilst weathering can often enhance permeability in some regions, this has not been observed in the Project area as the weathered zone is poorly developed and typically does not extend below the water table.

The groundwater salinity in the Project area is around 1,000 mg/L TDS, with salinity typically increasing away from recharge areas.

The groundwater levels at the proposed pits are about 309 mRL at Frasers, 316 mRL at Bald Hills and 323 mRL at Yangibana, with a groundwater flow direction towards the south south— west, towards the Lyons River.

6.0 GROUNDWATER MODELLING

A series of three numerical groundwater flow models were constructed for the deposits and surrounding groundwater system to simulate the impacts upon the groundwater environment from mining below the water table. The models comprised:

- Model 1: Fraser's pit
- Model 2: Bald Hill pit
- Model 3: Yangibana pit

The models were constructed using the MODFLOW 3D finite-difference code PMWIN pre-processor.

The numerical modelling was based upon a conceptual understanding of the groundwater system (Figure 7), developed using the data collected during recent investigations. No calibration data was available. However, sensitivity analyses were run to assess the implications of varying hydraulic properties.

The numerical model setup and results are discussed below.

6.1 Model Mesh and Layers

The models was constructed using three layers, with Layer 1 (L1) representing the hanging wall HU3, L2 representing HU2, and L3 representing the footwall HU3. The geometry of the layers reflected the conceptual model (Figure 7), with L2 outcropping on the northern / western boundaries of the proposed pits and plunging to south / south-east. The thickness of the L2 was set at a uniform 5 m for Fraser's and 4 m for Bald Hill and Yangibana.

The HU1 was not represented in the model as it is not known to extend below the water table in the immediate vicinity of the pits.

The model limits were set to about 5 km from the proposed pits, such that interference from regional boundaries would not influence the simulated impacts from dewatering.

The layer slices were constructed from:

- Fraser's Model: 24,975 rectangular cells (225 columns and 111 rows), covering an area of approximately 115 km^2. The cell sizes range from 10 m by 10 m in the area of the pit to 500 m by 500 m near the model boundary.
- Bald Hill Model: 37,185 rectangular cells (185 columns and 201 rows), covering an area of approximately 120 km^2. The cell sizes ranged from 10 m by 10 m in the area of the pits, to 500 by 500 m near the model boundary.
- Yangibana Model: 57,285 rectangular cells (285 columns and 201 rows), covering an area of approximately 131 km^2. The cell sizes range from 10 m by 10 m in the area of the pit to 500 m by 500 m near the model boundary.

The ambient pre-mining water level for each model was set at the average ambient water level recorded during the field investigations, namely; 309 mRL for the Fraser's model, 316 mRL for the Bald Hills model and 323 mRL for the Yangibana model. The lower boundary was set at about 10 m below the base of the proposed pits.

6.2 Hydraulic Parameters

Values for hydraulic conductivity and storage were assigned to each layer. The baseline values used for horizontal hydraulic conductivity were based upon the average results of the hydraulic testing analysis presented in Section 4.2, whilst vertical hydraulic conductivity was set at 10% of the corresponding horizontal conductivity value.

Values for aquifer storage were based upon a combination of the test data, published values (Kruseman and de Ridder 1994) and experience with other modelling studies.

In addition to the baseline simulation, sensitivity analysis was carried out on the model to assess the impacts from variation in hydraulic parameters. The parameter values used in the baseline and sensitivity runs are presented in Table 14.

Table 14: Adopted Baseline Hydraulic Parameters

Pit	Model Layer	Baseline Model Parameters			
		Kh (m/d)	Kv (m/d)	Sy	Ss
Fraser's	L1	0.012	0.0012	0.01	0.0001
	L2	2.5	0.25	0.01	0.0001
	L3	0.001	0.0001	0.01	0.0001
Bald Hill	L1	0.03	0.003	0.01	0.0001
	L2	5	0.5	0.01	0.0001
	L3	0.001	0.0001	0.01	0.0001
Yangibana	L1	0.03	0.003	0.01	0.0001
	L2	5	0.5	0.01	0.0001
	L3	0.001	0.0001	0.01	0.0001

Note Kh = horizontal hydraulic conductivity, Kv = vertical hydraulic conductivity, Sy = specific yield, Ss = specific storage.

6.3 Boundary Conditions

All lateral boundaries were designated as constant head boundaries, using the ambient groundwater levels of 309 mRL, 316 mRL and 323 mRL for the three pits, Fraser's, Bald Hill and Yangibana respectively. A no flow boundary was adopted for the base of the models.

6.4 Model Recharge

Groundwater recharge was not included in the model given the low hydraulic conductivity of the fresh bedrock and the short LoM. This is a conservative approach with respect to drawdown impacts, which will be reduced under recharge conditions. However, the model is not conservative with respect to the dewatering rate, which may show periodic increases in response to rainfall recharge. Though, these increases are expected to be short lived during and immediately after rainfall events.

6.5 Mine Dewatering

The mine dewatering strategy adopted for the purpose of modelling comprised:

- Two dewatering bores installed into the higher permeability HU2 zone, adjacent to the Fraser's and Bald Hill pits (i.e. FRW03 and BHW05).
- Sump pumping in all pits.

Mine dewatering was simulated using a combination of MODFLOW's well and drain packages.

The MODFLOW well package applies pumping rates to the layer model cells associated with the assigned production bore locations. A maximum pumping rate of 6 L/sec was applied to FRW03 and 8 L/sec to BRW05 initially. This rate was adjusted downward as drawdown was achieved to prevent the model cell drying out and to maintain sufficient drawdown ahead of mining.

The MODFLOW drain package simulates dewatering by sump pumping methods, by allowing flow out of the model domain based upon a drain head elevation and a conductance term. The drain head is equivalent to the elevation of the pit floor, and was adjusted at each stress period to simulate mining progress in the pits.

The drain head elevations used to simulate lowering of the pit floors were based on the scoping study mining schedule, provided by Snowden. The schedule comprised maximum pit depths for each year that the pits are operational. The schedule indicates that Bald Hill will be mined in year's 1 to 4, Fraser's in year's 2 to 4, and Yangibana in years 3 to 7.

The conductance term describes the conductivity at this boundary (i.e. the inverse of the resistance to outflow from the model domain). For the numerical models a high conductance value of 20 m^2/d was adopted, allowing the water levels in the model drain cells to equilibrate with the fixed head specified for the drain, whilst maintaining sufficient resistance to assist in model convergence.

A summary of the drain elevations adopted in the models are provided in Table 15. The final pit outline as provided by Snowden, is presented for each pit in Figures 8 to 10.

Table 15: Interpolated Drain Elevations

Mining Year	Drain Elevation (mRL)		
	Fraser's	Bald Hills	Yangibana
1	-	355	-
2	325	335	-
3	300	305	340
4	255	280	315
5	-	-	290
6	-	-	250
7	-	-	250

6.6 Model Layer Type

An unconfined model layer type was used for L1, and confined/unconfined for L2 and L3. The model layers were set to calculate transmissivity.

6.7 Model Run Time

The model simulations were run for the period of active mining below the ambient groundwater level, which included:

- Fraser's model was run for 2 years representing the final two years of mining (i.e. years 3 and 4), comprising one stress period of 365 days and 4 stress periods of 91.25 days.
- Bald Hill model was run for 1.5 years representing the final 1.5 years of mining (i.e. half of year 3 and year 4), comprising 6 stress periods of 91.25 days.
- Yangibana model was run for 3.5 years representing the final 3.5 years of mining (i.e. half of year 4 to year 7), comprising 7 stress periods of 182 days.

6.8 Predictive Simulations

6.8.1 Model Runs

Five model runs for each of the three models were undertaken, comprising a baseline run using the expected hydraulic parameter values for each layer and three sensitivity runs to investigate variations (within likely limits) in hydraulic parameters.

The sensitivity runs are described as follows:

- Model Run R02: reduced the hydraulic conductivity in the HU2 (L2) outside of the pit area.
- Model Run R03: increased the hydraulic conductivity in the HU2 (L2) for Fraser's and Bald Hill, and reduced the hydraulic conductivity in the HU2 (L2) for Yangibana.
- Model Run R04: increased specific storage, based upon a factor of 1.5.
- Model Run R05: decreased specific storage, based upon a factor of 0.5.

The decision to reduce the hydraulic conductivity for the Yangibana R03 model (rather than increase it, as per the other two pits) was based upon the large pit area and limited test locations for this pit. The field testing indicated the permeability was similar to Bald Hill (i.e. higher than Fraser's) and so it was more appropriate to decrease the hydraulic conductivity, in line with the Fraser's values, rather than increase it.

The values used in the sensitivity runs are provided in Tables 16 18.

Table 16: Fraser's Sensitivity Analysis Hydraulic Parameters

Model Layer	Model Parameters			
	Kh (m/d)	Kv (m/d)	Sy	Ss
R01 Baseline				
L1	0.012	0.0012	0.01	0.0001
L2	2.5	0.25	0.01	0.0001
L3	0.001	0.0001	0.01	0.0001
Sensitivity Run R02 Reduced ex-pit K				
L1	0.012	0.0012	0.01	0.0001
L2 pit	2.5	0.25	0.01	0.0001
L2 ex-pit	1	0.1	0.01	0.0001
L3	0.001	0.0001	0.01	0.0001
Sensitivity Run R03 High K				
L1	0.012	0.0012	0.01	0.0001
L2	5	0.5	0.01	0.0001
L3	0.001	0.0001	0.01	0.0001
Sensitivity Run R04 High Ss				
L1	0.012	0.0012	0.01	0.0002
L2	2.5	0.25	0.01	0.0002
L3	0.001	0.0001	0.01	0.0002
Sensitivity Run R05 Low Ss				
L1	0.012	0.0012	0.01	0.00005
L2	2.5	0.25	0.01	0.00005
L3	0.001	0.0001	0.01	0.00005

Note Kh = horizontal hydraulic conductivity, Kv = vertical hydraulic conductivity, Sy = specific yield, Ss = specific storage.

Table 17: Bald Hills Sensitivity Analysis Hydraulic Parameters

Model Layer	Model Parameters			
	Kh (m/d)	Kv (m/d)	Sy	Ss
R01 Baseline				
L1	0.03	0.003	0.01	0.0001
L2	5	0.5	0.01	0.0001
L3	0.001	0.0001	0.01	0.0001
Sensitivity Run R02 Reduced ex-pit K				
L1	0.03	0.003	0.01	0.0001
L2 pit	5	0.5	0.01	0.0001
L2 ex-pit	1	0.1	0.01	0.0001
L3	0.001	0.0001	0.01	0.0001
Sensitivity Run R03 High K				
L1	0.03	0.003	0.01	0.0001
L2	8	0.8	0.01	0.0001
L3	0.001	0.0001	0.01	0.0001
Sensitivity Run R04 High Ss				
L1	0.03	0.003	0.01	0.0002
L2	5	0.5	0.01	0.0002
L3	0.001	0.0001	0.01	0.0002
Sensitivity Run R05 Low Ss				
L1	0.03	0.003	0.01	0.00005
L2	5	0.5	0.01	0.00005
L3	0.001	0.0001	0.01	0.00005

Note Kh = horizontal hydraulic conductivity, Kv = vertical hydraulic conductivity, Sy = specific yield, Ss = specific storage.

Table 18: Yangibana Sensitivity Analysis Hydraulic Parameters

Model Layer	Model Parameters			
	Kh (m/d)	Kv (m/d)	Sy	Ss
R01 Baseline				
L1	0.03	0.003	0.01	0.0001
L2	5	0.5	0.01	0.0001
L3	0.001	0.0001	0.01	0.0001
Sensitivity Run R02 Reduced ex-pit K				
L1	0.03	0.003	0.01	0.0001
L2 pit	5	0.5	0.01	0.0001
L2 ex-pit	1	0.1	0.01	0.0001
L3	0.001	0.0001	0.01	0.0001
Sensitivity Run R03 High K				
L1	0.03	0.003	0.01	0.0001
L2	3	0.3	0.01	0.0001
L3	0.001	0.0001	0.01	0.0001
Sensitivity Run R04 High Ss				
L1	0.03	0.003	0.01	0.0002
L2	5	0.5	0.01	0.0002
L3	0.001	0.0001	0.01	0.0002
Sensitivity Run R05 Low Ss				
L1	0.03	0.003	0.01	0.00005
L2	5	0.5	0.01	0.00005
L3	0.001	0.0001	0.01	0.00005

Note Kh = horizontal hydraulic conductivity, Kv = vertical hydraulic conductivity, Sy = specific yield, Ss = specific storage.

6.8.2 Predicted Dewatering Requirement

The predicted dewatering requirements for the baseline run and five sensitivity runs for all deposits are presented in Tables 19 and 20.

The modelling results show the following:

- In year 1 mining does not extend below the ambient groundwater level.
- Under baseline conditions and once mining extends below the ambient groundwater level, the average combined inflows range from 6 L/sec during year 2 to approximately 51 L/sec during year 7.
- The highest inflows are reported from the Yangibana pit, as a result of the larger pit area.
- The modelling indicates that a combination of dewatering bores and sump pumping should be a suitable strategy to achieve sufficient drawdown.

- The model is moderately sensitive to changes in hydraulic conductivity, with inflows from year 4 reducing from 31.8 L/sec to 17.5 L/sec under low ex-pit K conditions and increasing to 45.3 L/sec under high K conditions.

It is important to note that the model does not allow for rainfall recharge, which is a conservative modelling approach with regard to drawdown impacts. Increased groundwater inflows following significant rainfall events are likely. For this reason it would be prudent to allow contingency for groundwater inflows of up to 50 L/sec following high rainfall events.

Additional contingency will also be necessary to account for surface water inflows (rainfall and runoff) following high rainfall events. It is understood Hastings is initiating a surface water assessment in early 2017, to assess potential surface water catchments and inflows.

Table 19: Predicted Base Case Dewatering Rates

Pit	Method	Average Simulated Dewatering Rate (L/sec)						
		Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7
Fraser's	Bores	-	6	6	4	-	-	-
	Sump	-	-	0.1	8.5	-	-	-
Bald Hill	Bores	-	-	8	7	-	-	-
	Sump	-	-	0.5	10	-	-	-
Yangibana	Sump	-	-	-	2.3	7.5	25	51
Total		**-**	**6**	**14.6**	**31.8**	**7.5**	**25**	**51**

Table 20: Sensitivity Analysis Results

Pit	Method	Average Simulated Dewatering Rates (L/sec)													
		Sensitivity Run R02 – Reduced Ex-Pit K							Sensitivity Run R03 – High K (Low K Yangibana)						
		Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7
Fraser's	Bores	-	6	6	-	-	-	-	-	6	6	6	-	-	-
	Sump	-	-	0.1	6.8	-	-	-	-	-	0.1	14	-	-	-
Bald Hill	Bores	-	-	8	3	-	-	-	-	-	8	8	-	-	-
	Sump	-	-	0.5	5.4	-	-	-	-	-	1	15	-	-	-
Yangibana	Sump	-	-	-	2.3	6.2	22	27	-	-	-	2.3	7	24	38
Total			**6**	**14.6**	**17.5**	**6.2**	**22**	**27**	**-**	**6**	**15.1**	**45.3**	**7**	**24**	**38**

Pit	Method	Average Simulated Dewatering Rates (L/sec)													
		Sensitivity Run R04 – High Ss							Sensitivity Run – Low Ss						
		Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7
Fraser's	Bores	-	6	6	4	-	-	-	-	6	6	4	-	-	-
	Sump	-	-	0.1	8.8	-	-	-	-	-	0.1	7.7	-	-	-
Bald Hill	Bores	-	-	8	7	-	-	-	-	-	8	7	-	-	-
	Sump	-	-	0.5	10	-	-	-	-	-	0.5	9.7	-	-	-
Yangibana	Sump	-	-	-	2.4	7.7	33	55	-	-	-	2.3	7.5	24	48
Total		**-**	**6**	**14.6**	**32.2**	**7.7**	**33**	**55**	**-**	**6**	**14.6**	**30.7**	**7.5**	**24**	**48**

6.8.3 Predicted Groundwater Level Drawdown

The predicted groundwater level drawdown for the baseline runs at the end of mining are presented as contour plots in Figures 8 to 10. The plot shows the following:

- The asymmetrical drawdown reflects the geometry of the aquifer, with the steep hydraulic gradient corresponding to the ironstone extending above the water table, whilst the drawdown propagates along strike and down-dip of the ironstone aquifer.

- At the end of mining the predicted 5 m drawdown contour extends up to 1.5 km from the pit perimeter at Fraser's, 1.25 km from the pit perimeter at Bald Hill and 2 km from the pit perimeter at Yangibana (Figures 8 to 10).

- Steep hydraulic gradients are predicted in the fresh basement (HU3) beyond the outcropping ironstone, with the 5 m contour extending only about 500 m from the pit perimeter (Figure 8 to 10).

- The groundwater drawdown contours suggest that other groundwater users in the area are not expected to be impacted by dewatering (Figure 11). The nearest identified other groundwater user (Yangibana Bore) is located 2.7 km from the predicted 5 m drawdown contour.

7.0 PIT LAKE MODELLING

The pit lake model was developed using the generic systems modelling package GoldSim, which is ideally suited to coupled water and solute balance modelling. The model was run over a 500 year period to estimate pit lake conditions after mine closure.

The final mining depth in the three planned pits lies below the ambient groundwater level. At mine closure pumping will cease and the pits will start to flood forming a pit lake. Flooding will be primarily from the inflow of groundwater, which in conjunction with sporadic inflows from rainfall and runoff, will initially exceed losses from evaporation. This regime will be maintained until the combined inflow is balanced by the combined outflow, allowing for seasonal variability.

In the Gascoyne region, where evaporation far exceeds rainfall, the main drivers controlling the pit lake level will be groundwater inflow and evaporative outflow. Once the pit lake level stabilises one of two conditions are likely to develop. If the hydraulic conductivity of the groundwater systems associated with the pit lakes is sufficiently low, then a steep hydraulic gradient will be required to provide the necessary groundwater inflow to balance the evaporative loss. This will result in a depressed lake level and the development of a local groundwater sink (i.e. where the lake level lies below the groundwater level down-gradient of the pit), with no discharge of lake water to the groundwater environment.

Alternatively, if the hydraulic conductivity of the pit walls is sufficiently high then the hydraulic gradient needed to balance groundwater inflow against evaporative outflow will be low. In this instance, it is possible that the pit lake level will lie above the ambient groundwater level on the down-gradient side of the pit, thereby allowing pit lake water to discharge to the environment, forming a flow through cell.

If pit lake water is released, then there is a risk that any groundwater resources in the area could become impacted by mixing with pit water that may be contaminated.

7.1 Water Balance Set-Up

The GoldSim pit lake model includes three sub-models that simulate the development of pit void lakes in the three proposed pits. The model comprises the following components.

- Pit lake storage volumes.
- Inflows to the pits comprising:
  - groundwater inflows, which occur when the pit lake water level lies below the ambient groundwater level;
  - direct (incidental) rainfall onto the pit lakes;
  - rainfall runoff from the pit catchments into the pit void lakes.
- Outflows from the pit comprising:
  - evaporation from the pit lakes;
  - groundwater outflows, which occur if the pit lake water level exceeds the ambient groundwater level.

7.1.1 Pit Lake Storage Volume

The volume stored in the pit lake is estimated by the model based upon the total inflows and outflows to the lake over a time step, and the volume of the lake at the previous time step. At time zero (i.e. the start of the model run) the lake is assumed to have a nominal volume of 50 m^3. GoldSim requires a volume at the start of the model run for the solute balance calculations.

The water balance equation used to calculate the stored volume is presented below.

$$Storage_i = (Inflow - Outflow) + Storage_{i-1}$$

Where $Storage_i$ = the pit lake volume at the current time step

Inflow = the total inflow to the pit lake

Outflow = the total outflow from the pit lake

$Storage_{i-1}$ = the pit lake volume at the previous time step

7.1.2 Groundwater Inflows and Outflows

Estimation of seepage outflows and inflows from the pit lakes were calculated based upon the Dupuit equation for horizontal groundwater flow in an unconfined aquifer:

$$Q = P \; x \; K \; x \; \frac{(h_{B^2} \; - \; h_{A^2})}{2L}$$

Where,

Q = seepage flow rate

P = pit perimeter length

K = hydraulic conductivity of the geological units adjacent to the pit lake

h_B = difference in height between the ambient groundwater level and the base of aquifer (assumed to be equivalent to the pit floor elevation)

h_A =difference in height between the pit lake water level and the base of pit lake (i.e. the lake depth)

L = flow path length.

All parameters in the equation, apart from h_A, are applied as constants by the water balance. The perimeter length was estimated from mine plans provided by Snowden.

The height of the ambient groundwater level, which represents the natural water level unaffected by mining or groundwater production, was taken from monitoring data collected during the field investigation. Hydraulic conductivity and flow path length were based upon modelling studies completed during the dewatering assessment (Section 6.0) and adjusted during model verification.

The parameter values used in the water balance models are provided in Table 21.

Table 21: Baseline Groundwater Flow Parameters

Pit	K (m/d)	Ambient GWL (mAHD)	Flow Path Length (m)
Fraser's	0.32	309	800
Bald Hill	0.66	316	1,000
Yangibana	0.40	323	1,200

Note K = hydraulic conductivity.

7.1.3 Rainfall and Runoff

Rainfall and rainfall runoff inflows are estimated by the model using daily rainfall data from the nearby Wanna meteorological station.

Average and wet rainfall conditions were tested, based upon the analysis of the daily 10-year rolling rainfall totals for the station. The average rainfall conditions were taken from the 10 year period 1985 to 1994 inclusive which best matched the mean rainfall for the station, and the wet conditions were taken from the record from 1992 to 2001 inclusive which had the highest 10 year rainfall total. Each 10-year sequence was looped to cover the model run-time. The use of daily data is preferred as it captures the high rainfall variability characteristic of the region.

The external (ex-pit) catchment areas which could report to the pits after mine closure has not been assessed at this stage. It is understood that the surface water management assessment is to be completed in early 2017. In the absence of catchment information, two conditions were run for each pit; the pit catchment only, which comprised the area within the pit crest; and the pit catchment plus 20%. These values will need to be adjusted in the models once the surface water management assessment has been completed.

Rainfall runoff from external catchments is affected by losses from evaporation and infiltration, whilst direct rainfall on the pit walls will have minimal losses. However, in the absence of a surface water management assessment, a conservative runoff coefficient of 1 was applied to both the pit catchment only, and the pit catchment plus 20% conditions. Again, these values will need to be adjusted once the surface water management assessment has been completed.

Table 22: Pit and Assumed External Catchments

Pit	In-Pit Catchment (m^2)	Runoff Coefficient
Fraser's	114,000	1
Bald Hill	340,000	1
Yangibana	510,700	1

7.1.4 Evaporative Outflows

Evaporation losses are estimated by the model using the synthetic monthly evaporation rates estimated for the project area (Section 2.2), which uses the scaled mean of measured values at Paraburdoo and Learmonth. The monthly data is adjusted for pan to lake effects, using a coefficient of 0.7, and a salinity factor based on an empirical relationship developed by Turk (1970)[1]. The solute balance used to estimate the pit lake salinities is described in a later section below.

The adjusted evaporation rates were applied to the estimate area of the pit lakes, which were calculated from the relationship between lake volume and surface area at each time step (discussed in the following section).

7.1.5 Pit Geometry

The water balance uses the relationships between the pit volume (the independent variable), which is tracked by the model at each time step, and elevation and pit area (dependant variables) to estimate the groundwater-pit lake interaction, rainfall/runoff inflows and evaporative losses.

The pit geometry data (as provided by Snowden) is provided in Table 23.

[1] LJ Turk 1970. "Evaporation of brine: a field study of the Bonneville salt flats, Utah", August 1970. Water Resources Research 6(4), pp 1209-1215.

Table 23: Pit Geometry Data

Fraser's Pit			Bald Hill Pit			Yangibana Pit		
RL	Surface Area (m^2)	Cumulative Volume (m^3)	RL	Surface Area (m^2)	Cumulative Volume (m^3)	RL	Surface Area (m^2)	Cumulative Volume (m^3)
255	5,821	34,926	280	1,804	10,824	253	7,087	58,612
261	8,126	83,683	285	6,133	47,624	259	14,303	144,430
267	13,850	166,781	291	19,001	161,627	265	24,043	288,690
273	16,213	264,059	297	31,216	348,925	271	40,399	531,086
279	23,337	404,079	303	54,914	678,408	277	56,880	872,368
285	28,875	577,330	309	77,461	1,143,172	283	84,506	1,379,401
291	38,004	805,351	315	109,182	1,798,263	289	110,219	2,040,713
297	42,181	1,058,439	321	128,076	2,566,719	295	153,609	2,962,369
303	52,013	1,370,516	327	155,693	3,500,879	301	186,169	4,079,380
309	55,518	1,703,626	333	213,516	4,781,976	307	242,870	5,536,600
315	67,612	2,109,301	339	280,360	6,464,136	313	284,127	7,241,363
321	72,386	2,543,617	345	233,240	7,863,579	319	361,773	9,412,000
327	84,982	3,053,507	-	-	-	325	395,770	11,786,620
333	89,631	3,591,295	-	-	-	331	325,963	13,742,396
339	101,152	4,198,206	-	-	-	-	-	-

7.1.6 Solute Balance Set-Up

A simple solute balance was developed for the GoldSim model to track the salinity of the pit lakes after closure. This was achieved based on the following:

- a TDS concentration of 1,200 mg/L for the initial pit lakes at Fraser's, 1,000 mg/L for Bald Hill and 920 mg/L for Yangibana, equivalent to the laboratory analysis from the recent field investigations.
- similarly a TDS concentration of 1,200 mg/L for Fraser's, 1,000 mg/L for Bald Hill and 920 mg/L for Yangibana, for groundwater inflows to the pit lakes;
- a TDS concentration equivalent to the pit lake salinity for the previous time-step for groundwater outflows from the pit lakes;
- zero salt inflows from rainfall;
- zero salt losses from evaporation; and
- complete mixing within the pit lakes (i.e. no allowance was made for stratification).

7.2 Water Balance Modelling Results

A run time of 500 years was adopted for the water balance model simulations, using a one day time step.

Twelve model runs were completed, comprising:

- three base case runs (one per pit) using the pit only catchment and expected conditions
- three sensitivity runs (one per pit) using the pit only catchment and high rainfall conditions
- three sensitivity runs (one per pit) using the pit plus 20% catchment and expected conditions
- three sensitivity runs (one per pit) using the pit plus 20% catchment high rainfall conditions

The groundwater inflow rates predicted by the water balance for the three pits was verified by comparing the inflow rate against the dewatering requirements estimated in the groundwater flow models. The water balance inflow rates approximate those derived from the dewatering assessment at the end of mining.

Table 24: Model Runs

Run No	Pit	Rainfall	Catchment	Run Type
01	Fraser's	Average	Pit Only	Baseline
02	Fraser's	Wet	Pit Only	Sensitivity
03	Fraser's	Average	Pit plus 20%	Sensitivity
04	Fraser's	Wet	Pit plus 20%	Sensitivity
05	Bald Hill	Average	Pit Only	Baseline
06	Bald Hill	Wet	Pit Only	Sensitivity
07	Bald Hill	Average	Pit plus 20%	Sensitivity
08	Bald Hill	Wet	Pit plus 20%	Sensitivity
09	Yangibana	Average	Pit Only	Baseline
10	Yangibana	Wet	Pit Only	Sensitivity
11	Yangibana	Average	Pit plus 20%	Sensitivity
12	Yangibana	Wet	Pit plus 20%	Sensitivity

The predicted pit lake water levels for model Runs 01 to 12 are presented as time series plots in Figures 12 to 14. The figures also present the adopted ambient groundwater level at the deposits. The pit lake water levels and lake residual drawdowns[2] for the 12 model runs are presented in Table 17. The figures and table show the following:

- All model runs show a similar pattern following the cessation of mining:
    - A rapid pit lake level rise over the initial 10 years when groundwater inflow rates far exceed evaporation rates, because of the high groundwater hydraulic gradient and the comparatively small lake area available for evaporation.
    - The rate of rise reduces between 10 and 15 years after cessation of dewatering due to increased evaporation rates, because of the expanded pit lake area as the pit fills, and the reduced groundwater inflow rate in response to the lowering of the groundwater gradient towards the pit.

[2] The residual drawdown represents the vertical distance from the ambient groundwater level to the pit lake level. Positive values indicate the lake will form a groundwater sink, while negative values, where lake levels lie above the surrounding groundwater level, suggests seepage from the pit lake to the groundwater system will occur.

- The pit lake water levels equilibrate after 20 years as the falling groundwater and rainfall inflows are balanced by the evaporative losses.

- By the end of the 500 year model run, the pit lake levels have stabilised, with minor seasonal and annual variations in response to variation in rainfall and evaporation.

- For the baseline condition the final predicted pit lake level ranges from 300.9 mAHD in Fraser's, to 311.1 mAHD in Bald Hill, to 311.5 mAHD in Yangibana, which gives a residual drawdown range of 8.0 m (Fraser's), to 4.9 m (Bald Hill), to 11.5 m (Yangibana), indicating that all pits act as groundwater sinks under baseline conditions.

- For the sensitivity analyses relating to wet years (Runs 02, 04, 06, 08, 10, 12), the residual drawdown ranges from 2.5 m (Bald Hill) to 10.4 m (Yangibana), indicating that the pits continue to act as groundwater sinks under high rainfall conditions.

- The model also provides an estimate of TDS concentrations post-closure, based upon evaporative concentration in the pit lakes. The results indicate that after 500 years post closure the TDS in Fraser's increase from 1,200 mg/L to about 44,000 mg/L TDS, in Bald Hill increase from 1,000 mg/L to about 48,000 mg/L TDS, and in Yangibana increase from 920 mg/L to about 37,000 mg/L TDS.

The results of the pit lake modelling indicate that the risk of impact (i.e. discharge of lake water) to the groundwater environment post closure is low. However, it should be noted that the residual drawdown is a function of the ex-pit catchment parameters, i.e. pits with larger ex-pit catchments and lower rainfall coefficients report higher final predicted pit lake levels and corresponding lower residual drawdowns. Therefore the pit lake modelling will require re-running once the ex-pit catchment parameters are established as part of the pending surface water management assessment for the Project.

Table 25: Predicted Lake Levels and Residual Drawdowns

Pit	Run Number	Minimum Pit Lake Level (mAHD)	Maximum Pit Lake Level (mAHD)	Mean Pit Lake Level (mAHD)	Minimum Residual Drawdown (m)	Maximum Residual Drawdown (m)	Mean Residual Drawdown (m)
Fraser's	***Run 01***	***250.0***	***300.9***	***300.3***	***59.0***	***8.0***	***8.7***
	Run 02	250.0	302.1	301.0	59.0	6.9	8.0
	Run 03	250.0	301.4	300.7	59.0	7.6	8.3
	Run 04	250.0	302.9	301.6	59.0	6.1	7.4
Bald Hill	***Run 05***	***279.0***	***311.1***	***310.3***	***37.0***	***4.9***	***5.7***
	Run 06	279.0	312.6	311.3	37.0	3.4	4.7
	Run 07	279.0	311.7	310.8	37.0	4.3	5.2
	Run 08	279.0	313.5	311.9	37.0	2.5	4.1
Yangibana	***Run 09***	***250.0***	***311.5***	***310.8***	***73.0***	***11.5***	***12.2***
	Run 10	250.0	312.6	311.6	73.0	10.4	11.4
	Run 11	250.0	311.9	311.2	73.0	11.1	11.8
	Run 12	250.0	313.2	312.2	73.0	9.8	10.8

Note: bold italics = baseline condition

8.0 DEWATERING STRATEGY

The inflow rates predicted by the groundwater flow models indicate dewatering of the proposed pits will be best achieved by a combination of ex-pit dewatering bores and sump pumping methods.

Sufficient additional contingency of at least 50 L/sec should be considered to allow for short term, higher than anticipated groundwater inflow rates upon interception of additional water bearing features in the fresh bedrock, and to manage increases in groundwater inflows following high rainfall events. Further contingency will need to be considered to account for surface water inflows as a result of rainfall and runoff to the pits.

The dewatering bores should be positioned into a thick (preferably greater than 10 m) sequence of ironstone, and located just outside the crest of the pits, on the down dip side. One to two dewatering bores would be suitable for each of Fraser's and Bald Hill, and two to three bores would be suitable for Yangibana. Additional dewatering bores could be considered if higher than predicted inflow rates are observed during operations.

The test bores FRW03 and BHW05 are suitably located as dewatering bores. However given that they were constructed for testing purposes only, using uPVC casing, they may not withstand the pressure of blasting during mining. The test bores will be suitable during the construction phase but will likely require replacement or refurbishment prior to mining.

The dewatering bores should be constructed using 6" schedule 40 steel casing (7.1 mm wall thickness). The steel casing should be slotted across the main aquifer zone (as per the test bore construction), with the bore annulus gravel packed to just below the surface. The annulus will need to be sealed at the surface, with cement grout or bentonite, to prevent surface water ingress.

It is recommended the dewatering bores are installed at least 6 months prior to mining to achieve sufficient drawdown. However the bores can be operated prior to this, to provide additional make-up water to meet the Project demand if necessary (discussed further in Section 9.0), which will further aid mine dewatering.

Sump pumping will require ongoing management during the operational life of the pits. Sumps should be strategically located at low points along the pit floor.

All dewatering discharge will be transferred to a process water dam at the surface for use by the operation for dust suppression and mineral processing. At the predicted dewatering rates there should be no requirement to discharge mine water to the environment.

A monitoring programme will be required during mining to help assess the impacts upon the groundwater environment from groundwater abstraction as a result of dewatering activities. As part of the monitoring programme a network of monitoring bores will need to be installed to provide an indication of drawdown impacts upon the surrounding groundwater system. An operating strategy will be required as part of the conditions of a future groundwater abstraction (5C) licence, based upon the DoW guidelines (Operational Policy 5.08). A monitoring programme and operating strategy should be prepared upon completion of the Stage II DFS study.

9.0 WATER SUPPLY OPTIONS

The Project's estimated total water demand is in the order of 2.5 GL/annum (79.3 L/sec) of fresh to brackish quality groundwater, for the purposes of processing, dust suppression and domestic / potable use.

As discussed in Section 6.8.1, mine dewatering is anticipated to provide a water supply for the project after year 2, with average estimated dewatering rates ranging from 6 L/sec during year 2 to approximately 51 L/sec during year 7. Consequently an alternate water supply will be necessary to provide the full demand (79.3 L/sec) for the first year of operation, and part of the demand for the remainder of the LoM.

Additional water supply options for the Project include:

- Extended use of dewatering bores. It is recommended (Section 7.0) that the dewatering bores are operated at least 6 months prior to mining to achieve sufficient drawdown. However, at Yangibana, and to a lesser extent Fraser's, the dewatering bores could be operated from year 1, which could provide an additional supply of about 20 to 30 L/sec during the first few years of mining. Additional field investigations will be necessary to confirm suitable bore locations (other than at FRW03 and BHW05).

- Sacrificial bore at Yangibana. During the Stage I field investigations, a location for a potential sacrificial bore was identified (at YWRC057) within the pit area. The drill-hole yielded 8 L/sec during airlift recovery testing and could potentially provide a supply of 10 to 15 L/sec for years 1 to 3, prior to the commencement of mining at Yangibana.

- Extended use of sump pumping. Groundwater abstraction from the Fraser's and Bald Hill pits could continue after mining, providing an additional water supply during years 5 to 7. Groundwater modelling indicates that groundwater inflows to pit at the end of mining are about 10 L/sec at Fraser's and 14 L/sec at Bald Hill, potentially providing an additional 24 L/sec during the latter stages of the Project.

- Water supply bores Auer North. Auer North is located approximately 5 km west of Fraser's (Figure 11) and anecdotally reported groundwater inflows similar to those reported in Bald Hill. Further field investigations would be necessary to confirm the water supply potential from this area. However, anecdotal information suggests there is the potential for 1 to 2 bores at about 8 L/sec per bore. The proximity of Auer North to Fraser Well will need to be considered in the Stage II study.

- Water supply borefield Western Belt. Hastings has identified an area of approximately 12 km of ironstone strike length, referred to as the Western Belt (Figure 11), extending east of Yangibana. Resource drilling has indicated similar characteristics (i.e. thick sequence of fractured and vuggy ironstone) to those observed at Yangibana, suggesting the Belt may be suitable for a borefield. A borefield of up to 10 bores along the Belt could provide up to 60 L/sec for the duration of the Project. However additional field investigations will be necessary to confirm the water supply potential of this area.

- Palaeochannel water supply borefield. The WASANT Palaeovalley Map, produced by the National Water Commission, indicates that the Lyons Palaeovalley lies to the west of Yangibana and to the south of Bald Hill and Fraser's. Whilst there is very little data on likely yields from palaeochannel aquifers in the immediate area, palaeochannel aquifers provide reliable yields in other regions. The benefit of a palaeochannel borefield for the Project is that it removes the reliance on the ironstone aquifer, which potentially has limited storage. However, groundwater quality in palaeochannel aquifers are typically poorer; there is the potential for interaction with GDE's, and additional tenure may need to be acquired. Further investigations would be necessary, should Hastings wish to pursue this option, which would likely include an initial assessment of publicly available geophysical surveys to identify target transects, followed by further ground surveys (if necessary) and aircore drilling to identify the deepest part of the palaeochannel.

It is expected that the Project's water supply demand can be met from a combination of dewatering and some of the above-mentioned additional sources. However further hydrogeological investigations would be necessary to confirm this.

10.0 SUMMARY AND CONCLUSIONS

Hastings owns the Yangibana Rare Earths Project (the Project), located approximately 270 km east north-east of Carnarvon, in the Upper Gascoyne region of Western Australia.

The project has an estimated annual water demand of up to 2.5 GL/annum (79.3 L/sec), for the purposes of mineral processing, dust suppression and camp / potable supply (via reverse osmosis treatment).

The results of the Stage I study are as follows:

- The results of the exploration drilling confirmed modest groundwater inflows associated with the ironstone dykes, and identified suitable test bore locations at Fraser's and Bald Hill.

- The results of the hydraulic testing indicated; airlift yields ranged from 0.015 L/sec to 8 L/sec; three test locations reported low permeability conditions (hydraulic conductivity below 0.1 m/day); three test locations reported low to modest permeability conditions (hydraulic conductivity between 0.1 and 1 m/day); and six test locations reported modest permeability conditions (hydraulic conductivity above 1 m/day).

- Two test production bores were installed (FRW03 at Fraser's and BHW05 at Bald Hill), intercepting the ironstone aquifer, down-dip from the proposed pits. The bores were constructed using 155 mm Class 9 uPVC casing to depths of 95.2 and 104 m respectively.

- Three bores were test pumped (FRW03, BHW05 and the existing drilling supply bore YGWB03). Testing comprised a 3 to 4 hour step test and 48 hour constant rate test, and recovery test. The test pumping indicated drawdown patterns consistent with a semi-confined aquifer, with barrier boundary conditions observed in the Fraser's and Bald Hill bores, indicative of a fractured rock environment whereby smaller fractures are drained during testing. The results indicate a hydraulic conductivity range of 2.5 to 5.6 m/day, which is consistent with the hydraulic testing results.

- Estimated long term duty rates for FRW03 are 7 L/sec for peak use, and 6 L/sec for long term operational use, and for BHW05 are 10 L/sec for peak use, and 8 L/sec for long term operational use. YGWB03 is low yielding and probably unsuitable for a long term operational supply.

- It must be understood that the ironstone aquifer potentially has limited storage, and sufficient water supply contingency will be necessary for the Project to account for this.

- The groundwater salinity in the three production bores varies from about 920 mg/L TDS at Yangibana, 1,000 mg/L TDS at Bald Hill, and 1,200 mg/L TDS at Fraser's.

- Groundwater samples have been collected and submitted to ANSTO for isotope analysis to provide an indication of groundwater age. Results are expected in April 2017.

- The groundwater level along the deposits range from about 309 mRL at Fraser's to 316 mRL at Bald Hill and 323 mRL at Yangibana. The groundwater flow direction is south south-west towards the Lyons River.

- The results of the field testing programme were used to construct a 3D groundwater flow model for the deposits and surrounding groundwater system to simulate the impacts upon the groundwater environment from mining below the water table. Sensitivity analyses were run to assess the implications of varying hydraulic properties. The results of the modelling indicate:

  - Under baseline conditions the average inflows range from 0 L/sec during the first year to 51 L/sec during year 7. Additional contingency of about 50 L/sec will be necessary to allow for short term, higher than anticipated inflow rates. Additional contingency will be necessary to manage incidental rainfall into the pit void and rainfall runoff.

  - The drawdown extents at the end of mining are asymmetrical which reflects the geometry of the aquifer, with the steep hydraulic gradient corresponding to the ironstone extending above the water table, whilst the drawdown propagates along strike and down-dip of the ironstone.

  - At the end of mining the predicted 5 m drawdown contour extends up to 1.5 km from the pit perimeter at Fraser's, 1.25 km from the pit perimeter at Bald Hill and 2 km from the pit perimeter at Yangibana.

  - Steep hydraulic gradients are predicted in the fresh basement beyond the outcropping ironstone, with the 5 m contour extending only about 500 m from the pit perimeter.

  - The groundwater drawdown contours suggest that other groundwater users in the area are not expected to be impacted by dewatering.

- A pit lake model was developed for each pit using the systems modelling package GoldSim. The models were run over a 500 year period to estimate pit lake conditions after mine closure. The results indicate that the risk of impact (i.e. discharge of lake water) to the groundwater environment post closure is low. However pit catchment areas have not yet been characterised for the project, and so the models were based on a nominal ex-pit catchment size of 20% of the pit area. Considering that the residual drawdown in the pits is a function of the ex-pit catchment parameters, i.e. pits with larger ex-pit catchments and lower rainfall coefficients report higher final predicted pit lake levels and corresponding lower residual drawdowns, the pit lake modelling will require re-running once the ex-pit catchment parameters are established.

- The recommended dewatering strategy for the Project, based upon the groundwater inflow rates predicted by the modelling, is a combination of ex-pit dewatering bores and sump pumping. One to two dewatering bores would be suitable for each of Fraser's and Bald Hills, and two to three bores would be suitable for Yangibana. Additional dewatering bores could be considered if higher than predicted inflow rates are observed during operations. The dewatering bores should be constructed at least 6 months prior to mining to achieve sufficient drawdown, and constructed using 6" mild steel casing to prevent damage during blasting. Sump pumping will be required in all pits for the duration of mining.

- The Project will require additional water supply sources to supplement the dewatering supply and meet the Projects total water demand of 2.5 GL/annum (79.3 L/sec). Additional water supply options have been identified which include extended use of dewatering bores and sump pumping; a sacrificial bore at Yangibana; water supply bore/s at Auer North; a water supply borefield in the Western Belt; or a palaeochannel water supply borefield. The benefit of a palaeochannel borefield for the Project is that it removes the reliance on the ironstone aquifer, which potentially has limited storage. However, groundwater quality in palaeochannel aquifers are typically poorer; there is the potential for interaction with GDE's, and additional tenure may need to be acquired. Further investigations will be necessary to confirm additional water supply sources for the Project.

Groundwater Resource Management Pty Ltd

Kathy McDougall — **SENIOR HYDROGEOLOGIST**

Rob Garnham — **PRINCIPAL HYDROGEOLOGIST**

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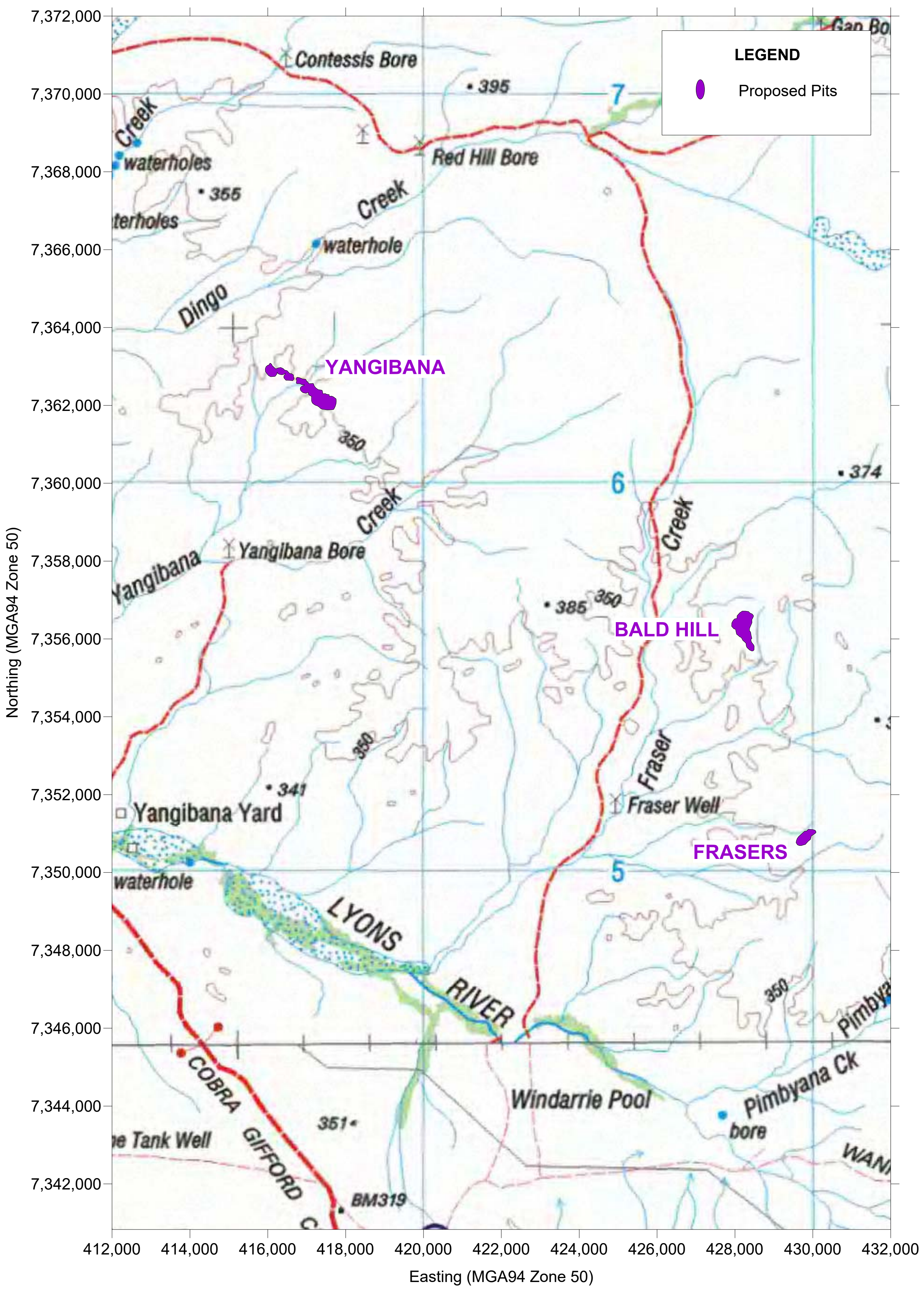
This report has been printed on paper that contains a proportion of recycled material as a gesture of Groundwater Resource Management's commitment to sustainable management of the environment.

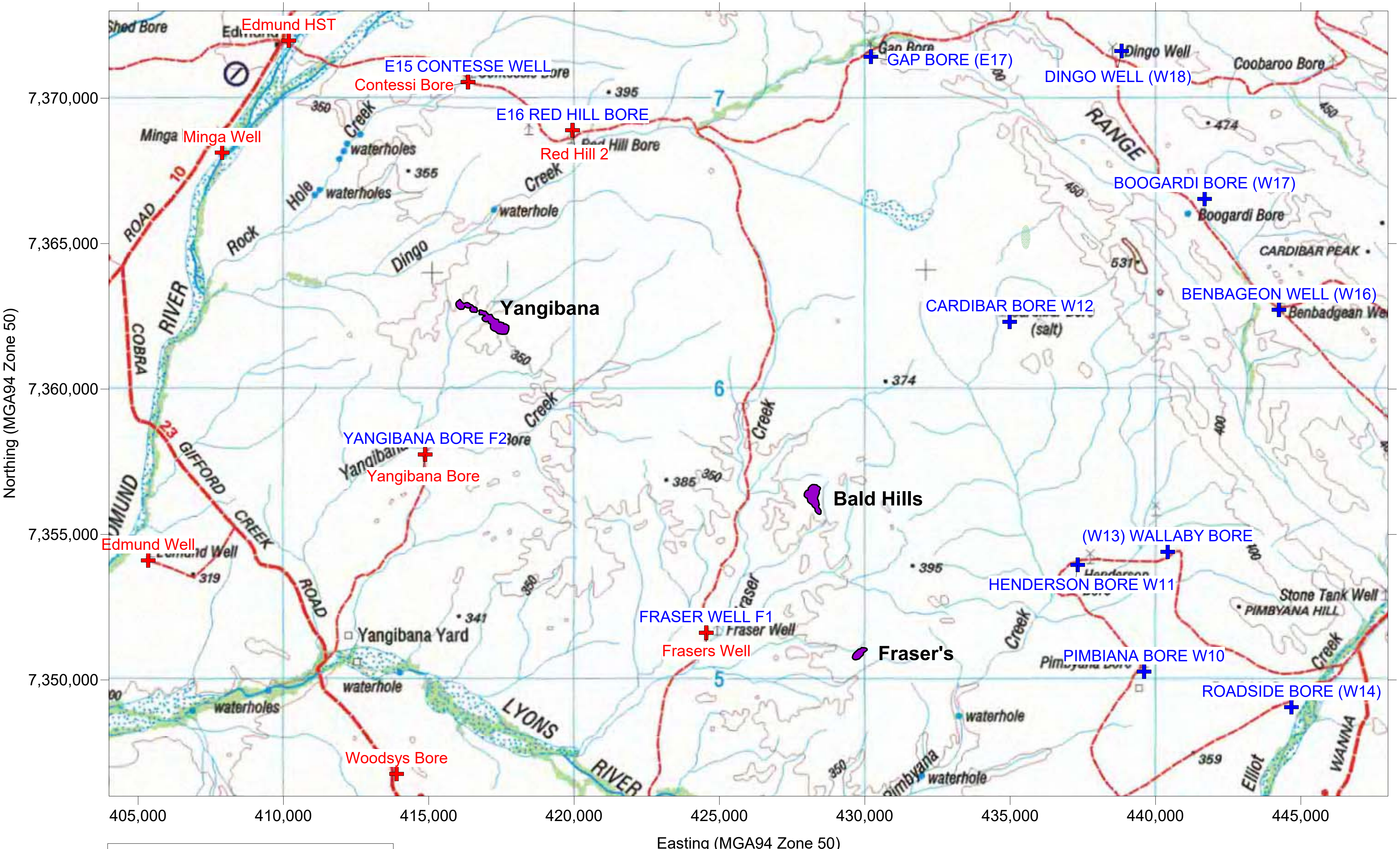
Yangibana DFS Stage I (J160014R01)			SITE LOCATION PLAN	GROUNDWATER RESOURCE MANAGEMENT
Hastings Technology Minerals Ltd				
KM	Jan 17	**FIGURE 1**		

FILE:\\G:\Jobs2016\J160014_YangibanaFS/figures/other/locplan.pptx



Yangibana DFS Stage 1 (J160014R01)			**SITE LAYOUT**	GROUNDWATER RESOURCE MANAGEMENT
Hastings Technology Minerals Ltd				
KM	Jan 17	**FIGURE 2**		

FILE://J160014_YangibanaDFS/figures/surfer/siteplan.srf



LEGEND

- WIR Bores
- Bores Sampled During PFS
- Proposed Pits

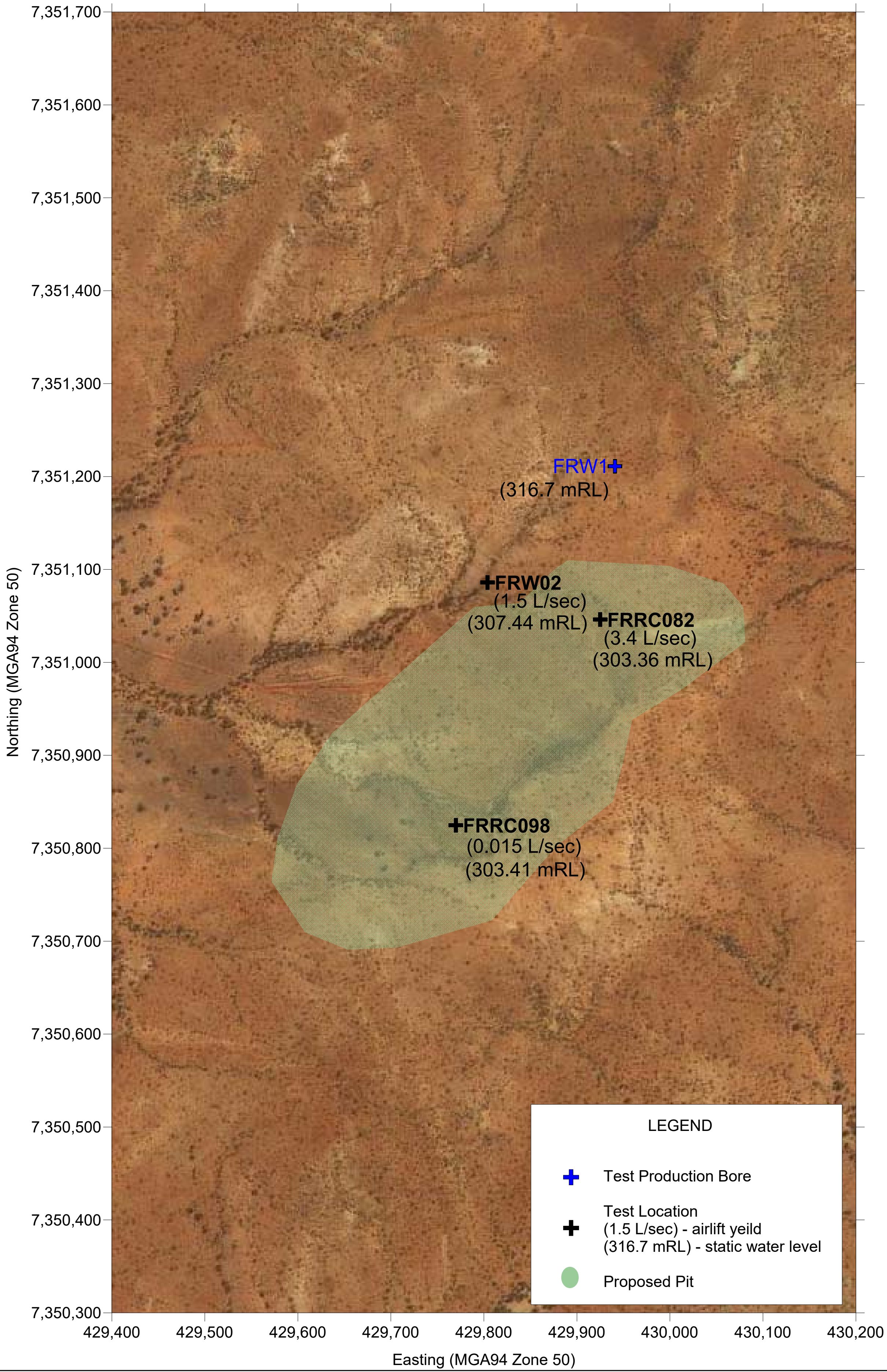
Yangibana DFS Stage 1 (J160014R01)	
Hastings Technology Minerals Ltd	
KM	Jan 2017

FIGURE 3

OTHER GROUNDWATER USERS

GROUNDWATER RESOURCE MANAGEMENT

FILE://J160014_Yangibana/figures/surfer/location plan.srf

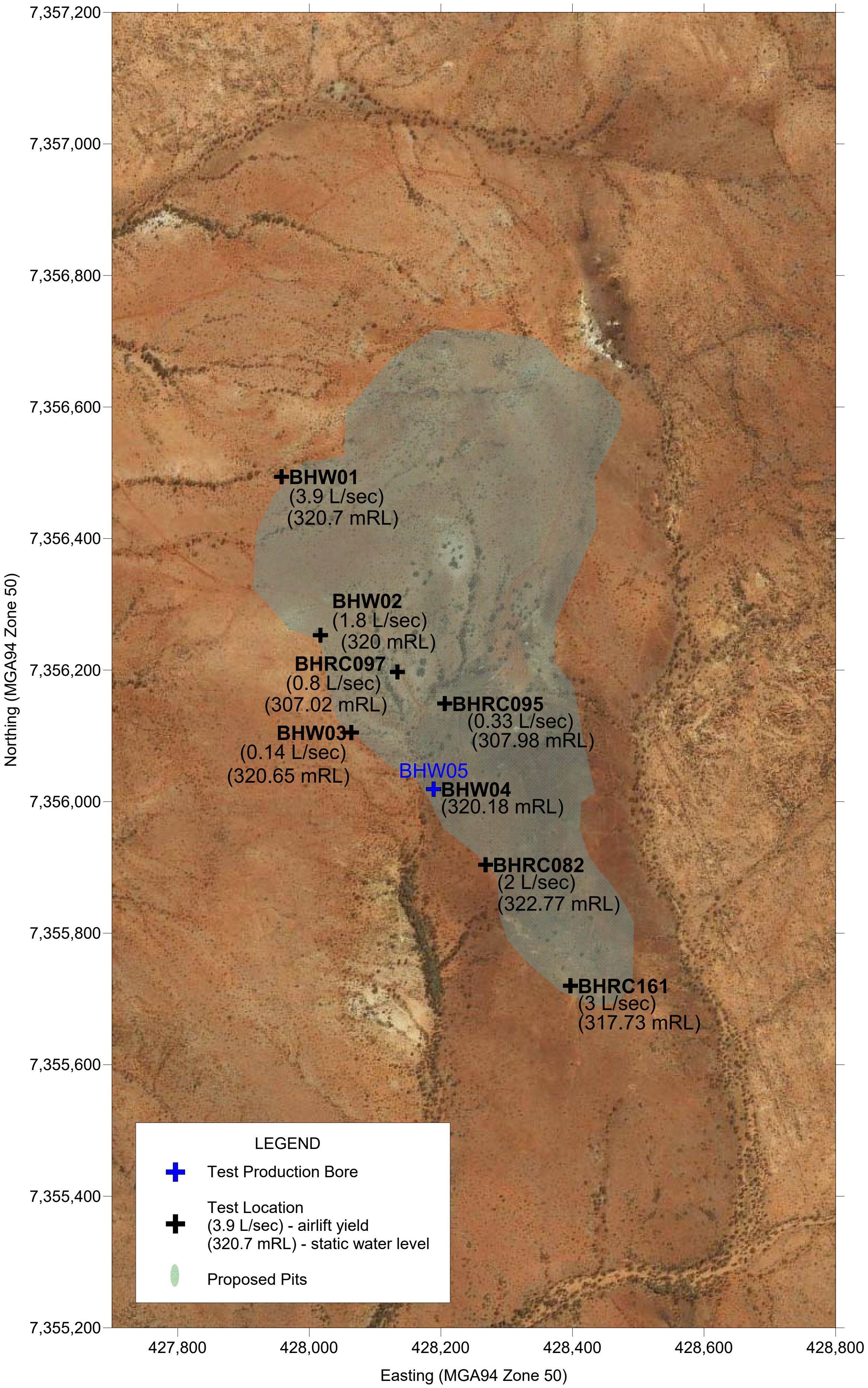


Yangibana DFS Stage 1 (J160014R01)		
Hastings Technology Minerals Ltd		
KM	Jan 2017	**FIGURE 4**

FRASER'S DRILLING RESULTS

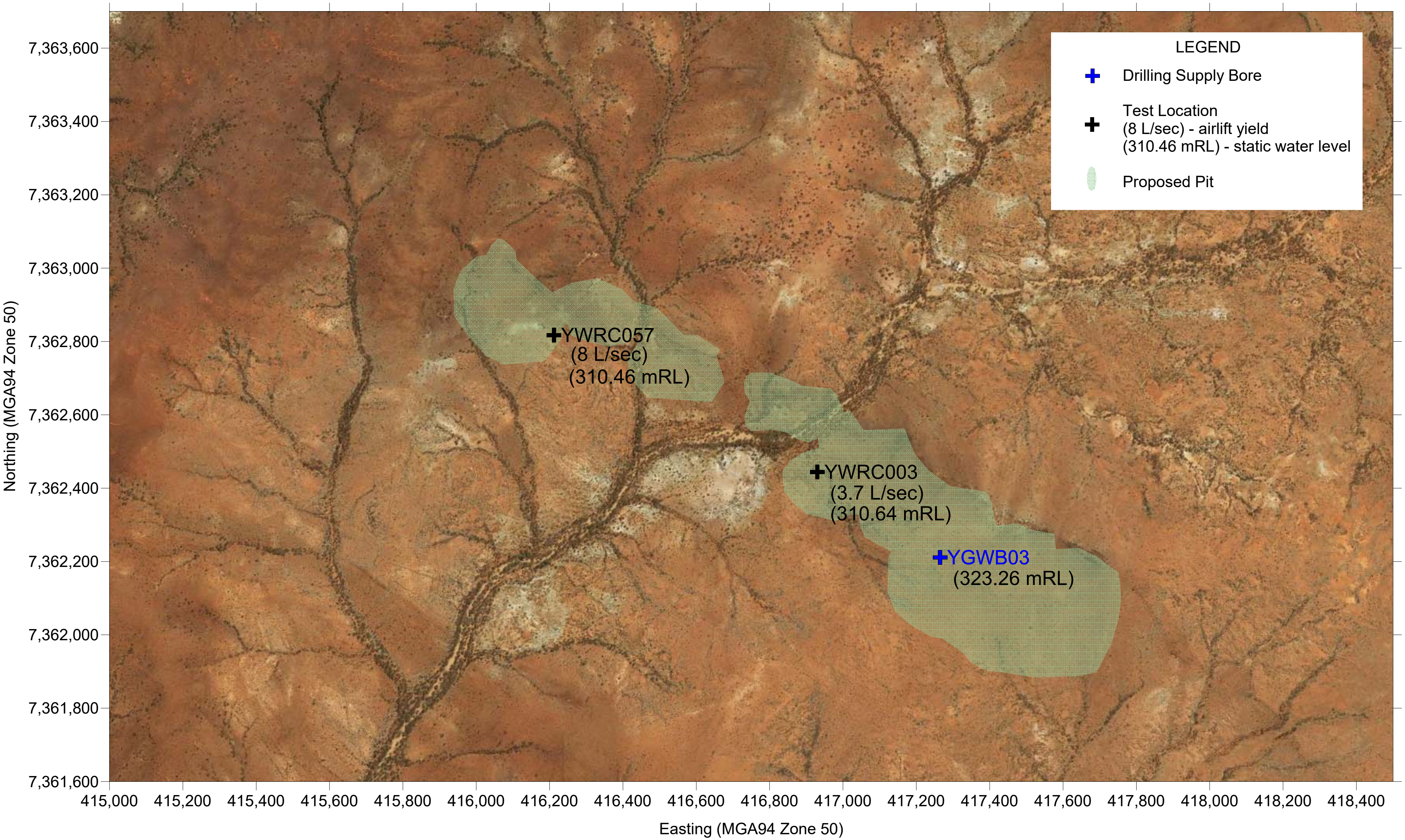
GROUNDWATER RESOURCE MANAGEMENT

FILE://Jobs2016/J160014_Yangibana/figures/surfer/frasers_drillingresults.srf



Yangibana DFS Stage I (J160014R01)			**BALD HILLS DRILLING RESULTS**	GROUNDWATER RESOURCE MANAGEMENT
Hastings Technology Minerals Ltd				
KM	Jan 2017	**FIGURE 5**		

FILE://Jobs2016/J160014_Yangibana/figures/surfer/baldhill_drillingresults.srf

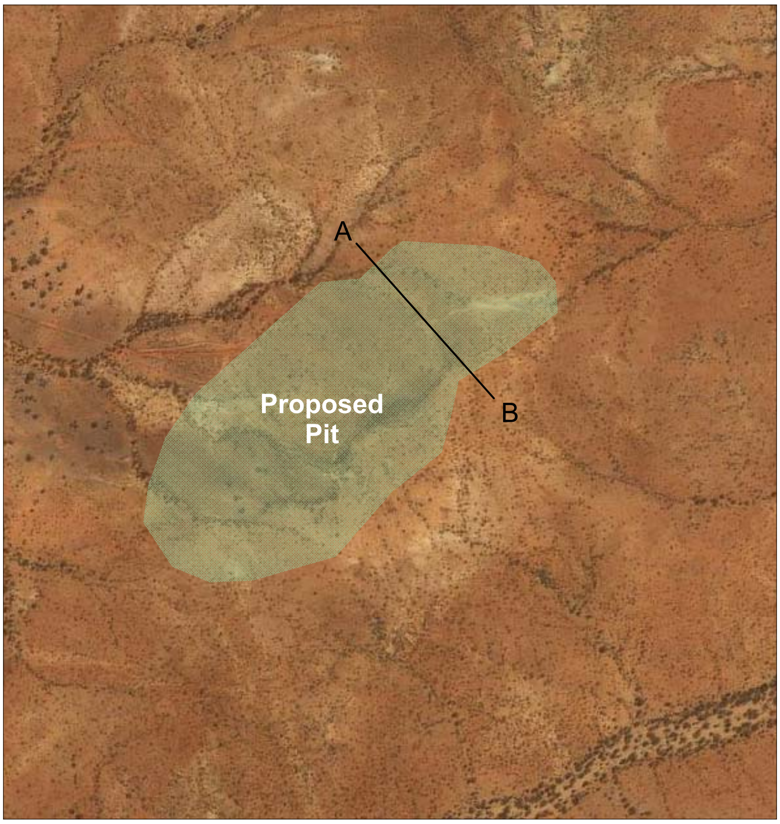


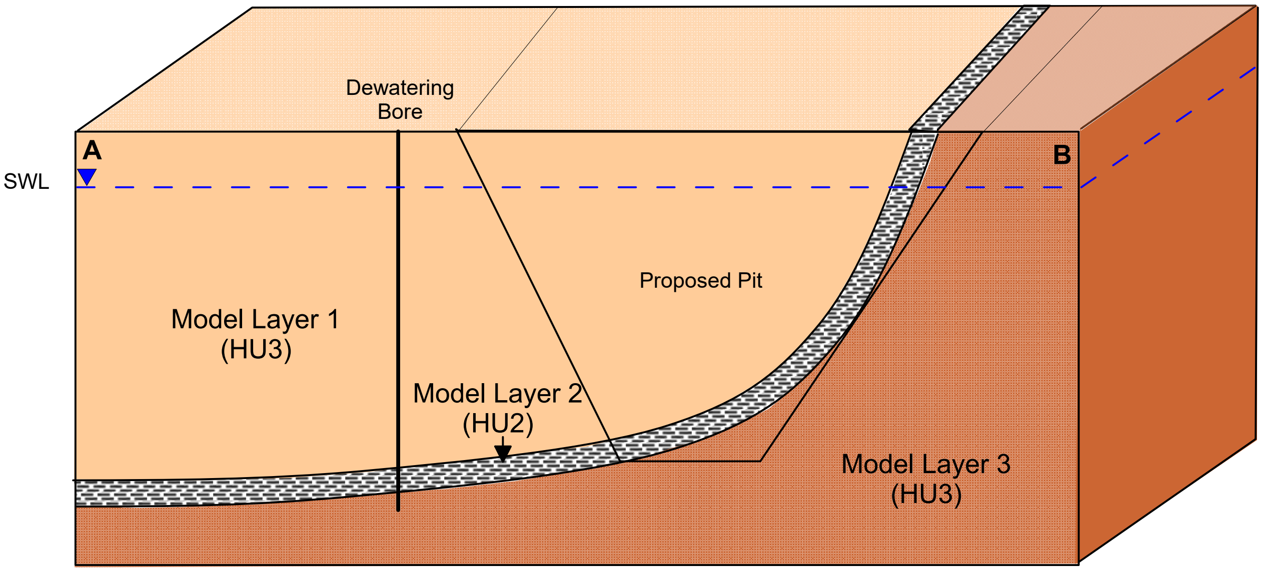
Yangibana DFS Stage I (J160014R01)		
Hastings Technology Minerals Ltd		
KM	Jan 2017	**FIGURE 6**

YANGIBANA DRILLING RESULTS

GROUNDWATER RESOURCE MANAGEMENT

FILE://J160014_Yangibana/figures/surfer/yangibana_drilling results.srf



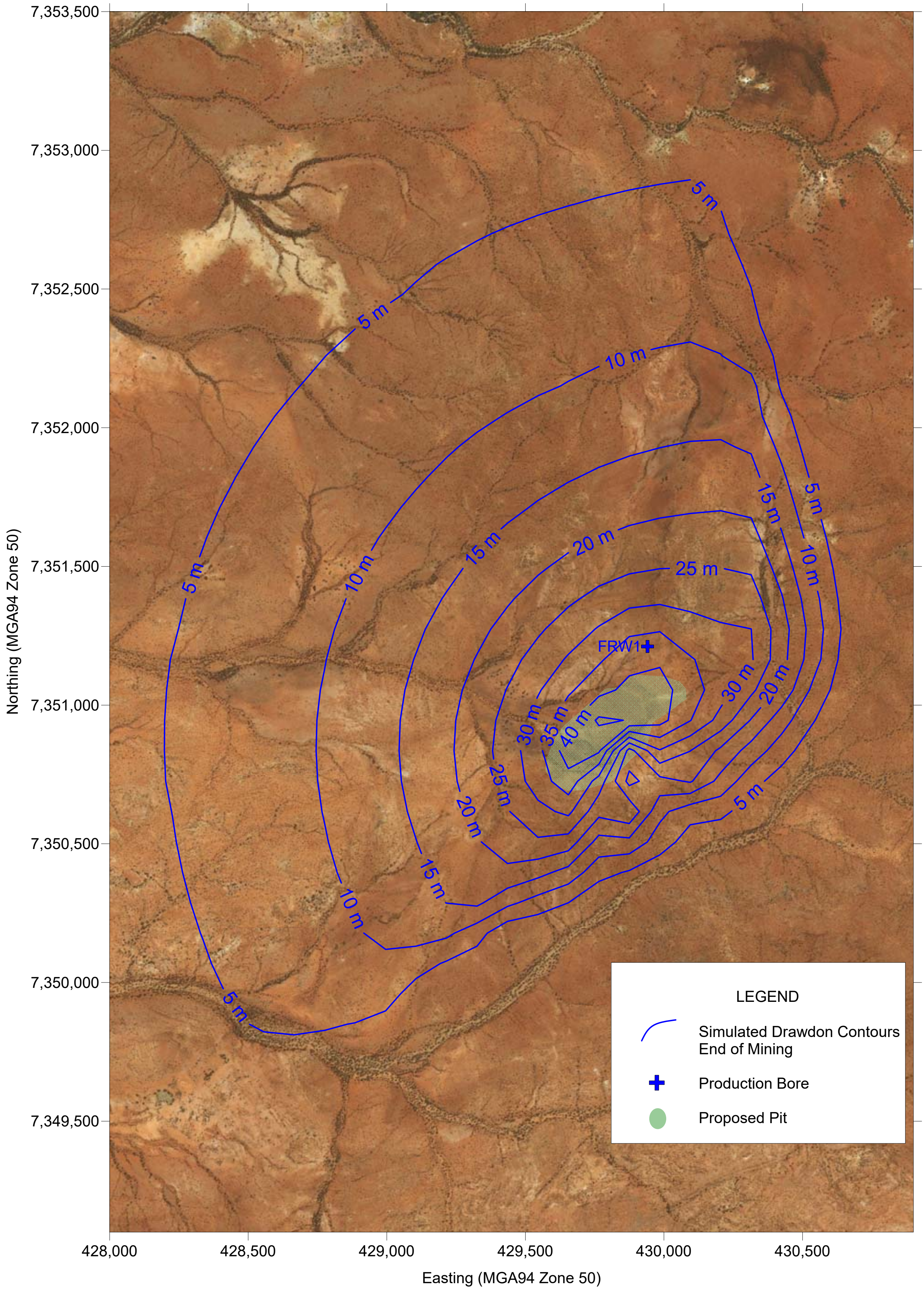


Yangibana DFS Stage I (J160014R01)		
Hastings Technology Minerals Ltd		
KM	Jan 2017	**FIGURE 7**

SCHEMATIC CONCEPTUAL MODEL

GROUNDWATER RESOURCE MANAGEMENT

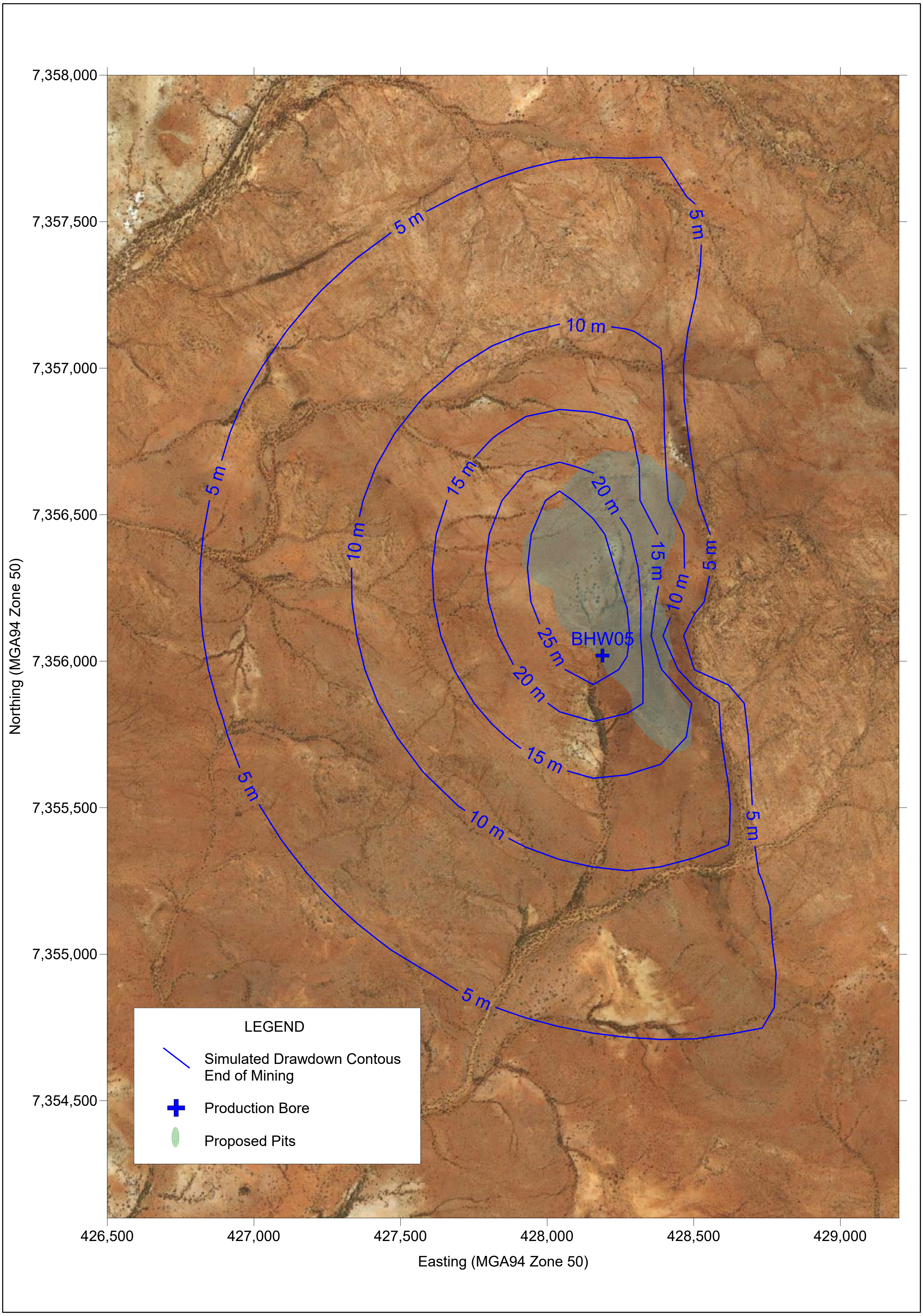
FILE://Jobs2016/J160014_Yangibana/figures/surfer/conceptual model.srf



Yangibana DFS Stage 1 (J160014R01)			**FRASER'S MODEL SIMULATED DRAWDOWN CONTOURS END OF MINING**
Hastings Technology Minerals Ltd			
KM	Jan 2017	**FIGURE 8**	

GROUNDWATER RESOURCE MANAGEMENT

FILE://Jobs2016/J160014_Yangibana/figures/surfer/frasers_modelling_results.srf

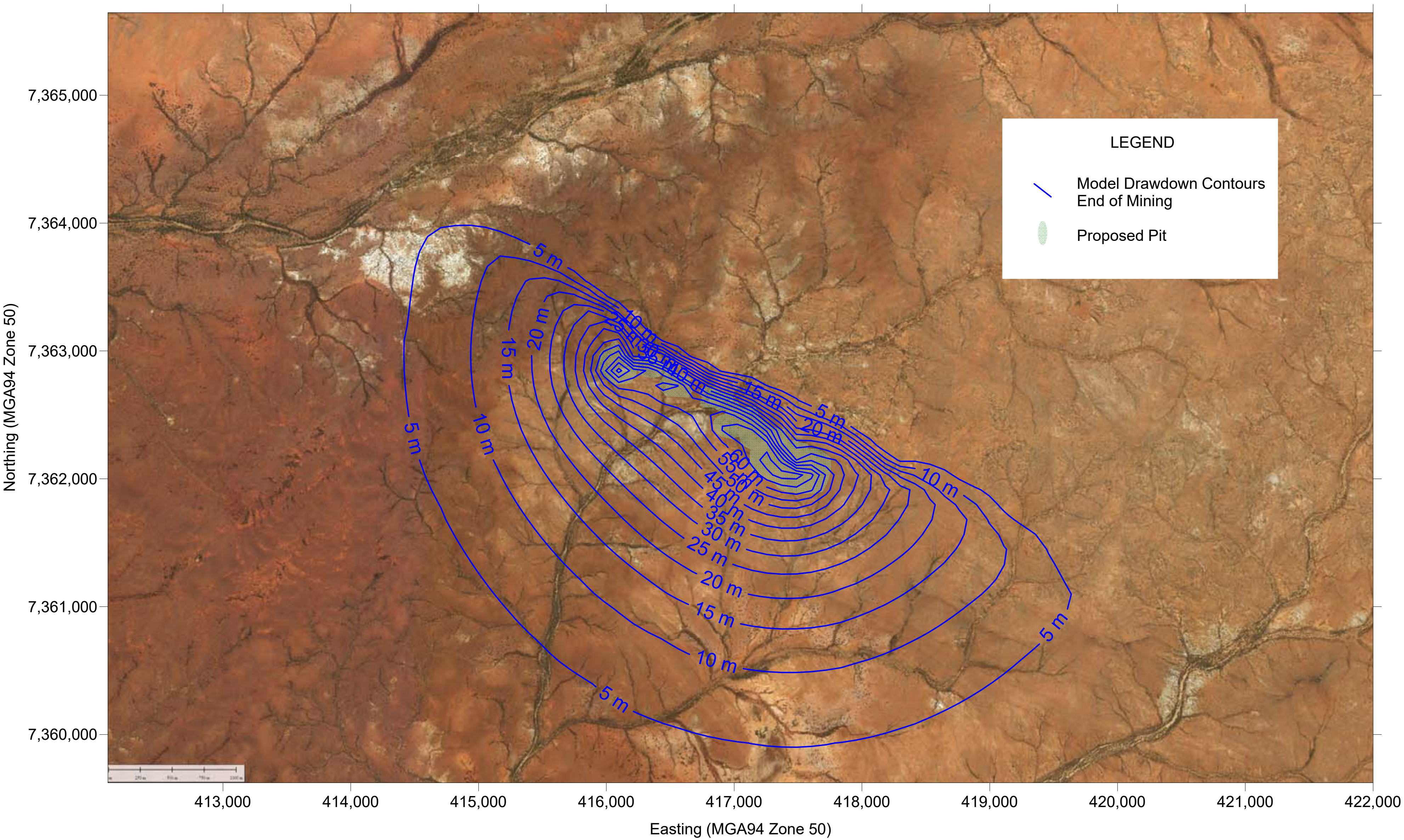


Yangibana DFS Stage I (J160014R01)		
Hastings Technology Minerals Ltd		
KM	Jan 2017	**FIGURE 9**

**BALD HILLS
MODEL SIMULATED
DRAWDOWN CONTOURS
END OF MINING**

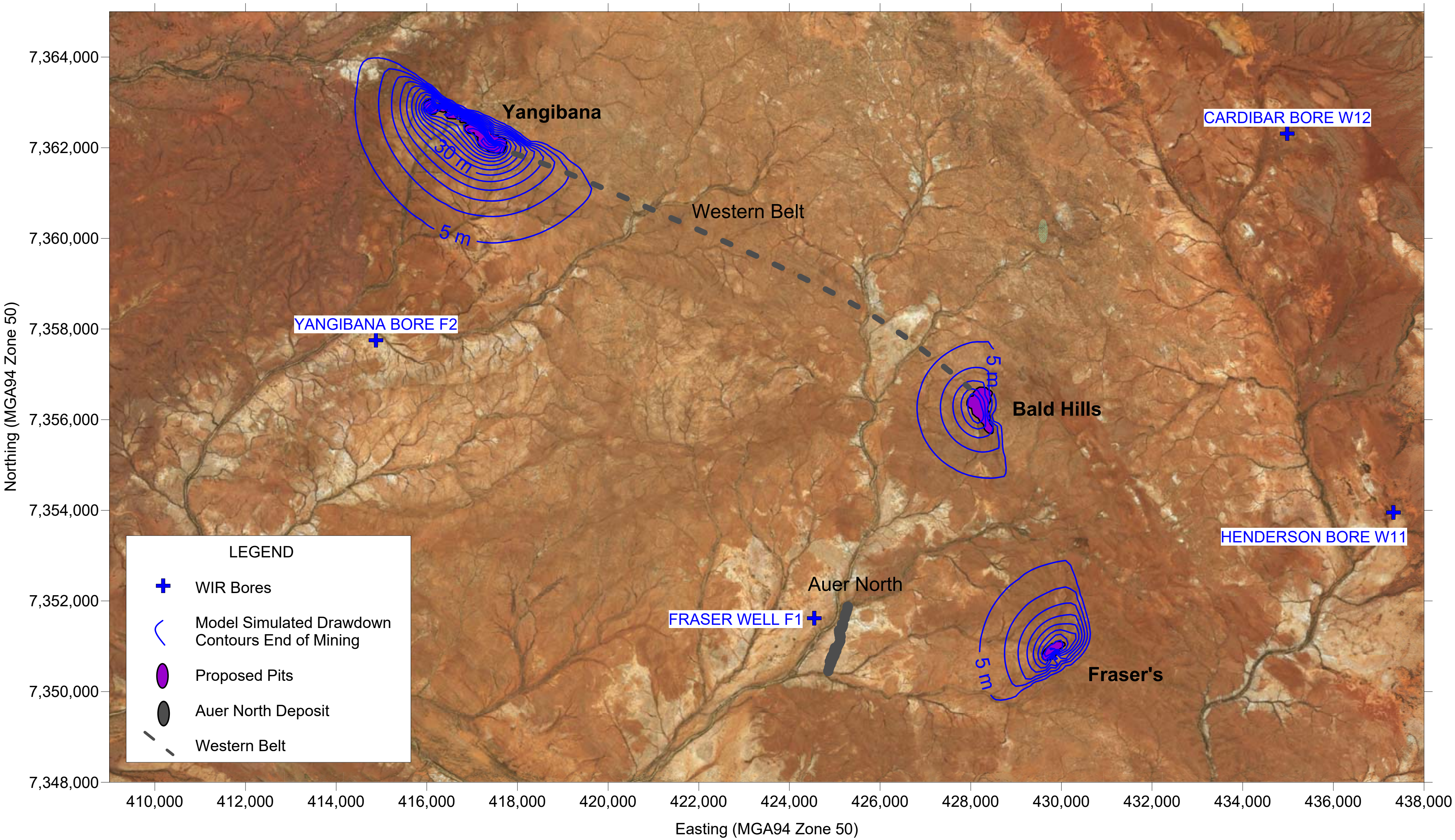
GROUNDWATER
RESOURCE MANAGEMENT

FILE://Jobs2016/J160014_Yangibana/figures/surfer/baldhill_modelling.srf



Yangibana DFS Stage I (J160014R01)			YANGIBANA MODEL SIMULATED DRAWDOWN CONTOURS END OF MINING	GROUNDWATER RESOURCE MANAGEMENT
Hastings Technology Minerals Ltd				
KM	Jan 2017	**FIGURE 10**		

FILE://J160014_Yangibana/figures/surfer/yangibana_drawdown.srf



Yangibana DFS Stage 1 (J160014R01)		
Hastings Technology Minerals Ltd		
KM	Jan 2017	**FIGURE 11**

MODEL SIMULATED DRAWDOWN REGIONAL PLAN

GROUNDWATER RESOURCE MANAGEMENT

FILE://J160014_Yangibana/figures/surfer/regional modelling results.srf

Yangibana DFS Stage I (J160014R01)

Hastings Technology Minerals Ltd

KM

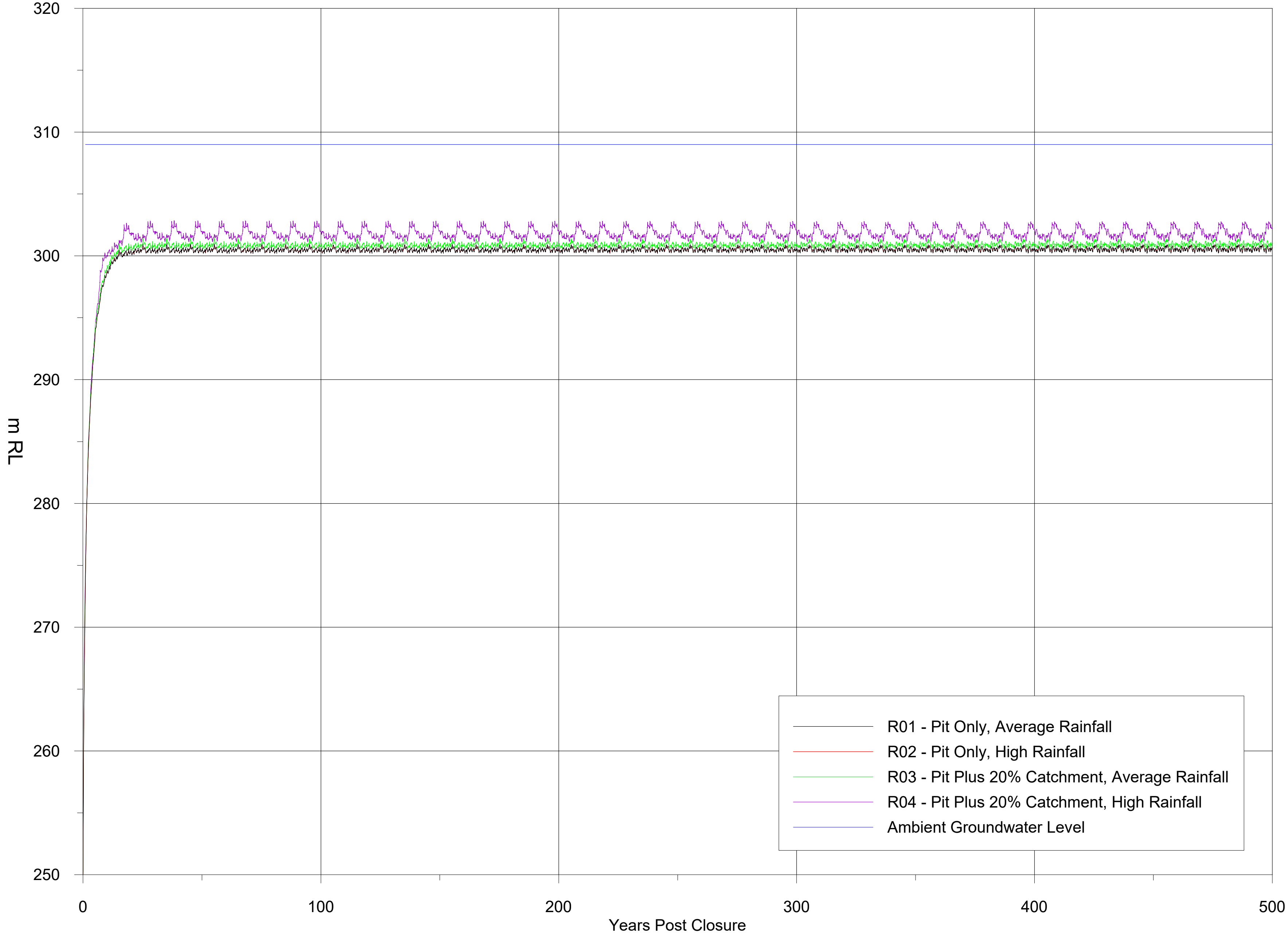
Jan 2017

FIGURE 12

FRASER'S MODEL SIMULATED POST CLOSURE PIT LAKE

GROUNDWATER RESOURCE MANAGEMENT

F:\J160014_Yangibana\figures\grapher\Frasers pit lake modelling.grf



Yangibana DFS Stage I (J160014R01)

Hastings Technology Minerals Ltd

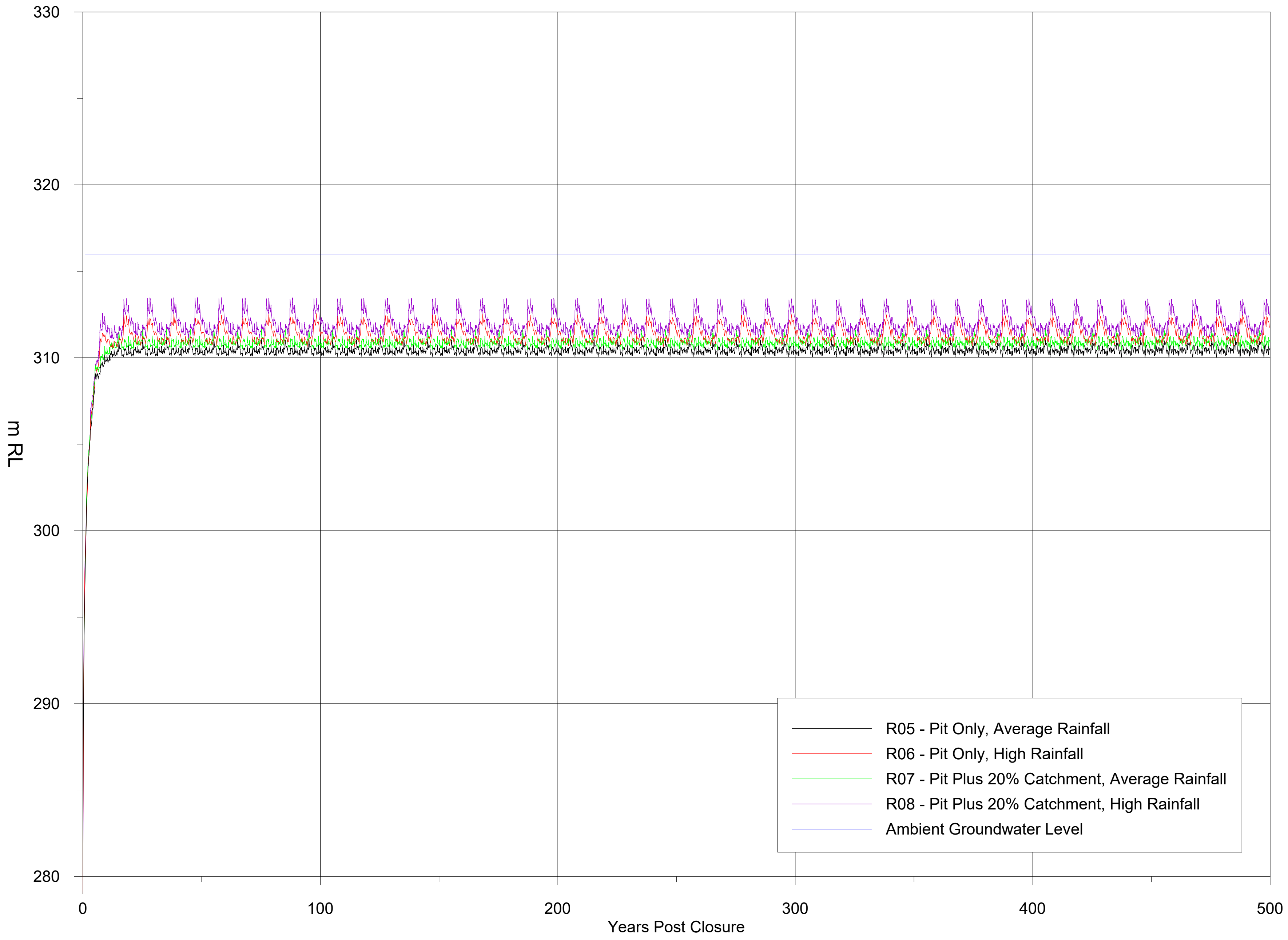
KM

Jan 2017

FIGURE 13

BALD HILLS
MODEL SIMULATED
POST CLOSURE PIT LAKE

GROUNDWATER
RESOURCE MANAGEMENT



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Yangibana DFS Stage I (J160014R01)

Hastings Technology Minerals Ltd

KM

Jan 2017

FIGURE 14

YANGIBANA MODEL SIMULATED POST CLOSURE PIT LAKE

GROUNDWATER RESOURCE MANAGEMENT

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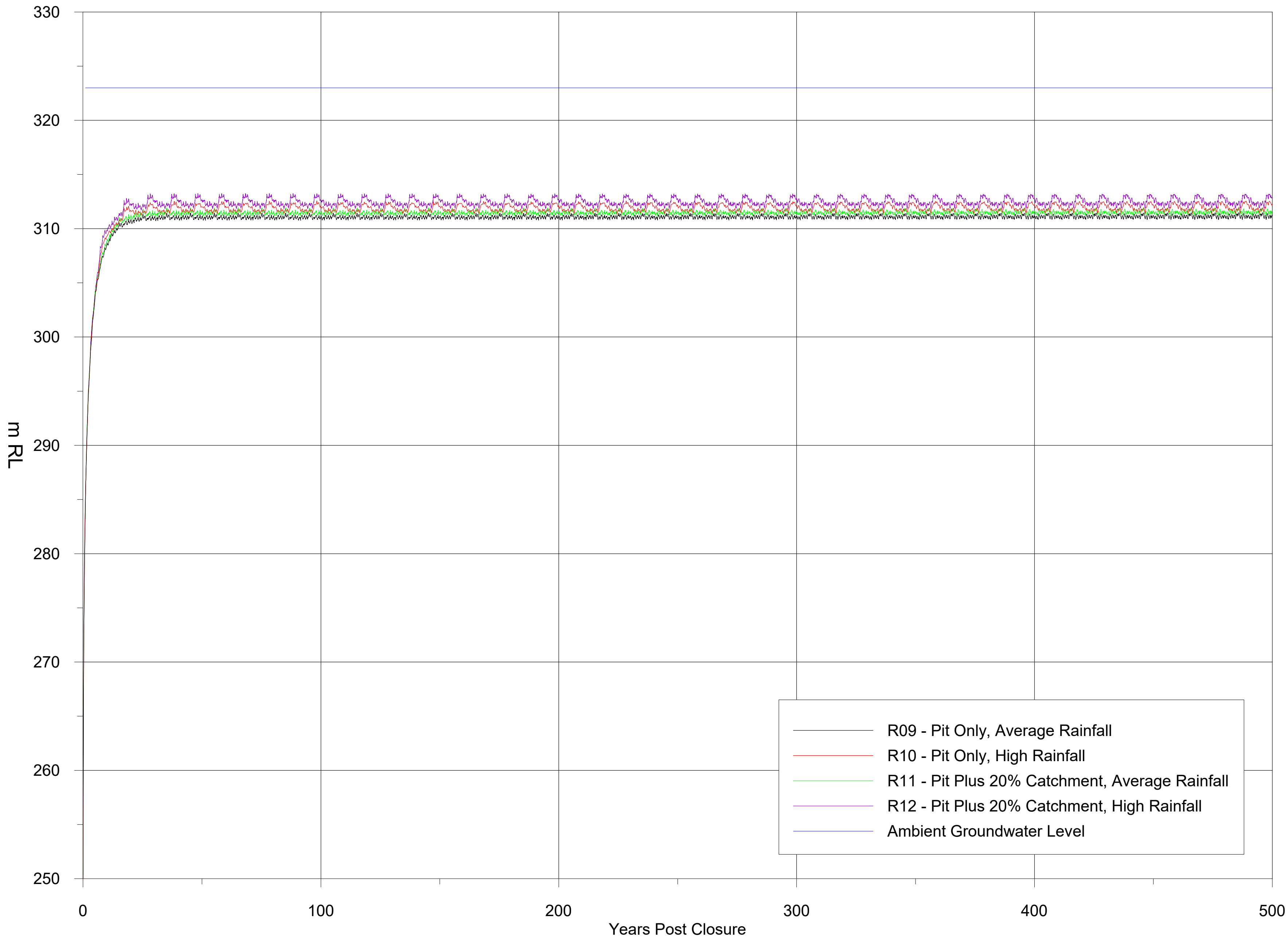
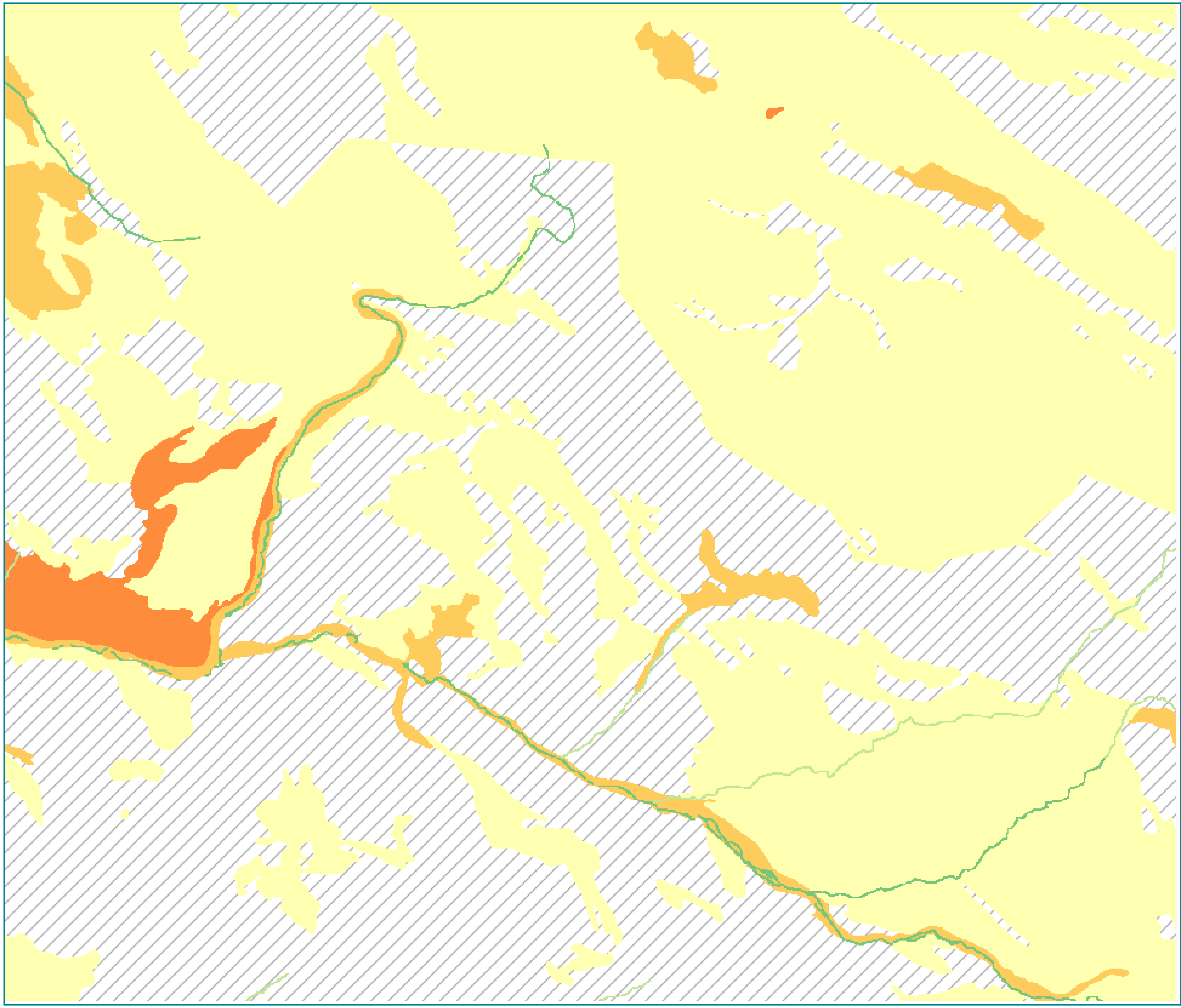


APPENDIX A

BoM GDE Report

Australian Government
Bureau of Meteorology

Groundwater Dependent Ecosystem Map Report



N

25km of 428,000mE 7,356,000mN

GDE, Reliant on surface expression of groundwater (rivers, springs, wetlands)

- Identified in previous study : fieldwork
- Identified in previous study : desktop
- High potential for groundwater interaction
- Moderate potential for groundwater interaction
- Low potential for groundwater interaction

GDE, Reliant on subsurface groundwater (vegetation)

- Identified in previous study : fieldwork
- Identified in previous study : desktop
- High potential for groundwater interaction
- Moderate potential for groundwater interaction
- Low potential for groundwater interaction
- No Ecosystems analysed

GDE, Subterranean (Cave & Aquifers)

- Identified in previous study : fieldwork
- Identified in previous study : desktop
- No Ecosystems analysed

1:626,209

Metres 10,000 20,000 30,000 40,000 50,000

Data source - Data are assumed to be correct as supplied from Commonwealth, State and Territory data suppliers or referenced projects.

Disclaimer - Use of the information and data contained within this document is at your sole risk. Neither the Bureau nor its agents make any warranties or representations regarding the quality, accuracy, merchantability or fitness for purpose of any material in this document.

Date: 30 January, 2017

APPENDIX B

Licence to Construct or Alter a Well

Government of **Western Australia**
Department of **Water**

looking after all our water needs

Your ref:
Our ref: RF14532
Enquiries: Erin Maher
Tel: 9965 7400

Andrew Border
Principal Geologist
Hastings Technology Metals Ltd
Q128
Queen Victoria Building NSW 1230

Dear Andrew

Re: Additional information required for a licence under the *Rights in Water and Irrigation Act 1914*
Property: M9/158 and M9/157 – Bald Hill and Frasers Pits

Thank you for your application dated 7 July 2016 for a licence to take water to draw 1,400,000 kilolitres per annum for dewatering and mining purposes.

The Department of Water has completed an initial review of your application however we require further information to complete the assessment. In accordance with Schedule 1, Division 2, Clause 4(1c) & (2) of the Rights in Water and Irrigation Act 1914, we require the following information to assess the application:

- H2 level Hydrogeological report prepared in accordance with Operational policy no. 5.12 – Hydrogeological reporting associated with a groundwater well licence.

- Operating strategy prepared in accordance with Operational policy no. 5.08 – Use of operating strategies in the water licensing process.

This letter is notifying you that you have until 2 August 2017 to provide this information to us. If you believe there are extenuating circumstances to justify why you cannot provide the information, you should write to us with these reasons.

Should the information (or explanation of the extenuating circumstances) not be received within this timeframe, we will return your application to you as it is incomplete and there is insufficient information to allow us to make an informed decision.

If you have any queries please contact Erin Maher on telephone 9965 7400.

Yours sincerely

Darryl Abbott
Regional Manager
Midwest Gascoyne region

Date: 4/8/16

Midwest Gascoyne Region
211 Robinson Street Carnarvon Western Australia 6701
PO Box 81 Carnarvon Western Australia 6701
Telephone (08) 9941 6100 Facsimile (08) 9941 4931
www.water.wa.gov.au
wa.gov.au

Government of **Western Australia**
Department of **Water**

looking after all our water needs

Your ref:
Our ref: RF14532
Enquiries: Erin Maher
Tel: 9965 7400

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If you have any queries please contact Erin Maher on telephone 9965 7400.

Yours sincerely

Darryl Abbott
Regional Manager
Midwest Gascoyne region

Date: 4/8/16

Midwest Gascoyne Region
211 Robinson Street Carnarvon Western Australia 6701
PO Box 81 Carnarvon Western Australia 6701
Telephone (08) 9941 6100 Facsimile (08) 9941 4931
www.water.wa.gov.au
wa.gov.au

XDWAL012

Government of **Western Australia**
Department of **Water**

looking after all our water needs

Your ref:
Our ref: RF14532
Enquiries: Erin Maher
Tel: 9965 7400

Andrew Border
Principal Geologist
Hastings Technology Metals Ltd
Q128
Queen Victoria Building NSW 1230

Dear Andrew

Re: Issue of a licence or permit under the *Rights in Water and Irrigation Act 1914*
Property*:* M9/158 and M9/157 - Bald Hill and Frasers Pits

Please find enclosed the following:

- Your licence to construct or alter a well *CAW183123*
- Form 2 "Information to be provided on completion of a non-artesian well"
- Brochure *Your licence to construct a well*

Please take time to read these documents as they contain important information about your rights and responsibilities.

You can now use online services to manage all of your licensing and metering needs. Water Online provides the easiest, fastest and most efficient way to:

- Apply for a new licence or permit
- Apply to amend, renew or transfer an existing licence
- Submit meter readings in accordance with a licence; and
- Manage your account details.

Register for Water Online at www.water.wa.gov.au by clicking on the Water Online Login icon.

The instructions for registering, checking your details and updating them where required can be found by selecting the Quick Reference Guides link on the water online home page.

Please check your details to ensure that they are correct. If they are not correct please contact the department's online business support unit on 1800 508 885 (select option 2).

If you have any queries about this or any other water licensing matter please contact Erin Maher on telephone 9965 7400.

Yours sincerely

Natalie Lauritsen
Senior Natural Resource Management Officer
Midwest Gascoyne Region

3/8/2016

LICENCE TO CONSTRUCT OR ALTER WELL

Granted by the Minister under section 26D of the Rights in Water and Irrigation Act 1914

Licensee(s)	Hastings Technology Metals Ltd	
Description of Water Resource	Gascoyne Combined - Fractured Rock West - Fractured Rock	
Location of Well(s)	M9/158, M9/157	
Authorised Activities	**Activity**	**Location of Activity**
	Construct 6 exploratory well(s). Construct 2 non-artesian well(s).	M9/158, M9/157
Duration of Licence	From 3 August 2016 to 2 August 2017	

This Licence is subject to the following terms, limitations and conditions:

1 The well must be constructed by a driller having a current class 1 water well drillers certificate issued by the Western Australian branch of the Australian Drilling Industry Association or equivalent certification recognised nationally by the Australian Drilling Industry Association.

End of terms, limitations and conditions

This Licence is granted subject to the Rights in Water and Irrigation Regulations 2000.

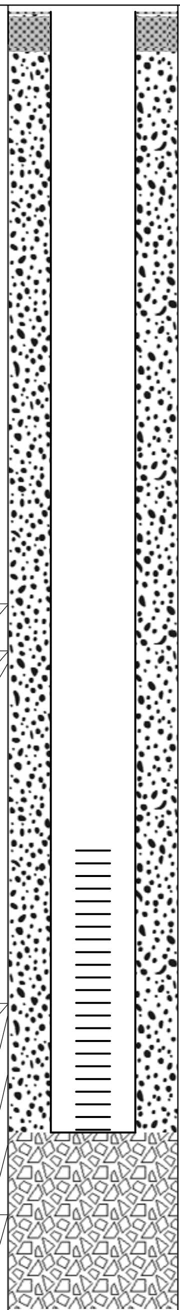
APPENDIX C

Bore Logs

GROUNDWATER RESOURCE MANAGEMENT
PO Box 2310 Kardinya WA 6163
23 Parry Street
Fremantle WA 6160
Ph: +61 8 9433 2222 Fx: +61 8 9433 2322
Email: water@g-r-m.com.au

ID: **FRW03**		JOB NUMBER: J160014	
CLIENT: Hastings		PROJECT: Yangibana DFS	
COMMENCED: 20-Oct-16	EASTING: 429941	INCLINATION: 90 degrees	
COMPLETED: 22-Oct-15	NORTHING: 7351211	AZIMUTH: 0 degrees	
DRILLED BY: TRD	ELEVATION: 350.5	SWL (date): 33.8 mbtoc (4-Nov-16)	
LOGGED BY: PH/KF	GRID SYSTEM: MGA z50		

Depth (m bgl)	Graphic + Stratigraphy	Lithological Description	Field Notes	Bore Construction
0–3		COLLUVIUM: brown, weakly lateritised, ferruginous, after granite		+0.4-+0.2m annular grout seal +0.4-2.3m collar pipe 0-3m cement annular seal with cement surround
3–11		SAPROCK: brown grey, after granite		
11–84		GRANITE: cream grey to grey, massive, distinctly to slightly weathered	50m: minor inflow 54m: minor inflow 55m: inflow >0.1 L/sec	3-110m 10 inch diameter air rotary drill-hole +0.4-71.2m 155mm ND class 9 uPVC blank casing +0.2-95m +3.2-6.4mm graded filter pack 71.2-95.2m 155mm ND class 9 uPVC slotted casing
84–95		IRONSTONE: dark grey, brown, fractured	84m: increased inflow 85m: inflow 1.2 L/sec, pH 7.88, EC 2.47 mS/cm 90m: inflow 1.5 L/sec, pH 7.97, EC 2.47 mS/cm	
95–110		GRANITE: dark grey, brown, weakly foliated	96m: inflow 1.5 L/sec, pH 8.03, EC 2.51 mS/cm 102m: inflow 1.5 L/sec, pH 8.17, EC 2.47 mS/cm	155mm uPVC end cap 95-110m fallback



GROUNDWATER RESOURCE MANAGEMENT

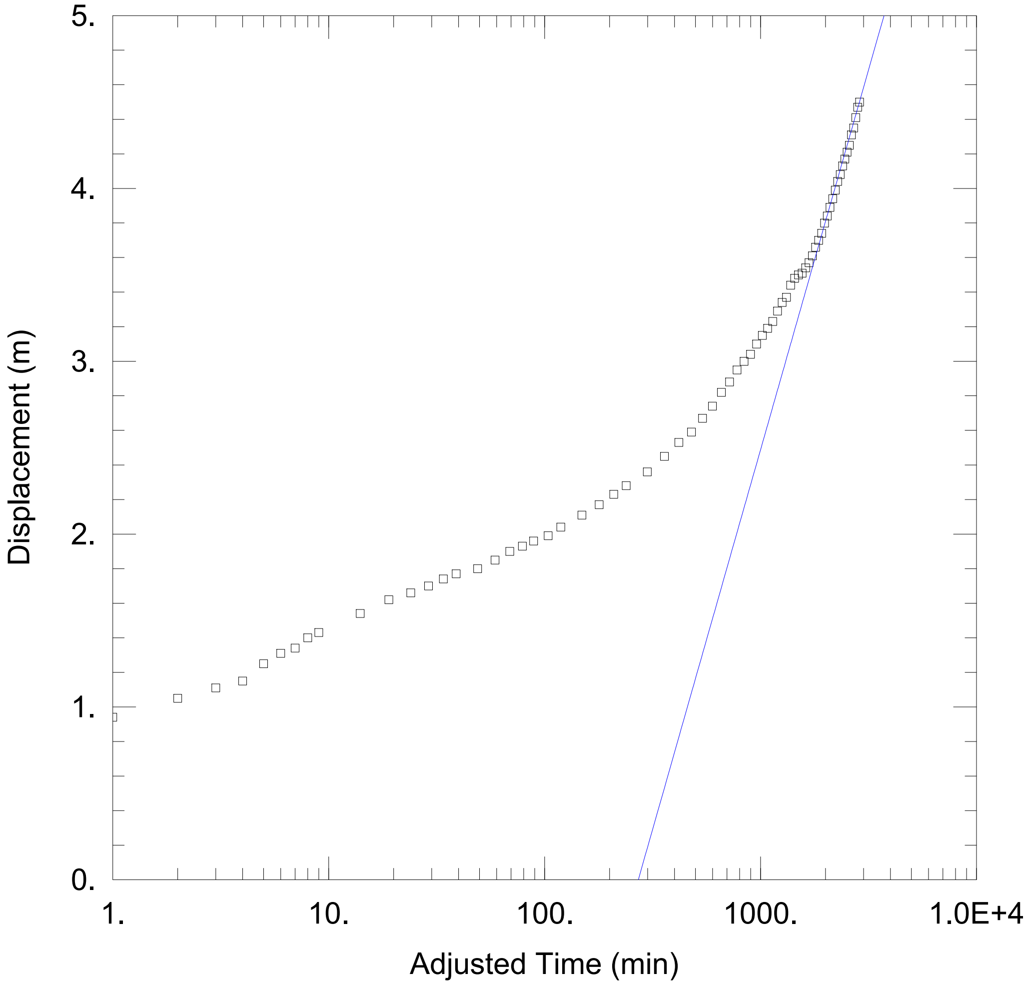
PO Box 2310 Kardinya WA 6163
23 Parry Street
Fremantle WA 6160
Ph: +61 8 9433 2222 Fx: +61 8 9433 2322
Email: water@g-r-m.com.au

ID: **BHW05**		JOB NUMBER: J160014	
CLIENT: Hastings		PROJECT: Yangibana DFS	
COMMENCED: 11-Nov-16	EASTING: 428189	INCLINATION: 90 degrees	
COMPLETED: 13-Nov-16	NORTHING: 7356019	AZIMUTH: 0 degrees	
DRILLED BY: TRD	ELEVATION: 346.7	SWL (date): mbtoc ( )	
LOGGED BY: PH/KF	GRID SYSTEM: MGA z50		

Depth (m bgl)	Graphic + Stratigraphy	Lithological Description	Field Notes	Bore Construction
0		COLLUVIUM: brown, weakly lateritised, ferruginous, after granite		+0.4-+0.2m annular grout seal; +0.4-2.3m collar pipe; 0-3m cement annular seal with cement surround
		SAPROCK: brown grey, after granite		
10				
20				3-110m 10 inch diameter air rotary drill-hole
30		GRANITE: cream grey to grey, massive, distinctly to slightly weathered, fractures 27-30m; 33-36m; and 41-45m	36m: minor inflow; 38m: inflow <0.1 L/sec	
40			42m: inflow <0.1 L/sec; 48m: inflow 0.2 L/sec	+0.4-80m 155mm ND class 9 uPVC blank casing; +0.2-104m +3.2-6.4mm graded filter pack
50		GRANITE: grey, massive, fresh to slightly weathered	55m: inflow 0.2 L/sec	
60			63m: inflow 0.1 L/sec; 68m: inflow 0.8 L/sec	
70		IRONSTONE: dark grey, brown, fractured	76m: inflow 1 L/sec; 78m: inflow 1.2 L/sec	
80			81m: inflow 2.9 L/sec; 83m: inflow 1.8 L/sec; 84m: inflow 2.2 L/sec	80-104m 155mm ND class 9 uPVC slotted casing
90		GRANITE: dark grey, brown, weakly foliated		
100				155mm uPVC end cap; 104-110m fallback
110				
120				

APPENDIX D

Test Analysis



WELL TEST ANALYSIS

Data Set: E:\to save to server\modelling\aqtesolv\FRW03_CR.aqt
Date: 02/09/17 Time: 14:05:10

PROJECT INFORMATION

Company: GRM
Client: Hastings
Project: J160014
Location: Yangibana
Test Well: FRW03
Test Date: 4 Nov 2016

AQUIFER DATA

Saturated Thickness: 11. m Anisotropy Ratio (Kz/Kr): 1.

WELL DATA

Pumping Wells

Well Name	X (m)	Y (m)
FRW03	0	0

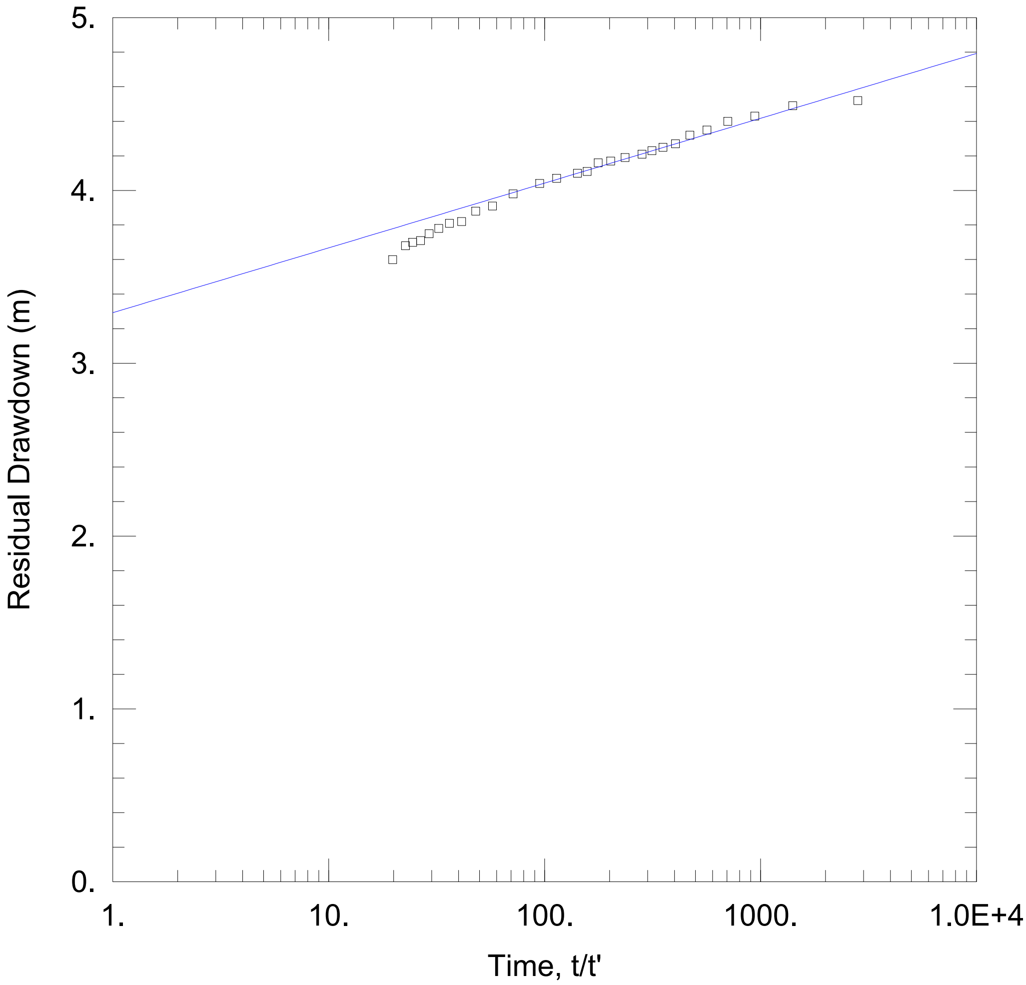
Observation Wells

Well Name	X (m)	Y (m)
□ FRW03	0	0

SOLUTION

Aquifer Model: Confined Solution Method: Cooper-Jacob

T = 28.1 m^2/day S = 827.1



WELL TEST ANALYSIS

Data Set: E:\to save to server\modelling\aqtesolv\FRW03_recET.aqt
Date: 02/09/17 Time: 14:07:30

PROJECT INFORMATION

Company: GRM
Client: Hastings
Project: J160014
Location: Yangibana
Test Well: FRW03
Test Date: 6 Nov 2016

AQUIFER DATA

Saturated Thickness: 11. m
Anisotropy Ratio (Kz/Kr): 1.

WELL DATA

Pumping Wells

Well Name	X (m)	Y (m)
FRW03	0	0

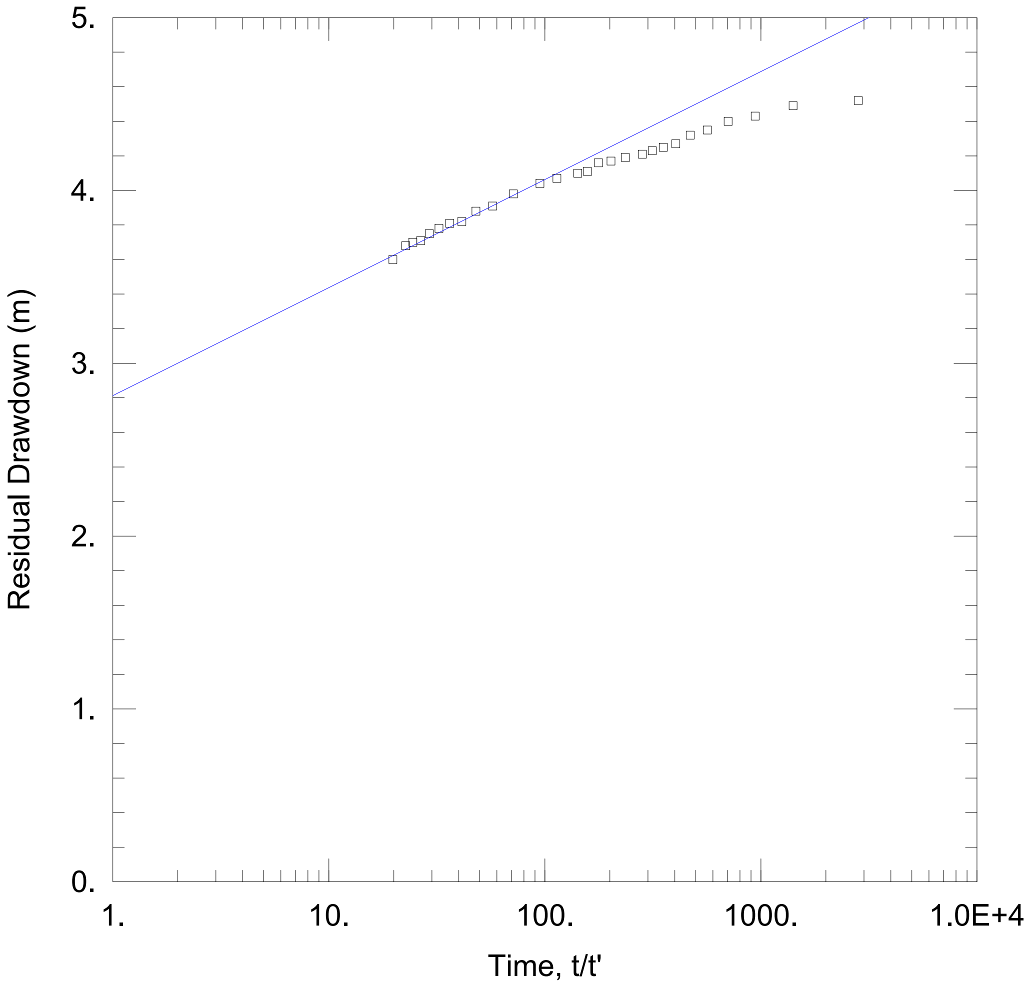
Observation Wells

Well Name	X (m)	Y (m)
□ FRW03	0	0

SOLUTION

Aquifer Model: Confined
Solution Method: Theis (Recovery)

T = 329.4 m^2/day
S/S' = 1.66E-9



WELL TEST ANALYSIS

Data Set: E:\to save to server\modelling\aqtesolv\FRW03_recLT.aqt
Date: 02/09/17 Time: 14:09:08

PROJECT INFORMATION

Company: GRM
Client: Hastings
Project: J160014
Location: Yangibana
Test Well: FRW03
Test Date: 6 Nov 2016

AQUIFER DATA

Saturated Thickness: 11. m Anisotropy Ratio (Kz/Kr): 1.

WELL DATA

Pumping Wells

Well Name	X (m)	Y (m)
FRW03	0	0

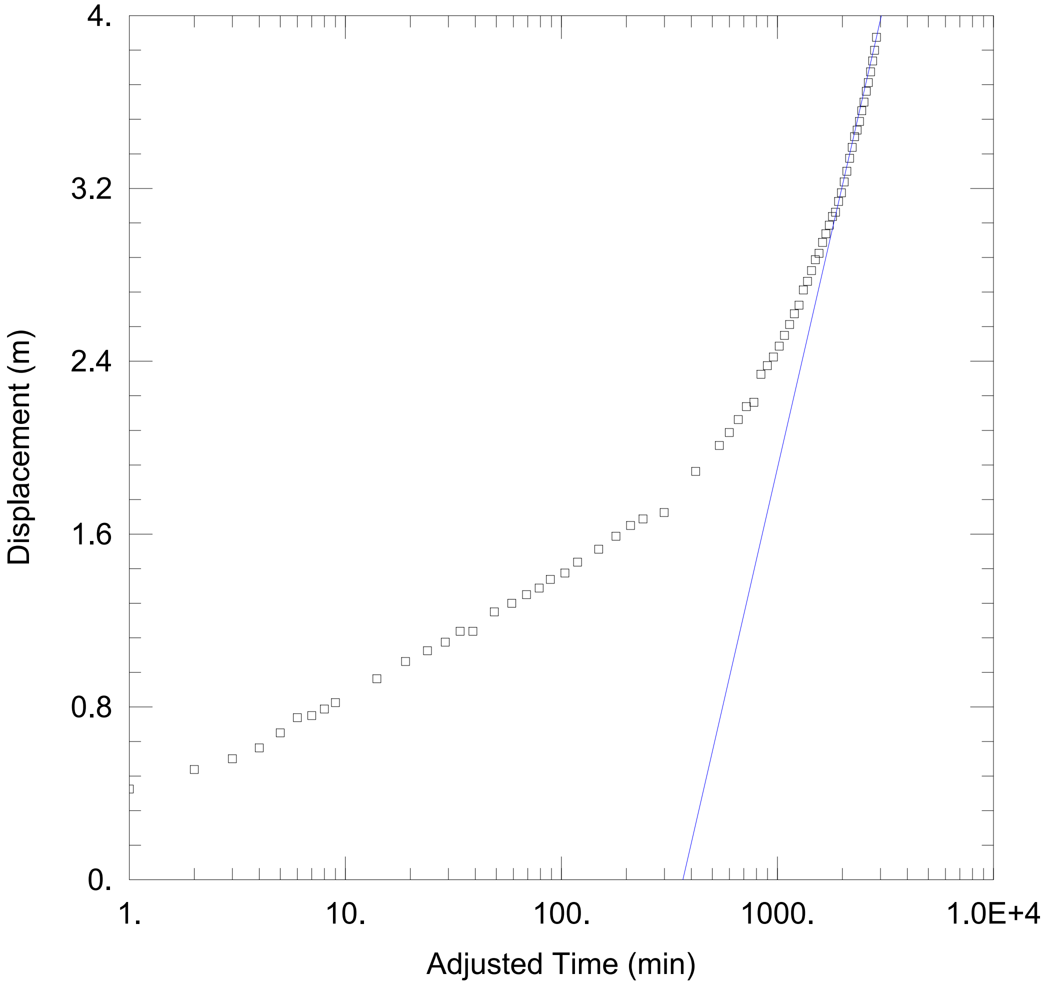
Observation Wells

Well Name	X (m)	Y (m)
□ FRW03	0	0

SOLUTION

Aquifer Model: Confined Solution Method: Theis (Recovery)

T = 197.6 m^2/day S/S' = 3.162E-5



WELL TEST ANALYSIS

Data Set: E:\to save to server\modelling\aqtesolv\FRW01obs_CR.aqt
Date: 02/09/17 Time: 14:10:34

PROJECT INFORMATION

Company: GRM
Client: Hastings
Project: J160014
Location: Yangibana
Test Well: FRW03
Test Date: 4 Nov 2016

AQUIFER DATA

Saturated Thickness: 11. m Anisotropy Ratio (Kz/Kr): 1.

WELL DATA

Pumping Wells

Well Name	X (m)	Y (m)
FRW03	0	0

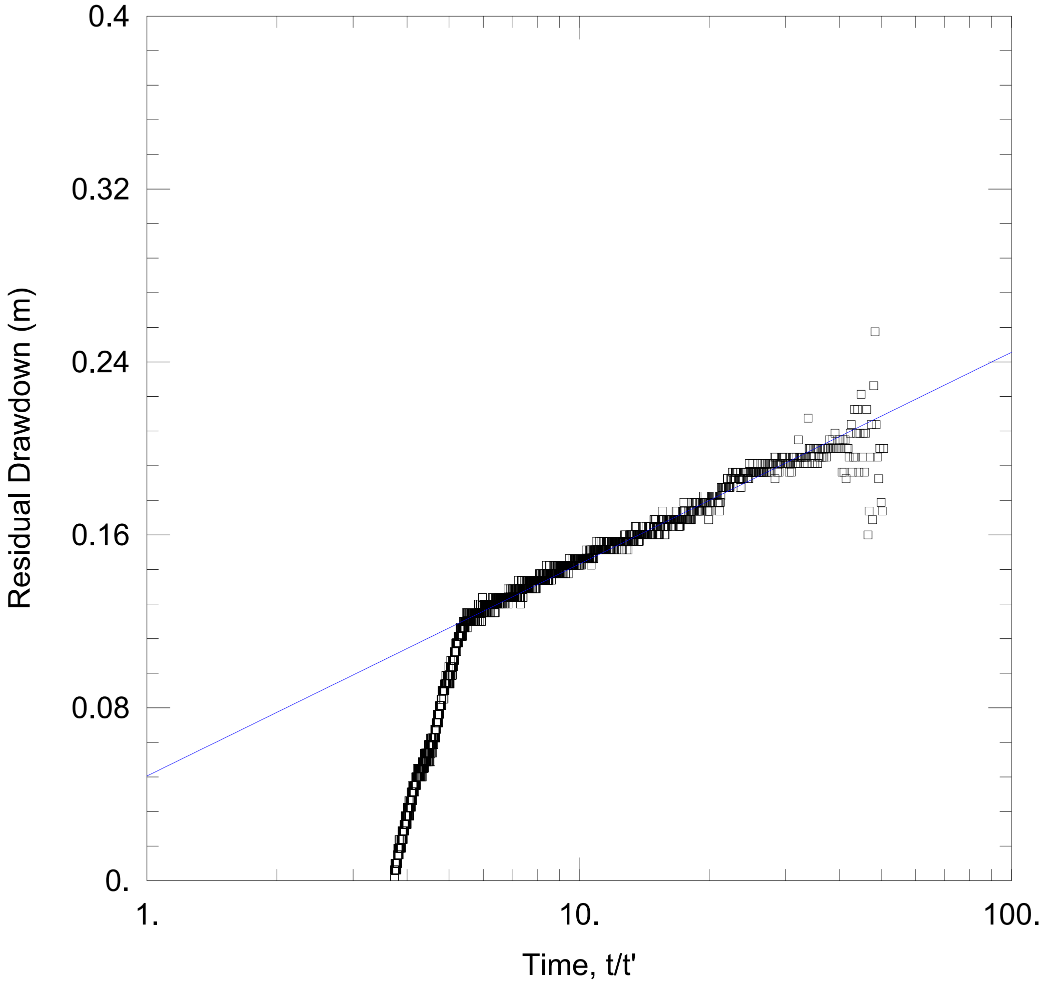
Observation Wells

Well Name	X (m)	Y (m)
□ FRW01	6	0

SOLUTION

Aquifer Model: Confined Solution Method: Cooper-Jacob

T = 28.37 m^2/day S = 0.4489



AIRLIFT RECOVERY FRW02

Data Set: F:\J160014_Yangibana\modelling\aqtesolv\FRW02_recET.aqt
Date: 01/14/17 Time: 10:26:42

PROJECT INFORMATION

Company: GRM
Client: Hastings
Project: J160014
Location: Yangibana
Test Well: FRW02
Test Date: 25/10/2016

AQUIFER DATA

Saturated Thickness: 10. m Anisotropy Ratio (Kz/Kr): 1.

WELL DATA

Pumping Wells

Well Name	X (m)	Y (m)
FRW02	0	0

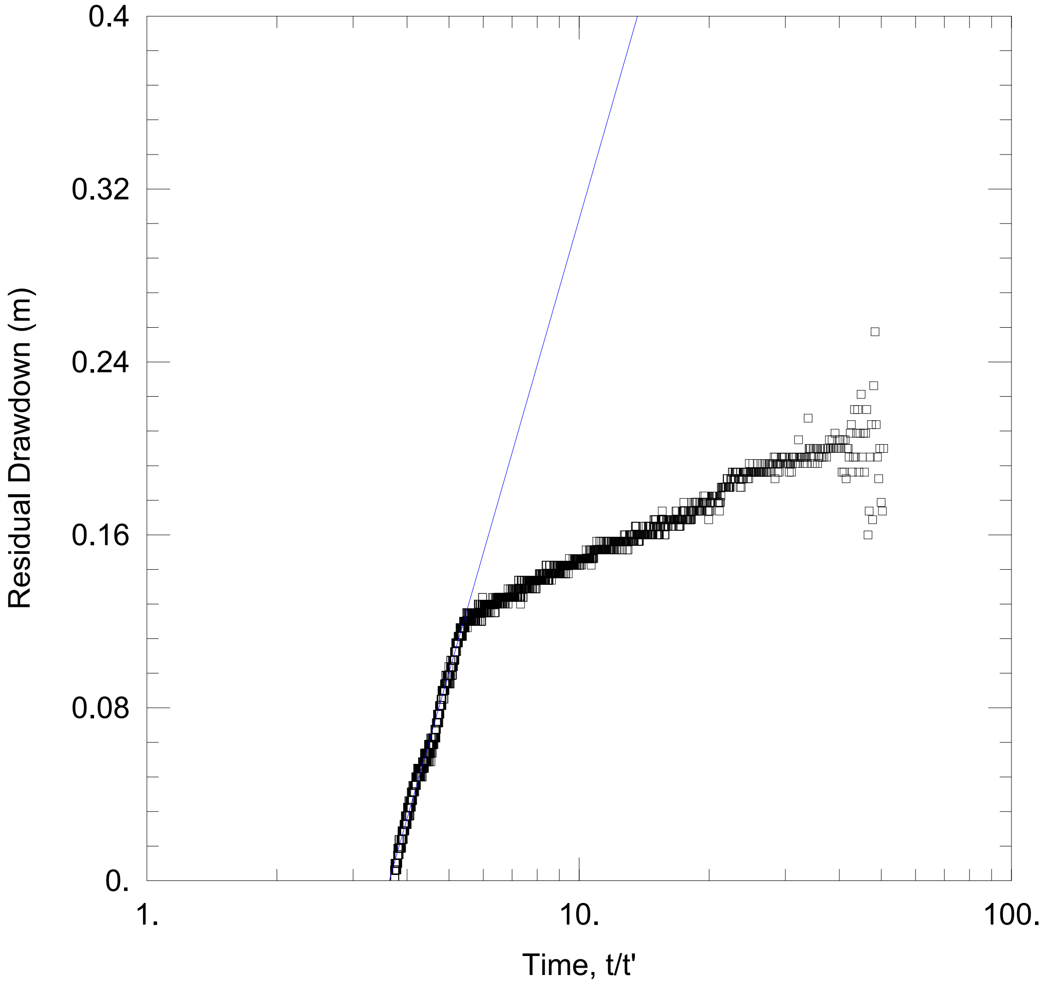
Observation Wells

Well Name	X (m)	Y (m)
□ FRW02	0	0

SOLUTION

Aquifer Model: Confined Solution Method: Theis (Recovery)

T = 242.3 m^2/day S/S' = 0.321



AIRLIFT RECOVERY FRW02

Data Set: F:\J160014_Yangibana\modelling\aqtesolv\FRW02_rec.aqt
Date: 01/14/17 Time: 10:26:14

PROJECT INFORMATION

Company: GRM
Client: Hastings
Project: J160014
Location: Yangibana
Test Well: FRW02
Test Date: 25/10/2016

AQUIFER DATA

Saturated Thickness: 10. m
Anisotropy Ratio (Kz/Kr): 1.

WELL DATA

Pumping Wells

Well Name	X (m)	Y (m)
FRW02	0	0

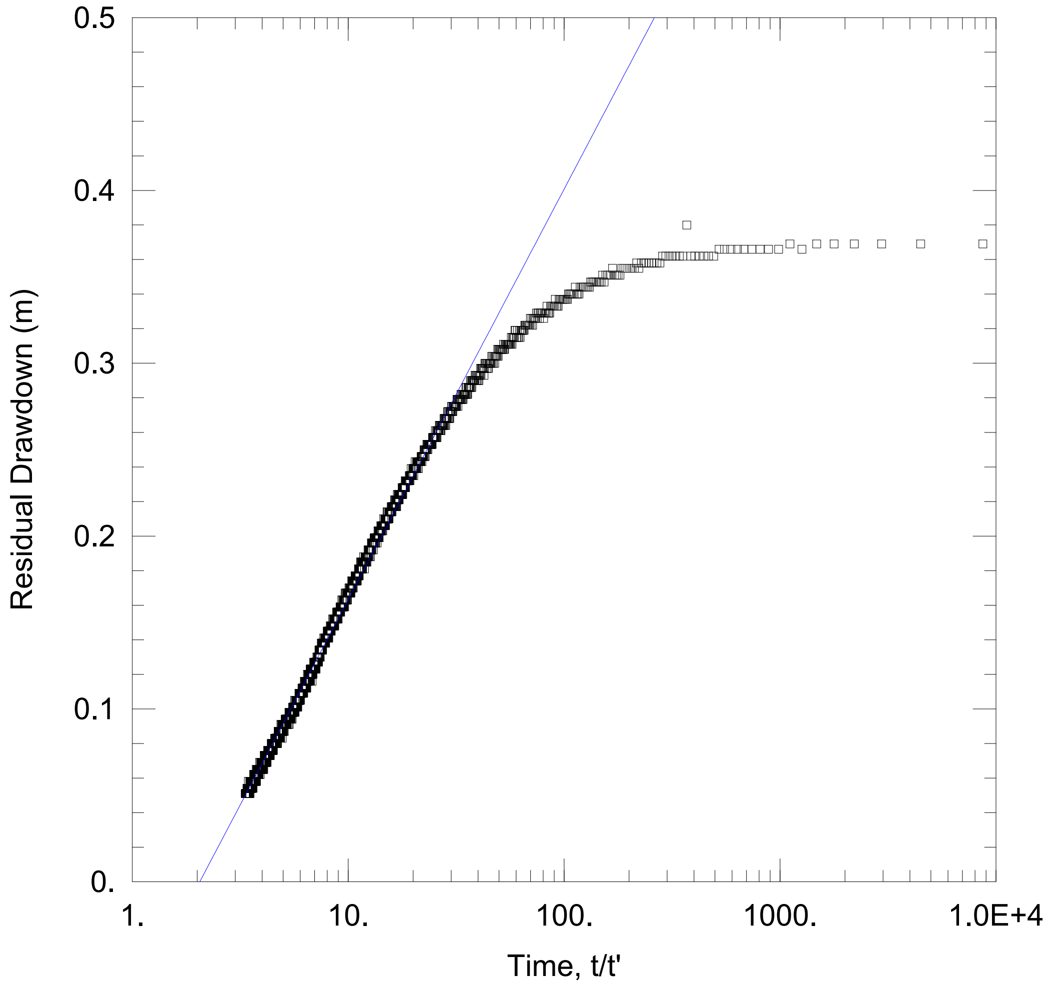
Observation Wells

Well Name	X (m)	Y (m)
□ FRW02	0	0

SOLUTION

Aquifer Model: Confined
Solution Method: Theis (Recovery)

T = 34.1 m^2/day
S/S' = 3.638



AIRLIFT RECOVERY FFRC082

Data Set: F:\J160014_Yangibana\modelling\aqtesolv\FRC082_rec_logger.aqt
Date: 01/06/17 Time: 15:39:04

PROJECT INFORMATION

Company: GRM
Client: Hastings
Project: J160014
Location: Yangibana
Test Well: FFRC082
Test Date: 26/10/2016

AQUIFER DATA

Saturated Thickness: 6. m Anisotropy Ratio (Kz/Kr): 1.

WELL DATA

Pumping Wells

Well Name	X (m)	Y (m)
FFRC082	0	0

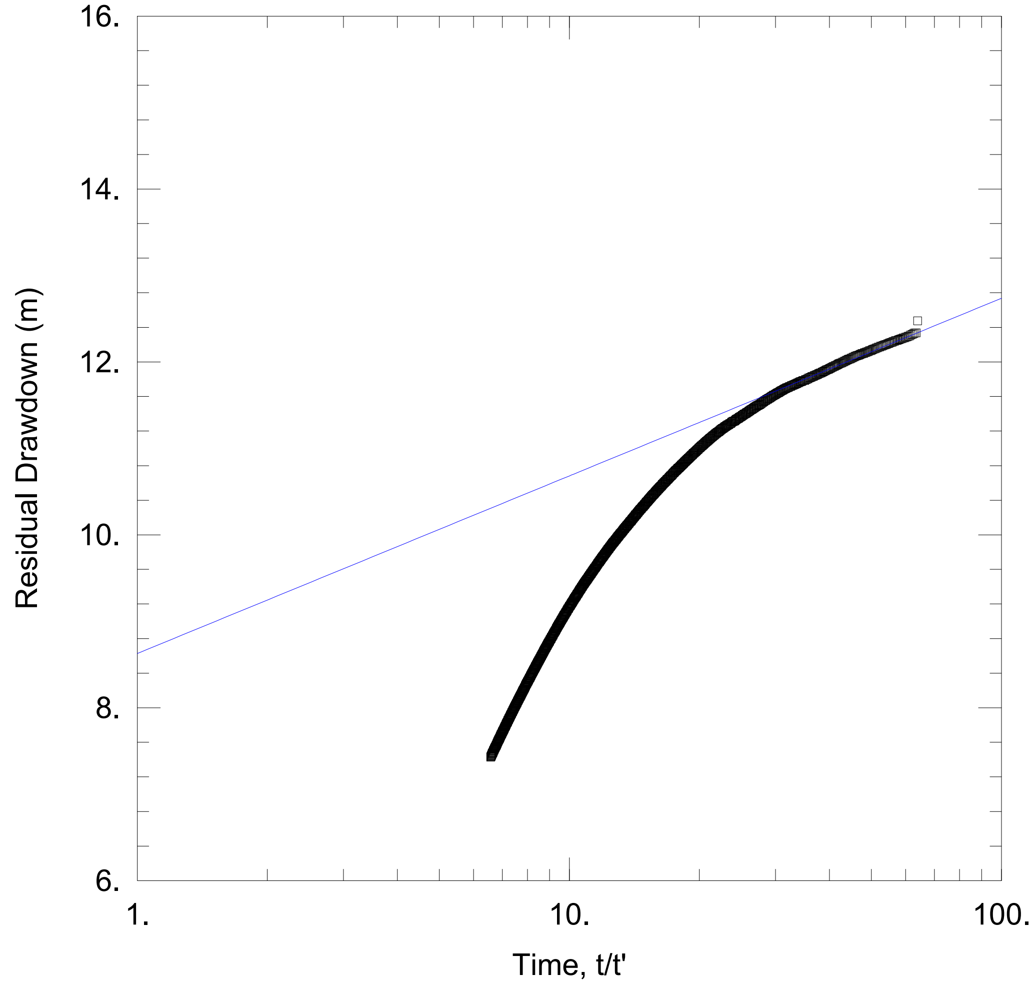
Observation Wells

Well Name	X (m)	Y (m)
□ FFRC082	0	0

SOLUTION

Aquifer Model: Confined Solution Method: Theis (Recovery)

T = 226.6 m^2/day S/S' = 2.057



AIRLIFT RECOVERY FFRC098

Data Set: F:\J160014_Yangibana\modelling\aqtesolv\FRC098_rec_logger.aqt
Date: 01/14/17 Time: 12:32:36

PROJECT INFORMATION

Company: GRM
Client: Hastings
Project: J160014
Location: Yangibana
Test Well: FFRC082
Test Date: 26/10/2016

AQUIFER DATA

Saturated Thickness: 14.9 m Anisotropy Ratio (Kz/Kr): 1.

WELL DATA

Pumping Wells

Well Name	X (m)	Y (m)
FFRC098	0	0

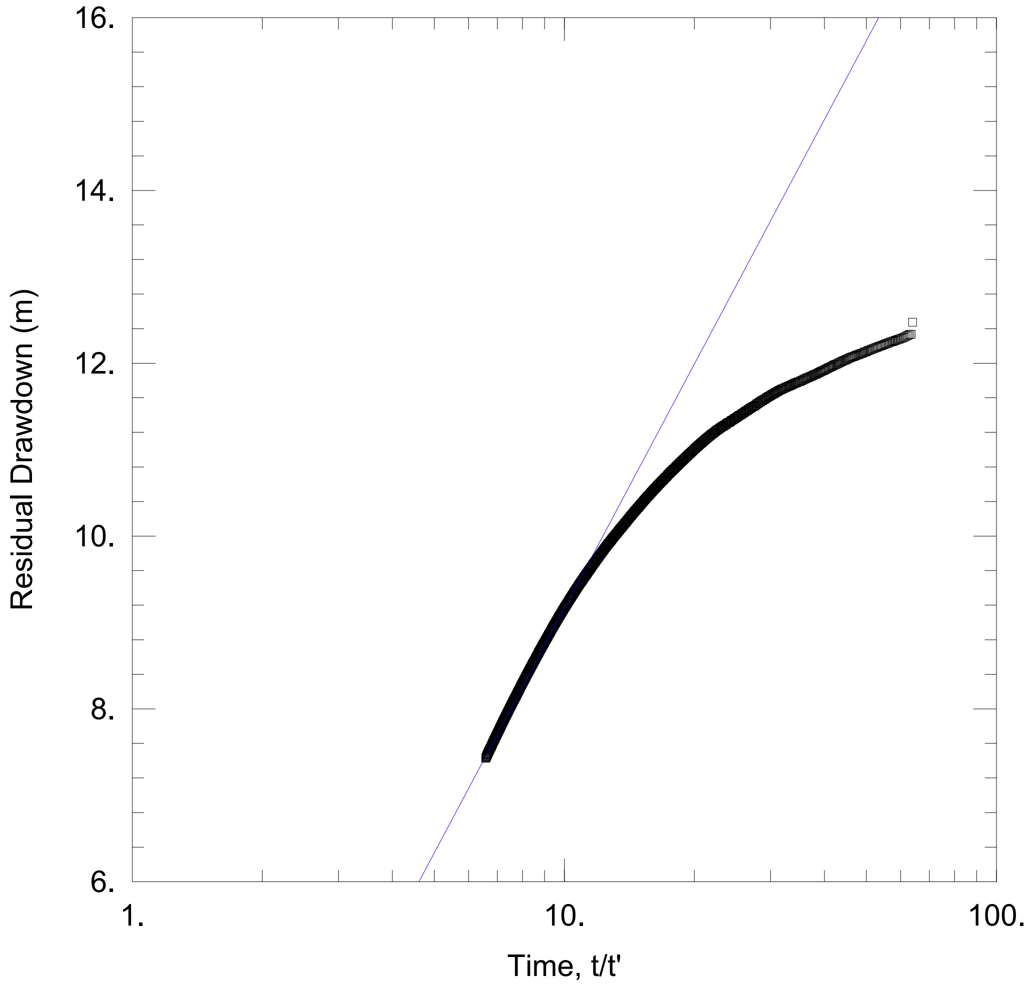
Observation Wells

Well Name	X (m)	Y (m)
□ FFRC098	0	0

SOLUTION

Aquifer Model: Confined Solution Method: Theis (Recovery)

T = 0.1156 m^2/day S/S' = 6.315E-5



AIRLIFT RECOVERY FFRC098

Data Set: F:\J160014_Yangibana\modelling\aqtesolv\FRC098_rec_loggerLT.aqt
Date: 01/14/17 Time: 12:32:12

PROJECT INFORMATION

Company: GRM
Client: Hastings
Project: J160014
Location: Yangibana
Test Well: FFRC082
Test Date: 26/10/2016

AQUIFER DATA

Saturated Thickness: 14.9 m Anisotropy Ratio (Kz/Kr): 1.

WELL DATA

Pumping Wells

Well Name	X (m)	Y (m)
FFRC098	0	0

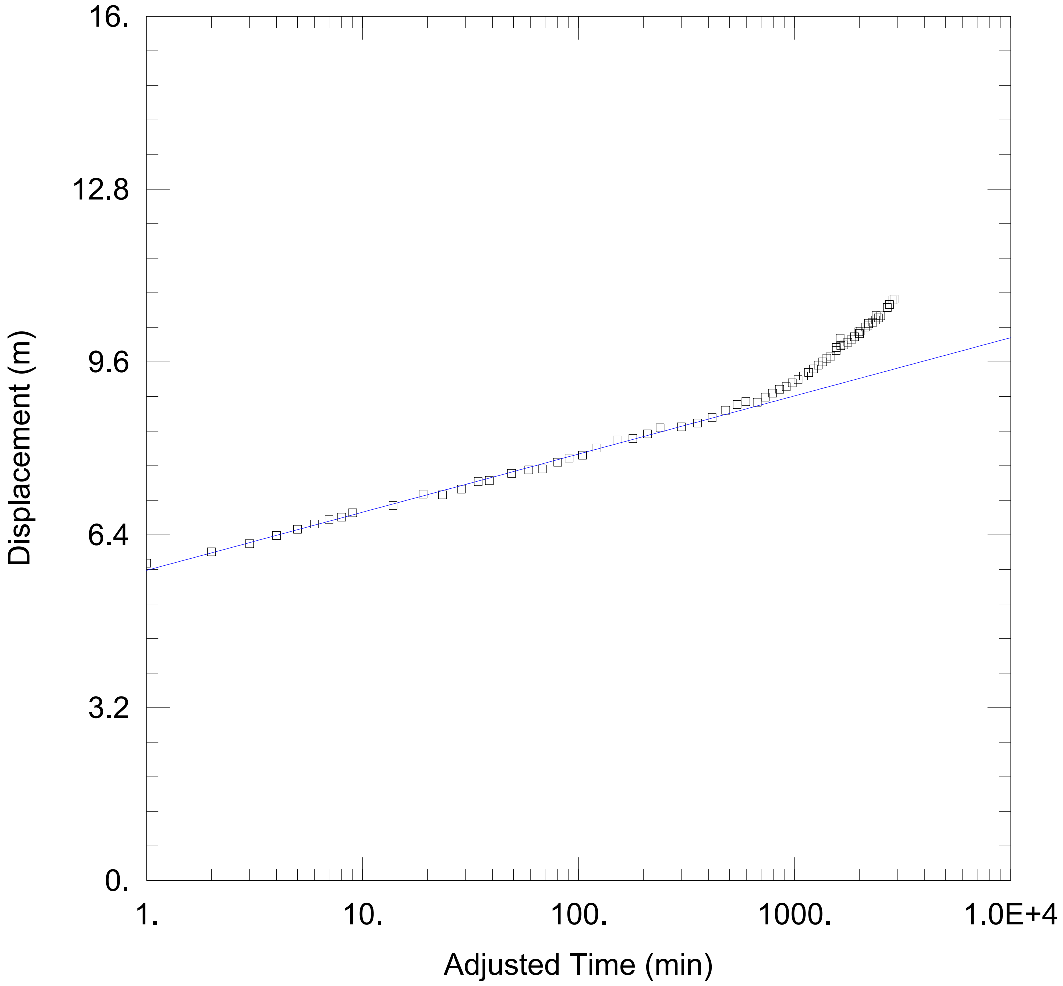
Observation Wells

Well Name	X (m)	Y (m)
□ FFRC098	0	0

SOLUTION

Aquifer Model: Confined Solution Method: Theis (Recovery)

T = 0.02527 m^2/day S/S' = 1.06



WELL TEST ANALYSIS

Data Set: F:\J160014_Yangibana\modelling\aqtesolv\BHW05_CR.aqt
Date: 01/14/17 Time: 14:15:52

PROJECT INFORMATION

Company: GRM
Client: Hastings
Project: J160014
Location: Yangibana
Test Well: BHW05
Test Date: 9 Dec 2016

AQUIFER DATA

Saturated Thickness: 20. m Anisotropy Ratio (Kz/Kr): 1.

WELL DATA

Pumping Wells

Well Name	X (m)	Y (m)
BHW05	0	0

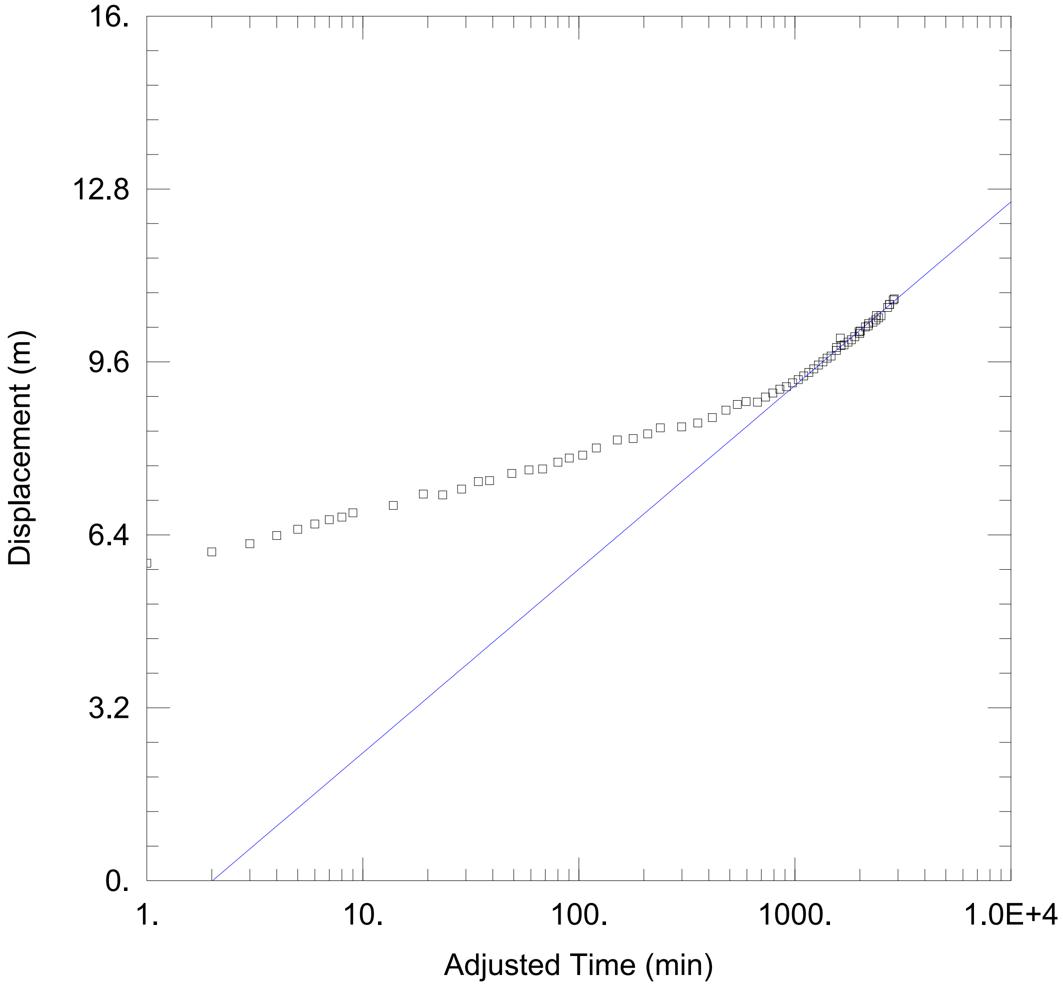
Observation Wells

Well Name	X (m)	Y (m)
□ BHW05	0	0

SOLUTION

Aquifer Model: Confined Solution Method: Cooper-Jacob

T = 236.1 m^2/day S = 0.0001196



WELL TEST ANALYSIS

Data Set: F:\J160014_Yangibana\modelling\aqtesolv\BHW05_crtLT.aqt
Date: 01/14/17 Time: 14:14:42

PROJECT INFORMATION

Company: GRM
Client: Hastings
Project: J160014
Location: Yangibana
Test Well: BHW05
Test Date: 9 Dec 2016

AQUIFER DATA

Saturated Thickness: 20. m Anisotropy Ratio (Kz/Kr): 1.

WELL DATA

Pumping Wells

Well Name	X (m)	Y (m)
BHW05	0	0

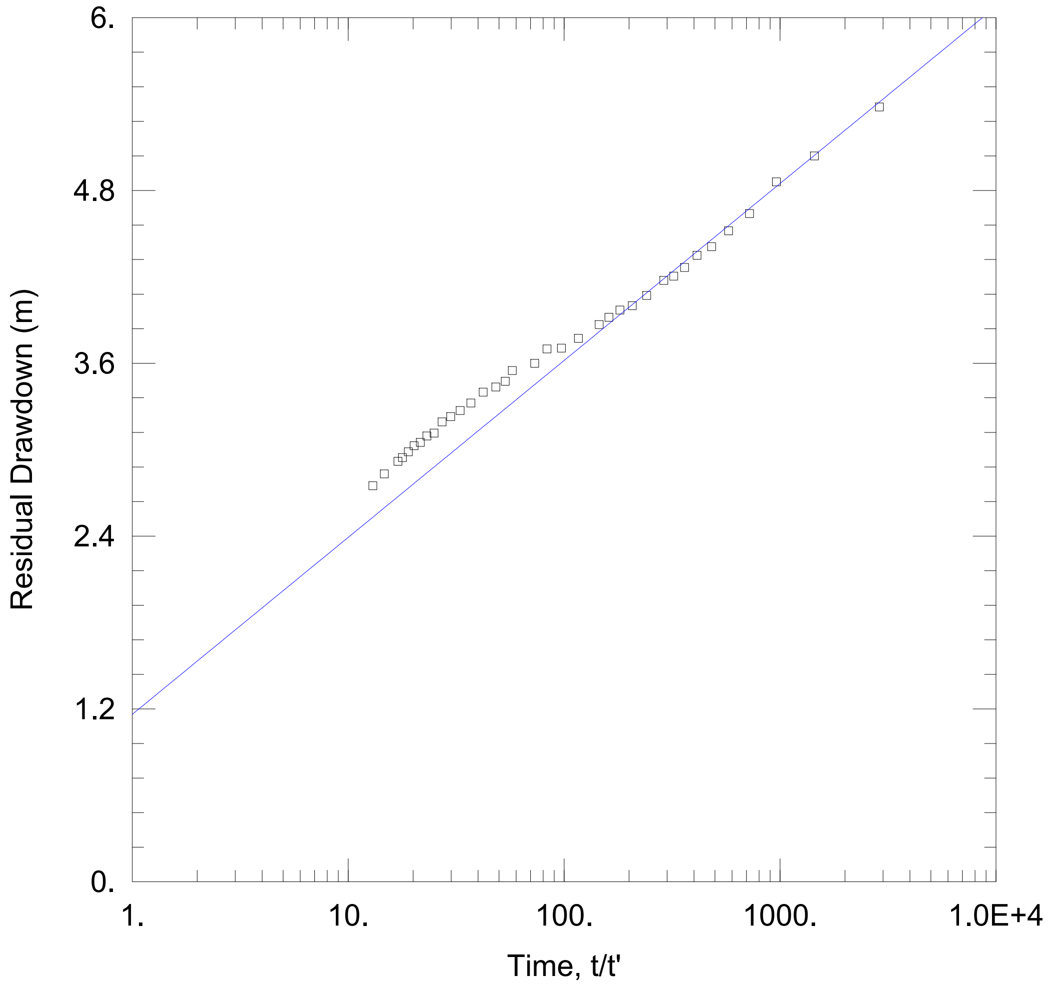
Observation Wells

Well Name	X (m)	Y (m)
□ BHW05	0	0

SOLUTION

Aquifer Model: Confined Solution Method: Cooper-Jacob

T = 74.81 m^2/day S = 16.34



WELL TEST ANALYSIS

Data Set: F:\J160014_Yangibana\modelling\aqtesolv\BHW05_recET.aqt
Date: 01/14/17 Time: 14:32:01

PROJECT INFORMATION

Company: GRM
Client: Hastings
Project: J160014
Location: Yangibana
Test Well: BHW05
Test Date: 11 Dec 2016

AQUIFER DATA

Saturated Thickness: 20. m Anisotropy Ratio (Kz/Kr): 1.

WELL DATA

Pumping Wells

Well Name	X (m)	Y (m)
BHW05	0	0

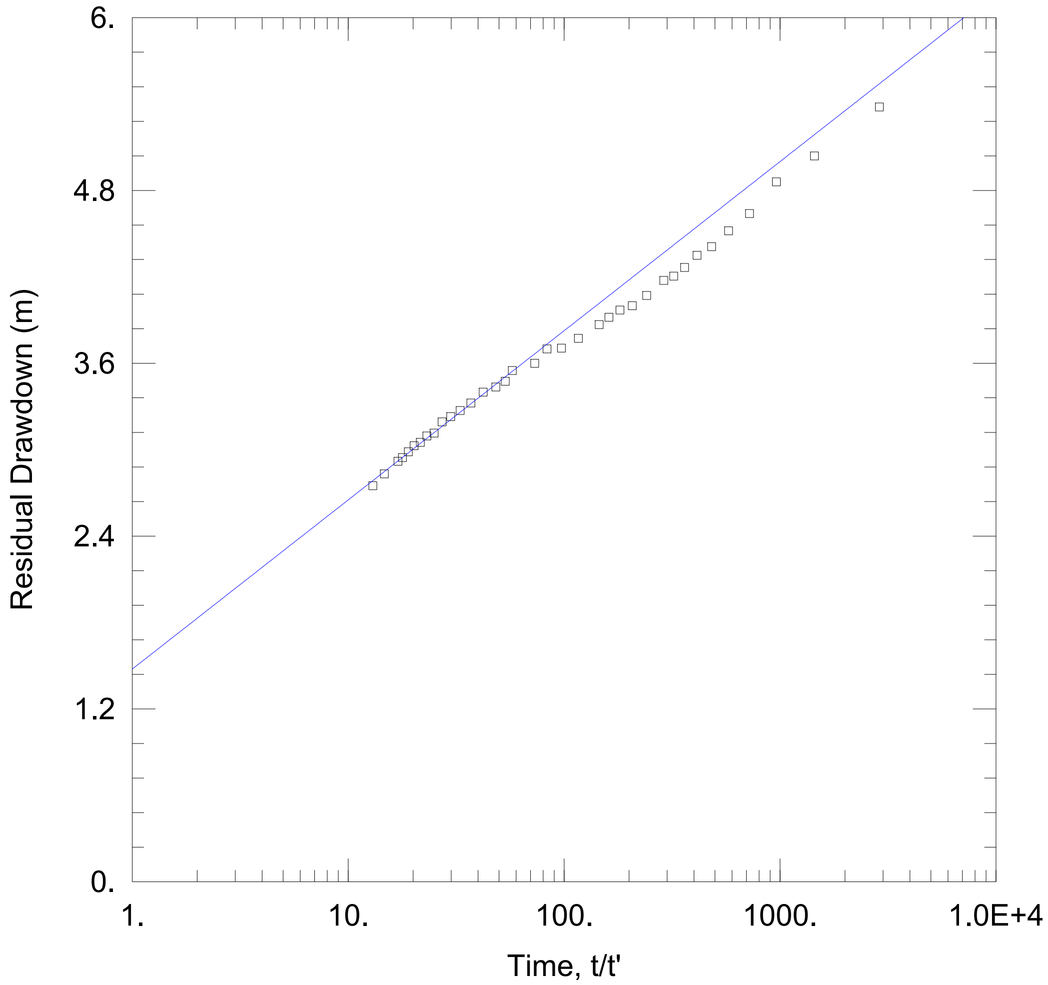
Observation Wells

Well Name	X (m)	Y (m)
□ BHW05	0	0

SOLUTION

Aquifer Model: Confined Solution Method: Theis (Recovery)

T = 207. m^2/day S/S' = 0.1134



WELL TEST ANALYSIS

Data Set: F:\J160014_Yangibana\modelling\aqtesolv\BHW05_recLT.aqt
Date: 01/14/17 Time: 14:31:26

PROJECT INFORMATION

Company: GRM
Client: Hastings
Project: J160014
Location: Yangibana
Test Well: BHW05
Test Date: 11 Dec 2016

AQUIFER DATA

Saturated Thickness: 20. m Anisotropy Ratio (Kz/Kr): 1.

WELL DATA

Pumping Wells

Well Name	X (m)	Y (m)
BHW05	0	0

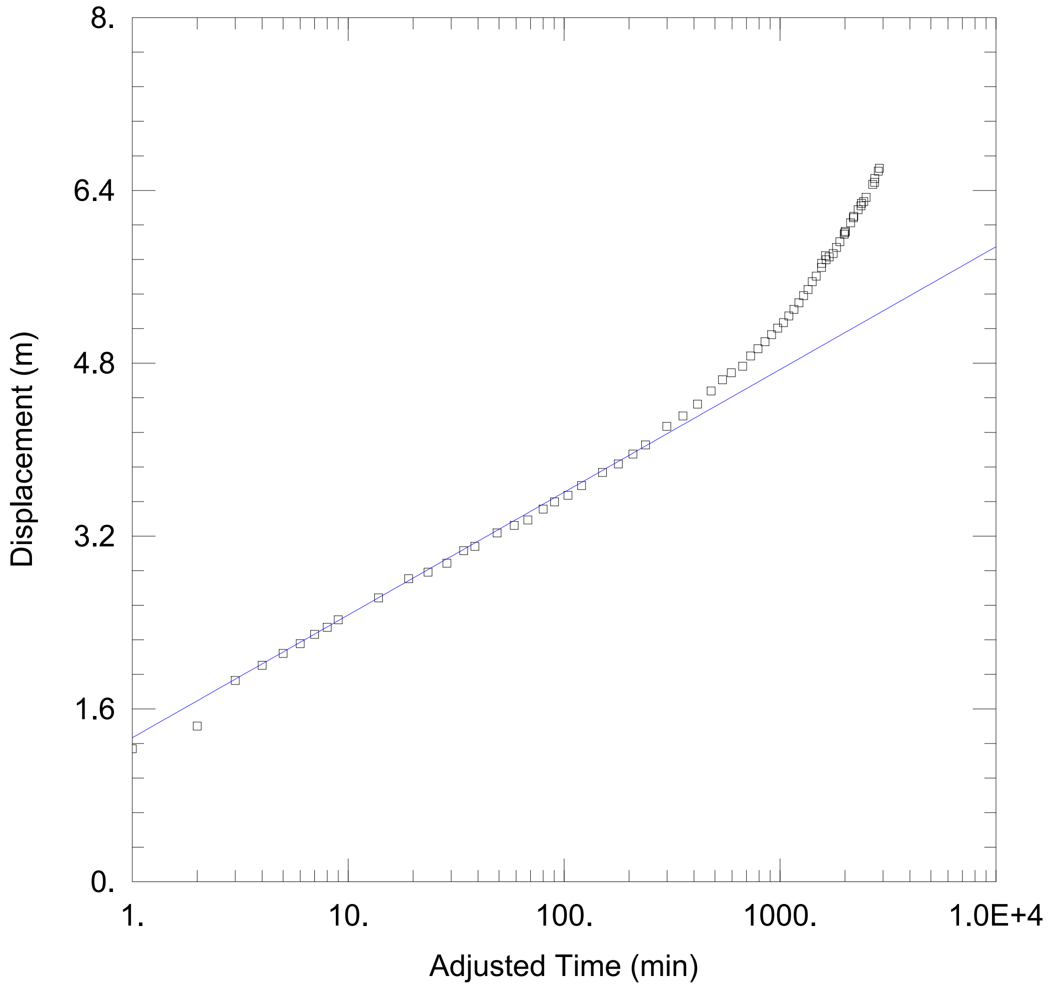
Observation Wells

Well Name	X (m)	Y (m)
□ BHW05	0	0

SOLUTION

Aquifer Model: Confined Solution Method: Theis (Recovery)

T = 216.5 m^2/day S/S' = 0.05542



WELL TEST ANALYSIS

Data Set: F:\J160014_Yangibana\modelling\aqtesolv\BHW05obs_crtET.aqt
Date: 01/14/17 Time: 15:06:24

PROJECT INFORMATION

Company: GRM
Client: Hastings
Project: J160014
Location: Yangibana
Test Well: BHW05
Test Date: 9 Dec 2016

AQUIFER DATA

Saturated Thickness: 20. m Anisotropy Ratio (Kz/Kr): 1.

WELL DATA

Pumping Wells

Well Name	X (m)	Y (m)
BHW05	0	0

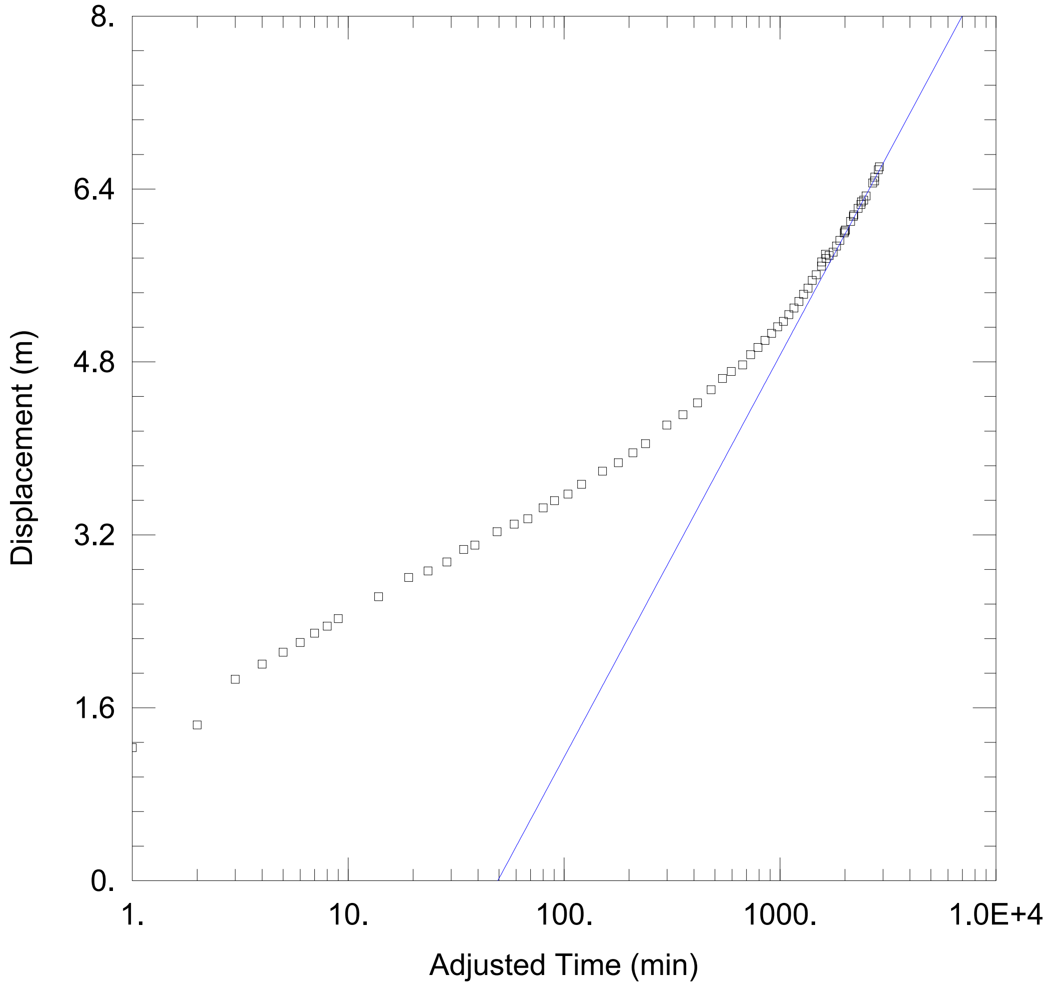
Observation Wells

Well Name	X (m)	Y (m)
□ BHW05obs	7.4	0

SOLUTION

Aquifer Model: Confined Solution Method: Cooper-Jacob

T = 223.8 m^2/day S = 0.0004285



WELL TEST ANALYSIS

Data Set: F:\J160014_Yangibana\modelling\aqtesolv\BHW05obs_crtLT.aqt
Date: 01/14/17 Time: 15:06:05

PROJECT INFORMATION

Company: GRM
Client: Hastings
Project: J160014
Location: Yangibana
Test Well: BHW05
Test Date: 9 Dec 2016

AQUIFER DATA

Saturated Thickness: 20. m Anisotropy Ratio (Kz/Kr): 1.

WELL DATA

Pumping Wells

Well Name	X (m)	Y (m)
BHW05	0	0

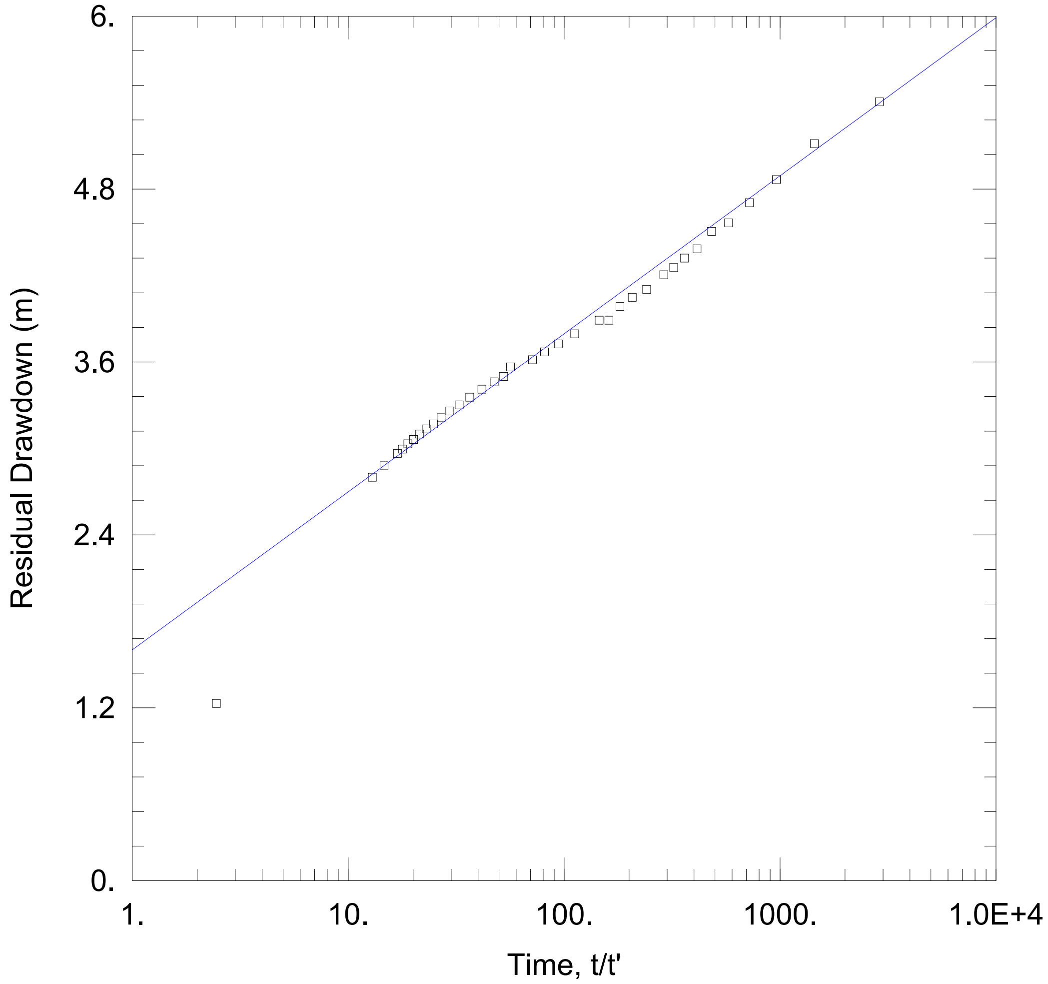
Observation Wells

Well Name	X (m)	Y (m)
□ BHW05obs	7.4	0

SOLUTION

Aquifer Model: Confined Solution Method: Cooper-Jacob

T = 68.36 m^2/day S = 0.09607



WELL TEST ANALYSIS

Data Set: F:\J160014_Yangibana\modelling\aqtesolv\BHW05_obs recLT.aqt
Date: 01/14/17 Time: 14:50:55

PROJECT INFORMATION

Company: GRM
Client: Hastings
Project: J160014
Location: Yangibana
Test Well: BHW05obs
Test Date: 11 Dec 2016

AQUIFER DATA

Saturated Thickness: 20. m Anisotropy Ratio (Kz/Kr): 1.

WELL DATA

Pumping Wells

Well Name	X (m)	Y (m)
BHW05obs	7.4	0

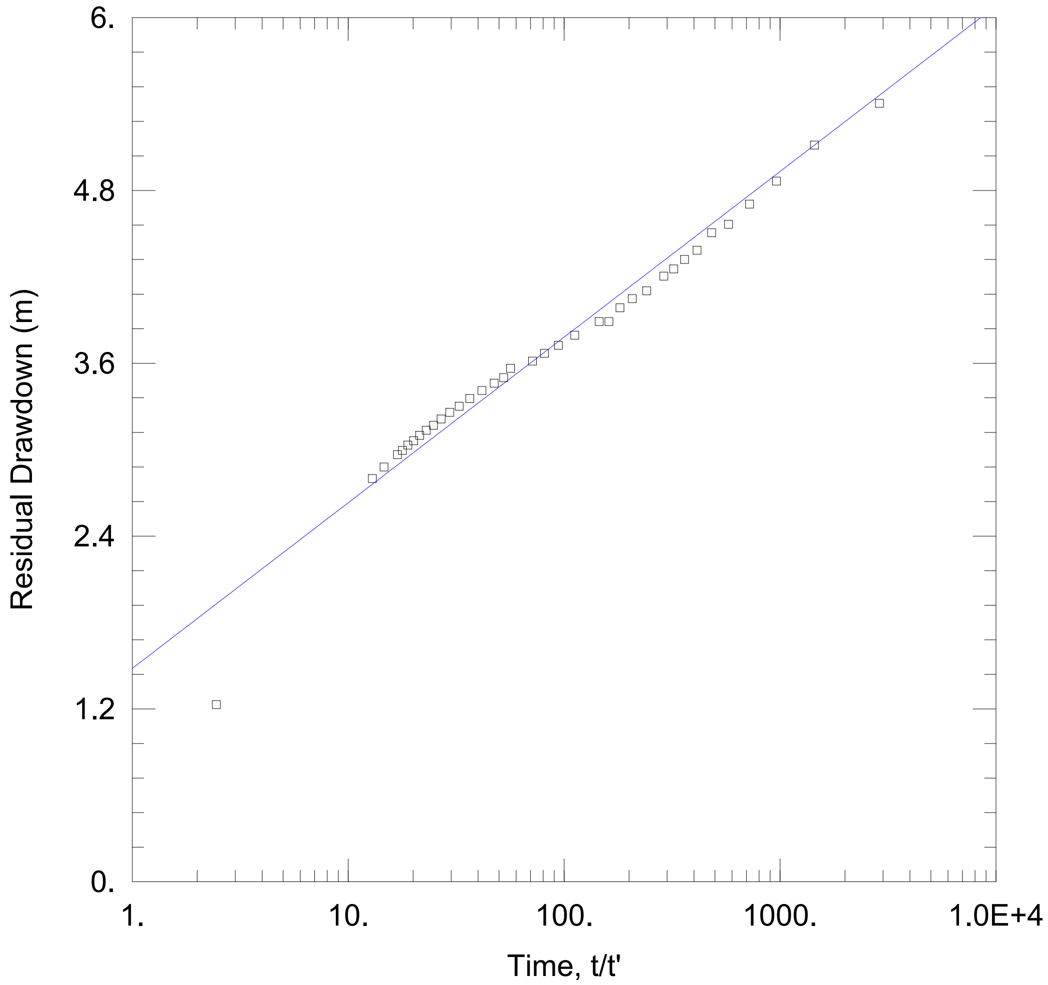
Observation Wells

Well Name	X (m)	Y (m)
□ BHW05obs	7.4	0

SOLUTION

Aquifer Model: Confined Solution Method: Theis (Recovery)

T = 231.9 m^2/day S/S' = 0.0347



WELL TEST ANALYSIS

Data Set: F:\J160014_Yangibana\modelling\aqtesolv\BHW05_recET.aqt
Date: 01/14/17 Time: 15:09:38

PROJECT INFORMATION

Company: GRM
Client: Hastings
Project: J160014
Location: Yangibana
Test Well: BHW05
Test Date: 11 Dec 2016

AQUIFER DATA

Saturated Thickness: 20. m
Anisotropy Ratio (Kz/Kr): 1.

WELL DATA

Pumping Wells

Well Name	X (m)	Y (m)
BHW05	0	0

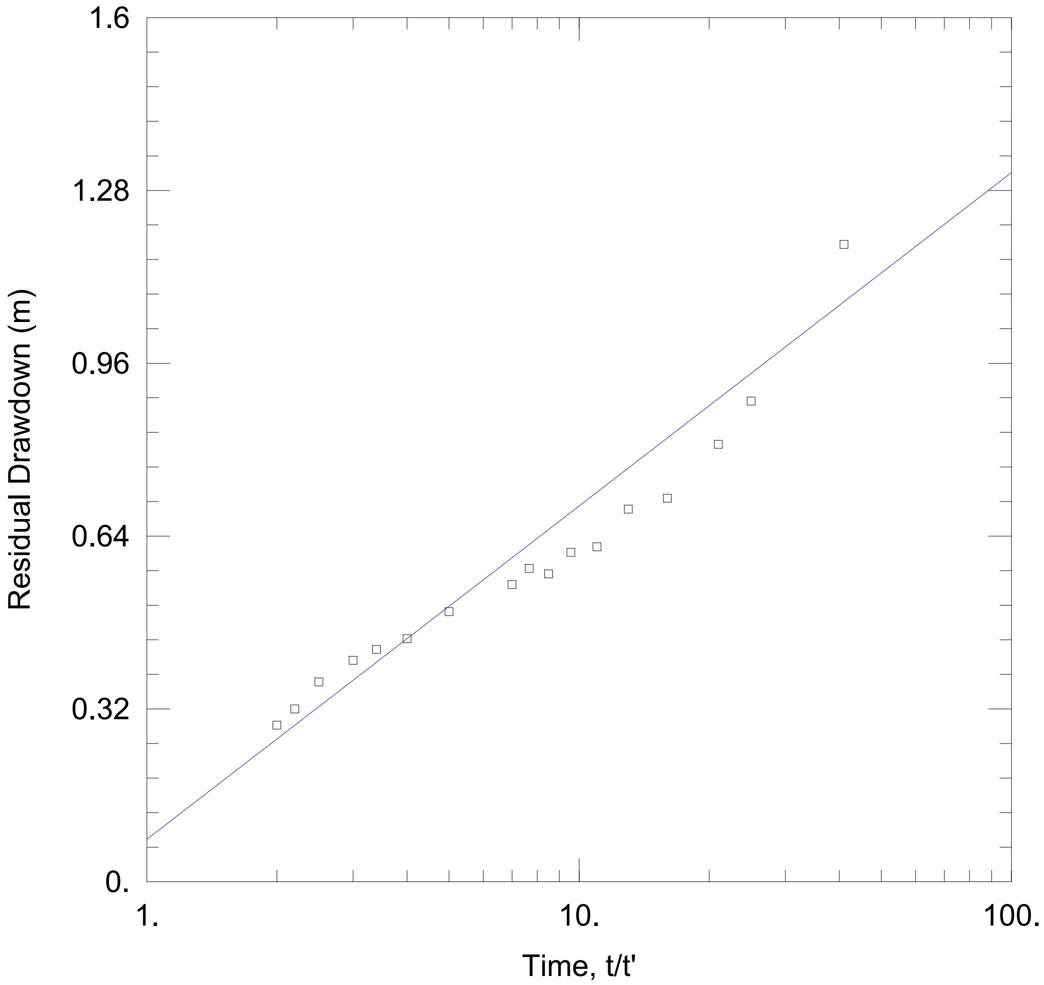
Observation Wells

Well Name	X (m)	Y (m)
□ BHW05obs	7.4	0

SOLUTION

Aquifer Model: Confined
Solution Method: Theis (Recovery)

T = 221.2 m^2/day
S/S' = 0.05159



AIRLIFT RECOVERY BHW01

Data Set: F:\J160014_Yangibana\modelling\aqtesolv\BHW01.aqt
Date: 01/14/17 Time: 15:48:09

PROJECT INFORMATION

Company: GRM
Client: Hastings
Project: J160014
Location: Yangibana
Test Well: BHW01
Test Date: 18/11/2016

AQUIFER DATA

Saturated Thickness: 20. m Anisotropy Ratio (Kz/Kr): 1.

WELL DATA

Pumping Wells

Well Name	X (m)	Y (m)
BHW01	0	0

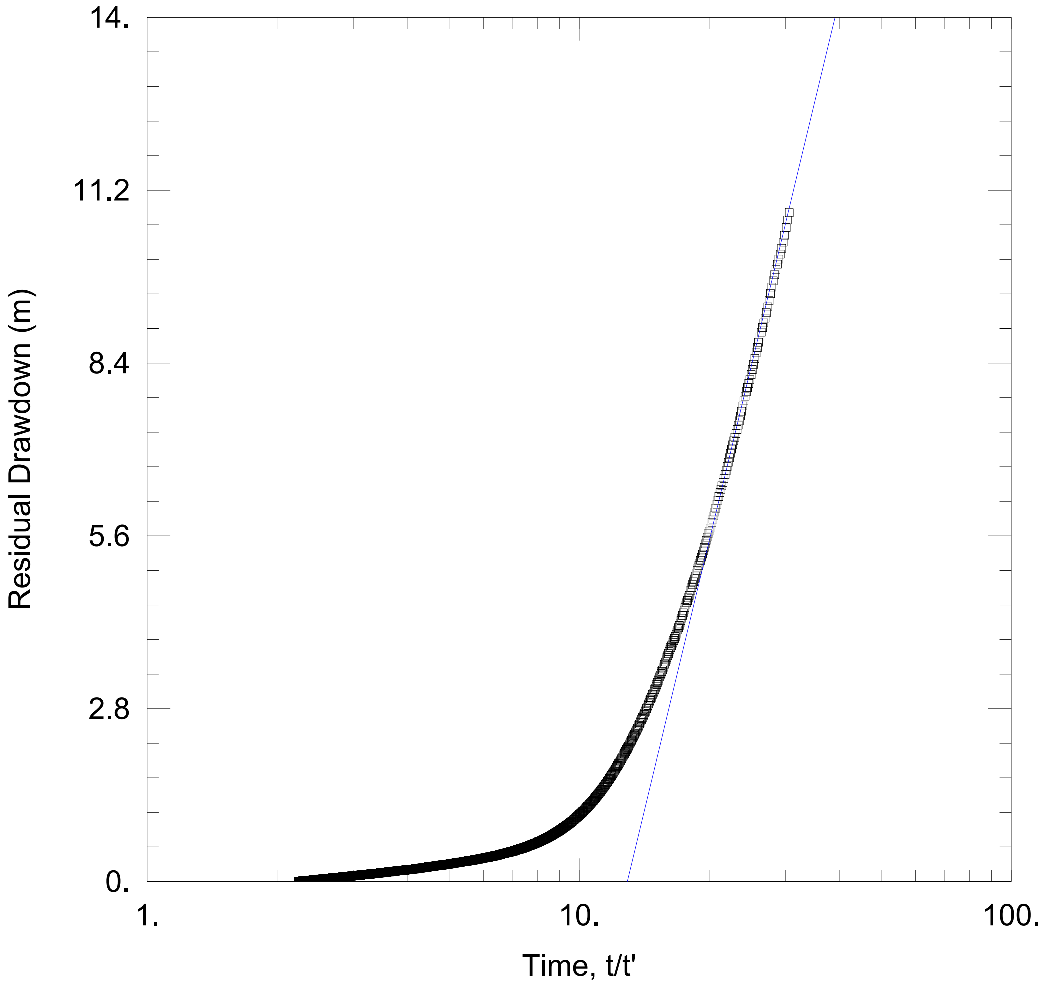
Observation Wells

Well Name	X (m)	Y (m)
□ BHW01	0	0

SOLUTION

Aquifer Model: Confined Solution Method: Theis (Recovery)

T = 100. m^2/day S/S' = 0.7462



AIRLIFT RECOVERY BHW02

Data Set: F:\J160014_Yangibana\modelling\aqtesolv\BHW02ET.aqt
Date: 01/14/17 Time: 15:41:28

PROJECT INFORMATION

Company: GRM
Client: Hastings
Project: J160014
Location: Yangibana
Test Well: BHW02
Test Date: 16/11/2016

AQUIFER DATA

Saturated Thickness: 20. m
Anisotropy Ratio (Kz/Kr): 1.

WELL DATA

Pumping Wells

Well Name	X (m)	Y (m)
BHW02	0	0

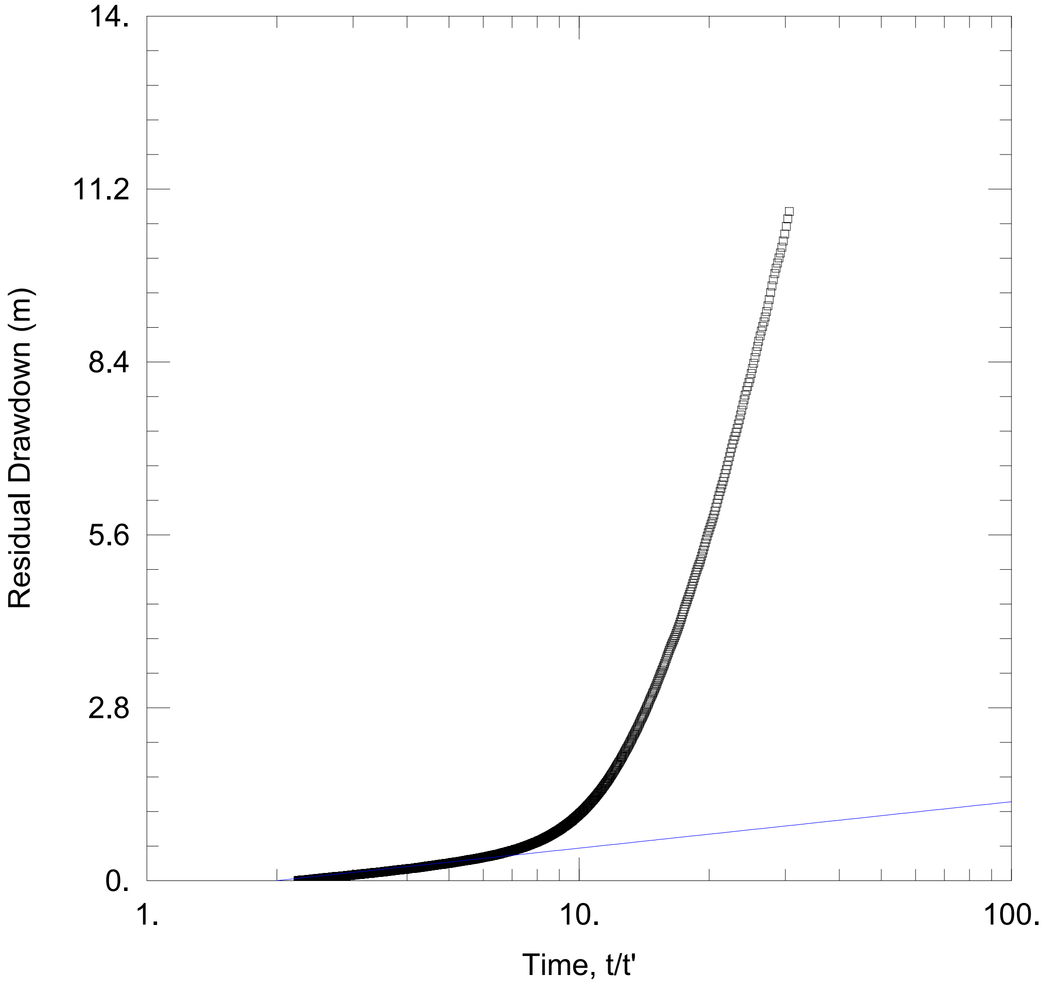
Observation Wells

Well Name	X (m)	Y (m)
□ BHW02	0	0

SOLUTION

Aquifer Model: Confined
Solution Method: Theis (Recovery)

T = 0.8155 m^2/day
S/S' = 12.94



AIRLIFT RECOVERY BHW02

Data Set: F:\J160014_Yangibana\modelling\aqtesolv\BHW02.aqt
Date: 01/07/17 Time: 15:11:04

PROJECT INFORMATION

Company: GRM
Client: Hastings
Project: J160014
Location: Yangibana
Test Well: BHW02
Test Date: 16/11/2016

AQUIFER DATA

Saturated Thickness: 20. m Anisotropy Ratio (Kz/Kr): 1.

WELL DATA

Pumping Wells

Well Name	X (m)	Y (m)
BHW02	0	0

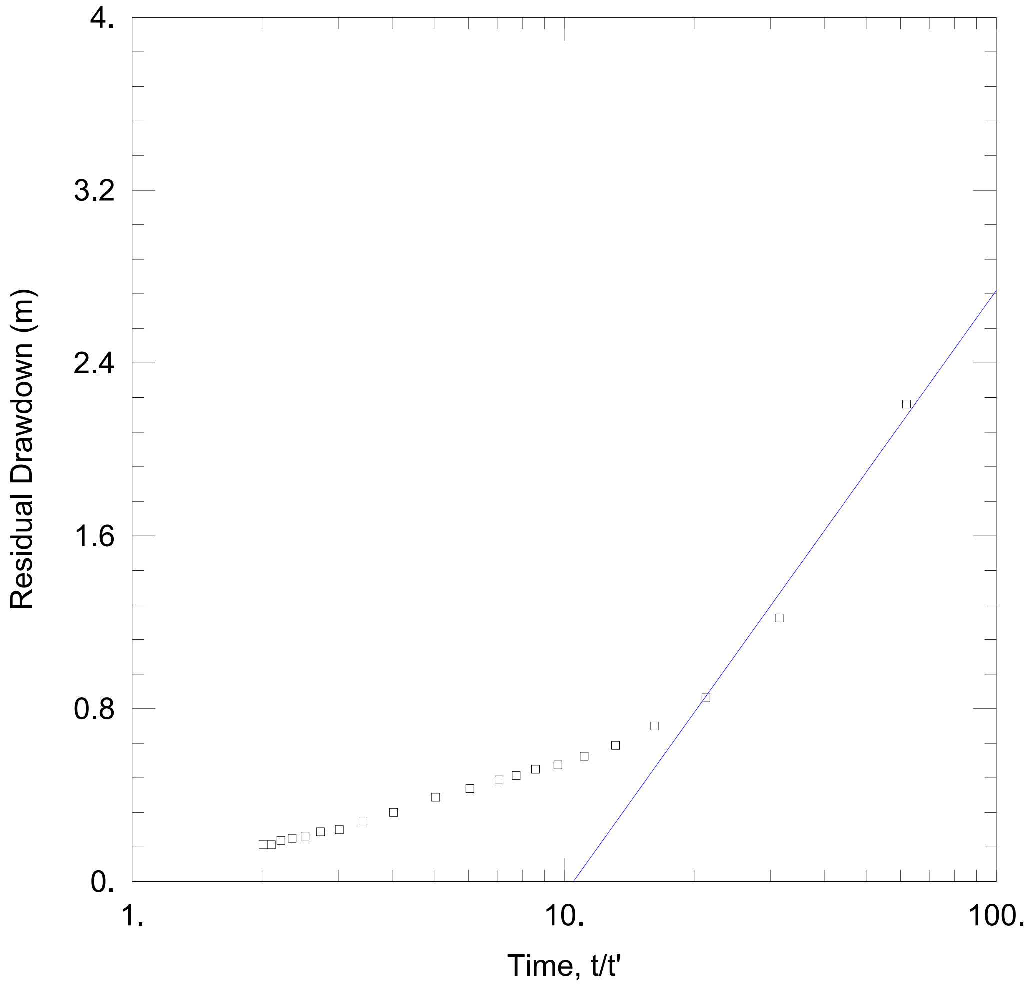
Observation Wells

Well Name	X (m)	Y (m)
□ BHW02	0	0

SOLUTION

Aquifer Model: Confined Solution Method: Theis (Recovery)

T = 31.58 m^2/day S/S' = 1.999



AIRLIFT RECOVERY BHRC161

Data Set: F:\J160014_Yangibana\modelling\aqtesolv\BHRC161 early.aqt
Date: 01/14/17 Time: 15:55:21

PROJECT INFORMATION

Company: GRM
Client: Hastings
Project: J160014
Location: Yangibana
Test Well: BHRC161
Test Date: 20/11/2016

AQUIFER DATA

Saturated Thickness: 5. m Anisotropy Ratio (Kz/Kr): 1.

WELL DATA

Pumping Wells

Well Name	X (m)	Y (m)
BHRC161	0	0

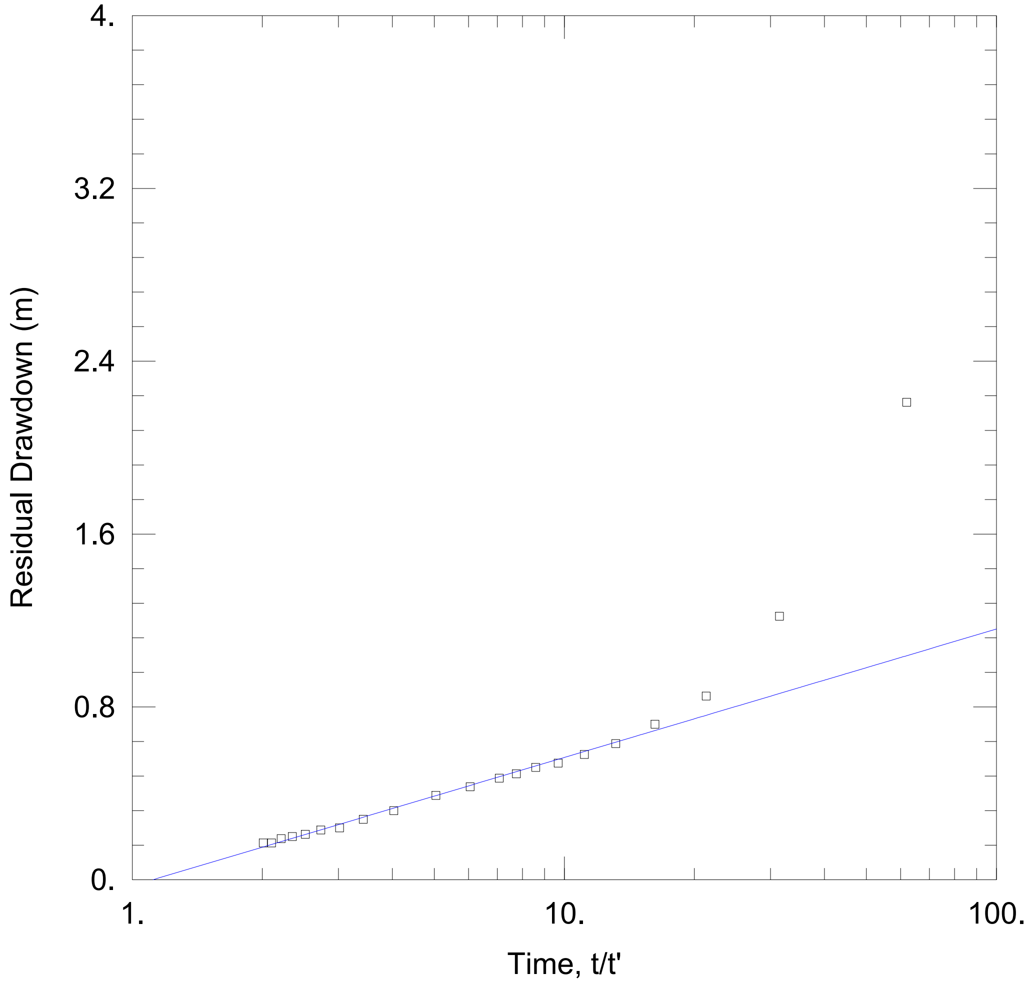
Observation Wells

Well Name	X (m)	Y (m)
□ BHRC161	0	0

SOLUTION

Aquifer Model: Confined Solution Method: Theis (Recovery)

T = 16.99 m^2/day S/S' = 10.51



AIRLIFT RECOVERY BHRC161

Data Set: F:\J160014_Yangibana\modelling\aqtesolv\BHRC161.aqt
Date: 01/06/17 Time: 16:26:26

PROJECT INFORMATION

Company: GRM
Client: Hastings
Project: J160014
Location: Yangibana
Test Well: BHRC161
Test Date: 20/11/2016

AQUIFER DATA

Saturated Thickness: 5. m
Anisotropy Ratio (Kz/Kr): 1.

WELL DATA

Pumping Wells

Well Name	X (m)	Y (m)
BHRC161	0	0

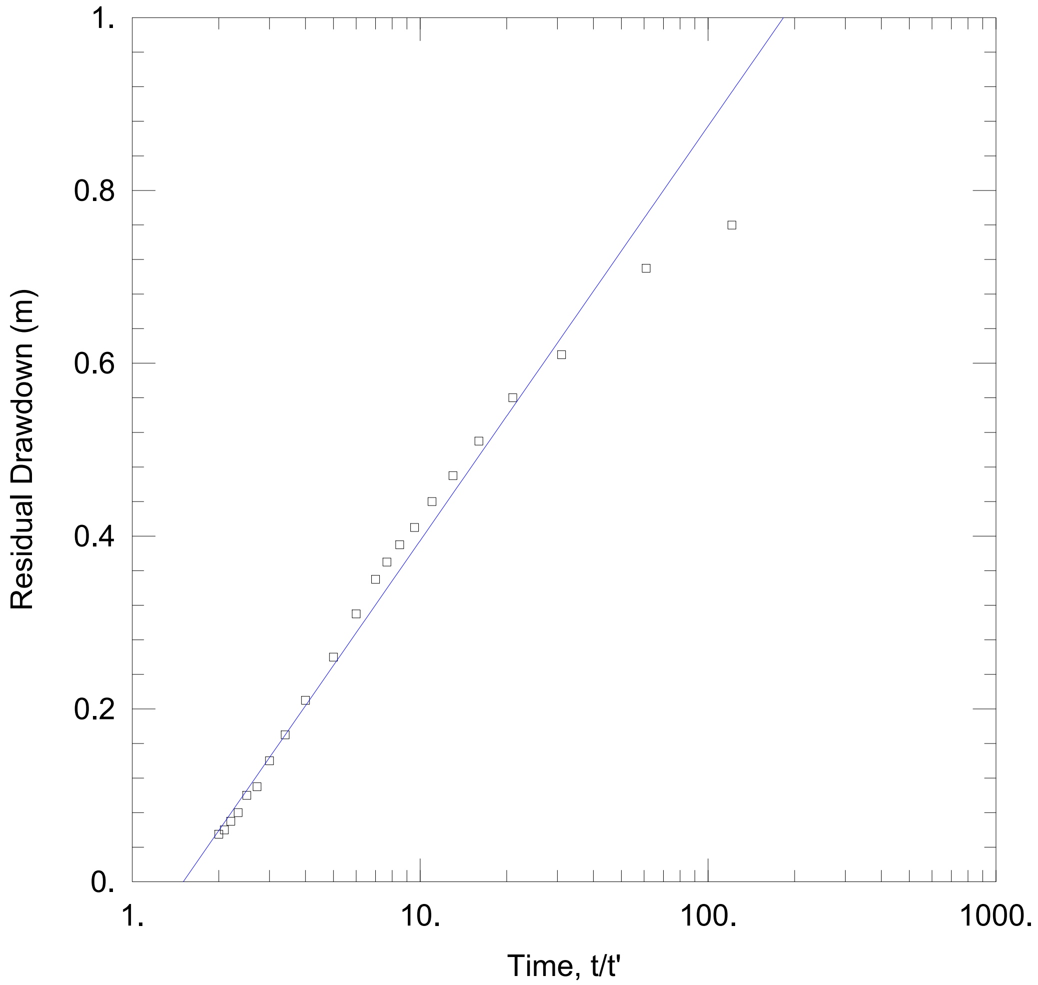
Observation Wells

Well Name	X (m)	Y (m)
□ BHRC161	0	0

SOLUTION

Aquifer Model: Confined
Solution Method: Theis (Recovery)

T = 79.91 m^2/day
S/S' = 1.117



AIRLIFT RECOVERY BHRC082

Data Set: F:\J160014_Yangibana\modelling\aqtesolv\BHRC082.aqt
Date: 01/14/17 Time: 16:01:00

PROJECT INFORMATION

Company: GRM
Client: Hastings
Project: J160014
Location: Yangibana
Test Well: BHRC082
Test Date: 20/11/2016

AQUIFER DATA

Saturated Thickness: 34.77 m Anisotropy Ratio (Kz/Kr): 1.

WELL DATA

Pumping Wells

Well Name	X (m)	Y (m)
BHRC082	0	0

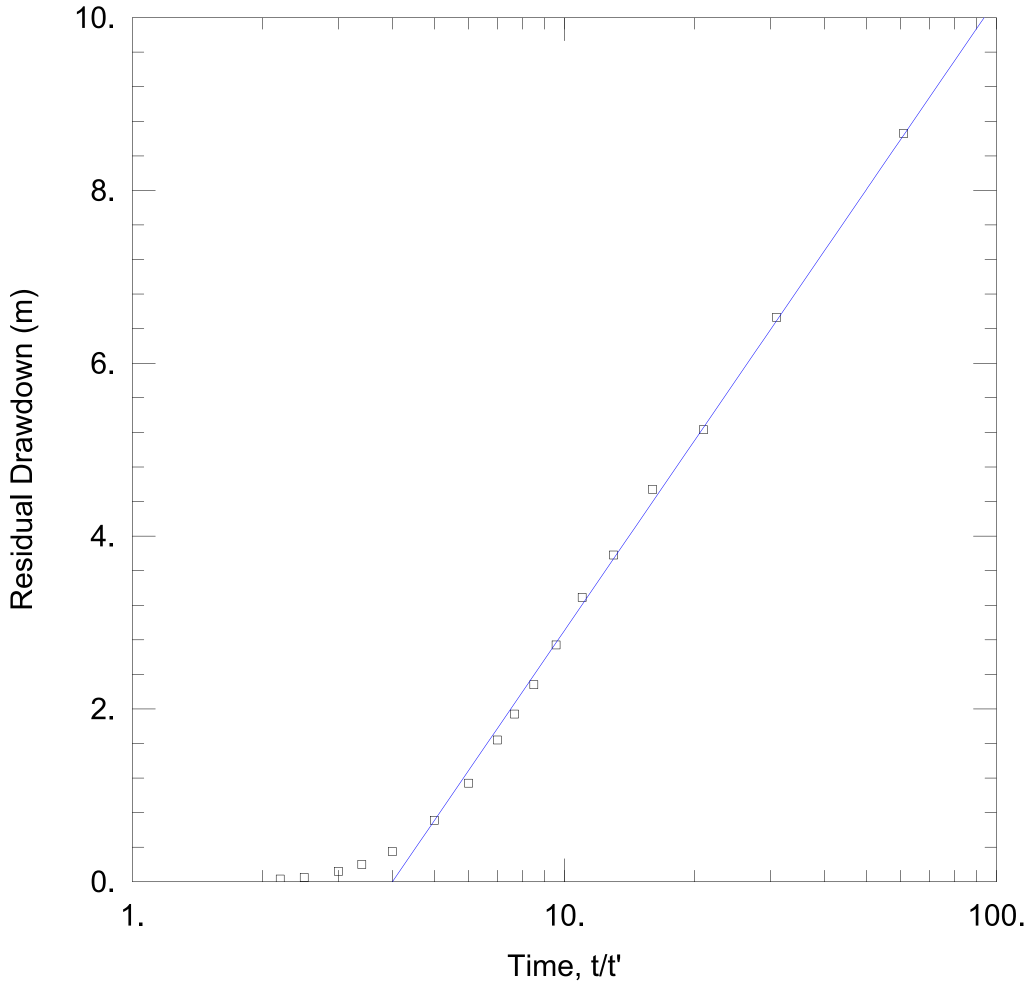
Observation Wells

Well Name	X (m)	Y (m)
□ BHRC082	0	0

SOLUTION

Aquifer Model: Confined Solution Method: Theis (Recovery)

T = 66.01 m^2/day S/S' = 1.505



AIRLIFT RECOVERY BHRC095

Data Set: F:\J160014_Yangibana\modelling\aqtesolv\BHRC095.aqt
Date: 01/06/17 Time: 17:13:29

PROJECT INFORMATION

Company: GRM
Client: Hastings
Project: J160014
Location: Yangibana
Test Well: BHRC095
Test Date: 20/11/2016

AQUIFER DATA

Saturated Thickness: 14. m Anisotropy Ratio (Kz/Kr): 1.

WELL DATA

Pumping Wells

Well Name	X (m)	Y (m)
BHRC095	0	0

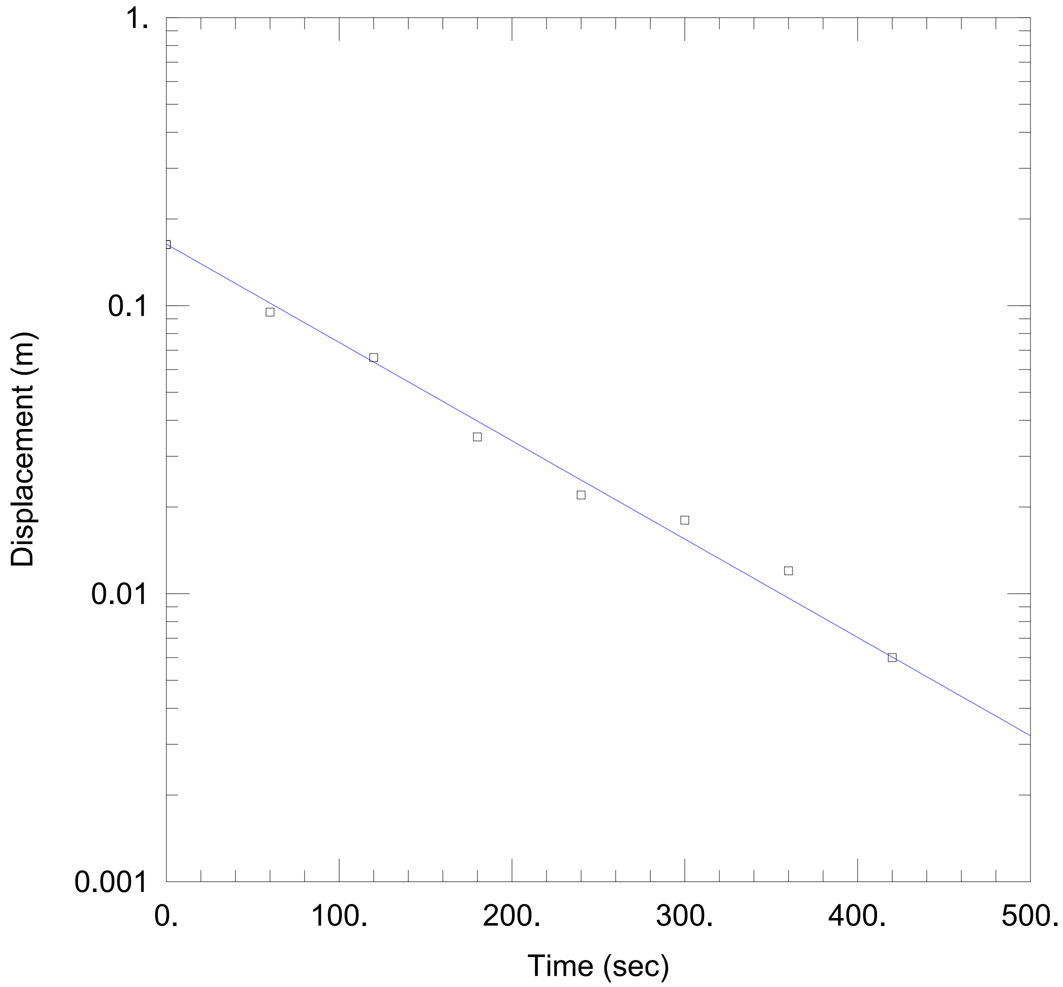
Observation Wells

Well Name	X (m)	Y (m)
□ BHRC095	0	0

SOLUTION

Aquifer Model: Confined Solution Method: Theis (Recovery)

T = 0.7155 m^2/day S/S' = 4.002



WELL TEST ANALYSIS

Data Set: F:\J160014_Yangibana\modelling\aqtesolv\Daves\BHRC097.aqt
Date: 01/14/17 Time: 16:14:46

PROJECT INFORMATION

Company: GRM
Client: Hastings
Project: J160014
Location: Yangibana
Test Well: BHRC097
Test Date: 18 Dec 2016

AQUIFER DATA

Saturated Thickness: 40.48 m
Anisotropy Ratio (Kz/Kr): 1.

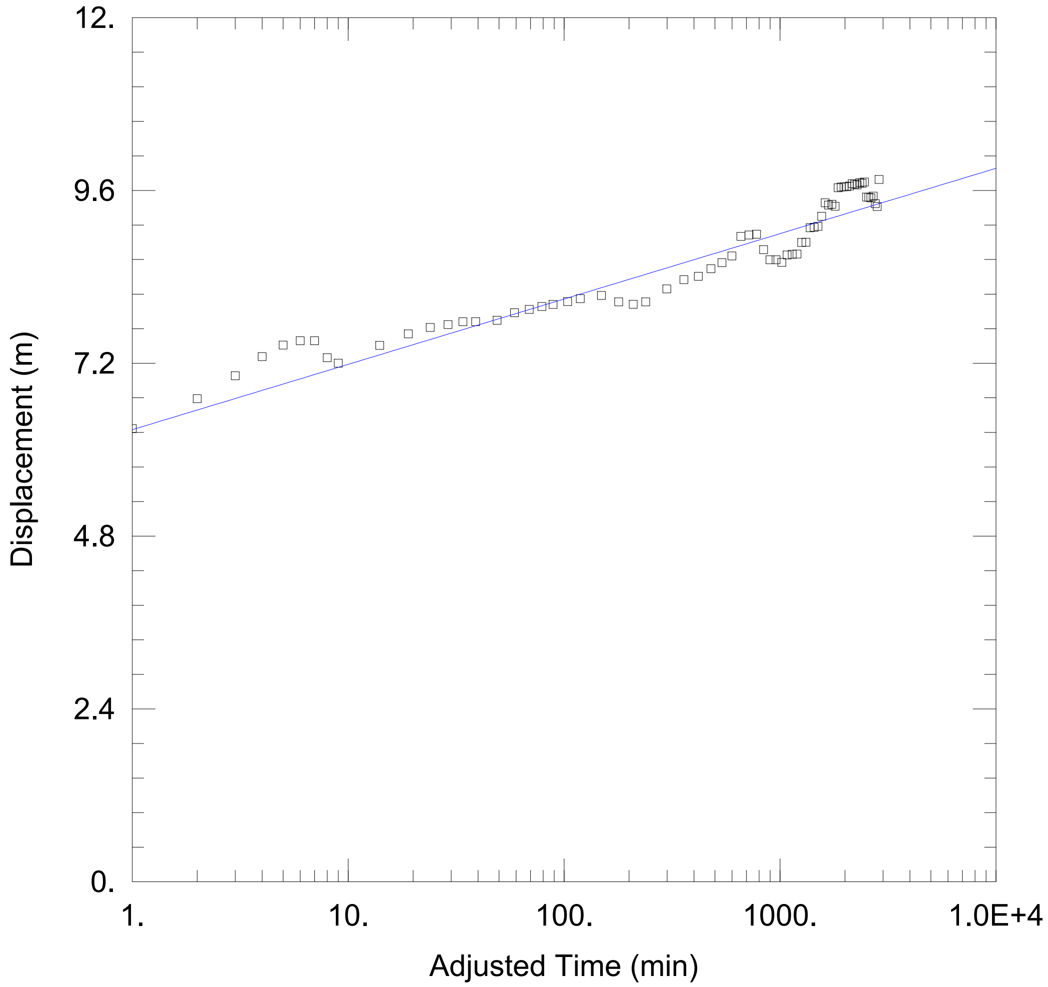
WELL DATA (BHRC097)

Initial Displacement: 0.1628 m
Total Well Penetration Depth: 40.48 m
Casing Radius: 0.075 m
Static Water Column Height: 40.48 m
Screen Length: 40.48 m
Well Radius: 0.075 m
Gravel Pack Porosity: 1.

SOLUTION

Aquifer Model: Unconfined
Solution Method: Hvorslev

K = 0.25 m/day
y0 = 0.1635 m



WELL TEST ANALYSIS

Data Set: F:\J160014_Yangibana\modelling\aqtesolv\Daves\YGWB003.aqt
Date: 01/14/17 Time: 20:24:01

PROJECT INFORMATION

Company: GRM
Client: Hastings
Project: J160014
Location: Yangibana
Test Well: YGWB003
Test Date: 14 Dec 2016

AQUIFER DATA

Saturated Thickness: 10. m Anisotropy Ratio (Kz/Kr): 1.

WELL DATA

Pumping Wells

Well Name	X (m)	Y (m)
YGWB003	0	0

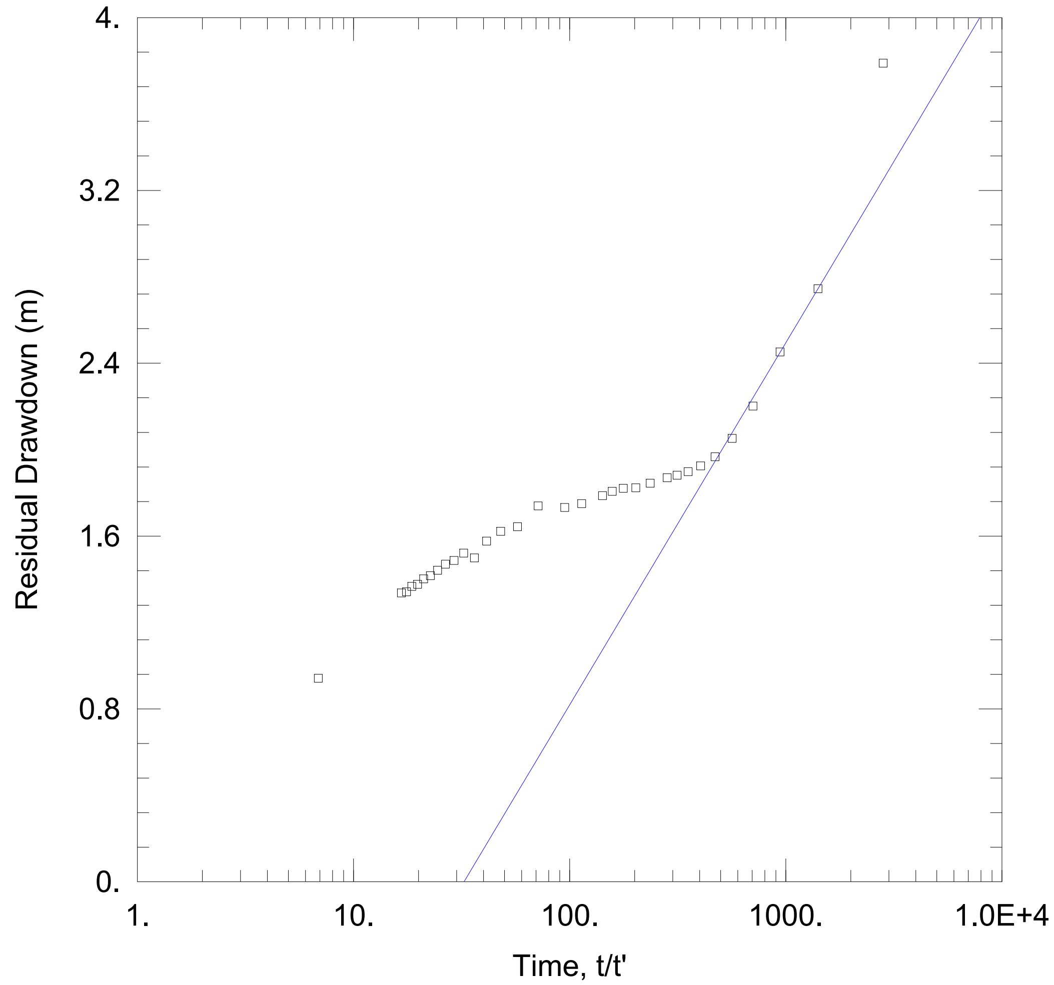
Observation Wells

Well Name	X (m)	Y (m)
□ YGWB003	0	0

SOLUTION

Aquifer Model: Confined Solution Method: Cooper-Jacob

T = 54.95 m^2/day S = 1.008E-6



WELL TEST ANALYSIS

Data Set: F:\J160014_Yangibana\modelling\aqtesolv\YGWB003recET.aqt
Date: 01/15/17 Time: 14:42:30

PROJECT INFORMATION

Company: GRM
Client: Hastings
Project: J160014
Location: Yangibana
Test Well: YGWB003
Test Date: 16 Dec 2016

AQUIFER DATA

Saturated Thickness: 10. m Anisotropy Ratio (Kz/Kr): 1.

WELL DATA

Pumping Wells

Well Name	X (m)	Y (m)
YGWB003	0	0

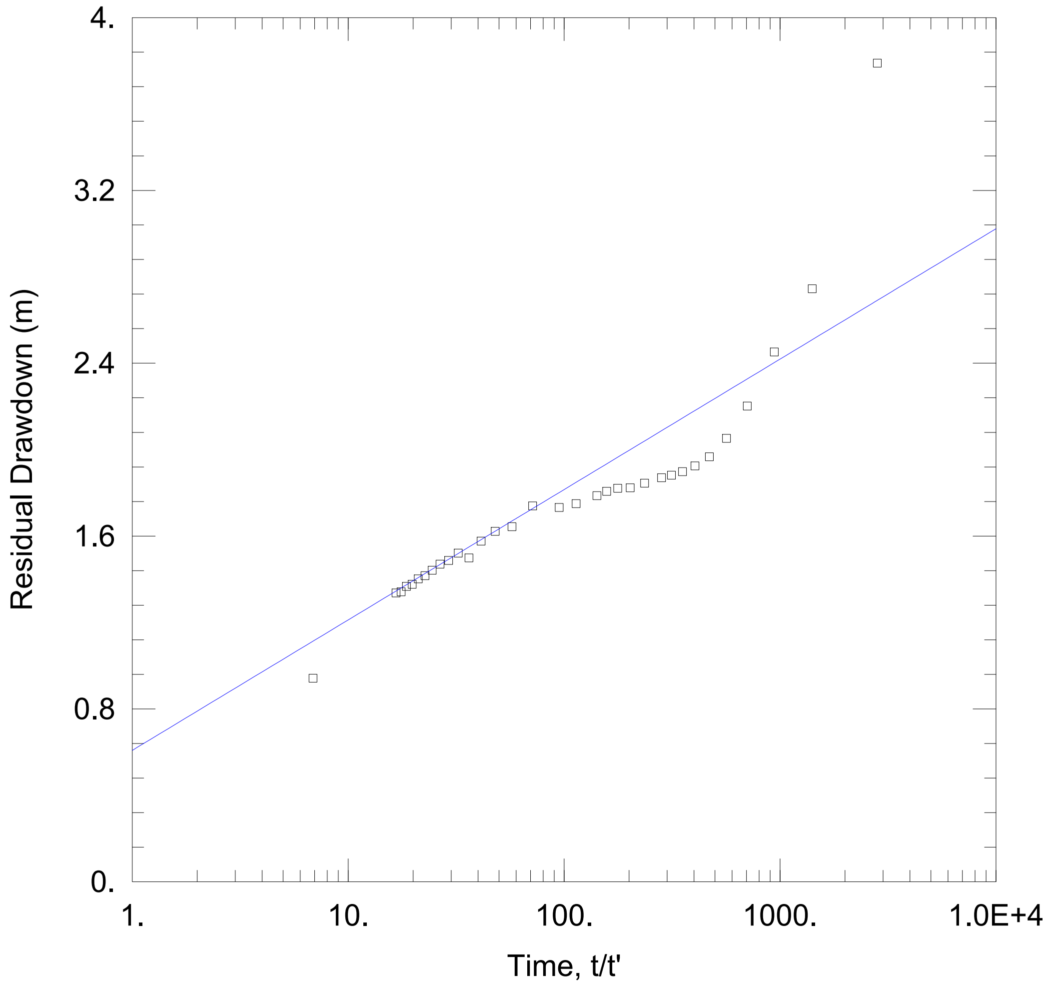
Observation Wells

Well Name	X (m)	Y (m)
□ YGWB003	0	0

SOLUTION

Aquifer Model: Confined Solution Method: Theis (Recovery)

T = 29.75 m^2/day S/S' = 32.49



WELL TEST ANALYSIS

Data Set: F:\J160014_Yangibana\modelling\aqtesolv\YGWB003recLT.aqt
Date: 01/15/17 Time: 14:42:57

PROJECT INFORMATION

Company: GRM
Client: Hastings
Project: J160014
Location: Yangibana
Test Well: YGWB003
Test Date: 16 Dec 2016

AQUIFER DATA

Saturated Thickness: 10. m Anisotropy Ratio (Kz/Kr): 1.

WELL DATA

Pumping Wells

Well Name	X (m)	Y (m)
YGWB003	0	0

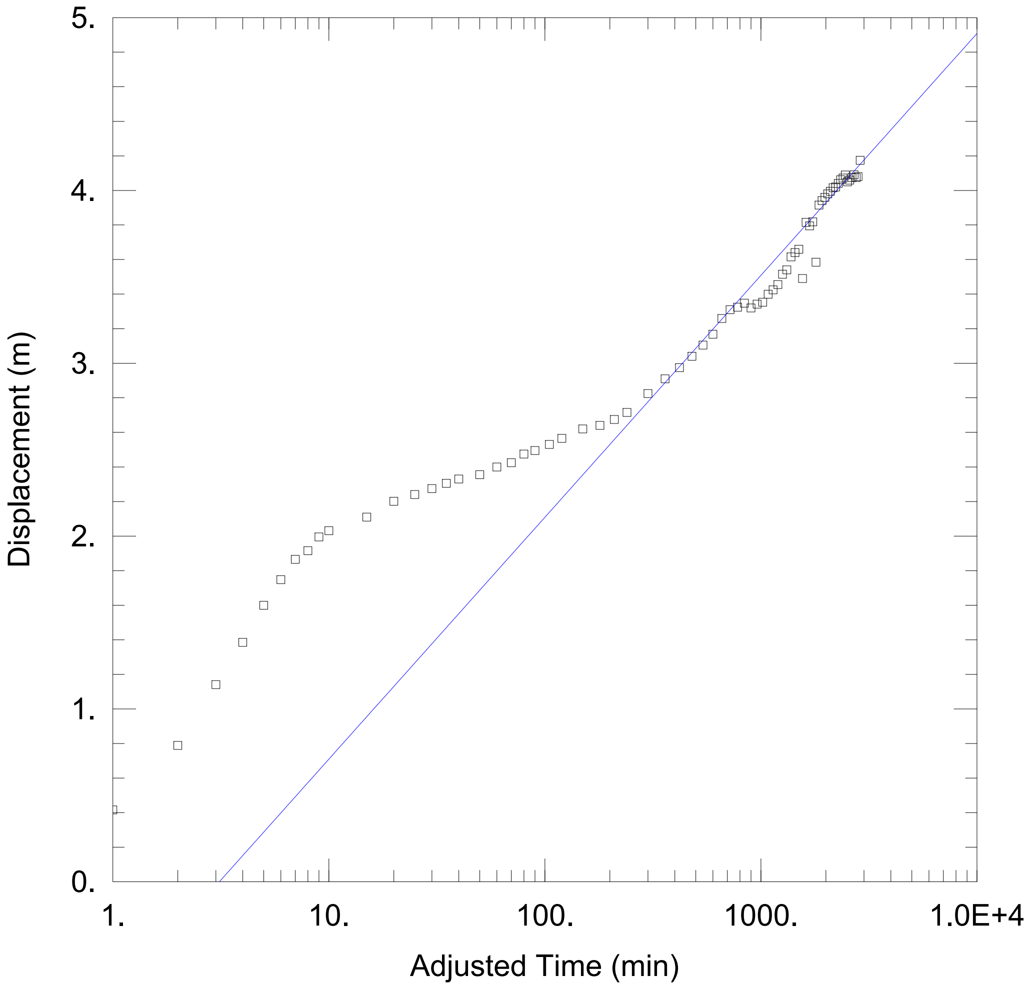
Observation Wells

Well Name	X (m)	Y (m)
□ YGWB003	0	0

SOLUTION

Aquifer Model: Confined Solution Method: Theis (Recovery)

T = 82.61 m^2/day S/S' = 0.0985



WELL TEST ANALYSIS

Data Set: F:\J160014_Yangibana\modelling\aqtesolv\YGWB003obs bore crt.aqt
Date: 01/14/17 Time: 20:14:32

PROJECT INFORMATION

Company: GRM
Client: Hastings
Project: J160014
Location: Yangibana
Test Well: YGWB003
Test Date: 14 Dec 2016

AQUIFER DATA

Saturated Thickness: 42. m Anisotropy Ratio (Kz/Kr): 2.848

WELL DATA

Pumping Wells

Well Name	X (m)	Y (m)
YGWB003	0	0

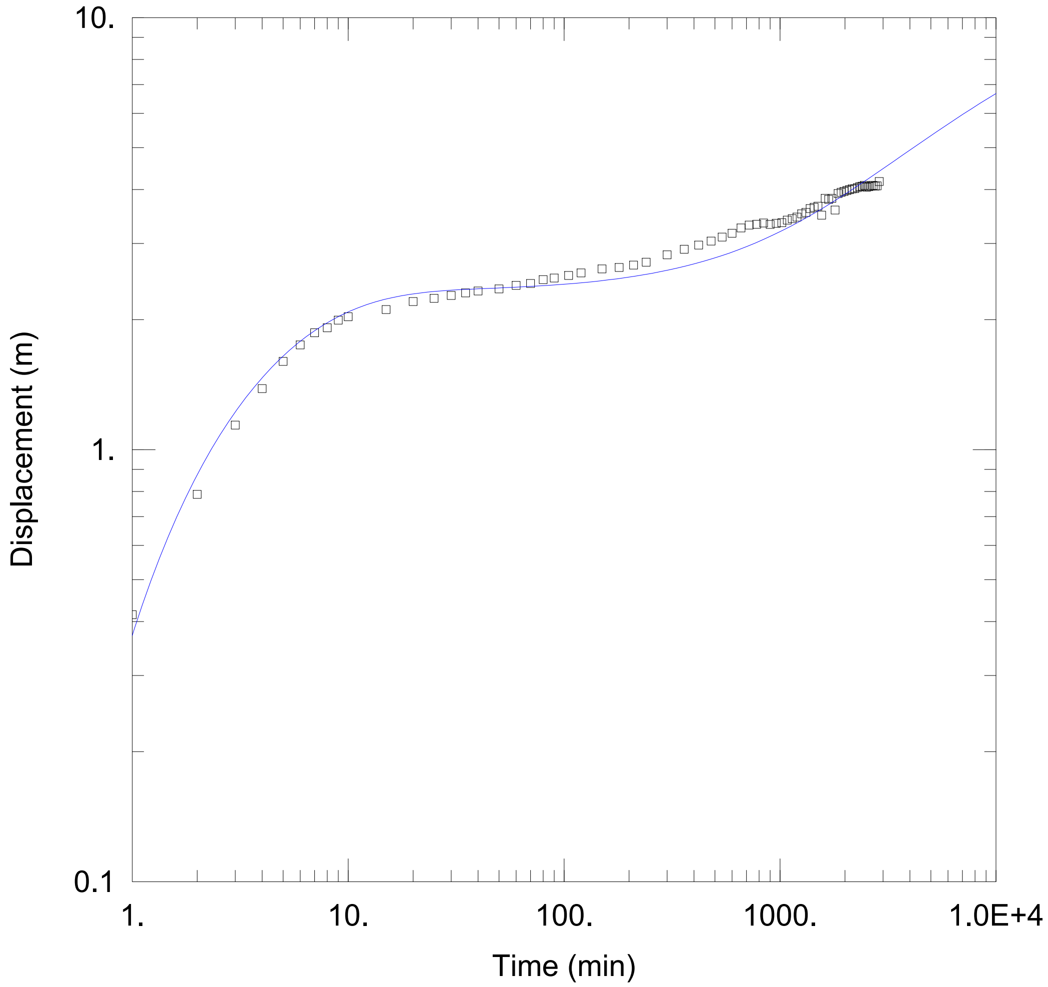
Observation Wells

Well Name	X (m)	Y (m)
□ YGWB001	7.87	0

SOLUTION

Aquifer Model: Confined Solution Method: Cooper-Jacob

T = 35.63 m^2/day S = 0.002797



WELL TEST ANALYSIS

Data Set: F:\J160014_Yangibana\modelling\aqtesolv\YGWB003 Obs.aqt
Date: 01/15/17 Time: 15:40:51

PROJECT INFORMATION

Company: GRM
Client: Hastings Metals Limited
Project: J160014
Location: Yangibana
Test Well: YGWB003
Test Date: 14/12/16

AQUIFER DATA

Saturated Thickness: 42. m

WELL DATA

Pumping Wells

Well Name	X (m)	Y (m)
YGWB003	0	0

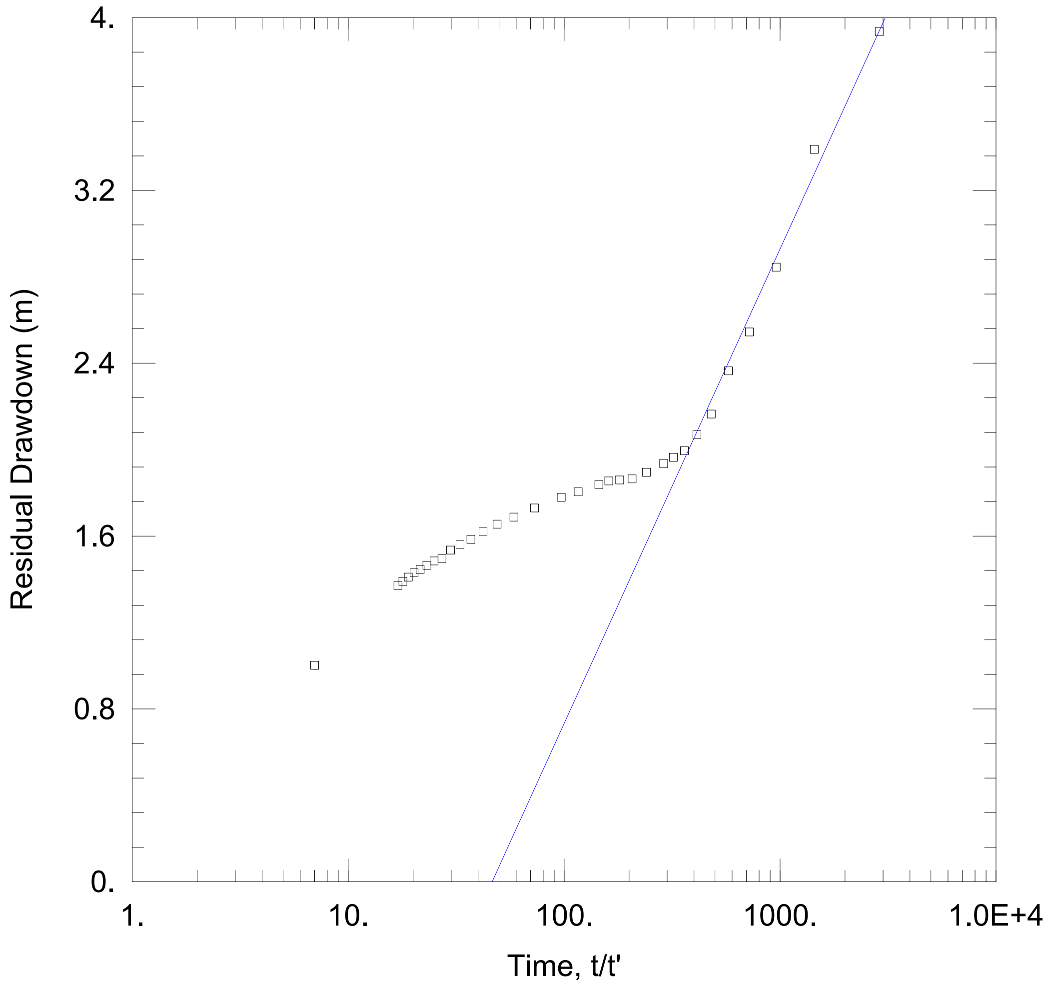
Observation Wells

Well Name	X (m)	Y (m)
□ YGWB001	7.87	0

SOLUTION

Aquifer Model: Unconfined
Solution Method: Neuman

T = 10.11 m^2/day
S = 0.0004562
Sy = 0.1169
ß = 0.2



WELL TEST ANALYSIS

Data Set: F:\J160014_Yangibana\modelling\aqtesolv\YGWB003 Obs recET.aqt
Date: 01/15/17 Time: 14:46:03

PROJECT INFORMATION

Company: GRM
Client: Hastings Metals Limited
Project: J160014
Location: Yangibana
Test Well: YGWB003
Test Date: 14/12/16

AQUIFER DATA

Saturated Thickness: 42. m Anisotropy Ratio (Kz/Kr): 1.

WELL DATA

Pumping Wells

Well Name	X (m)	Y (m)
YGWB003	0	0

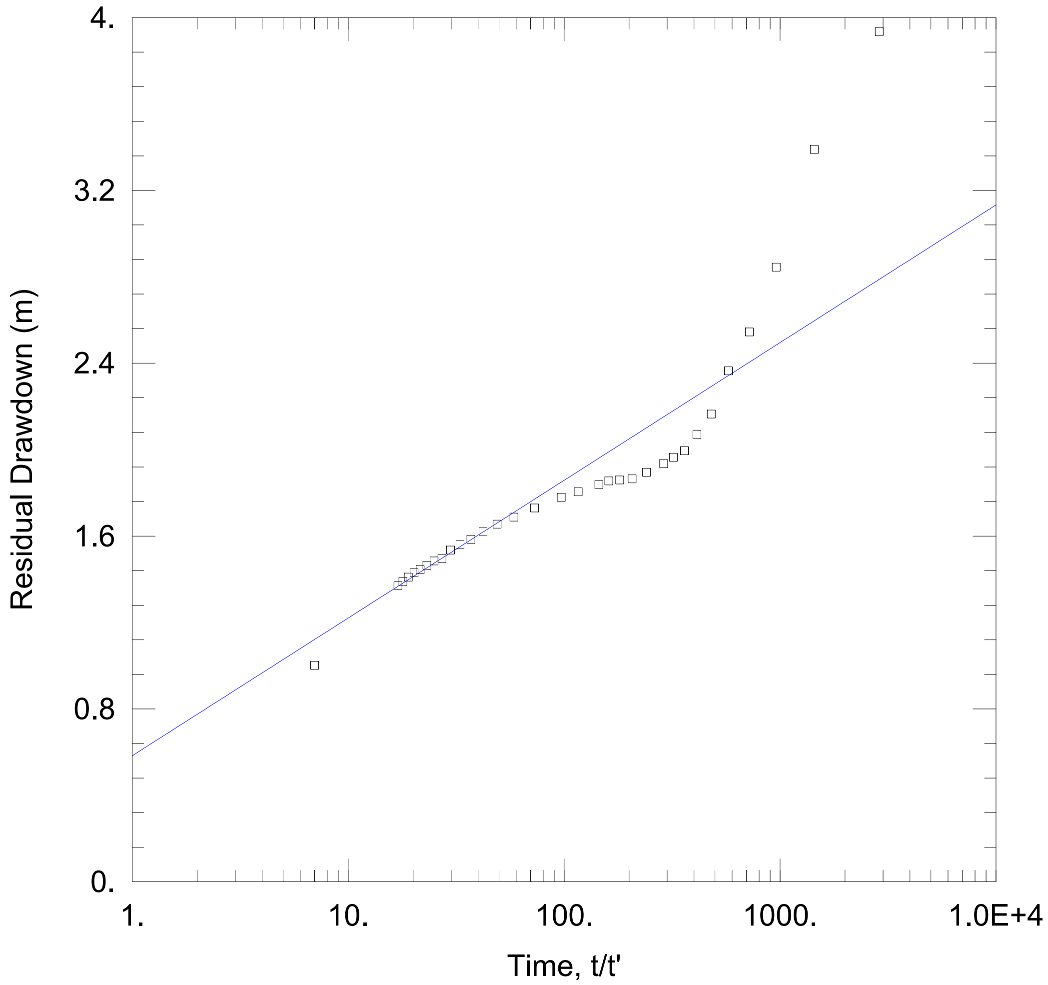
Observation Wells

Well Name	X (m)	Y (m)
□ YGWB001	7.87	0

SOLUTION

Aquifer Model: Confined Solution Method: Theis (Recovery)

T = 22.7 m^2/day S/S' = 46.47



WELL TEST ANALYSIS

Data Set: F:\J160014_Yangibana\modelling\aqtesolv\YGWB003 Obs rec.aqt
Date: 01/11/17 Time: 08:43:06

PROJECT INFORMATION

Company: GRM
Client: Hastings Metals Limited
Project: J160014
Location: Yangibana
Test Well: YGWB003
Test Date: 14/12/16

AQUIFER DATA

Saturated Thickness: 42. m Anisotropy Ratio (Kz/Kr): 1.

WELL DATA

Pumping Wells

Well Name	X (m)	Y (m)
YGWB003	0	0

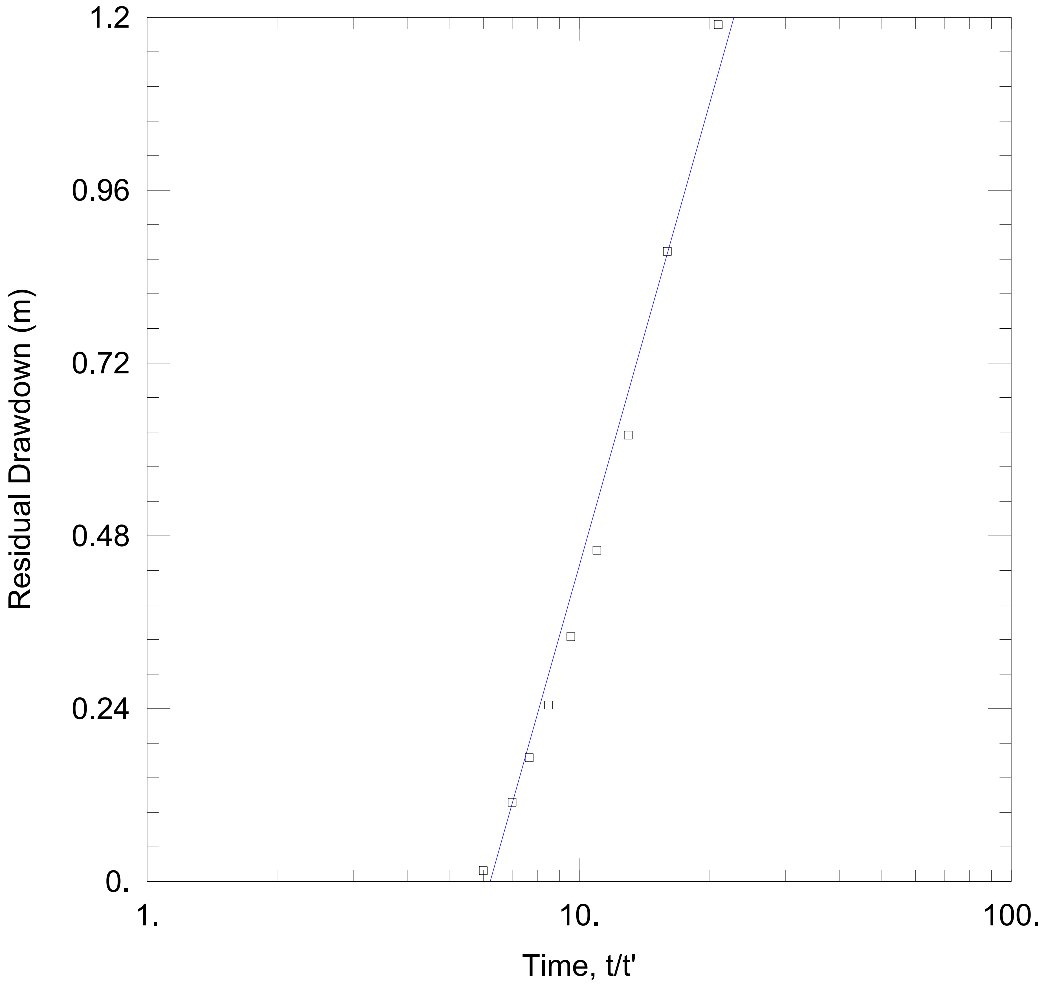
Observation Wells

Well Name	X (m)	Y (m)
□ YGWB001	7.87	0

SOLUTION

Aquifer Model: Confined Solution Method: Theis (Recovery)

T = 78.24 m^2/day S/S' = 0.1218



WELL TEST ANALYSIS

Data Set: F:\J160014_Yangibana\modelling\aqtesolv\ygrc003.aqt
Date: 01/15/17 Time: 15:02:26

PROJECT INFORMATION

Company: GRM
Client: Hastings
Project: J160014
Location: Yangibana
Test Well: YGRC003
Test Date: 17 Dec 2016

AQUIFER DATA

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

WELL DATA

Pumping Wells

Well Name	X (m)	Y (m)
YWRC005	0	0

Observation Wells

Well Name	X (m)	Y (m)
□ YWRC005	0	0

SOLUTION

Aquifer Model: Confined Solution Method: Theis (Recovery)

T = 27.55 m^2/day S/S' = 6.227

APPENDIX E

Laboratory Certificates

ANALYTICAL REPORT

Accreditation No. 2562

CLIENT DETAILS

Contact	Kathy McDougall
Client	Groundwater Resource Management
Address	PO Box 8110 Fremantle High Street, Fremantle, WA, 6160 23 Parry Street Fremantle 6160 KARDINYA WA
Telephone	9433 2222
Facsimile	9433 2322
Email	kathy@g-r-m.com.au
Project	**Yangibana**
Order Number	**J160014**
Samples	1

LABORATORY DETAILS

Manager	Ros Ma
Laboratory	SGS Perth Environmental
Address	28 Reid Rd Perth Airport WA 6105
Telephone	(08) 9373 3500
Facsimile	(08) 9373 3556
Email	au.environmental.perth@sgs.com
SGS Reference	**PE112997 R0**
Date Received	22 Dec 2016
Date Reported	09 Jan 2017

COMMENTS

Accredited for compliance with ISO/IEC 17025. NATA accredited laboratory 2562(898/20210).

SIGNATORIES

Donald Smith
Chemist

Michael McKay
Inorganics and ARD Supervisor

Tommy Cheng
ICP Chemist

Parameter	Units	LOR	Sample Number: PE112997.001 Sample Matrix: Water Sample Name: YGWB03

pH in water   Method: AN101   Tested: 23/12/2016

pH**	pH Units	-	7.8

Conductivity and TDS by Calculation - Water   Method: AN106   Tested: 23/12/2016

Conductivity @ 25 C	µS/cm	2	1500

Total Dissolved Solids (TDS) in water   Method: AN113   Tested: 5/1/2017

Total Dissolved Solids Dried at 175-185°C	mg/L	10	920

Alkalinity   Method: AN135   Tested: 23/12/2016

Total Alkalinity as CaCO3	mg/L	5	270
Carbonate Alkalinity as CO3	mg/L	1	<1
Bicarbonate Alkalinity as HCO3	mg/L	5	330

Chloride by Discrete Analyser in Water   Method: AN274   Tested: 29/12/2016

Chloride, Cl	mg/L	1	250

Sulphate in water   Method: AN275   Tested: 29/12/2016

Sulphate, SO4	mg/L	1	89

Parameter	Units	LOR	Sample Number PE112997.001 / Sample Matrix Water / Sample Name YGWB03
Nitrate Nitrogen and Nitrite Nitrogen (NOx) by FIA — Method: AN258 — Tested: 28/12/2016			
Nitrite, NO_2 as NO_2	mg/L	0.2	<0.2
Nitrate, NO_3 as NO_3	mg/L	0.2	63
Metals in Water (Dissolved) by ICPOES — Method: AN320/AN321 — Tested: 23/12/2016			
Calcium, Ca	mg/L	0.2	85
Magnesium, Mg	mg/L	0.1	44
Potassium, K	mg/L	0.1	7.5
Silica, Soluble	mg/L	0.05	91
Silicon, Si	mg/L	0.02	43
Sodium, Na	mg/L	0.5	180
Total Hardness by Calculation	mg CaCO3/L	1	390
Calculation of Anion-Cation Balance (SAR Calc) — Method: AN121 — Tested: 9/1/2017			
Sum of Ions*	mg/L	-	996
Anion-Cation Balance	%	-100	1
Trace Metals (Dissolved) in Water by ICPMS — Method: AN318 — Tested: 28/12/2016			
Aluminium, Al	µg/L	5	<5
Iron, Fe	µg/L	5	5
Manganese, Mn	µg/L	1	<1
Selenium, Se	µg/L	1	6

QC SUMMARY

MB blank results are compared to the Limit of Reporting
LCS and MS spike recoveries are measured as the percentage of analyte recovered from the sample compared the the amount of analyte spiked into the sample.
DUP and MSD relative percent differences are measured against their original counterpart samples according to the formula : *the absolute difference of the two results divided by the average of the two results as a percentage.* Where the DUP RPD is 'NA' , the results are less than the LOR and thus the RPD is not applicable.

Alkalinity Method: ME-(AU)-[ENV]AN135

Parameter	QC Reference	Units	LOR	MB	DUP %RPD	LCS %Recovery
Total Alkalinity as CaCO3	LB126451	mg/L	5	<5	1 - 6%	99%
Carbonate Alkalinity as CO3	LB126451	mg/L	1	<1		
Bicarbonate Alkalinity as HCO3	LB126451	mg/L	5	<5		

Chloride by Discrete Analyser in Water Method: ME-(AU)-[ENV]AN274

Parameter	QC Reference	Units	LOR	MB	DUP %RPD	LCS %Recovery	MS %Recovery
Chloride, Cl	LB126429	mg/L	1	<1	0 - 1%	103%	62 - 65%

Conductivity and TDS by Calculation - Water Method: ME-(AU)-[ENV]AN106

Parameter	QC Reference	Units	LOR	MB	DUP %RPD	LCS %Recovery
Conductivity @ 25 C	LB126450	µS/cm	2	<2	0 - 1%	96 - 102%

Metals in Water (Dissolved) by ICPOES Method: ME-(AU)-[ENV]AN320/AN321

Parameter	QC Reference	Units	LOR	MB	DUP %RPD	LCS %Recovery	MS %Recovery
Calcium, Ca	LB126378	mg/L	0.2	<0.2	2%	91%	87%
Magnesium, Mg	LB126378	mg/L	0.1	<0.1	1 - 2%	96%	92%
Potassium, K	LB126378	mg/L	0.1	<0.1	0 - 3%	98%	90%
Silica, Soluble	LB126378	mg/L	0.05	<0.05			
Silicon, Si	LB126378	mg/L	0.02	<0.02	1 - 2%	100%	97%
Sodium, Na	LB126378	mg/L	0.5	<0.5	1 - 2%	97%	95%
Total Hardness by Calculation	LB126378	mg CaCO3/L	1	<1			

pH in water Method: ME-(AU)-[ENV]AN101

Parameter	QC Reference	Units	LOR	MB	DUP %RPD	LCS %Recovery
pH**	LB126450	pH Units	-	6.1 - 6.2	0%	101%

QC SUMMARY

MB blank results are compared to the Limit of Reporting
LCS and MS spike recoveries are measured as the percentage of analyte recovered from the sample compared the the amount of analyte spiked into the sample.
DUP and MSD relative percent differences are measured against their original counterpart samples according to the formula : *the absolute difference of the two results divided by the average of the two results as a percentage.* Where the DUP RPD is 'NA' , the results are less than the LOR and thus the RPD is not applicable.

Sulphate in water Method: ME-(AU)-[ENV]AN275

Parameter	QC Reference	Units	LOR	MB	DUP %RPD	LCS %Recovery	MS %Recovery
Sulphate, SO4	LB126429	mg/L	1	<1	0 - 1%	103%	83 - 92%

Total Dissolved Solids (TDS) in water Method: ME-(AU)-[ENV]AN113

Parameter	QC Reference	Units	LOR	MB	DUP %RPD	LCS %Recovery	MS %Recovery	MSD %RPD
Total Dissolved Solids Dried at 175-185°C	LB126602	mg/L	10	<10	0 - 1%	93%	103%	4%

Trace Metals (Dissolved) in Water by ICPMS Method: ME-(AU)-[ENV]AN318

Parameter	QC Reference	Units	LOR	MB	DUP %RPD	LCS %Recovery	MS %Recovery
Aluminium, Al	LB126410	µg/L	5	<5	0%	80%	105%
Iron, Fe	LB126410	µg/L	5	<5	1%	110%	112%
Manganese, Mn	LB126410	µg/L	1	<1	0%	101%	103%
Selenium, Se	LB126410	µg/L	1	<1	0%	113%	80%

METHOD	METHODOLOGY SUMMARY
	Nitrate and Nitrite by FIA: In an acidic medium, nitrate is reduced quantitatively to nitrite by cadmium metal. This nitrite plus any original nitrite is determined as an intense red-pink azo dye at 540 nm following diazotisation with sulphanilamide and subsequent coupling with N-(1-naphthyl) ethylenediamine dihydrochloride. Without the cadmium reduction only the original nitrite is determined. Reference APHA 4500-NO3- F.
AN101	pH in Soil Sludge Sediment and Water: pH is measured electrometrically using a combination electrode (glass plus reference electrode) and is calibrated against 3 buffers purchased commercially. For soils, an extract with water is made at a ratio of 1:5 and the pH determined and reported on the extract. Reference APHA 4500-H+.
AN106	Conductivity and TDS by Calculation: Conductivity is measured by meter with temperature compensation and is calibrated against a standard solution of potassium chloride. Conductivity is generally reported as µmhos/cm or µS/cm @ 25°C. For soils, an extract with water is made at a ratio of 1:5 and the EC determined and reported on the extract, or calculated back to the as-received sample. Total Dissolved Salts can be estimated from conductivity using a conversion factor, which for natural waters, is in the range 0.55 to 0.75. SGS use 0.6. Reference APHA 2510 B.
AN113	Total Dissolved Solids: A well-mixed filtered sample of known volume is evaporated to dryness at 180°C and the residue weighed. Approximate methods for correlating chemical analysis with dissolved solids are available. Reference APHA 2540 C.
AN121	This method is used to calculation the balance of major Anions and Cations in water samples and converts major ion concentration to milliequivalents and then summed. Anions sum and Cation sum is calculated as a difference and expressed as a percentage.
AN121	The sum of cations and anions in mg/L may also be reported. This sums Na, K, Ca, Mg, NH3, Fe, Cl, Total Alkalinity, SO4 and NO3.
AN135	Alkalinity (and forms of) by Titration: The sample is titrated with standard acid to pH 8.3 (P titre) and pH 4.5 (T titre) and permanent and/or total alkalinity calculated. The results are expressed as equivalents of calcium carbonate or recalculated as bicarbonate, carbonate and hydroxide. Reference APHA 2320. Internal Reference AN135
AN274	Chloride by Aquakem DA: Chloride reacts with mercuric thiocyanate forming a mercuric chloride complex. In the presence of ferric iron, highly coloured ferric thiocyanate is formed which is proportional to the chloride concentration. Reference APHA 4500Cl-
AN275	sulfate by Aquakem DA: sulfate is precipitated in an acidic medium with barium chloride. The resulting turbidity is measured photometrically at 405nm and compared with standard calibration solutions to determine the sulfate concentration in the sample. Reference APHA 4500-SO42-. Internal reference AN275.
AN318	Determination of elements at trace level in waters by ICP-MS technique, in accordance with USEPA 6020A.
AN320/AN321	Metals by ICP-OES: Samples are preserved with 10% nitric acid for a wide range of metals and some non-metals. This solution is measured by Inductively Coupled Plasma. Solutions are aspirated into an argon plasma at 8000-10000K and emit characteristic energy or light as a result of electron transitions through unique energy levels. The emitted light is focused onto a diffraction grating where it is separated into components .
AN320/AN321	Photomultipliers or CCDs are used to measure the light intensity at specific wavelengths. This intensity is directly proportional to concentration. Corrections are required to compensate for spectral overlap between elements. Reference APHA 3120 B.
Calculation	Free and Total Carbon Dioxide may be calculated using alkalinity forms only when the samples TDS is <500mg/L. If TDS is >500mg/L free or total carbon dioxide cannot be reported. APHA4500CO2 D.

FOOTNOTES

IS	Insufficient sample for analysis.	LOR	Limit of Reporting
LNR	Sample listed, but not received.	↑↓	Raised or Lowered Limit of Reporting
*	NATA accreditation does not cover the performance of this service.	QFH	QC result is above the upper tolerance
**	Indicative data, theoretical holding time exceeded.	QFL	QC result is below the lower tolerance
		-	The sample was not analysed for this analyte
		NVL	Not Validated

Samples analysed as received.
Solid samples expressed on a dry weight basis.

Where "Total" analyte groups are reported (for example, Total PAHs, Total OC Pesticides) the total will be calculated as the sum of the individual analytes, with those analytes that are reported as <LOR being assumed to be zero. The summed (Total) limit of reporting is calcuated by summing the individual analyte LORs and dividing by two. For example, where 16 individual analytes are being summed and each has an LOR of 0.1 mg/kg, the "Totals" LOR will be 1.6 / 2 (0.8 mg/kg). Where only 2 analytes are being summed, the " Total" LOR will be the sum of those two LORs.

Some totals may not appear to add up because the total is rounded after adding up the raw values.

If reported, measurement uncertainty follow the ± sign after the analytical result and is expressed as the expanded uncertainty calculated using a coverage factor of 2, providing a level of confidence of approximately 95%, unless stated otherwise in the comments section of this report.

Results reported for samples tested under test methods with codes starting with ARS-SOP, radionuclide or gross radioactivity concentrations are expressed in becquerel (Bq) per unit of mass or volume or per wipe as stated on the report. Becquerel is the SI unit for activity and equals one nuclear transformation per second.
Note that in terms of units of radioactivity:

a. 1 Bq is equivalent to 27 pCi
b. 37 MBq is equivalent to 1 mCi

For results reported for samples tested under test methods with codes starting with ARS-SOP, less than (<) values indicate the detection limit for each radionuclide or parameter for the measurement system used. The respective detection limits have been calculated in accordance with ISO 11929.

The QC criteria are subject to internal review according to the SGS QAQC plan and may be provided on request or alternatively can be found here : http://www.sgs.com.au/~/media/Local/Australia/Documents/Technical%20Documents/MP-AU-ENV-QU-022%20QA%20QC%20Plan.pdf

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ANALYTICAL REPORT

Accreditation No. 2562

CLIENT DETAILS

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Project	**Yangibana**
Order Number	**J160014**
Samples	1

LABORATORY DETAILS

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SGS Reference	**PE112242 R0**
Date Received	23 Nov 2016
Date Reported	02 Dec 2016

COMMENTS

Accredited for compliance with ISO/IEC 17025. NATA accredited laboratory 2562(898/20210).

For determination of soluble metals, filtered sample was not received so samples were laboratory filtered on receipt. This may give soluble metals results that do not represent the concentrations present at the time of sampling.
Metals: Dissolved: Spike recovery failed due to the presence of significant concentration of the target analyte (i.e. the concentration of analyte exceed spike level).

SIGNATORIES

Donald Smith
Chemist

Louise Hope
Laboratory Technician

Mary Ann Ola-A
Inorganics Team Leader

Michael McKay
Inorganics and ARD Supervisor

Tommy Cheng
ICP Chemist

Parameter	Units	LOR	Sample Number: PE112242.001 Sample Matrix: Water Sample Date: 06 Nov 2016 Sample Name: FRWI

pH in water Method: AN101 Tested: 23/11/2016

pH**	pH Units	-	8.5

Conductivity and TDS by Calculation - Water Method: AN106 Tested: 23/11/2016

Conductivity @ 25 C	µS/cm	2	2100

Total Dissolved Solids (TDS) in water Method: AN113 Tested: 30/11/2016

Total Dissolved Solids Dried at 175-185°C	mg/L	10	1200

Alkalinity Method: AN135 Tested: 23/11/2016

Carbonate Alkalinity as CO3	mg/L	1	11
Bicarbonate Alkalinity as HCO3	mg/L	5	280

Chloride by Discrete Analyser in Water Method: AN274 Tested: 25/11/2016

Chloride, Cl	mg/L	1	380

Sulphate in water Method: AN275 Tested: 25/11/2016

Sulphate, SO4	mg/L	1	160

Parameter	Units	LOR	Sample Number: PE112242.001 Sample Matrix: Water Sample Date: 06 Nov 2016 Sample Name: FRWI

Nitrate Nitrogen and Nitrite Nitrogen (NOx) by FIA   Method: AN258   Tested: 28/11/2016

Nitrate Nitrogen, NO_3 as N	mg/L	0.05	9.1
Nitrite, NO_2 as NO_2	mg/L	0.2	<0.2

Metals in Water (Dissolved) by ICPOES   Method: AN320/AN321   Tested: 30/11/2016

Calcium, Ca	mg/L	0.2	72
Magnesium, Mg	mg/L	0.1	67
Potassium, K	mg/L	0.1	9.5
Silica, Soluble	mg/L	0.05	52
Sodium, Na	mg/L	0.5	230
Total Hardness by Calculation	mg CaCO3/L	1	460

Trace Metals (Dissolved) in Water by ICPMS   Method: AN318   Tested: 29/11/2016

Aluminium, Al	µg/L	5	<5
Manganese, Mn	µg/L	1	<1
Selenium, Se	µg/L	1	4

Trace Metals (Total) in Water by ICPMS   Method: AN022/AN318   Tested: 25/11/2016

Total Iron	µg/L	5	73

QC SUMMARY

MB blank results are compared to the Limit of Reporting
LCS and MS spike recoveries are measured as the percentage of analyte recovered from the sample compared the the amount of analyte spiked into the sample.
DUP and MSD relative percent differences are measured against their original counterpart samples according to the formula : *the absolute difference of the two results divided by the average of the two results as a percentage.* Where the DUP RPD is 'NA' , the results are less than the LOR and thus the RPD is not applicable.

Alkalinity Method: ME-(AU)-[ENV]AN135

Parameter	QC Reference	Units	LOR	MB
Carbonate Alkalinity as CO3	LB125163	mg/L	1	<1
Bicarbonate Alkalinity as HCO3	LB125163	mg/L	5	<5

Chloride by Discrete Analyser in Water Method: ME-(AU)-[ENV]AN274

Parameter	QC Reference	Units	LOR	MB	DUP %RPD	LCS %Recovery	MS %Recovery
Chloride, Cl	LB125188	mg/L	1	<1	0 - 1%	102 - 105%	89 - 103%

Conductivity and TDS by Calculation - Water Method: ME-(AU)-[ENV]AN106

Parameter	QC Reference	Units	LOR	MB	DUP %RPD	LCS %Recovery
Conductivity @ 25 C	LB125162	µS/cm	2	<2	0%	99 - 101%

Metals in Water (Dissolved) by ICPOES Method: ME-(AU)-[ENV]AN320/AN321

Parameter	QC Reference	Units	LOR	MB	DUP %RPD	LCS %Recovery	MS %Recovery
Calcium, Ca	LB125348	mg/L	0.2	<0.2	4%	94 - 97%	104%
Magnesium, Mg	LB125348	mg/L	0.1	<0.1	3%	91 - 94%	-507%
Potassium, K	LB125348	mg/L	0.1	<0.1	3%	95 - 96%	-115%
Silica, Soluble	LB125348	mg/L	0.05	<0.05			
Sodium, Na	LB125348	mg/L	0.5	<0.5	5%	99 - 101%	10290%
Total Hardness by Calculation	LB125348	mg CaCO3/L	1	<1			

Nitrate Nitrogen and Nitrite Nitrogen (NOx) by FIA Method: ME-(AU)-[ENV]AN258

Parameter	QC Reference	Units	LOR	MB	DUP %RPD	LCS %Recovery
Nitrate Nitrogen, NO_3 as N	LB125253	mg/L	0.05	<0.05	0 - 44%	NA

MB blank results are compared to the Limit of Reporting
LCS and MS spike recoveries are measured as the percentage of analyte recovered from the sample compared the the amount of analyte spiked into the sample.
DUP and MSD relative percent differences are measured against their original counterpart samples according to the formula : *the absolute difference of the two results divided by the average of the two results as a percentage.* Where the DUP RPD is 'NA' , the results are less than the LOR and thus the RPD is not applicable.

pH in water **Method: ME-(AU)-[ENV]AN101**

Parameter	QC Reference	Units	LOR	MB	DUP %RPD	LCS %Recovery
pH**	LB125162	pH Units	-	6.0 - 6.2	0 - 1%	101%

Sulphate in water **Method: ME-(AU)-[ENV]AN275**

Parameter	QC Reference	Units	LOR	MB	DUP %RPD	LCS %Recovery	MS %Recovery
Sulphate, SO4	LB125188	mg/L	1	<1	0 - 1%	102 - 106%	100 - 102%

Total Dissolved Solids (TDS) in water **Method: ME-(AU)-[ENV]AN113**

Parameter	QC Reference	Units	LOR	MB	DUP %RPD	LCS %Recovery	MS %Recovery	MSD %RPD
Total Dissolved Solids Dried at 175-185°C	LB125237	mg/L	10	<10	1 - 6%	96%	95%	1%

Trace Metals (Dissolved) in Water by ICPMS **Method: ME-(AU)-[ENV]AN318**

Parameter	QC Reference	Units	LOR	MB	LCS %Recovery	MS %Recovery
Aluminium, Al	LB125311	µg/L	5	<5	81%	99%
Manganese, Mn	LB125311	µg/L	1	<1	97%	101%
Selenium, Se	LB125311	µg/L	1	<1	114%	122%

Trace Metals (Total) in Water by ICPMS **Method: ME-(AU)-[ENV]AN022/AN318**

Parameter	QC Reference	Units	LOR	MB	DUP %RPD	LCS %Recovery	MS %Recovery
Total Iron	LB125178	µg/L	5	<5	4%	86%	251%

METHOD	METHODOLOGY SUMMARY
	Nitrate and Nitrite by FIA: In an acidic medium, nitrate is reduced quantitatively to nitrite by cadmium metal. This nitrite plus any original nitrite is determined as an intense red-pink azo dye at 540 nm following diazotisation with sulphanilamide and subsequent coupling with N-(1-naphthyl) ethylenediamine dihydrochloride. Without the cadmium reduction only the original nitrite is determined. Reference APHA 4500-NO3- F.
AN022/AN318	Following acid digestion of un filtered sample, determination of elements at trace level in waters by ICP-MS technique, in accordance with USEPA 6020A.
AN101	pH in Soil Sludge Sediment and Water: pH is measured electrometrically using a combination electrode (glass plus reference electrode) and is calibrated against 3 buffers purchased commercially. For soils, an extract with water is made at a ratio of 1:5 and the pH determined and reported on the extract. Reference APHA 4500-H+.
AN106	Conductivity and TDS by Calculation: Conductivity is measured by meter with temperature compensation and is calibrated against a standard solution of potassium chloride. Conductivity is generally reported as µmhos/cm or µS/cm @ 25°C. For soils, an extract with water is made at a ratio of 1:5 and the EC determined and reported on the extract, or calculated back to the as-received sample. Total Dissolved Salts can be estimated from conductivity using a conversion factor, which for natural waters, is in the range 0.55 to 0.75. SGS use 0.6. Reference APHA 2510 B.
AN113	Total Dissolved Solids: A well-mixed filtered sample of known volume is evaporated to dryness at 180°C and the residue weighed. Approximate methods for correlating chemical analysis with dissolved solids are available. Reference APHA 2540 C.
AN121	This method is used to calculation the balance of major Anions and Cations in water samples and converts major ion concentration to milliequivalents and then summed. Anions sum and Cation sum is calculated as a difference and expressed as a percentage.
AN121	The sum of cations and anions in mg/L may also be reported. This sums Na, K, Ca, Mg, NH3, Fe, Cl, Total Alkalinity, SO4 and NO3.
AN135	Alkalinity (and forms of) by Titration: The sample is titrated with standard acid to pH 8.3 (P titre) and pH 4.5 (T titre) and permanent and/or total alkalinity calculated. The results are expressed as equivalents of calcium carbonate or recalculated as bicarbonate, carbonate and hydroxide. Reference APHA 2320. Internal Reference AN135
AN274	Chloride by Aquakem DA: Chloride reacts with mercuric thiocyanate forming a mercuric chloride complex. In the presence of ferric iron, highly coloured ferric thiocyanate is formed which is proportional to the chloride concentration. Reference APHA 4500Cl-
AN275	sulfate by Aquakem DA: sulfate is precipitated in an acidic medium with barium chloride. The resulting turbidity is measured photometrically at 405nm and compared with standard calibration solutions to determine the sulfate concentration in the sample. Reference APHA 4500-SO42-. Internal reference AN275.
AN318	Determination of elements at trace level in waters by ICP-MS technique, in accordance with USEPA 6020A.
AN320/AN321	Metals by ICP-OES: Samples are preserved with 10% nitric acid for a wide range of metals and some non-metals. This solution is measured by Inductively Coupled Plasma. Solutions are aspirated into an argon plasma at 8000-10000K and emit characteristic energy or light as a result of electron transitions through unique energy levels. The emitted light is focused onto a diffraction grating where it is separated into components .
AN320/AN321	Photomultipliers or CCDs are used to measure the light intensity at specific wavelengths. This intensity is directly proportional to concentration. Corrections are required to compensate for spectral overlap between elements. Reference APHA 3120 B.
Calculation	Free and Total Carbon Dioxide may be calculated using alkalinity forms only when the samples TDS is <500mg/L. If TDS is >500mg/L free or total carbon dioxide cannot be reported. APHA4500CO2 D.

METHOD	METHODOLOGY SUMMARY

FOOTNOTES

IS	Insufficient sample for analysis.	LOR	Limit of Reporting
LNR	Sample listed, but not received.	↑↓	Raised or Lowered Limit of Reporting
*	NATA accreditation does not cover the performance of this service.	QFH	QC result is above the upper tolerance
**	Indicative data, theoretical holding time exceeded.	QFL	QC result is below the lower tolerance
		-	The sample was not analysed for this analyte
		NVL	Not Validated

Samples analysed as received.
Solid samples expressed on a dry weight basis.

Where "Total" analyte groups are reported (for example, Total PAHs, Total OC Pesticides) the total will be calculated as the sum of the individual analytes, with those analytes that are reported as <LOR being assumed to be zero. The summed (Total) limit of reporting is calcuated by summing the individual analyte LORs and dividing by two. For example, where 16 individual analytes are being summed and each has an LOR of 0.1 mg/kg, the "Totals" LOR will be 1.6 / 2 (0.8 mg/kg). Where only 2 analytes are being summed, the " Total" LOR will be the sum of those two LORs.

Some totals may not appear to add up because the total is rounded after adding up the raw values.

If reported, measurement uncertainty follow the ± sign after the analytical result and is expressed as the expanded uncertainty calculated using a coverage factor of 2, providing a level of confidence of approximately 95%, unless stated otherwise in the comments section of this report.

Results reported for samples tested under test methods with codes starting with ARS-SOP, radionuclide or gross radioactivity concentrations are expressed in becquerel (Bq) per unit of mass or volume or per wipe as stated on the report. Becquerel is the SI unit for activity and equals one nuclear transformation per second.
Note that in terms of units of radioactivity:

a. 1 Bq is equivalent to 27 pCi
b. 37 MBq is equivalent to 1 mCi

For results reported for samples tested under test methods with codes starting with ARS-SOP, less than (<) values indicate the detection limit for each radionuclide or parameter for the measurement system used. The respective detection limits have been calculated in accordance with ISO 11929.

The QC criteria are subject to internal review according to the SGS QAQC plan and may be provided on request or alternatively can be found here : http://www.sgs.com.au/~/media/Local/Australia/Documents/Technical%20Documents/MP-AU-ENV-QU-022%20QA%20QC%20Plan.pdf

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ANALYTICAL REPORT

Accreditation No. 2562

CLIENT DETAILS		LABORATORY DETAILS	
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Project	**Yangibana**	SGS Reference	**PE112957 R0**
Order Number	**J160014**	Date Received	21 Dec 2016
Samples	1	Date Reported	05 Jan 2017

COMMENTS

Accredited for compliance with ISO/IEC 17025. NATA accredited laboratory 2562(898/20210).

SIGNATORIES

Donald Smith Chemist	Hue Thanh Ly Metals Team Leader	Michael McKay Inorganics and ARD Supervisor

ANALYTICAL REPORT

PE112957 R0

Parameter	Units	LOR	Sample Number: PE112957.001 Sample Matrix: Water Sample Name: BHW5
pH in water Method: AN101 Tested: 21/12/2016			
pH**	pH Units	0.1	8.0
Conductivity and TDS by Calculation - Water Method: AN106 Tested: 21/12/2016			
Conductivity @ 25 C	µS/cm	2	1900
Total Dissolved Solids (TDS) in water Method: AN113 Tested: 3/1/2017			
Total Dissolved Solids Dried at 175-185°C	mg/L	10	1000
Alkalinity Method: AN135 Tested: 21/12/2016			
Carbonate Alkalinity as CO3	mg/L	1	<1
Bicarbonate Alkalinity as HCO3	mg/L	5	<5
Chloride by Discrete Analyser in Water Method: AN274 Tested: 22/12/2016			
Chloride, Cl	mg/L	1	330
Sulphate in water Method: AN275 Tested: 22/12/2016			
Sulphate, SO4	mg/L	1	100

ANALYTICAL REPORT

PE112957 R0

Parameter	Units	LOR	Sample Number: PE112957.001 Sample Matrix: Water Sample Name: BHW5
Low Level Nitrate Nitrogen and Nitrite Nitrogen (NOx) by FIA — Method: AN258 — Tested: 22/12/2016			
Nitrate, NO_3 as NO_3	mg/L	0.05	65
Nitrite, NO_2 as NO_2	mg/L	0.05	<0.05
Metals in Water (Dissolved) by ICPOES — Method: AN320/AN321 — Tested: 21/12/2016			
Calcium, Ca	mg/L	0.2	81
Magnesium, Mg	mg/L	0.1	51
Potassium, K	mg/L	0.1	9.0
Silica, Soluble	mg/L	0.05	72
Silicon, Si	mg/L	0.02	34
Sodium, Na	mg/L	0.5	240
Total Hardness by Calculation	mg CaCO3/L	1	410
Trace Metals (Dissolved) in Water by ICPMS — Method: AN318 — Tested: 21/12/2016			
Aluminium, Al	µg/L	5	<5
Iron, Fe	µg/L	5	9
Manganese, Mn	µg/L	1	<1
Selenium, Se	µg/L	1	7

QC SUMMARY

MB blank results are compared to the Limit of Reporting
LCS and MS spike recoveries are measured as the percentage of analyte recovered from the sample compared the the amount of analyte spiked into the sample.
DUP and MSD relative percent differences are measured against their original counterpart samples according to the formula : *the absolute difference of the two results divided by the average of the two results as a percentage.* Where the DUP RPD is 'NA' , the results are less than the LOR and thus the RPD is not applicable.

Alkalinity   Method: ME-(AU)-[ENV]AN135

Parameter	QC Reference	Units	LOR	MB
Carbonate Alkalinity as CO3	LB126339	mg/L	1	<1
Bicarbonate Alkalinity as HCO3	LB126339	mg/L	5	<5

Chloride by Discrete Analyser in Water   Method: ME-(AU)-[ENV]AN274

Parameter	QC Reference	Units	LOR	MB	DUP %RPD	LCS %Recovery	MS %Recovery
Chloride, Cl	LB126336	mg/L	1	<1	1%	102 - 103%	80 - 96%

Conductivity and TDS by Calculation - Water   Method: ME-(AU)-[ENV]AN106

Parameter	QC Reference	Units	LOR	MB	DUP %RPD	LCS %Recovery
Conductivity @ 25 C	LB126337	µS/cm	2	<2	0 - 2%	96 - 99%

Low Level Nitrate Nitrogen and Nitrite Nitrogen (NOx) by FIA   Method: ME-(AU)-[ENV]AN258

Parameter	QC Reference	Units	LOR	MB
Nitrate, NO_3 as NO_3	LB126342	mg/L	0.05	<0.05
Nitrite, NO_2 as NO_2	LB126342	mg/L	0.05	<0.05

Metals in Water (Dissolved) by ICPOES   Method: ME-(AU)-[ENV]AN320/AN321

Parameter	QC Reference	Units	LOR	MB	DUP %RPD	LCS %Recovery	MS %Recovery
Calcium, Ca	LB126304	mg/L	0.2	<0.2	1 - 3%	95%	92%
Magnesium, Mg	LB126304	mg/L	0.1	<0.1	0 - 3%	98%	93%
Potassium, K	LB126304	mg/L	0.1	<0.1	0 - 3%	95%	87%
Silica, Soluble	LB126304	mg/L	0.05	<0.05			
Silicon, Si	LB126304	mg/L	0.02	<0.02	0%	103%	
Sodium, Na	LB126304	mg/L	0.5	<0.5	1 - 4%	108%	100%
Total Hardness by Calculation	LB126304	mg CaCO3/L	1	<1			

QC SUMMARY

MB blank results are compared to the Limit of Reporting
LCS and MS spike recoveries are measured as the percentage of analyte recovered from the sample compared the the amount of analyte spiked into the sample.
DUP and MSD relative percent differences are measured against their original counterpart samples according to the formula : *the absolute difference of the two results divided by the average of the two results as a percentage.* Where the DUP RPD is 'NA' , the results are less than the LOR and thus the RPD is not applicable.

pH in water Method: ME-(AU)-[ENV]AN101

Parameter	QC Reference	Units	LOR	MB	DUP %RPD	LCS %Recovery
pH**	LB126337	pH Units	0.1	5.7 - 6.0	0 - 1%	100 - 101%

Sulphate in water Method: ME-(AU)-[ENV]AN275

Parameter	QC Reference	Units	LOR	MB	DUP %RPD	LCS %Recovery	MS %Recovery
Sulphate, SO4	LB126336	mg/L	1	<1	0 - 2%	98 - 99%	90 - 94%

Total Dissolved Solids (TDS) in water Method: ME-(AU)-[ENV]AN113

Parameter	QC Reference	Units	LOR	MB	DUP %RPD	LCS %Recovery	MS %Recovery	MSD %RPD
Total Dissolved Solids Dried at 175-185°C	LB126510	mg/L	10	<10	0 - 2%	89%	101%	3%

Trace Metals (Dissolved) in Water by ICPMS Method: ME-(AU)-[ENV]AN318

Parameter	QC Reference	Units	LOR	MB	DUP %RPD	LCS %Recovery	MS %Recovery
Aluminium, Al	LB126303	µg/L	5	<5	0%	99%	107%
Iron, Fe	LB126303	µg/L	5	<5	7%	103%	109%
Manganese, Mn	LB126303	µg/L	1	<1	0%	100%	105%
Selenium, Se	LB126303	µg/L	1	<1	0%	107%	

METHOD SUMMARY

METHOD	METHODOLOGY SUMMARY
AN101	pH in Soil Sludge Sediment and Water: pH is measured electrometrically using a combination electrode (glass plus reference electrode) and is calibrated against 3 buffers purchased commercially. For soils, an extract with water is made at a ratio of 1:5 and the pH determined and reported on the extract. Reference APHA 4500-H+.
AN106	Conductivity and TDS by Calculation: Conductivity is measured by meter with temperature compensation and is calibrated against a standard solution of potassium chloride. Conductivity is generally reported as µmhos/cm or µS/cm @ 25°C. For soils, an extract with water is made at a ratio of 1:5 and the EC determined and reported on the extract, or calculated back to the as-received sample. Total Dissolved Salts can be estimated from conductivity using a conversion factor, which for natural waters, is in the range 0.55 to 0.75. SGS use 0.6. Reference APHA 2510 B.
AN113	Total Dissolved Solids: A well-mixed filtered sample of known volume is evaporated to dryness at 180°C and the residue weighed. Approximate methods for correlating chemical analysis with dissolved solids are available. Reference APHA 2540 C.
AN135	Alkalinity (and forms of) by Titration: The sample is titrated with standard acid to pH 8.3 (P titre) and pH 4.5 (T titre) and permanent and/or total alkalinity calculated. The results are expressed as equivalents of calcium carbonate or recalculated as bicarbonate, carbonate and hydroxide. Reference APHA 2320. Internal Reference AN135
AN258	Nitrate and Nitrite by FIA: In an acidic medium, nitrate is reduced quantitatively to nitrite by cadmium metal. This nitrite plus any original nitrite is determined as an intense red-pink azo dye at 540 nm following diazotisation with sulphanilamide and subsequent coupling with N-(1-naphthyl) ethylenediamine dihydrochloride. Without the cadmium reduction only the original nitrite is determined. Reference APHA 4500-NO3- F.
AN274	Chloride by Aquakem DA: Chloride reacts with mercuric thiocyanate forming a mercuric chloride complex. In the presence of ferric iron, highly coloured ferric thiocyanate is formed which is proportional to the chloride concentration. Reference APHA 4500Cl-
AN275	sulfate by Aquakem DA: sulfate is precipitated in an acidic medium with barium chloride. The resulting turbidity is measured photometrically at 405nm and compared with standard calibration solutions to determine the sulfate concentration in the sample. Reference APHA 4500-SO42-. Internal reference AN275.
AN318	Determination of elements at trace level in waters by ICP-MS technique, in accordance with USEPA 6020A.
AN320/AN321	Metals by ICP-OES: Samples are preserved with 10% nitric acid for a wide range of metals and some non-metals. This solution is measured by Inductively Coupled Plasma. Solutions are aspirated into an argon plasma at 8000-10000K and emit characteristic energy or light as a result of electron transitions through unique energy levels. The emitted light is focused onto a diffraction grating where it is separated into components .
AN320/AN321	Photomultipliers or CCDs are used to measure the light intensity at specific wavelengths. This intensity is directly proportional to concentration. Corrections are required to compensate for spectral overlap between elements. Reference APHA 3120 B.
Calculation	Free and Total Carbon Dioxide may be calculated using alkalinity forms only when the samples TDS is <500mg/L. If TDS is >500mg/L free or total carbon dioxide cannot be reported. APHA4500CO2 D.

FOOTNOTES

IS	Insufficient sample for analysis.	LOR	Limit of Reporting
LNR	Sample listed, but not received.	↑↓	Raised or Lowered Limit of Reporting
*	NATA accreditation does not cover the performance of this service.	QFH	QC result is above the upper tolerance
**	Indicative data, theoretical holding time exceeded.	QFL	QC result is below the lower tolerance
		-	The sample was not analysed for this analyte
		NVL	Not Validated

Samples analysed as received.
Solid samples expressed on a dry weight basis.

Where "Total" analyte groups are reported (for example, Total PAHs, Total OC Pesticides) the total will be calculated as the sum of the individual analytes, with those analytes that are reported as <LOR being assumed to be zero. The summed (Total) limit of reporting is calcuated by summing the individual analyte LORs and dividing by two. For example, where 16 individual analytes are being summed and each has an LOR of 0.1 mg/kg, the "Totals" LOR will be 1.6 / 2 (0.8 mg/kg). Where only 2 analytes are being summed, the " Total" LOR will be the sum of those two LORs.

Some totals may not appear to add up because the total is rounded after adding up the raw values.

If reported, measurement uncertainty follow the ± sign after the analytical result and is expressed as the expanded uncertainty calculated using a coverage factor of 2, providing a level of confidence of approximately 95%, unless stated otherwise in the comments section of this report.

Results reported for samples tested under test methods with codes starting with ARS-SOP, radionuclide or gross radioactivity concentrations are expressed in becquerel (Bq) per unit of mass or volume or per wipe as stated on the report. Becquerel is the SI unit for activity and equals one nuclear transformation per second.
Note that in terms of units of radioactivity:

a. 1 Bq is equivalent to 27 pCi
b. 37 MBq is equivalent to 1 mCi

For results reported for samples tested under test methods with codes starting with ARS-SOP, less than (<) values indicate the detection limit for each radionuclide or parameter for the measurement system used. The respective detection limits have been calculated in accordance with ISO 11929.

The QC criteria are subject to internal review according to the SGS QAQC plan and may be provided on request or alternatively can be found here : http://www.sgs.com.au/~/media/Local/Australia/Documents/Technical%20Documents/MP-AU-ENV-QU-022%20QA%20QC%20Plan.pdf

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