Appendix 3

Supplementary Assessment of Groundwater Availability

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Note: A colour version of this Appendix is available on the Project CD

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3 July 2015

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Dear Jonathon,

Supplementary Assessment of Groundwater Availability,
Hera Project, Nymagee NSW

Executive Summary

Groundwater extraction at the Hera Mine Site (the Site) to date has primarily taken place from the underground workings and three production bores. For most of the approximately two years of groundwater extraction, the underground workings have contributed the majority of the produced water. However, recently, the net rate of water production from the underground has reduced and the net rate of extraction from bores has increased such that approximately 350-400 m^3/day has been produced from each for much of this year.

Groundwater yields, which depend on aquifer properties, have generally been less than anticipated from pre-mining investigations. However, a comprehensive database of extraction volumes and groundwater levels being maintained by Aurelia Metals has facilitated re-evaluation of aquifer properties from long-term drawdowns. From this information, the feasibility of future extraction at a combined rate of 1 ML/day has been investigated.

Predictive modelling has shown that a total groundwater extraction rate of 1 ML/day is expected to be achievable for a period of several years if additional production bores and associated infrastructure are installed. Maintaining a groundwater extraction rate of 1 ML/day for a total of 10 years may be feasible but is likely to be challenging. It will depend on continuation of relevant monitoring, regular interpretation of that data to minimise uncertainty in predictive modelling, and adaptive management in terms of future bore and infrastructure installation. It will also depend on efficient construction and operation of production bores, with the capability to monitor drawdown in the bores during pumping.

It can be expected that, as the drawdown cone of each production bore grows in magnitude and extent, drawdown cones will progressively overlap and the effective transmissivity of the aquifer will reduce such that the potential yield of each bore reduces with time. This is the primary limitation on extraction, rather than drawdowns induced off site. New groundwater trigger levels outlined in the latest Management Plan are considered unlikely to be exceeded over a 10-year period, except possibly in the southwest corner of the site.

From the assessment of the conceptual hydrogeology and aquifer properties herein, the area with the greatest potential for relatively high bore yields is considered to be the gently sloping, western part of the site underlain by the rocks of the Lower Amphitheatre Group. Logs from previous drilling should be taken into account to prioritise drilling locations.

1.0 Introduction and Background

This document builds on a previous letter report, entitled Desktop Assessment of Groundwater Availability, Hera Project, Nymagee NSW (Aquade, August 2014). The August 2014 report is hereafter referred to as Report 1. Report 1 provided a preliminary review of bore performance based on the aquifer testing originally undertaken in 2010-11 (Impax Group, 2011) and on actual operational groundwater extraction and drawdown data up to July 2014. In that document, I reported that:

- The drawdowns observed during operation of the bores WB8, WB11 and Back Bore were greater than would be expected from the original aquifer testing and the reported volumes pumped over the period up to July 2014.
- At the time of writing, the bores had produced little water in comparison to the mine dewatering and, even if the aquifer properties are less favourable than originally thought, the bores were not being used to their full potential.
- A possible reason for the discrepancy between actual and expected yield per unit drawdown (specific capacity), at least in part, was that measurement of bore yield may be erroneous.
- Another possible reason for the specific capacity discrepancy was that boundaries not seen during the pumping tests may be accelerating the drawdown such that the effective large-scale aquifer properties are less favourable than interpreted from the pumping tests.
- In Report 1, I considered some of the depth-to-groundwater limitations in the extraction licenses to be overly restrictive.

I also made the following recommendations:

- Review of bore pump and pipe infrastructure
- Review of extraction license conditions
- Reinterpretation of aquifer properties based on the long-term extraction and drawdowns during mining operations since late 2013.
- A revised prediction of the long-term drawdown impacts of groundwater extraction on neighbouring bores; and
- An application to change the licence conditions, if warranted, based on the above.
- Checking of the bore flow meters.

I understand that the bore infrastructure, including flow meters, has been checked by Aurelia Metals (Aurelia).

The scope of this supplementary assessment was partly based on the recommendations above. It was initially defined in an email addressed to Jonathon Thompson, dated 20 March 2015.

The scope includes consideration of the following

- new groundwater pumping and drawdown and information collected over the past year (up to March 2015) in addition to the previous data,
- Updated extraction licenses and new water management plan.
- Updated locations and values of proposed trigger level monitoring and trigger level assumptions from the water management plan.

The scope includes generation of this letter report, which presents the following:

- Updated conceptualisation of site hydrogeology, including best estimates of aquifer properties based on drawdowns recorded during mining operations to date.
- Forward prediction of potential combined yield from the lease area based on the above.
- Investigation of the technical feasibility (in terms of both availability of groundwater and trigger levels) of increasing groundwater extraction rates to 1 ML/day.
- Identification of any key data gaps and recommendations for addressing those data gaps.

The scope of this report does not include review of extraction license conditions or application to reset/change those conditions.

2.0 Groundwater Extraction and Drawdown Data

2.1 Groundwater Extraction Rates

Groundwater extraction data from the period May 2013 to June 2015 were reviewed for this report. Groundwater extraction has been dominated by dewatering of the underground workings and by three groundwater extraction bores, WB8, WB11 and the Back Bore. WB8, WB11 and the Back Bore are all located within 1 km of the southern boundary of the Hera Project Site (hereafter referred to as the Site) whereas the mine workings are 2.5-3 km to the north of the bores, within 500 m of the northern site boundary. The area of WB8, WB11 and the Back Bore in the southern part of the Site is hereafter referred to as the Borefield Area. The metered cumulative pumping data from the Borefield Area and the net extraction rates from the underground workings were graphed for this report (Appendix A). Although there were some periods of pumping prior to May 2013, as in Report 1 it was assumed that consistent pumping from the bores at a significant rate effectively began in October 2013 (Appendix A).

2.1.1 Extraction from Bores

Cumulative extraction and peak rates from the bores are summarised in Table 1. From the cumulative extraction plots in Appendix A and from Table 1, the bores have, for most of the past 20 months, been operating at significantly lower rates than they are capable of. However, for most of 2015, the extraction rates from bores WB8 and WB11 have been increased significantly such that they have been considerably more productive and are now likely to be operating at close to their maximum capacity. It is understood that it is not currently possible to measure water levels in the extraction bores themselves due to crushed or kinked access tubes. Therefore, the actual drawdown within the extraction bores is not being measured and it is not possible to confirm from such measurements that all of the available drawdown is being utilised.

Review of the latest WB8 data showed that the WB8 data considered and reported in Report 1 were erroneous. The cumulative volume on the flow meter at WB8 had been misread by an order of magnitude such that the volume extracted was, in fact, ten times what was previously thought. It is understood that this error was first recognised in late 2014 (personal communication Jonathon Thompson, May 2015) such that WB8 cumulative volume was correctly recorded from 1 December 2014 onwards. Cumulative volumes reported for WB8 prior to 1 December 2014 were corrected accordingly herein. Therefore, the data for WB8 in Table 1 and Appendix A does not agree with the same period of data presented in Report 1.

It is understood that the flow meters were replaced on the Back Bore, Bore 8 and Bore 11 on 20 March 2015. The meter on the Back Bore was replaced again in early May. Thus, there has been some uncertainty regarding the bore yields. In particular, there have been two periods since early March when the meter on the Back Bore was seized. Also, there has been little pumping from the Back Bore since April. Therefore, for the Back Bore, cumulative pumping is presented up to early March rather than to June 2015 in Appendix A.

It is understood that a small quantity of groundwater has also been pumped from the House Bore and WB10. The total volume of groundwater extracted from the Back Bore, WB8 and WB11 has been more than 120 ML. In contrast, less than 2 ML has been extracted using the House Bore and WB10.

In the figures in Appendix A, the cumulative pumping from each of WB8, WB11 and the Back Bore was separated into straight-line segments, each segment having a different approximately constant rate. From the slope of each segment, the rate during that period of pumping was calculated. These rates are listed in Table A1 in Appendix A and were used in the analysis of drawdowns to evaluate aquifer properties (Section 3).

Table 1. Volumes Pumped from Bores to Date

Bore ID	Cumulative Volume Pumped between start of October 2013 and late June 2015	Maximum Sustained (Days to Weeks) Pumping Rate between start of October 2013 and late June 2015	Nearby Observation Bore	Maximum Drawdown to Date in Nearby Observation Bore since October 2013
WB8	53 ML	250 m^3/day	OB2	6.3 m
WB11	34 ML	180 m^3/day	WB18 Recently Installed 600 m SE of WB11	Insufficient data
Back Bore	36 ML	64 m^3/day	OB1	9.4 m
House Bore	1.2 ML	26 m^3/day	NA	NA
WB10	0.4 ML	20 m^3/day	NA	NA

Note: Back bore cumulative volume is approximate due to problems with flow meters.

2.1.2 Extraction from the Decline

Appendix A includes Figure A4, showing the long-term average inflow rate to the Decline up to July 2014. In this figure, the long-term average inflow rate is the net inflow rate averaged over the cumulative period shown. From this information, the net inflow rate to the underground workings averaged approximately 550 m^3/day from May 2013 to July 2014. The total net volume of groundwater extracted from the Decline was several times greater than the total volume extracted from the bores over this same period.

It is understood that, between July 2014 and February 2015, there was some uncertainty regarding the net inflow rate to the underground workings. Since replacement of a flow meter in February 2015, the net inflow rate to the underground workings has been more accurately recorded. From the available information, the total groundwater extraction to date from the Decline is estimated to be more than 300 ML.

Table 2 lists some specific observations regarding water inflows to the Decline and how this has varied with depth, based primarily on personal communications with Stuart Jeffrey in May 2015.

Table 2. Summary of Decline Progress and Observations

Decline Level	Timing when Decline Reached this Level	Approximate RL (m)	Closest Obs. Bore	Net Inflow Observations	Comments
Northern (first) corner	20 May 2013	250 (75 m below portal)	OB3, approximately 75 m to the northwest of first corner	Rate of approximately 350 m^3/day began and then tailed off.	At Base of Weathering.
Southern (second) corner	27 July 2013	192 (133 m below portal)	WB5, approximately 360 m to the south of second corner.	1000+ m^3/day for several days, then tailed off.	Elevated inflow rate coming from mineralised zone.
Current Level	February 2015.	-100 (425 m below portal)	OB3 and WB5	Approximately 350 to 400 m^3/day, with decreasing trend	Decline has been halted at this level for 4 months.

Appendix A includes a figure showing daily net discharge from the underground workings between March and June 2015, while the Decline has been halted at a level of RL -100 m (Figure A5). Although there is considerable scatter in the data, there is sufficient duration of data to show a trend in the net discharge rate. The rate of decrease has been approximately 50 m^3/day over a period of 16 weeks, from approximately 400 m^3/day to approximately 350 m^3/day. In the long term, the decrease in net inflow rate would not be expected to continue to follow a linear trend, but would be expected to decrease asymptotically to a steady state rate.

2.1.3 Recent Combined Extraction Rate

Although extraction from the underground workings has previously made up the majority of groundwater extraction, the recent proportions extracted from the Borefield and from the Decline have been similar, i.e. approximately 350-400 m^3/day from each source.

2.2 Groundwater Hydrographs

Appendix B presents plots of measured depth to groundwater in select observation bores, including in OB1 and OB2, located in the vicinity of the Back Bore and WB8, respectively, and OB3, which is located near the Decline.

The fluctuating levels in OB1 and OB2 reflect the changing pumping rates in the nearby extraction bores. The overall trend has been downwards in bores close to the extraction bores and in bores close to the Decline. However, other bores away from the areas of extraction have shown negligible change in water level (e.g. WB4).

2.2.1 Hydrographs from the Borefield Area

The groundwater levels in OB1 and OB2 show trends that would be expected based on the nearby variations in extraction rates. The total drawdowns at OB1 and OB2 are not large considering the volumes pumped from the nearby extraction bores. However, the drawdowns at OB1 are greater than would be expected from the aquifer properties that were evaluated from pumping tests.

2.2.2 Hydrographs near the Decline

Appendix B includes figures showing groundwater levels in OB3 and WB5 over a period of approximately 3 years up to June 2015. There was a significant drawdown of 72 m in OB3 between May 2013 and May 2014, from 70 m below ground level (mbgl), to a new steady state level of 142 mbgl (approximate RL 182 m). The start of the drawdown in OB3 coincided with the Decline reaching the first corner less than 100 m away. The base of the screen in OB3 is reported to be at a depth of 150 mbgl (Impax, 2011), which is 8 m below the lowest water level measurement in this bore. Therefore, assuming these depths are correct, the new steady water level in OB3 is approximately 8 m above the base of the bore such that OB3 to still considered to be providing a representative measurement of the water table.

OB3 is also less than 50 m east of the Main North spiral of the Decline, which is the most northern part of the Decline. The water level in OB3 stopped dropping at a level that is approximately 70 m below the first corner, 10 m below the second corner, and 65 m above the level of the Main North Spiral of the Decline.

Drawdown began in WB5 at the time the Decline reached the second corner (Appendix B). The drawdown at WB5 due to the Decline has been at a much slower rate than observed at OB3, but has been continuous, i.e. the groundwater level has not yet stabilised at a new, lower level. Drawdown at WB13, which is very close to WB5, has been similar to drawdown at WB5. Therefore, the WB5 measurements are considered to be a representative of drawdown in this area. By June 2015, 16 m of drawdown had been generated at WB5 over a period of approximately 22 months.

3.0 Conceptual Hydrogeology

3.1 Geological Framework

The Site is located within the Darling Basin of Lachlan Fold Belt where folded and faulted Palaeozoic sedimentary rocks outcrop. This region is one of significant mineralisation (Kingham, 1998).

Quartz-rich clastics of the Lower Amphitheatre Group and the Mouramba Group (both part of the Cobar Supergroup) are represented in outcrop and in the shallow subsurface at the Site, overlain by a veneer of alluvium and colluvium over most of the Site area (Impax, 2011). These rocks are dominated by sandstone with some siltstone and conglomerates. The borehole logs of the water bores installed for baseline studies show fractured siltstone and sandstone within the screened intervals (Impax, 2011 and Geoterra, 2006).

The regional strike of these rocks is NNW-SSE. Sedimentary rocks of the Lower Amphitheatre Group underlie the more gently sloping western part of the Site and the outcrops in the eastern part of the Site consist of the Burnong Formation and the younger Roset Sandstone, which are both within the Mouramba Group (Impax, 2011). The ore body is within the Burnong Formation (personal communication, Stuart Jeffrey, May 2015).

The syn-depositional Rookery Fault, which defines the eastern margin of the Cobar Basin, passes across the Site close to the eastern boundary, aligned approximately NNW-SSE (personal communication, Stuart Jeffrey, May 2015).

The local sedimentary rocks are steeply dipping, with evident jointing/cleavage. There is evidence, in the form of iron staining, of groundwater movement through fractures/joints (personal communication, Stuart Jeffrey, May 2015). Groundwater storage in, and flow through, these sedimentary rocks is likely to be controlled by the fractures. A zone of local structural disruption has been interpreted in the vicinity of the ore body (Impax, 2011).

3.2 Groundwater Flow System and Aquifer Properties

3.2.1 Baseline Water Table

Figure 1 shows the baseline water table surface generated from baseline groundwater levels that were included in the original Hera Project Groundwater Assessment (Impax, 2011). This type of figure is typically a standard component of a baseline groundwater assessment. However, it was not included in the baseline assessment for this project.

Figure 1 facilitates interpretation of baseline groundwater flow directions and assessment of the potential impacts of the project to groundwater and other receptors. In addition, and of most relevance to this report, this figure is useful for indicating large-scale variations in aquifer transmissivity (T) that may not be evident from bore testing, which affect more local areas. Large-scale T is the most important aquifer property controlling long-term bore yields and mine inflow rates. Areas of relatively steep hydraulic gradient typically indicate areas of relatively low T and, conversely, areas of relatively flat hydraulic gradient typically indicate relatively high T.

Figure 1 shows that, under baseline conditions, the water table surface is a subdued form of the ground surface, as is typical of groundwater flow systems. Groundwater moves from the high ground areas to the lower areas. All groundwater levels shown in Figure 1 are tens of metres below ground level. This shows the fracture flow system is reasonably well drained, i.e. the fracture T is generally quite significant. An area with a relatively low T, i.e. with a T typical of an aquitard rather than an aquifer, would be expected to have a relatively shallow water table due to the poor drainage in the subsurface.

Figure 1 shows that the hydraulic gradient is significantly greater (by a factor of approximately 4) in the eastern part of the Site, where the rocks of the Mouramba Group outcrop and subcrop than it is in the western part of the Site, where the Lower Amphitheatre Group subcrops. This is evidence that the rocks of the Lower Amphitheatre Group at the Site generally have a greater T than the Mouramba Group. This is supported by anecdotal information from RC drilling. It is understood that, in general, the boreholes drilled furthest east have been the least productive in terms of water yields (Stuart Jeffrey, personal communication, May 2015).

Impax (2011) state that there is unlikely to be any significant hydraulic connection between the Back Bore and WB8. In Report 1, I noted that this conclusion is incorrect. No evidence of connection over the timescale of a pumping test does not translate to no connection in the long term. The hydraulic connection between WB8 and WB11 is stronger than between WB8 and the Back Bore but, over a timeframe of months to years, there is a normal local groundwater flow system at the Site with hydraulic connection throughout.

Impax (2011) also state that, due to the northwest-southeast structures on site, "it is possible that groundwater flow occurs primarily along a northwest / southeast plane with little connectivity in the southwest to northeast plane". This is also incorrect. Groundwater flows perpendicular to the lines of equal hydraulic head, i.e. perpendicular to the water table contours, as shown by the arrows in Figure 1. The baseline groundwater flow direction is between west and southwest over most of the Site, with the baseline flow direction in the vicinity of WB8 and WB11 being approximately west southwest. Along the southern Site boundary, groundwater moves from the area east of the Back Bore, towards WB8 and ultimately across the southern site boundary near WB18.

The groundwater flow direction is reflected in the groundwater chemistry. Table 3 includes Electrical Conductivity (EC) values for the bores listed. EC provides an indication of total dissolved solids (TDS). The EC increases between the Back Bore, WB8 and WB11, which would be expected as more salts are dissolved into the groundwater as it migrates along its flow path. The Back Bore has a relatively low EC, likely due to enhanced recharge in the vicinity of this bore which takes place during runoff events. This bore is located close to a waterway which drains an area of several km^2 to the east.

Impax (2011) considered it likely that the primary "water bearing zones", i.e. those rocks with significant fracture permeability, are likely to be encountered only within 250 m of the ground surface. Below that depth, additional significant groundwater inflows were considered unlikely due to the fractures becoming tighter. This author concurs with that opinion. The most transmissive rocks, which contribute groundwater to bores and the Decline, are likely to be no more than 100-200 m below the water table – more likely 100 m rather than 200 m. Although the Decline is now considerably below this level, it is likely that the groundwater produced from it originates from higher up and cascades down through the multiple open drill holes.

3.2.2 Aquifer Properties Previously Evaluated from Aquifer Testing

Aquifer testing was undertaken on the bores listed in Table 3 as part of the baseline assessment (Impax, 2011). The estimates of T and storage coefficient from those tests are also included in Table 3.

Table 3. Previous Aquifer Property Interpretations and EC Measurements

Bore	EC of Groundwater (uS/cm)	Pumping Test Rate (L/s)	Duration of Pumping Test (days)	Interpreted Transmissivity (T) (m^2/day)	Interpreted Storativity from Obs Bore Analysis
Back bore	2200-2700	3.8	7	6.7	0.0007
WB8	3200-3800	2.2 L/s	6	19*	0.002
WB11	3900-4200	2.0 L/s	6	10	NA
Decline Bore	3500-4000	0.75	7	3.0	0.0009
WB10	3400-3900	0.5	1.1	1.3	NA
WB13	2800-3300	1.7 L/s	3	4.8	NA

Notes: Aquifer property estimates were from pumping tests (Impax, 2011). T interpretation for WB8 did not take into account evidence of a barrier boundary towards the end of the test. This would have lowered the interpreted T. EC values are from an Aurelia Metals spreadsheet.

In the aquifer testing, the highest estimates of T were derived from testing of bores WB8 and WB11. This agrees with the conceptualisation above of relatively high T west of WB8, interpreted from Figure 1.

3.2.3 Aquifer Properties Evaluated from Long-Term Extraction

Approach

Aquifer properties in the vicinity of the Borefield and the Decline were evaluated herein from the long-term extraction rates reported in Appendix A and the resulting drawdowns in observation bores (Appendix B). Analysis using this long-term data provides a considerably more reliable estimation of effective aquifer properties than one-week aquifer testing because the extent of drawdown cones increases with the duration of pumping such that the properties are representative of a much larger area.

Appendix C presents the analyses of the data presented in Appendices A and B. The analytical model used for the analyses is the Theis model (Theis, 1935), incorporating drawdown corrections for the unconfined conditions. The software used in the analytical modelling was Aqtesolv (Duffield, 2007).

The Theis analysis has simplifying assumptions associated with it. The most significant assumption is that the aquifer is homogeneous, i.e. it has uniform properties of T and storage coefficient.

The Theis analysis was derived for confined aquifers. For an unconfined aquifer such as this, a correction to the observed drawdown is also required. The observed (real) drawdown is greater than it would be if it were a confined aquifer due to the partial dewatering causing a reduction in T. The analyses in Appendix C show the corrected drawdown rather than the observed drawdown. The corrected drawdown is less than the actual drawdown – it is found from the following formula:

$s' = s - (s^2/2b)$,

where s is the observed drawdown
s' is the corrected drawdown
and b is the original saturated thickness of the aquifer (assumed to be 90 m in the analyses herein).

Separate analyses were undertaken for the Borefield Area along the southern site boundary and for the Decline area. There is no evidence to date of drawdown interference between these two areas.

In each analysis for the Borefield area, all the phases of pumping interpreted from Appendix A were simulated for all three of the operating bores in the area, i.e. the Back Bore, WB8, and WB11. However, drawdowns observed in OB1, close to the Back Bore, were analysed separately from drawdowns observed in OB2, close to WB8, because the drawdown response was significantly different, indicating different aquifer properties. This difference would be expected from Figure 1. There is no observation bore that has been monitoring groundwater levels over the long-term in the vicinity of WB11. For the Mine Area, the drawdowns analysed were those observed in WB5, to the south of the Decline.

The primary purpose of the aquifer property analyses herein is to derive representative large-scale properties such that long-term predictions can be undertaken of the drawdown that would be expected at specific locations, at future pumping rates. In this way, the feasibility of elevated extraction rates could be evaluated.

Any additional bores that may be installed for increased groundwater extraction would likely be located in the area of relatively high T in which WB8 and WB11 are screened. Therefore, the long term analysis of the OB2 drawdown is considered to be of greater relevance than OB1 for evaluation of aquifer properties and forward predictions. Similarly, the portion of the drawdown data that is the most important in the analyses is the most recent data and, consequently, fitting of type-curves to the late-time data was generally prioritised over the early time data.

In the Aqtesolv software, although the aquifer is simulated as homogeneous, boundaries to the aquifer can be simulated using "image wells". The aquifer may then be simulated with uniform properties up to the boundary but with no flow across the boundary. This approach was used in one of the analyses to simulate a boundary to the east of WB8. In reality at the Hera Project Site, T may be lower to the east of WB8 than to the west of WB8 but there is not a true no-flow boundary to the east of WB8. The area to the east of WB8 does contribute groundwater throughflow to the west and can contribute groundwater to bores (e.g. the Back Bore).

In evaluating conditions in the vicinity of the Decline, it was assumed that the cause of the observed drawdown at WB5 is the inflow associated with the nearby second (southern) corner of the Decline. The drawdown at WB5 began when the Decline reached the second corner (Section 2.2.2).

Recent drawdown at WB5 plots in a straight line when plotted semi-logarithmically, i.e. drawdown against the log of time since the Decline reached the second corner. In the Cooper-Jacob simplification (Cooper and Jacob, 1946 and Jacob, 1950) of the Theis analysis (Theis, 1935), T and S can be evaluated from this straight line if the pumping rate is constant. For most of the period of pumping from the Decline, the extraction rate has not been constant. However, for the late-time period of drawdown shown, the extraction rate was reasonably constant at approximately 400 m^3/day. Therefore, the Cooper-Jacob method was used to estimate aquifer properties in the vicinity of the Decline from the drawdown at WB5.

Results

Table 4 below summarises the results of the Aqtesolv analyses herein.

Table 4. Summary of Aquifer Property Interpretations in Appendix C

Analysis Number	Observation Bore Data	Transmissivity (T) (m^2/day)	Specific Yield, S_y	Boundaries Simulated
OB2-1	**OB2**	**9.6**	**0.005**	**No boundaries**
OB2-2	OB2	21	0.005	One north-south boundary 100 m east of WB8
OB1-1	OB1	1.1	0.0036	No boundaries
WB5-1	WB5	5.2	0.0088	No boundaries

Borefield Area

From the output in Appendix C, it can be seen that the fit of the analytical model to the corrected drawdown in the two reported analyses of the OB2 data (OB2-1 and OB2-2) is similar. Although not shown in the analyses, the future trend of these two analytical models is also similar.

The actual transmissivity in the vicinity of WB8 is likely to be greater than 10 but less than 21 m^2/day as the boundary simulated to the east of WB8 in Analysis OB2-2 is, in reality, likely to contribute some flow rather than no flow. However, the OB2-1 analysis is considered to provide a reasonable estimate of the effective T and specific yield of this area. The OB2-1 and OB2-2 analyses are not sensitive to the pumping that has taken place from WB11 because this bore is a considerable distance from WB8. The OB1-1 analysis is considered to provide a reasonable estimate of the effective large-scale T and specific yield in the vicinity of the Back Bore.

These are average interpretations over the areas of the drawdown cones. In reality, the aquifer properties will not be homogeneous or isotropic such that T will vary with direction and location and new boreholes may or may not intersect the connected fractures which contribute to these average properties.

The T interpretations from the OB2-1 and OB2-2 analyses are similar to the values that were interpreted from the pumping tests of WB8 and WB11 (Impax, 2011). However, T interpreted from Analysis OB1-1 is considerably less than was originally interpreted from the pumping test of the Back Bore (Impax, 2011).

Values of the long-term specific yield, S_y, derived from the above analyses (Table 4) are generally greater than the equivalent storage coefficient values estimated from the pumping tests (Table 3). They are considered to be more representative of actual aquifer conditions due to the timescale of the data used in the analysis. Over the timeframe of a pumping test, there is likely to be a delayed yield effect which means that the system behaves more like a confined aquifer than an unconfined aquifer. Over a longer time period, the fractures drain and some water can be produced from the rock matrix such that the storage coefficient derived from long-term data is a true long-term specific yield. A S_y of less than 1% is not unusual in bedrock aquifers where groundwater flow is dominated by fractures.

The analyses of drawdowns at OB2 are considered to be more relevant than at OB1 for future predictions. This is because it would make sense to locate any additional extraction bores in the relatively high T area. Therefore, the properties derived from the OB2 analyses are more relevant to forward predictions of increased extraction than the properties derived from OB1 analysis. It would be possible to obtain a better fit to the early time data in the OB1-1 analysis by simulating boundaries and a higher local T. However, this would not improve forward predictions for the above reason.

The aquifer properties from the bolded OB2-1 Analysis can be considered to be the best estimates of the **effective** T and S_y of the area of low hydraulic gradient in the vicinity of WB8 and WB11. Therefore, these are considered to be the most appropriate values for simulation of future groundwater extraction in this area and prediction of resulting drawdowns. At these values of T and S_y, the interference between extraction bores spaced 1-2 km apart would be significant over a period of years.

The Aqtesolv analyses showed that, at the highest rates at which WB8, WB11 and the Back Bore have been operating, it is likely that the full available drawdowns in the bores is being utilised. Therefore, it is unlikely these bores could be operated at significantly higher rates.

Mine Area

As described in Section 1, the ore body is within the Burthong Formation of the Mouramba Group, approximately along strike from the Back Bore area. However, considerable structural disruption has been observed in the vicinity of the ore body. Therefore, the local T is likely to be enhanced in comparison to the Back Bore area. It is also likely to be anisotropic in that T along strike is likely to be greater than T across strike. The T of approximately 5.2 m^2/day estimated for the Decline-area from the drawdown in WB5 (Table 4) is approximately double the T evaluated from the Decline bore pumping test (Table 3).

4.0 Predictions

None of the predictions herein assume any recharge to the aquifer. Recharge would have the effect of attenuating drawdowns and increasing the potential yield of bores. In this sense, the predictions are conservative.

Separate predictions were undertaken for the Borefield area and the mine due to the different hydrogeological domains with different interpreted aquifer properties. It is not possible to simulate both in the same model without the use of a numerical model, which is beyond the scope of this assessment. There may be a slight overlap in the drawdown cones which would have the effect of causing a slight increase in the drawdown where this takes place. However, this is not expected to make a significant difference to predicted drawdowns compared to other factors such as variations in large-scale transmissivity and effective aquifer thickness.

4.1 Theis-Based Predictions

Appendix D presents predictions of drawdown over a total period of 10 years from the start of extraction, i.e. up to approximately 8 years from now. Forward predictions P1 and P2 were run separately for the Borefield area and for the vicinity of the Decline respectively due to the different aquifer properties interpreted. P3 is a distance-drawdown prediction of drawdown associated with the underground workings. The Theis model was used (Theis, 1935).

The key monitoring locations at which groundwater level triggers will apply are understood to be Harland, WB4, WB18 and WB15, from the most recent version of the Water Management Plan (Corkery and YTC Metals, 2015). The trigger level for these bores is understood to be a depth to groundwater of 75 mbgl (Corkery and YTC Metals, 2015). The locations of these bores were therefore included in the predictive modelling.

Table 5 summarises the input attributes and assumptions of the forward predictions. In simulation P1, a future combined pumping rate of 700 m^3/day was simulated from five bores including existing bores WB8, WB11 and the Back Bore but also including bores WB12 and WB20 further north. The locations of all extraction and observation bores are listed in the outputs in Appendix D.

In simulation P1, drawdowns were predicted at key locations to investigate the feasibility of the rates simulated by considering the predicted drawdowns both at the pumping bores themselves and at observation bores WB4, WB18, Harland and OB4. In simulation P2, the drawdown was predicted at WB15.

Table 5. Summary of Predictive Model Runs

Simul -ation	Extract- ion Points	Source of Aquifer Properties	Combined Rate Simulated (m^3/day)	Drawdown Prediction Points	Comments
P1	Five Bores (8, 11, 12, 20, BB)	Analysis OB2-1, Table 4	700	8, 11, 12, 20, BB, 4, 18, OB2, Harland, OB4	Typical future extraction rate from individual bore 150 m^3/day. New bore WB20 simulated approximately 1500 m NE of WB11. New observation point OB4 simulated approximately equidistant between WB8, WB11 and WB20.
P2	Decline	Analysis WB5-1, Table 4	350	15, Decline	Rate of 350 m^3/day may not be sustained from the Decline.

Outputs in Appendix D show predicted drawdowns with time at each of the locations, including the extraction locations. Note that the predicted drawdowns in Appendix D are not corrected for the reduction in T caused by partial dewatering. Therefore, actual drawdowns would be greater, based on the formula in Section 3.2.3. Table 6 below summarises the outputs from Simulations P1 and P2 in terms of predicted drawdown and resulting depth to groundwater. Table 6 includes predicted drawdowns that have been corrected for the reduction in T caused by the drawdown.

Table 6. Predicted Drawdowns and Depths to Groundwater at Key Locations

Observ-ation Bore	Model Output Drawdown at End of Simulation (m)	Predicted Drawdown incorporating Correction for Partial Dewatering	Baseline Depth to Water (m bgl)	Predicted Depth to Water at End of Simulation (m bgl)
WB4	3.5	3.5	53	57
WB18	11.5	12.4	68	75
Harland	5.5	5.7	59	64
WB15	1.3	1.3	54	55

Overall, the modelling predicted that, in terms of exceedances of the above trigger levels, increased extraction rates would be expected to be sustainable. From the predictive model runs in Appendix 4, the greatest drawdown at the nominated trigger points in the Management Plan is predicted to take place at WB18, the most proximal trigger point to existing extraction bores. The modelling predicts that the depth to water will reach the trigger level at WB18 by ten years of pumping (including approximately two years to date). Of the above locations, of the non-pumping bores, it would be expected that the greatest drawdown takes place at WB18 because this location is relatively close to WB11 (and WB8).

Groundwater levels are not predicted to reach the trigger level in the other trigger bores in Table 6. Only 1 m of drawdown is predicted at WB15 due to pumping from the decline. This is considered to be conservative (i.e. a high estimate) because it depends on an extraction rate of 350 m^3/day being sustainable, as well as the relatively high T derived from analysis WB5-1 extending as far as WB15. In reality, the relatively high T in the vicinity of the ore body may be localised and associated with the area of structural disruption rather than extending as far as WB15.

The limited available drawdown in extraction bores is considered to be a more likely and significant potential limitation on groundwater extraction than the observation bore trigger levels. After the five-year mark in simulation P1, uncorrected predicted drawdowns at the extraction bores themselves exceed 30 m (Appendix D). This would be equivalent to 38 m of actual drawdown, assuming an effective aquifer thickness of 90 m. The available drawdown in the existing bores is given as 35-40 m in the baseline Groundwater Assessment (Impax, 2011). Therefore, the typical future extraction rate simulated in P1, i.e. 150 m^3/day per bore, may not be sustainable from all the extraction bores. Note also that the predicted drawdowns at the extraction bores in simulation P1 are for 100% efficient bores. In reality, some well losses are likely which would increase the drawdown in the bores themselves.

The output from P1 (Appendix D) includes the predicted drawdown at OB4, a point approximately equidistant between three simulated extraction bores, is predicted to be 13 m after 10 years. When corrected, this would translate to 14 m of drawdown. This shows that there is predicted to be significant remaining available drawdown between the extraction points simulated in prediction P1 after 10 years. As the individual extraction rates reduce in the long term due to the limitation of available drawdown, there are two possible approaches to maximising the rate of extraction. One solution is to install more bores between existing bores and the other is to drill deeper. Both may be implemented. However, as the fracture T is expected to decrease with depth (Section 3.2.1), installing production bores to greater depth is unlikely to have the desired effect of increasing available drawdown.

In Simulation P2, the extraction rate simulated from the underground workings is 350 m3/day. Figure A5 of Appendix A shows a downward trend in the extraction rate from the underground workings. There may be some periods of elevated inflows into the underground as the mine progresses. However, an average extraction rate of 350 m^3/day is considered unlikely to be sustained from the underground workings. Thus, simulation P2 is conservative in its prediction of drawdown impacts.

4.2 Estimate of Minimum Inflow Rate to Underground Workings

The minimum future inflow rate to the underground workings was estimated using a standard steady state dewatering formula from the text “Construction Dewatering (Powers, 1992), as follows:

$$Q = \pi K (H^2 - h_w^2) / \ln(R_0 / r_w)$$

Where:
K is the hydraulic conductivity of the aquifer
H is the Height of water level above base of aquifer – see below.
h_w is the height of water table above the base of the aquifer at maximum drawdown (assumed to be 10 m)
R_0 = Radius of influence of drawdown = 2.2 km (based on analysis P3, Appendix D)

Equivalent radius of excavation, r_w = 30 m (approximate radius of a decline corner)

The above formula assumes steady state radial flow to a circular excavation. It does not allow for any recharge to the aquifer. In this formula, the steady state flow rate is most sensitive to the hydraulic conductivity and thickness and not particularly sensitive to the excavation radius. The T derived from analysis of the WB5 drawdown (Section 3) was assumed. As the intent was to evaluate the minimum inflow rate, H was set to the minimum value considered likely for the saturated thickness of the aquifer, i.e. 70 m. This is the approximate difference between the elevation of the second corner of the decline and the initial groundwater level.

In this way, the minimum steady state inflow rate to the underground workings was estimated to be 240 m^3/day. Note that, although this is a minimum inflow rate in terms of potential aquifer thickness, it is based on the assumption that the aquifer being drained by the excavation is of unlimited extent. In reality, the minimum inflow rate could be less than 240 m^3/day because the aquifer properties derived in analysis P2 may be localised such that effective T in the long term is less than derived from this analysis.

5.0 Summary

The comprehensive drawdown and groundwater extraction data collected to date are the appropriate data for assessing aquifer performance over the long term, and to evaluate and demonstrate compliance with licence requirements. They are also the data that would be required to support any application to change the licence requirements. The information being collected is generally of good quality and appropriate frequency. Where data quality issues have been identified, for example with the accuracy of flow meters, the issue has been addressed.

5.1 Groundwater Extraction

The majority of groundwater extraction at the Site to date has been from the Decline, within 500 m of the northern site boundary rather than the Borefield, which is located within 1 km of the southern site boundary. Total groundwater extraction to date from the Decline is calculated to be more than 300 ML. Groundwater extraction from bores has totalled more than 120 ML since sustained bore extraction began in October 2013. WB8, WB11 and the Back Bore, located close to the southern Site boundary, have been the primary bores utilised, with negligible contributions from other bores. Although they have not been used to their full capacity over much of the period of extraction, this year the rate of extraction from

WB11 and WB8 in particular has been increased significantly such that the rate of extraction from the underground workings and the Borefield are have been similar for much of 2015, at 350-400 m^3/day each.

The Decline has been halted at approximately RL -100 m for a period of months. While at this elevation, net water production from the underground has decreased by approximately 50 m^3 over a period of 16 weeks.

5.2 Drawdown

Except within 100 m of the Decline and in the extraction bores themselves, drawdown to date has generally been limited to less than 20 m, with less than 10 m of drawdown in observation bores in the Borefield Area. To date there has been no evidence of overlap between the drawdown caused by the Borefield and the drawdown due to the Decline.

In a previous report (Report 1) in August 2014, I noted that drawdowns in the vicinity of the Decline had resulted in exceedance of the licence criterion of maximum depth to water of 75 m below ground level in OB3 and WB5. The observed drawdowns in this area are not surprising. The original criterion on the extraction licenses of a maximum depth to water of 75 m in observation bores close to the Decline is unrealistic.

5.3 Conceptual Hydrogeology and Aquifer Properties

Aquifer properties of transmissivity, T, and Specific Yield, S_y, directly affect potential bore yields. The yield of bores at the Site has generally been less than was originally interpreted from pre-mining pumping tests. Therefore, the conceptual hydrogeology was revisited for this report, and in particular, aquifer properties were re-evaluated. Aquifer properties were interpreted both qualitatively from the baseline groundwater surface and quantitatively from long-term extraction and related drawdowns in observation bores. The new aquifer property estimates are considered to be more reliable than those interpreted in the baseline study as the new estimates were based on long-term extraction and drawdown data.

From this new work, the T of the rocks of the Lower Amphitheatre Group which underlie the relatively gently sloping western part of the Site, is interpreted to be generally greater than the T of the Mouramba Group rocks which underlie the higher relief eastern part of the Site. Therefore, bore yields from the Lower Amphitheatre Group rocks in the west would be expected to be generally greater than bore yields further east. WB8 and WB11 are located in the area of relatively high T whereas the Back Bore is located within the area of lower T.

The effective T and S_y of the Lower Amphitheatre Group rocks are estimated to be approximately 10 m^2/day and 0.005 respectively. This T estimate is of the initial, baseline T. In reality, T decreases with time in an unconfined aquifer such as this because a reduction in saturated thickness translates to a reduction in T. In addition, over a timeframe of years, the drawdown cones of individual bores would extend more than 2 km. Therefore, in this hydrogeological domain, the interference between pumping bores spaced 1-2 km apart is likely to be significant over a period of 10 years.

Although the effective T of the rocks of the Mouramba Group is generally interpreted to be significantly less than the Lower Amphitheatre Group, in the area of structural disruption in the vicinity of the mine, the effective T is interpreted to be relatively high, at approximately 5 m^2/day.

5.4 Feasibility of Increased Groundwater Extraction from Predictive Modelling

Predictive modelling of drawdowns was undertaken, incorporating the latest aquifer property interpretations. From this, the feasibility of extraction at increased rates was evaluated in terms of both available drawdown in extraction bores and induced drawdown at observation bores. The predictive modelling in this report differed significantly from equivalent assessments in the baseline study in that it simulated multiple extraction bores operating at the same time and utilised the latest interpreted aquifer properties.

Predictive modelling lead to the following conclusions:

- The new trigger levels in the Management Plan appear to be reasonable. Over a 10-year period of extraction, groundwater levels are unlikely to exceed these levels, except near the south-western corner of the Site.
- However, the feasibility of a sustained total groundwater extraction rate of 1 ML/day over a total mine life of ten years is considered to be marginal, due to an expected ongoing decrease in water production from the underground workings and the drawdowns induced at the extraction bores themselves which will limit their individual yield such that the yield of each bore will reduce with time.

Over a period of several years, a total groundwater extraction rate of 1 ML/day is expected to be achievable if additional productive extraction bores can be established to the north of WB11 and WB8. This is discussed further below. It may be feasible to sustain this rate for the total expected duration of the mine life, i.e. 10 years, by continuing to install additional extraction bores as the yield of existing bores reduces with time.

It can be expected that, without the installation of additional bores, the maximum yield of the existing Borefield, consisting of BW8, WB11 and the Back Bore, would reduce slowly with time. Apart from occasional short-term inflows when permeable fracture zones are intersected, it can also be expected that the production rate of water from the underground workings will decrease from the current rate of approximately 350 m^3/day. The final steady state production rate of water from the underground workings has been estimated herein to be 240 m^3/day. However, it may be lower if the permeable zone from which the water is flowing is limited in extent.

There remains some uncertainty regarding aquifer properties and, therefore, uncertainty regarding predictions of future drawdown and sustainable extraction rates. For the Borefield Area, the analysis herein has been based largely on observed drawdown at one observation bore, OB2, and has not been sensitive to aquifer properties to the west and north of this location. Another source of uncertainty is the effective thickness of the transmissive zone from which groundwater has been produced to date. It has been assumed herein that it is on the order of 70-90 m in thickness. If it is effectively thinner, T will decrease more rapidly than expected as a result of drawdown and bore yields will reduce more rapidly than expected.

6.0 Recommendations

In order to achieve a sustained combined extraction rate of 1 ML/day, it will be necessary to install additional productive extraction bores. I recommend the following:

- Exploration drilling for water in the Lower Amphitheatre Group and installation of 5-inch bores where suitable yields are identified. I recommend exploration drilling in the central western part of the Site, i.e. in the area between the existing Borefield and the mine site entrance, to the west and south of the TSF. I recommend drilling to approximately 200 mbgl. Although it is unlikely that the lower 50 m would make a significant difference to the yield from individual boreholes, there is a possibility it will.
- Logs of existing RC holes from this area should be reviewed to prioritise drilling locations. The logs should be reviewed for water strikes and possible drilling problems caused by water ingress. I understand that a significant yield of several L/s was noted in at least one RC hole south of the TSF (personal communication, Stuart Jeffrey, May 2015).

- Installation of monitoring tubes in all extraction bores such that the water level in the bore can always be measured. I have made separate recommendations regarding these tubes. These tubes should be incorporated into the equipping of future extraction bores. Their purpose is to optimise the efficiency and cost effectiveness of each extraction bore by fully utilising the available drawdown.

Groundwater exploration and the installation of new bores could be undertaken in an adaptive, stepped approach with a large initial spacing between bores, and possible “infilling” later in the mine life, if necessary, to optimise use of the available groundwater at the Site.

The monitoring undertaken to date has been critical to this assessment of aquifer performance and the feasibility of future groundwater extraction at an increased rate. It is important not only for compliance with the Water Management Plan, but also for subsequent predictions of extraction feasibility, that diligent monitoring of rates and drawdowns continues. I recommend that monitoring of groundwater levels within extraction bores be added to the monitoring list to optimise their performance.

WB18 and the Harland Bore have been recently added to the list of monitoring locations. To reduce existing uncertainty with the sustainability of groundwater extraction, I recommend future evaluation of the drawdown trend at these newly installed bores in addition to consideration of future data from the observation bores considered herein. In particular, groundwater level trends at newly installed bores WB18, WB15 and at the Harland Bore should be analysed by mid-2016 at the latest.

This assessment has shown that sustaining groundwater extraction at a rate of 1 ML/day for the full duration of the mine life is likely to be challenging. However, the predictive modelling herein assumed that local recharge will have a negligible effect on groundwater levels during the mine life. In addition to optimising efficiencies in water usage and water recycling, I recommend that the feasibility of artificial enhancement of groundwater recharge by the capture and infiltration of runoff is investigated, i.e. managed aquifer recharge.

I recommend that the bore flow meters are intermittently checked by measuring the time taken to fill or change the level in a container of known volume (e.g. by using the tank to which the water is being pumped).

For an increase in the licensed extraction from the Site, the purchase of additional existing groundwater entitlement(s) will be necessary within the Lachlan Fold Belt region. This is due to the embargo prohibiting the issue of new extraction licenses within the Murray-Darling Basin.

7.0 Closure

This letter report is provided subject to the attached limitations. If you have any questions or comments regarding this document, please do not hesitate to contact me.

Yours sincerely,

Alan Wade
Principal Hydrogeologist
Aquade Groundwater
Services Pty Ltd

Attachments:

- References
- Glossary of Terms
- Aquade General Limitations
- Figure 1. Baseline Water Table Surface, 2011
- Appendix A. Groundwater Extraction Data
- Appendix B. Hydrographs from Select Bores
- Appendix C. Analyses of Observed Drawdowns
- Appendix D. Predictions of Future Drawdown

8.0 References:

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9.0 Glossary of terms:

Anisotropy condition in which one or more of the hydraulic properties of an aquifer vary according to the direction of flow.

Aquifer. Rock or sediment that is a geological formation, group of formations, or part of a formation which is saturated and sufficiently permeable to transmit economic quantities of water to wells and springs.

Aquitard. A unit of low-permeability that can store groundwater and also transmit it slowly.

Bore. A hydraulic structure that facilitates the monitoring of groundwater level, collection of groundwater samples, or the extraction (or injection) of groundwater. Also known as a well.

Borehole an uncased drill hole.

Drawdown. Lowering of hydraulic head.

Electrical Conductivity (EC). The EC of water is a measure of its ability to conduct an electric current. This property is related to the ionic content of the sample, which is in turn a function of the total dissolved (ionisable) solids (TDS) concentration. An estimate of TDS in fresh water can be obtained by multiplying EC by 0.65.

Groundwater. The water held in the pores in the ground below the water table.

Hydraulic Head. The sum of the elevation head and the pressure head at a point in an aquifer. This is typically reported as an elevation above a fixed datum, such as sea level.

Hydraulic conductivity. A coefficient describing the rate at which water can move through a permeable medium. It has units of length per time.

Hydrostratigraphic unit. A formation, part of a formation, or group of formations in which there are similar hydrologic characteristics allowing for grouping into one aquifer or aquitard.

Hydrostratigraphy. The framework of a groundwater flow system described in terms of its hydrostratigraphic units.

Permeability. Property of porous medium relating to its ability to transmit or conduct liquid (usually water) under the influence of a driving force. Where water is the fluid, this is effectively the hydraulic conductivity.

Piezometric or Potentiometric Surface. A surface that represents the level to which water will rise in cased wells. The water table is the potentiometric surface in an unconfined aquifer.

Recharge Area. Location of the replenishment of an aquifer by a natural process such as addition of water at the ground surface, or by an artificial system such as addition through a well

Saturated Zone. Zone in which the rock or soil pores are filled (saturated) with water.

Specific Yield. The ratio of the volume of water a rock or soil will yield by gravity drainage to the volume of rock or soil.

Storativity. Volume of water stored or released by a confined aquifer per unit volume (of porous medium) per unit change in head.

Stratigraphy. Vertical sequence of geological units.

Total Dissolved Solids (TDS). Total dissolved salts comprising dissociated compounds and undissociated compounds, but not suspended material, colloids or dissolved gases.

Transmissivity. The rate at which water is transmitted through a unit width aquifer or aquitard under a unit hydraulic gradient. It is a function of the properties of the water, the porous medium and the thickness of the porous medium.

Unconfined aquifer. An aquifer in which the water table forms the upper boundary.

Water table. The interface between the saturated zone and the unsaturated zone above it. The surface in an aquifer at which pore water pressure is equal to atmospheric pressure.

Well. A hydraulic structure that facilitates the monitoring of groundwater level, collection of groundwater samples, or the extraction (or injection) of groundwater. Also known as a bore.

AQUADE GENERAL LIMITATIONS

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This document (the report) has been prepared in accordance with the scope of services set out in the contract, or as otherwise agreed, between the client and Aquade (scope of services). In some circumstances, the scope of services may have been limited by a range of factors such as time or budget constraints.

Reliance on Data

In preparing the report, Aquade has relied upon data, surveys, analyses, designs, plans and other information provided by the client and other individuals and organisations, most of which are referred to in the report (the data). Except as otherwise stated in the report, Aquade has not verified the accuracy or completeness of the data. To the extent that the statements, opinions, facts, information, conclusions and/or recommendations in the report (conclusions) are based in whole or part on the data, those conclusions are contingent upon the accuracy and completeness of the data. Aquade will not be liable in relation to incorrect conclusions should any data, information or condition be incorrect or have been concealed, withheld, misrepresented or otherwise not fully disclosed to Aquade.

Interpretations and Conclusions

In accordance with the scope of services, Aquade has relied upon the data provided in the preparation of the report. The nature and extent of monitoring and/or testing conducted and reviewed is described in the report. The report only applies to the Hera Mine Site.

On all sites, varying degrees of non-uniformity of the vertical and horizontal soil, rock and/or groundwater conditions are encountered. Hence no monitoring can eliminate the possibility that the data obtained are not totally representative of ground and/or groundwater conditions encountered. The interpretations and conclusions herein are based upon the available data and are therefore merely indicative of the conditions from the available data at the time of preparing the report. Also, it should be recognised that the data reviewed are from a limited time period and that site conditions can change with time.

Within the limitations imposed by the scope of services, the analysis performed and the preparation of this report have been undertaken and performed in a professional manner, in accordance with generally accepted practices and using a degree of skill and care ordinarily exercised by reputable hydrogeological consultants under similar circumstances. No other warranty, expressed or implied, is made.

Report for Benefit of Client Only

The report has been prepared for the benefit of the client and no other party. Aquade assumes no responsibility and will not be liable to any other person or organisation for or in relation to any matter dealt with or conclusions expressed in the report, or for any loss or damage suffered by any other person or organisation arising from matters dealt with or conclusions expressed in the report (including without limitation matters arising from any negligent act or omission of Aquade or for any loss or damage suffered by any other party relying upon the matters dealt with or conclusions expressed in the report). Parties other than the client should not rely upon the report or the accuracy or completeness of any conclusions and should make their own enquiries and obtain independent advice in relation to such matters.

Other limitations

Aquade will not be liable to update or revise the report to take into account any events or emergent circumstances or facts occurring or becoming apparent after the date of the report.

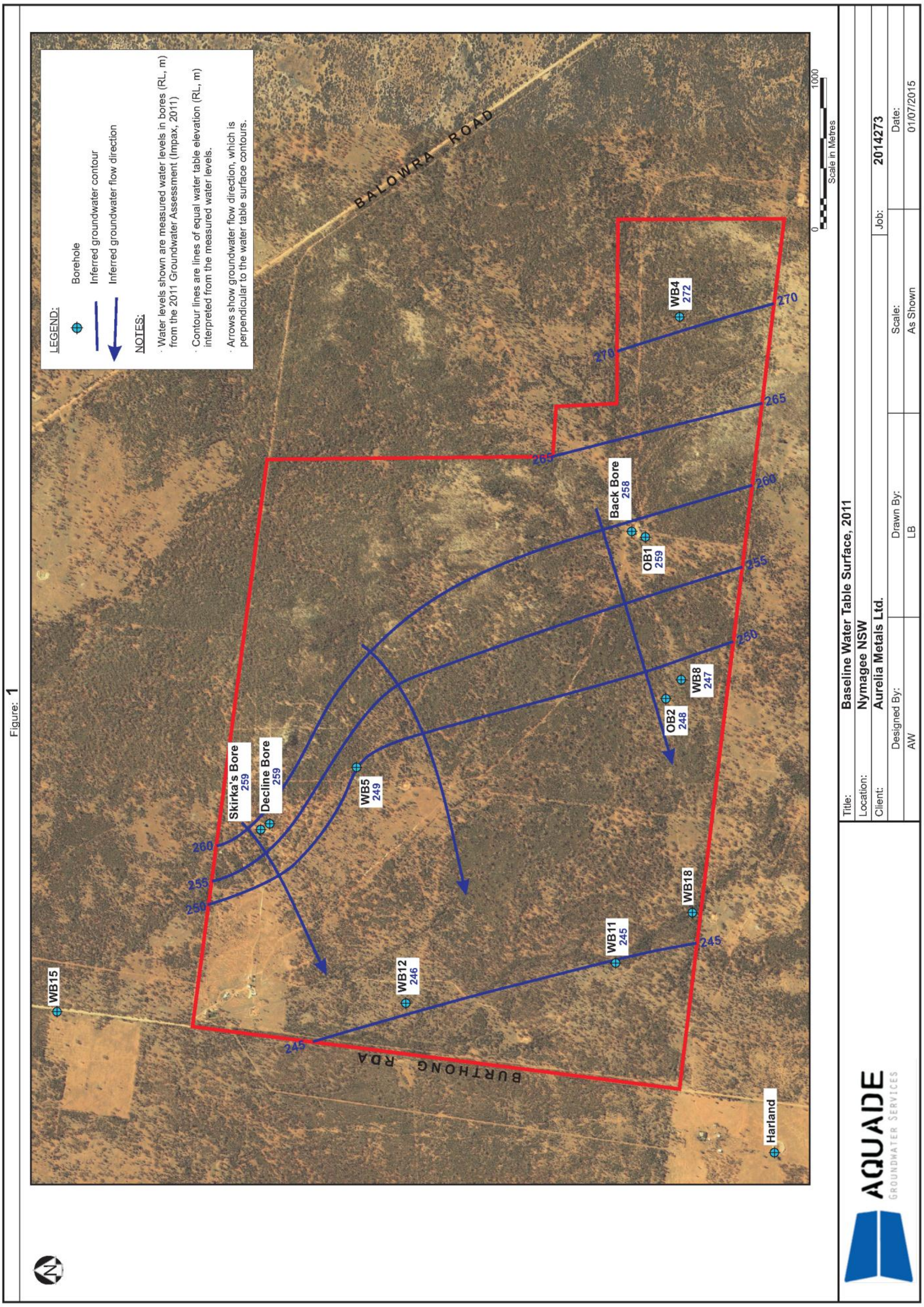
Figure: 1
LEGEND:
Borehole
Inferred groundwater contour
Inferred groundwater flow direction
NOTES:
· Water levels shown are measured water levels in bores (RL, m) from the 2011 Groundwater Assessment (Impax, 2011)
· Contour lines are lines of equal water table elevation (RL, m) interpreted from the measured water levels.
· Arrows show groundwater flow direction, which is perpendicular to the water table surface contours.
BALOWRA ROAD
BURTHONG ROAD
WB15
Skirka's Bore 259
Decline Bore 259
WB5 249
WB12 246
WB11 245
WB18
OB2 248
WB8 247
OB1 259
Back Bore 258
WB4 272
Harland
245
250
255
260
265
270
0
1000
Scale in Metres
Title: Baseline Water Table Surface, 2011
Location: Nymagee NSW
Client: Aurelia Metals Ltd.
Designed By: AW
Drawn By: LB
Scale: As Shown
Job: 2014273
Date: 01/07/2015
AQUADE GROUNDWATER SERVICES

Appendix A. Groundwater Extraction Data

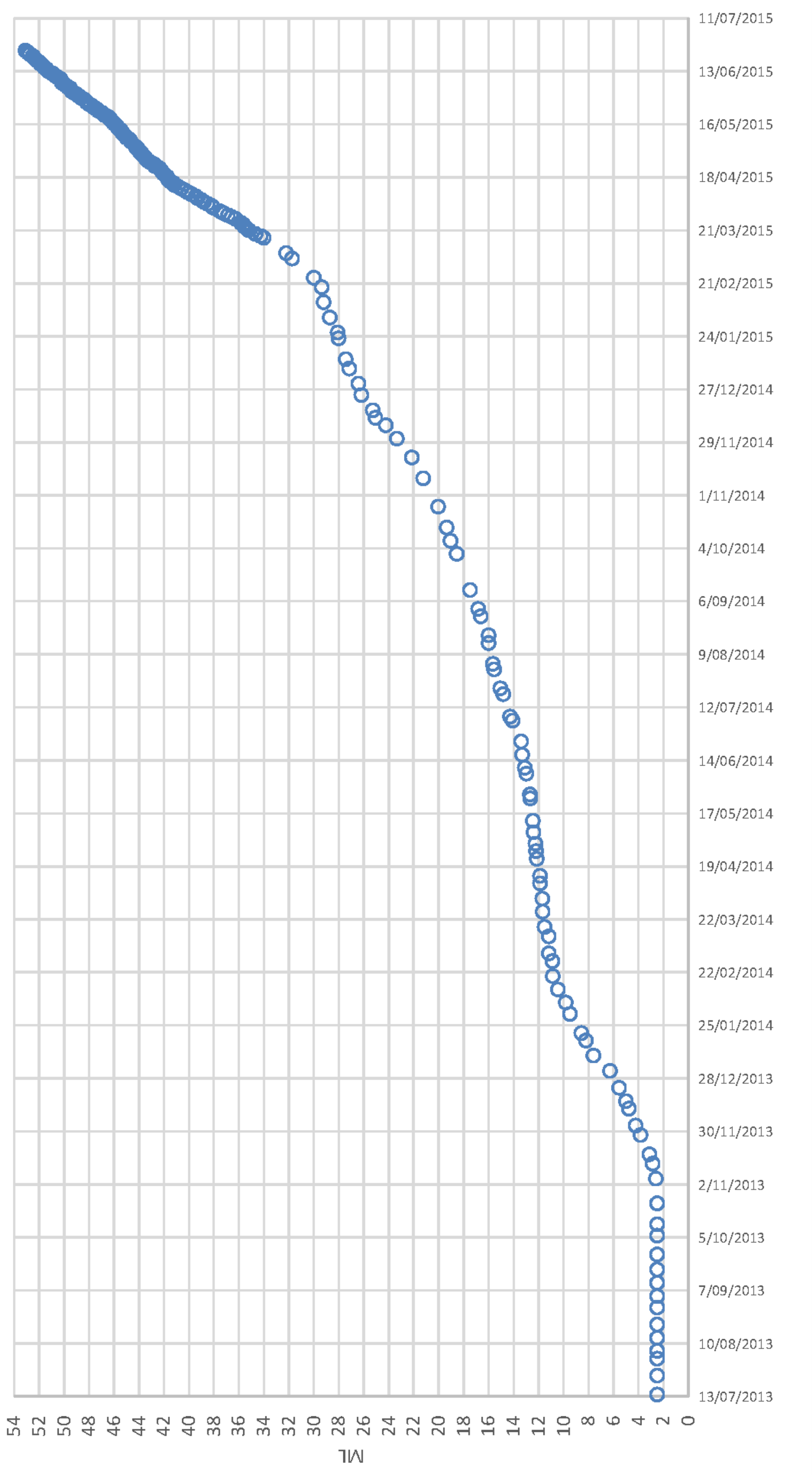

Figure A1. Cumulative Pumping from WB8

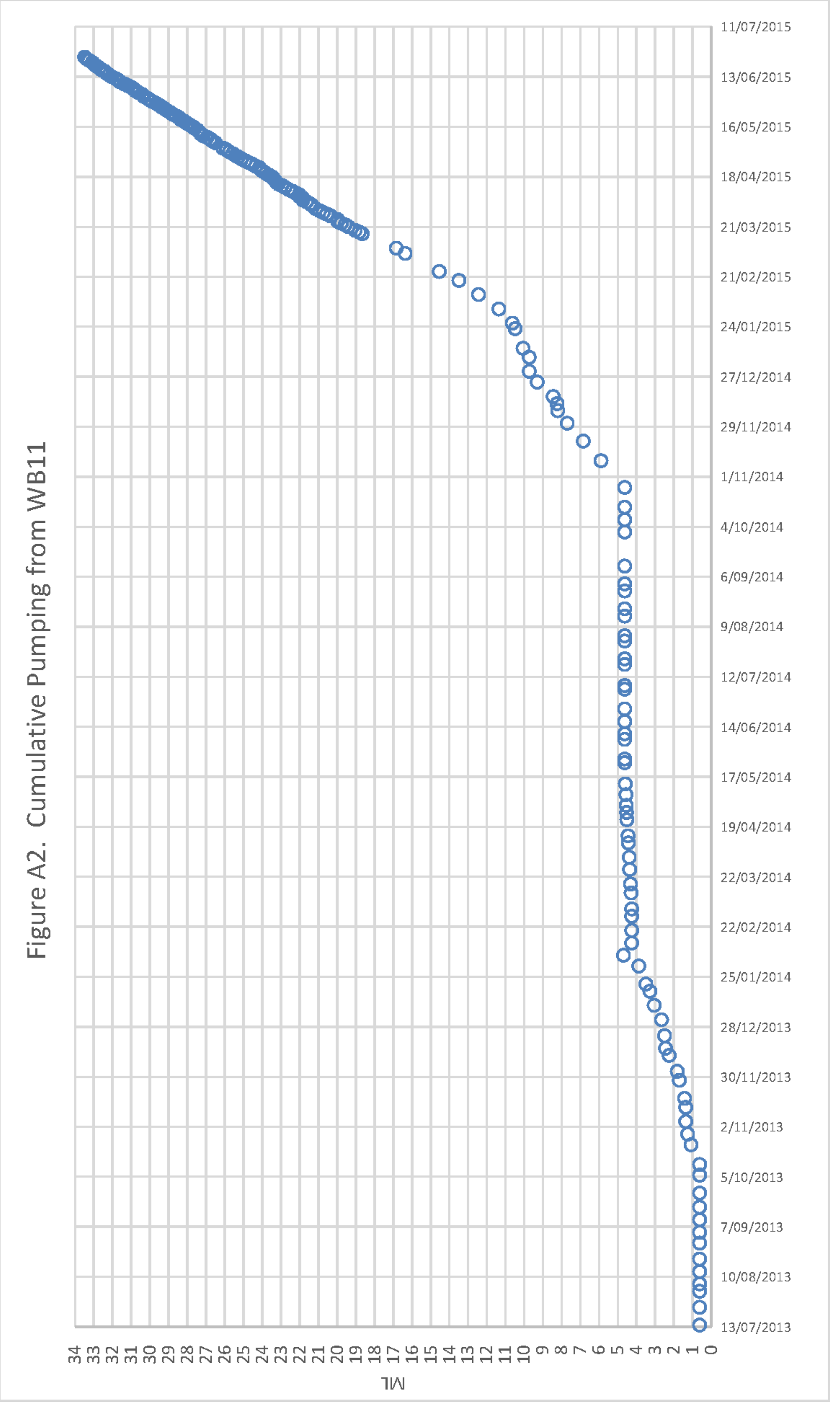

Figure A2. Cumulative Pumping from WB11

Figure A3. Cumulative Pumping from Back Bore

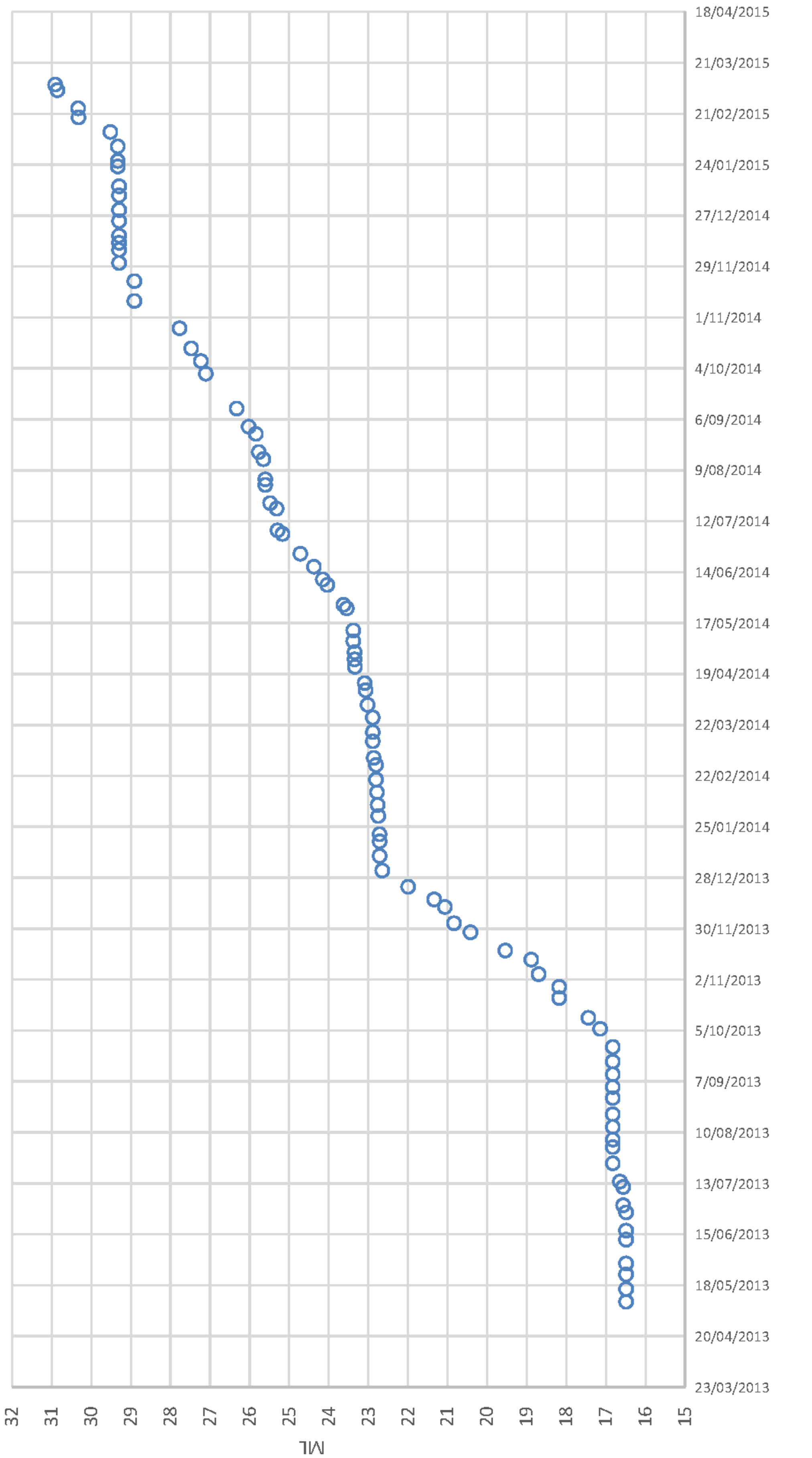

Figure A4. Long-Term Net Pumping Rate from Decline, May 2013 to July 2014

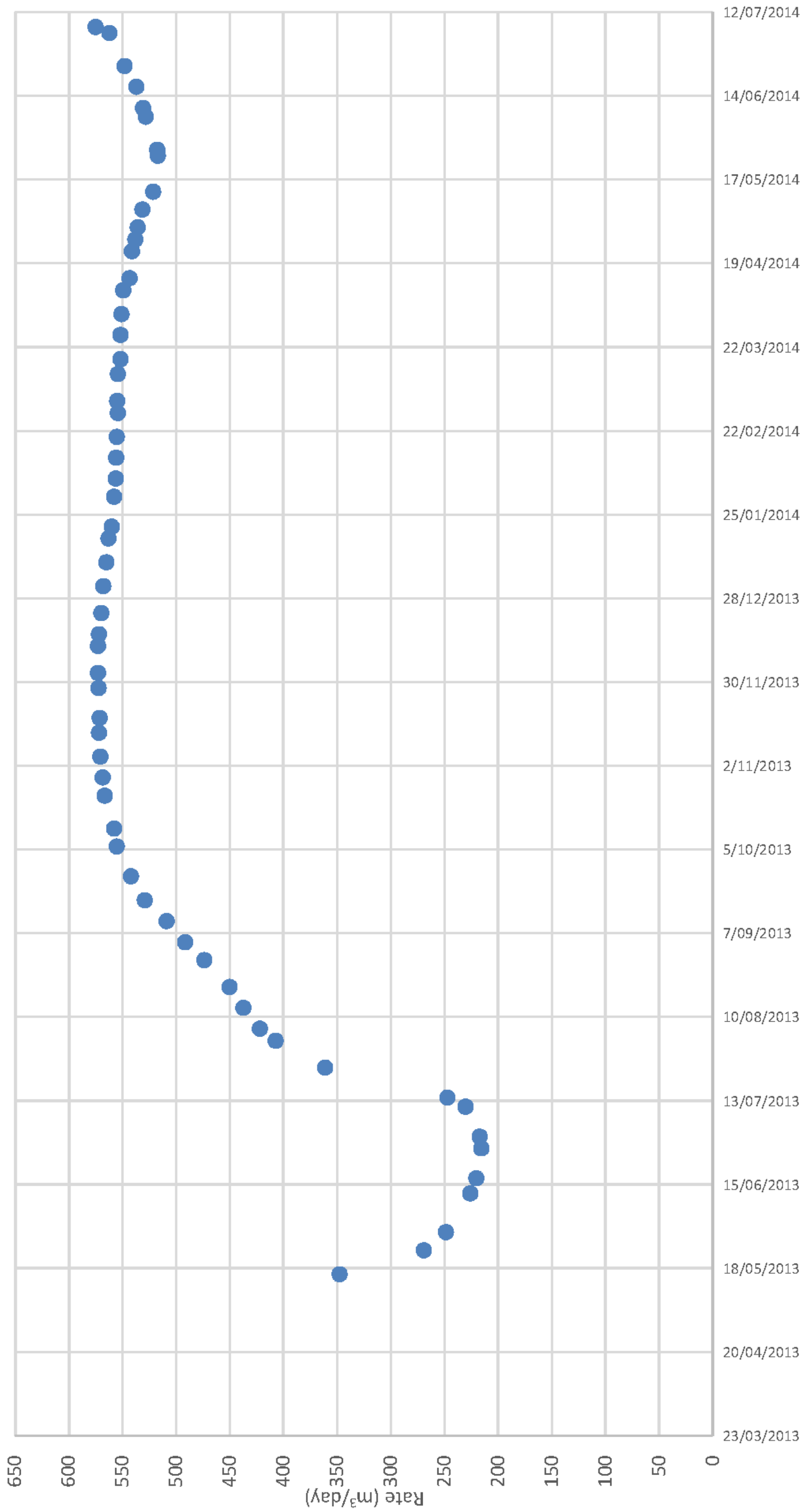

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Figure A5. Daily Net Pumping Rate from Decline while Halted at RL -100 m, Early 2015

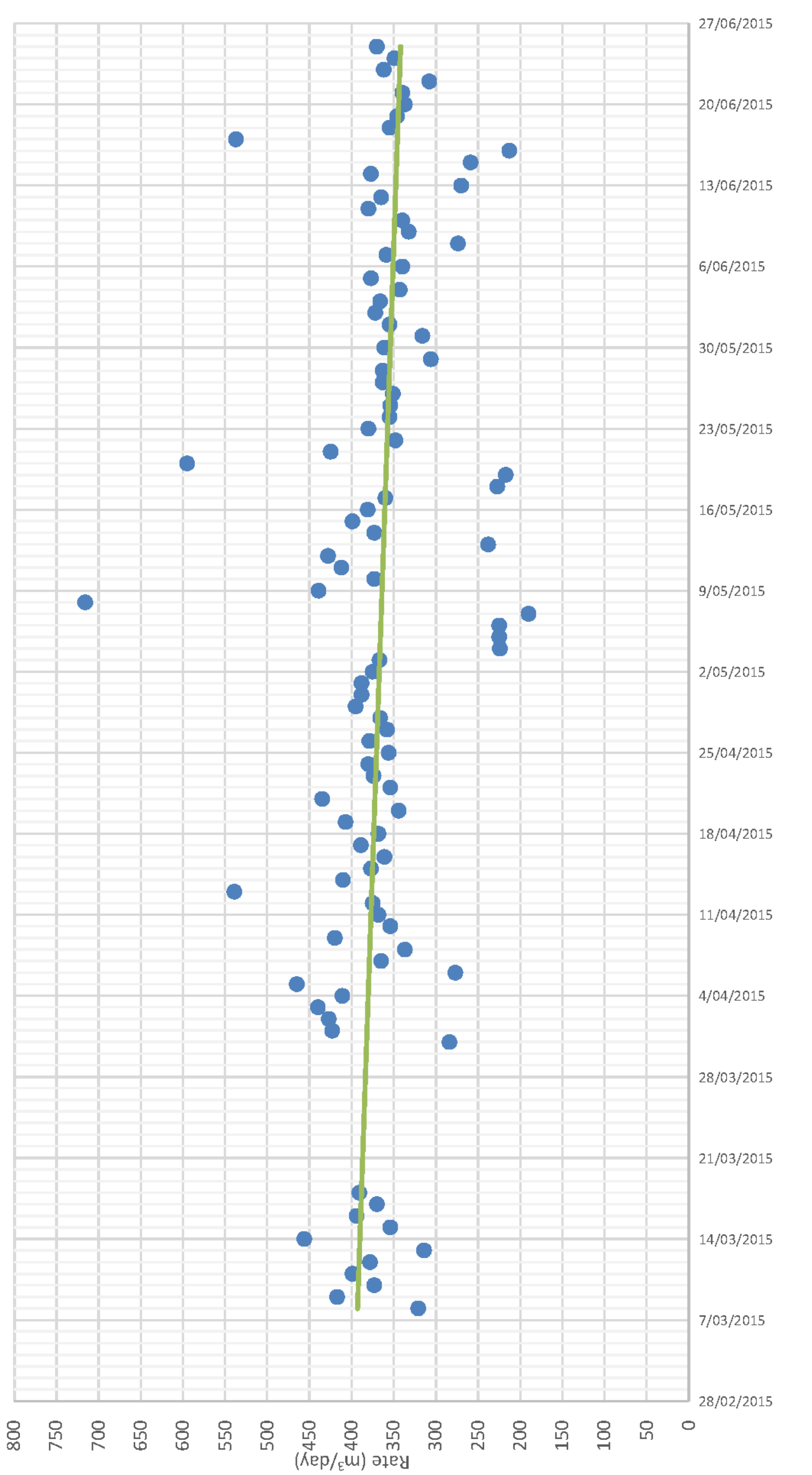


Table A1. Summary of Bore Extraction Rates Evaluated from Cumulative Volume Plots

WB8	
Time Since 1 October 2013 (days)	New Pumping Rate (m^3/day)
32	71
92	126
100	81
144	21
263	54
403	129
445	56
508	250
564	143
592	190

WB11	
Time Since 1 October 2013 (days)	New Pumping Rate (m^3/day)
6	30
130	2
389	79
445	41
491	179
544	149

Back Bore	
Time Since 1 October 2013 (days)	New Pumping Rate (m^3/day)
0	64
95	5
233	39
285	10
341	37
425	0
490	52

Appendix B. Hydrographs from Select Bores

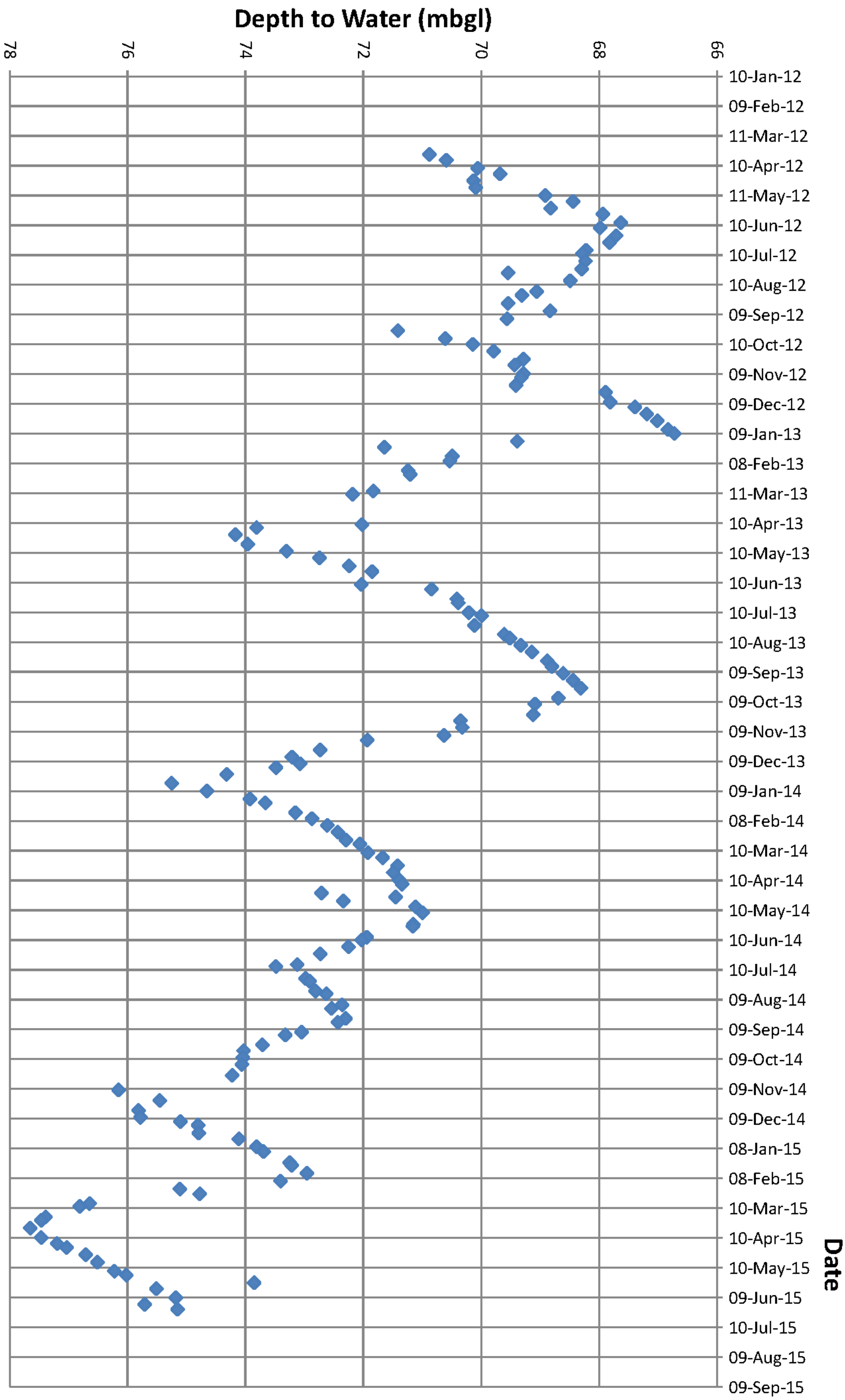


Figure B1. OB1 Groundwater Levels

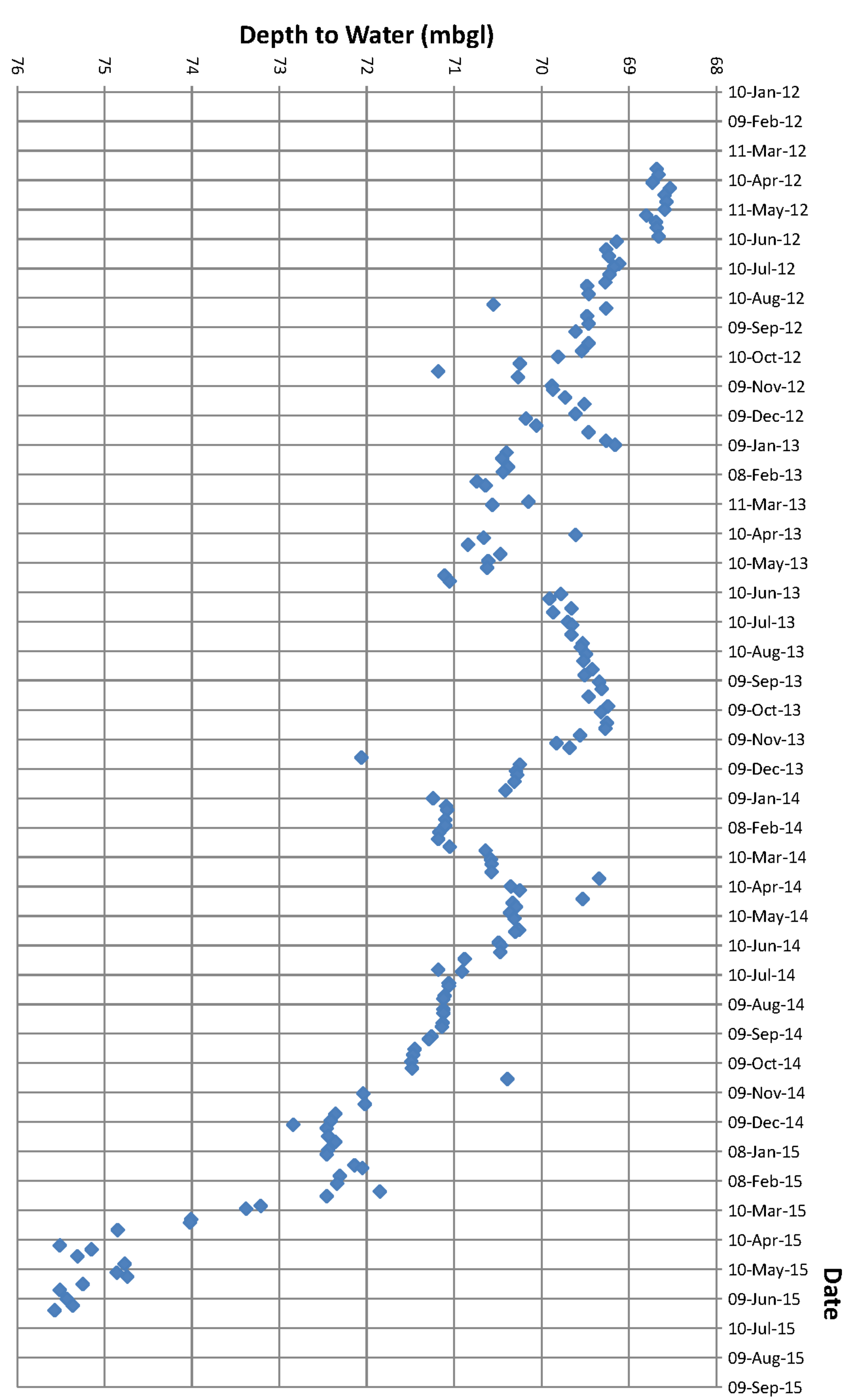


Figure B2. OB2 Groundwater Levels

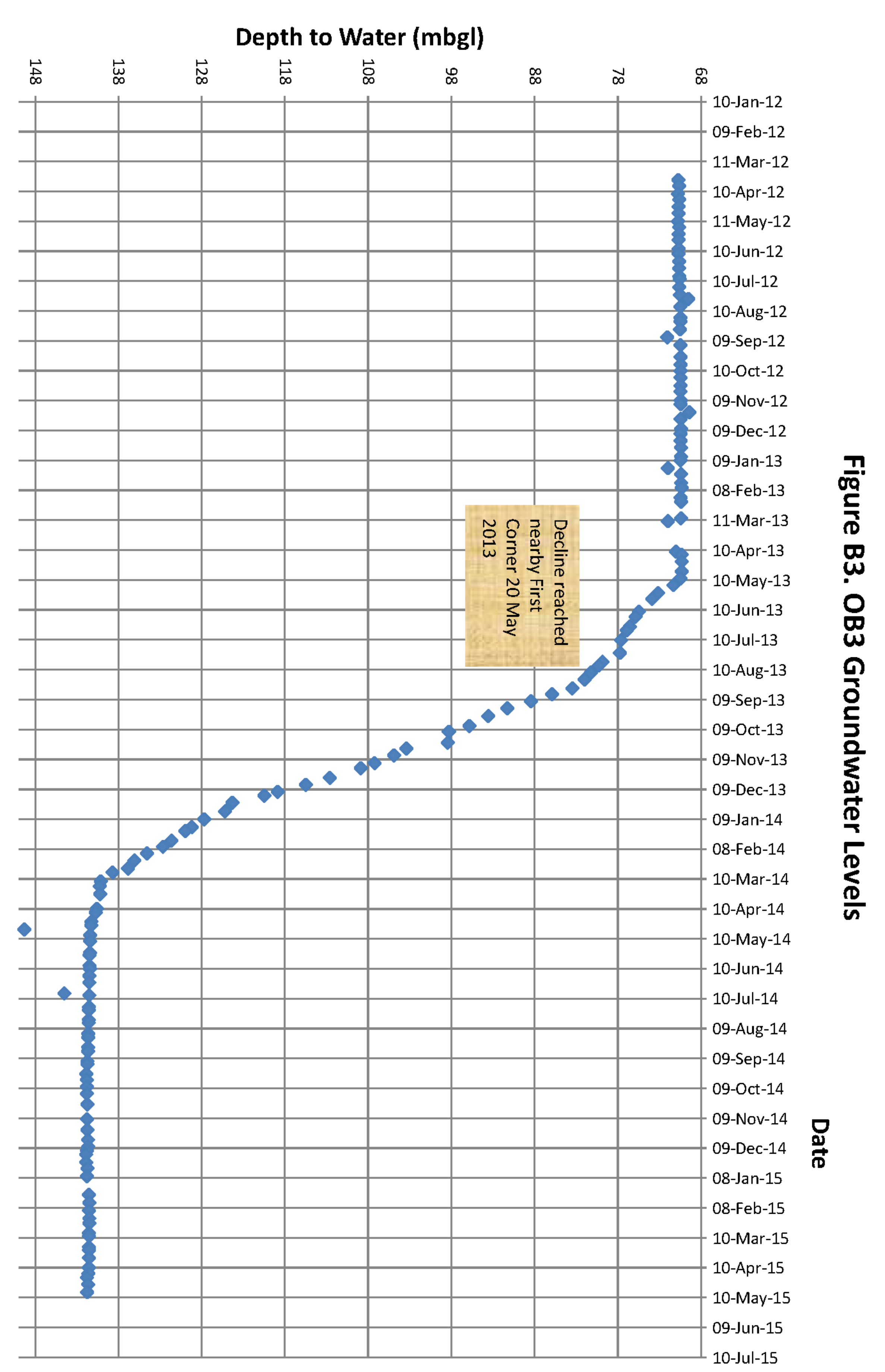


Figure B3. OB3 Groundwater Levels

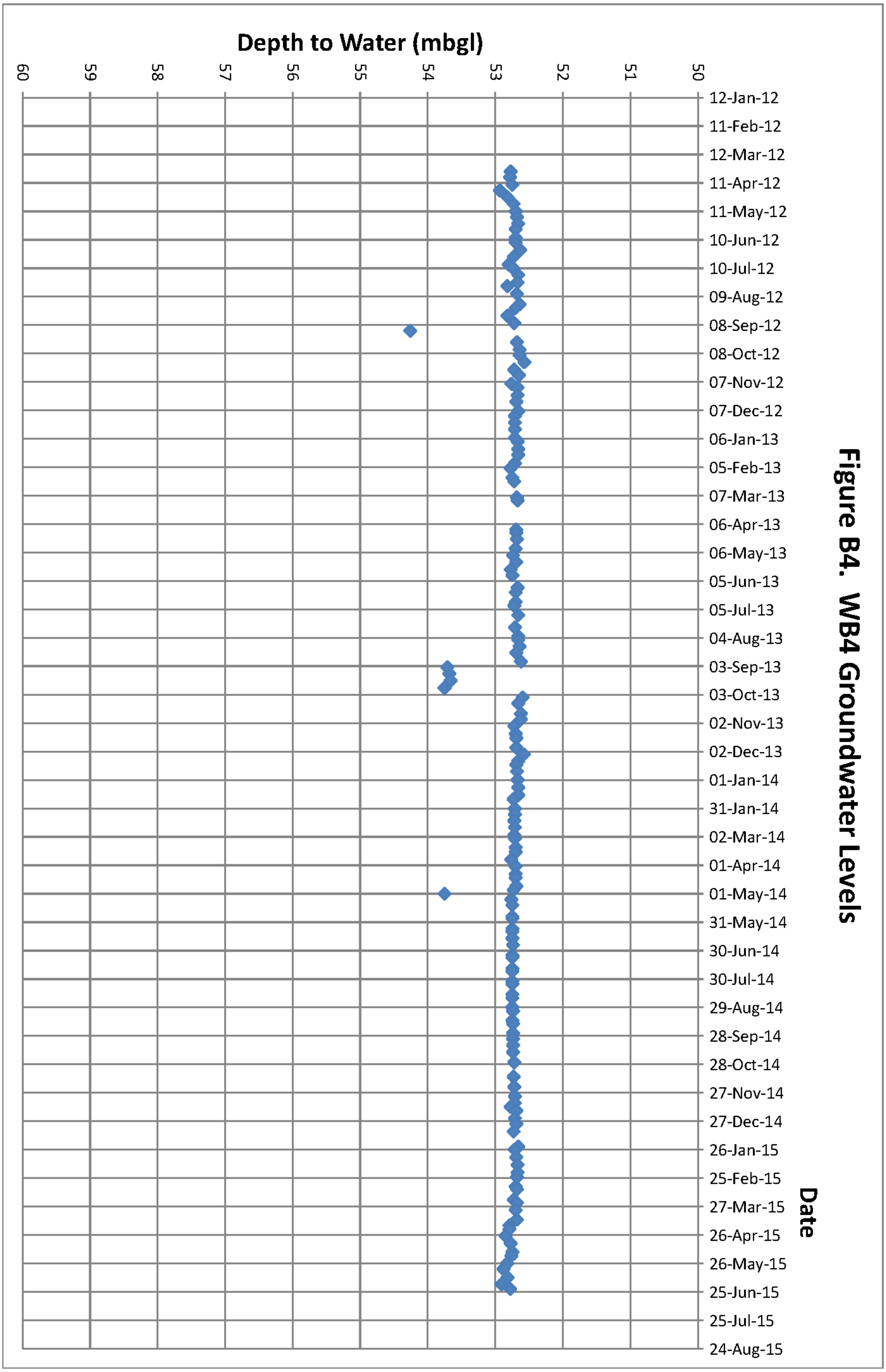


Figure B4. WB4 Groundwater Levels

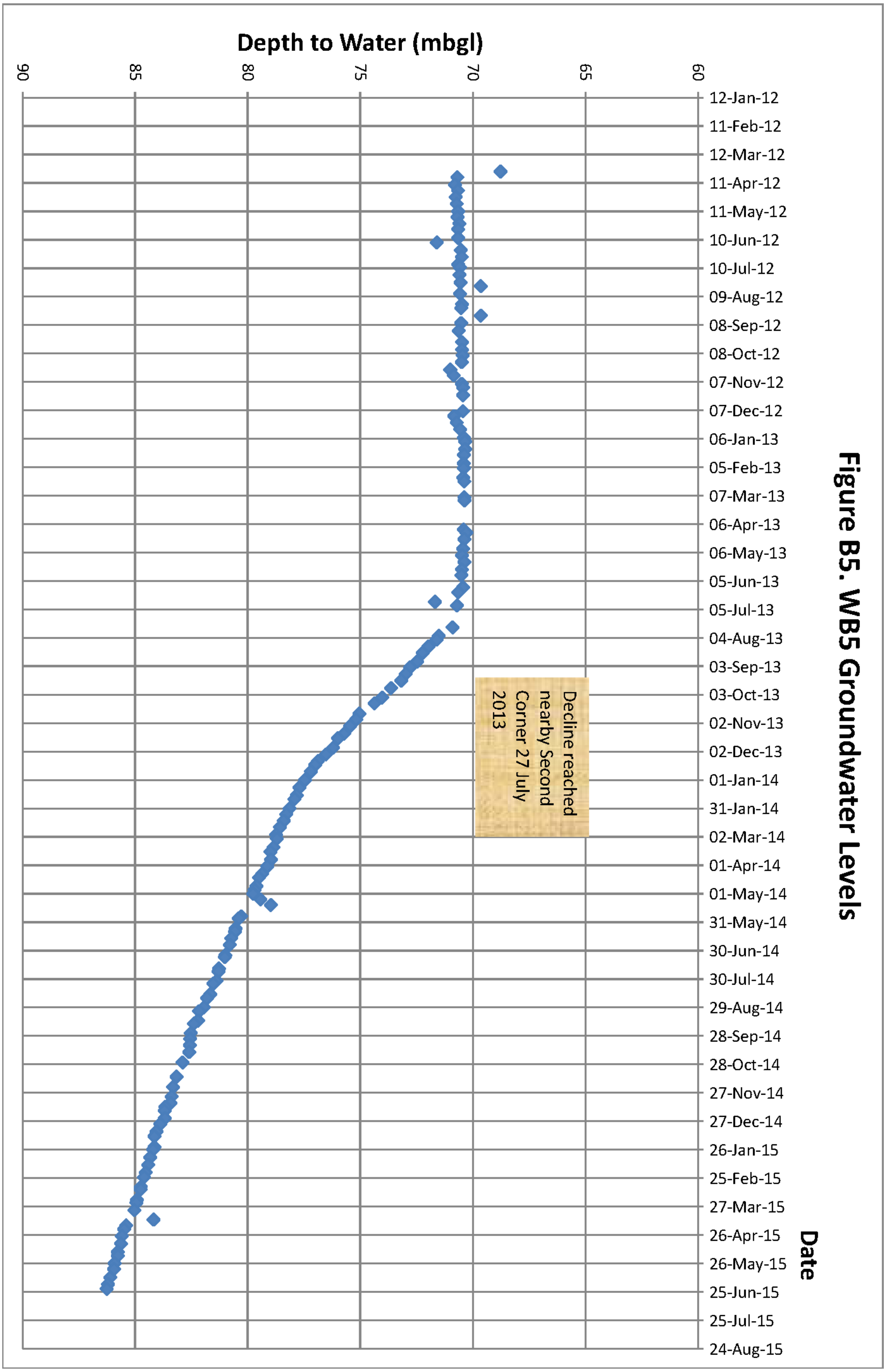


Figure B5. WB5 Groundwater Levels

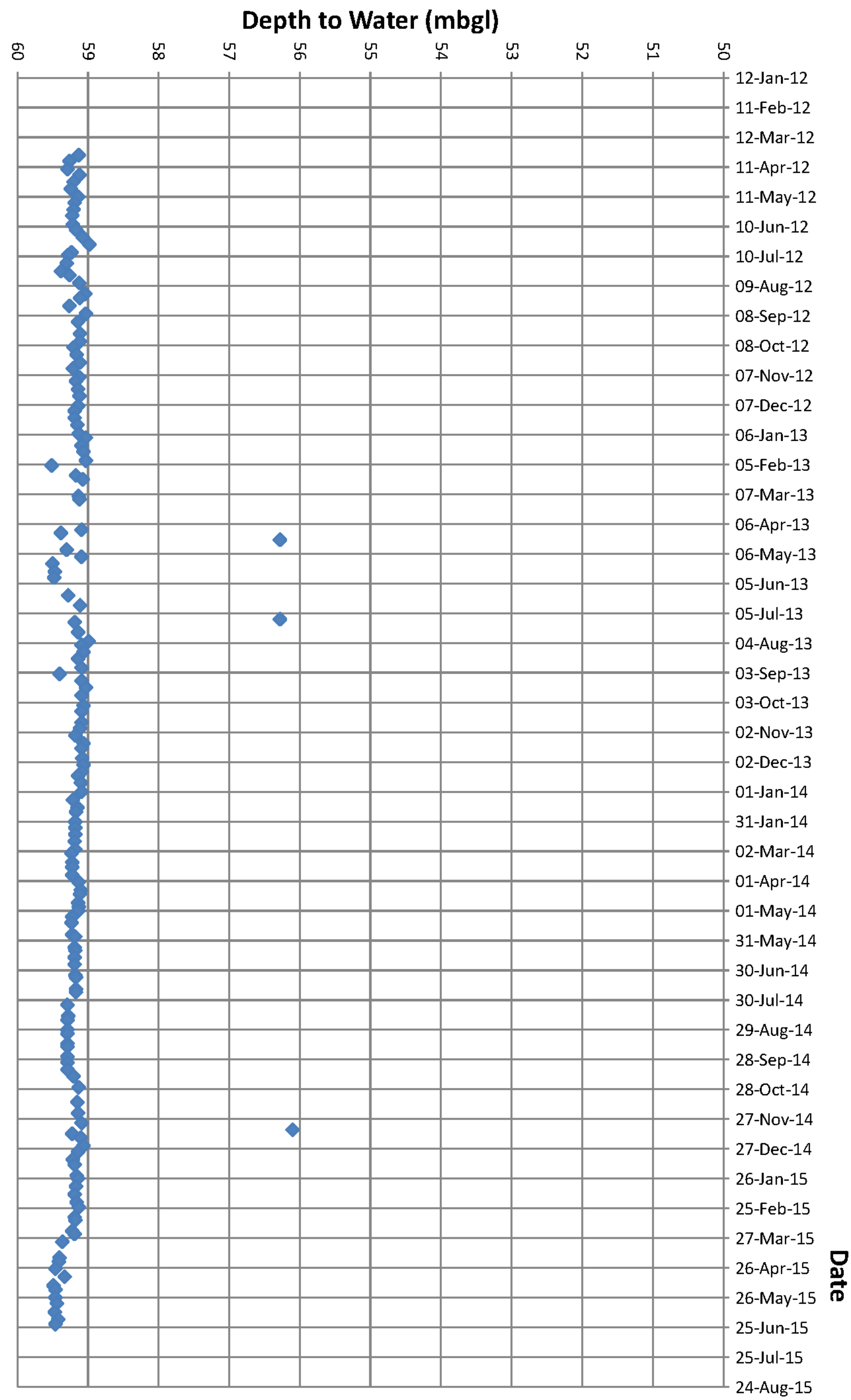
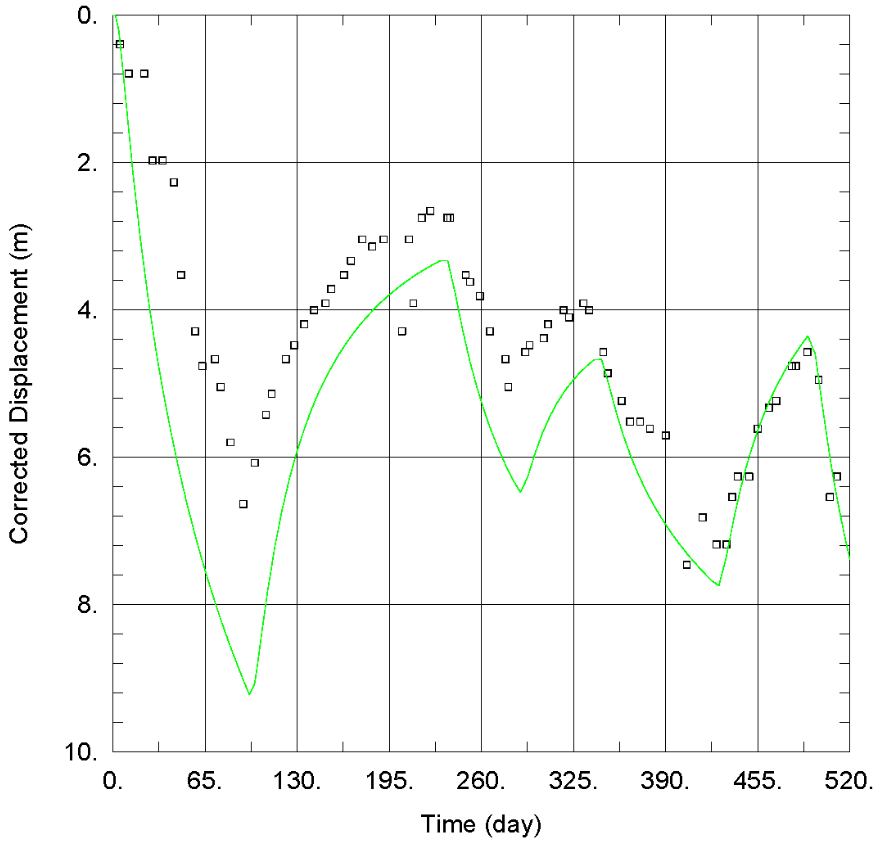


Figure B6. WB12 Groundwater Levels

Appendix C. Analyses of Observed Drawdowns



OB1-1. ANALYSIS OF OB1 DRAWDOWN WITH NO BOUNDARIES

Data Set: D:\...\3Bores0BNDObs1.aqt
Date: 06/30/15 Time: 18:34:00

PROJECT INFORMATION

Company: Aquade
Client: Aurelia Metals
Project: 2014273
Location: Nymagee
Test Well: BB, WB8, WB11
Test Date: 2015

WELL DATA

Pumping Wells

Well Name	X (m)	Y (m)
8	7115	4465
11	5231	4889
BB	8098	4799

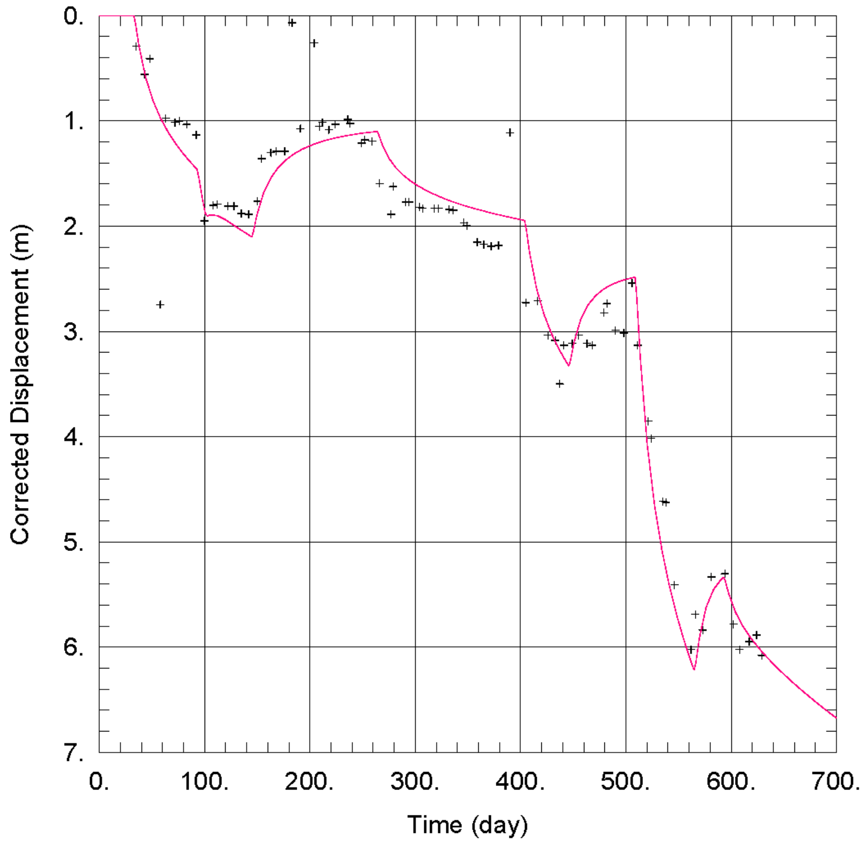
Observation Wells

Well Name	X (m)	Y (m)
OB1	8076	4701

SOLUTION

Aquifer Model: Unconfined
Solution Method: Theis

T = 1.069 m^2/day
S = 0.003639
Kz/Kr = 1.
b = 90. m



OB2-1. OB2 ANALYSIS WITH NO BOUNDARIES

Data Set: D:\...\3PBores0BNDOW2.aqt
Date: 06/30/15 Time: 19:06:38

PROJECT INFORMATION

Company: Aquade
Client: Aurelia Metals
Project: 2014273
Location: Nymagee
Test Well: 8, 11, BB
Test Date: 2015

WELL DATA

Pumping Wells

Well Name	X (m)	Y (m)
8	7115	4465
11	5231	4889
BB	8098	4799

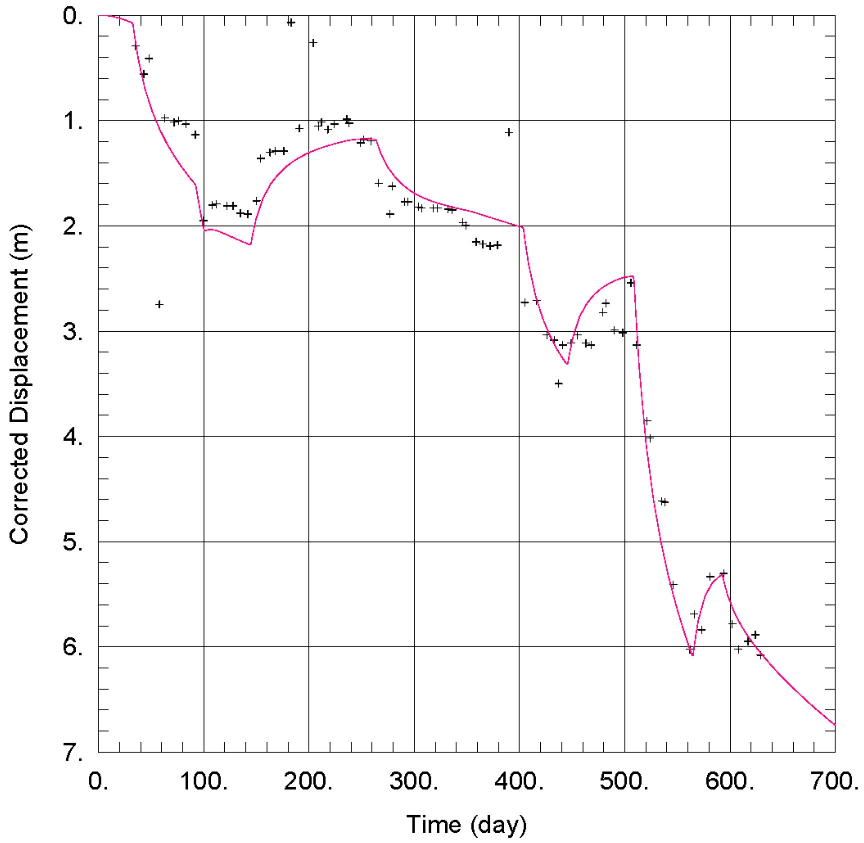
Observation Wells

Well Name	X (m)	Y (m)
+ OB2	6994	4566

SOLUTION

Aquifer Model: Unconfined
Solution Method: Theis

T = 9.629 m^2/day
S = 0.005
Kz/Kr = 1.
b = 90. m



OB2-2. OB2 ANALYSIS WITH ONE BOUNDARY @ X = 7215

Data Set: D:\...\3PBores1BNDOW2.aqt
Date: 06/30/15
Time: 19:05:57

PROJECT INFORMATION

Company: Aquade
Client: Aurelia Metals
Project: 2014284
Location: Nymagee
Test Well: 8, 11, BB
Test Date: 2015

WELL DATA

Pumping Wells

Well Name	X (m)	Y (m)
8	7115	4465
11	5231	4889
BB	8098	4799

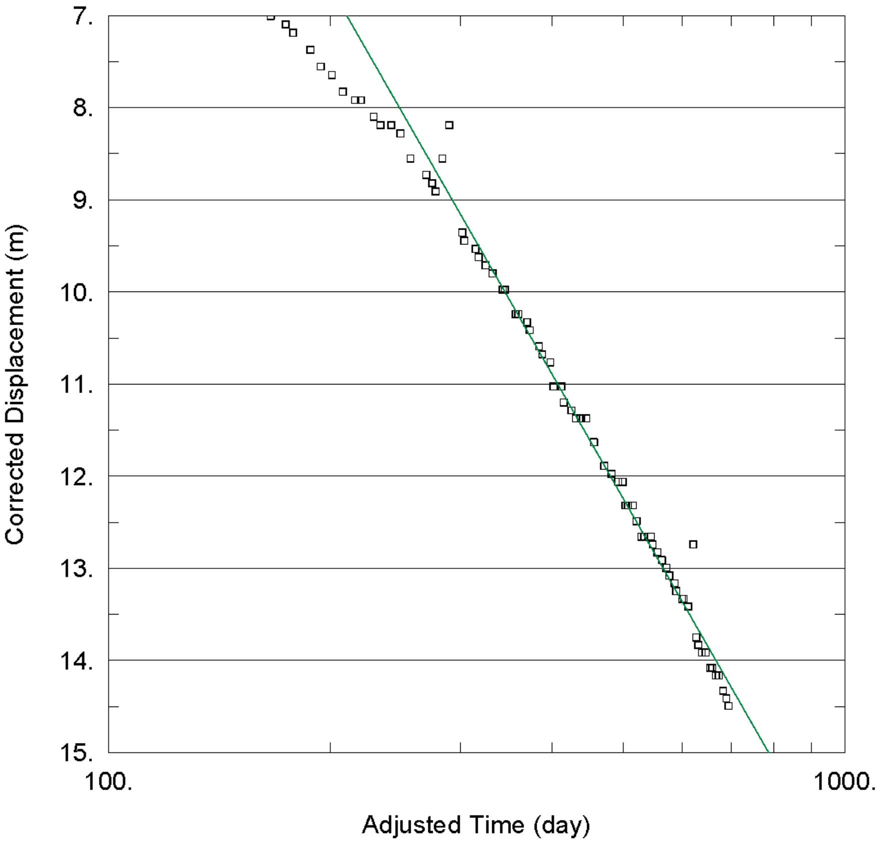
Observation Wells

Well Name	X (m)	Y (m)
+ OB2	6994	4566

SOLUTION

Aquifer Model: Unconfined
Solution Method: Theis

T = 20.94 m^2/day
S = 0.005
Kz/Kr = 1.
b = 90. m



WB5-1. ANALYSIS OF DRAWDOWN AT WB5 SINCE DECLINE REACHED SECOND CORNER

Data Set: D:\...\WB5.1. DeclineWB5.aqt
Date: 06/30/15 Time: 19:04:47

PROJECT INFORMATION

Company: Aquade
Client: Aurelia Metals
Project: 2014273
Location: Nymagee
Test Well: Decline
Test Date: 2015

AQUIFER DATA

Saturated Thickness: 90. m Anisotropy Ratio (Kz/Kr): 1.

WELL DATA

Pumping Wells

Well Name	X (m)	Y (m)
Decline 2nd Corner	6519	6938

Observation Wells

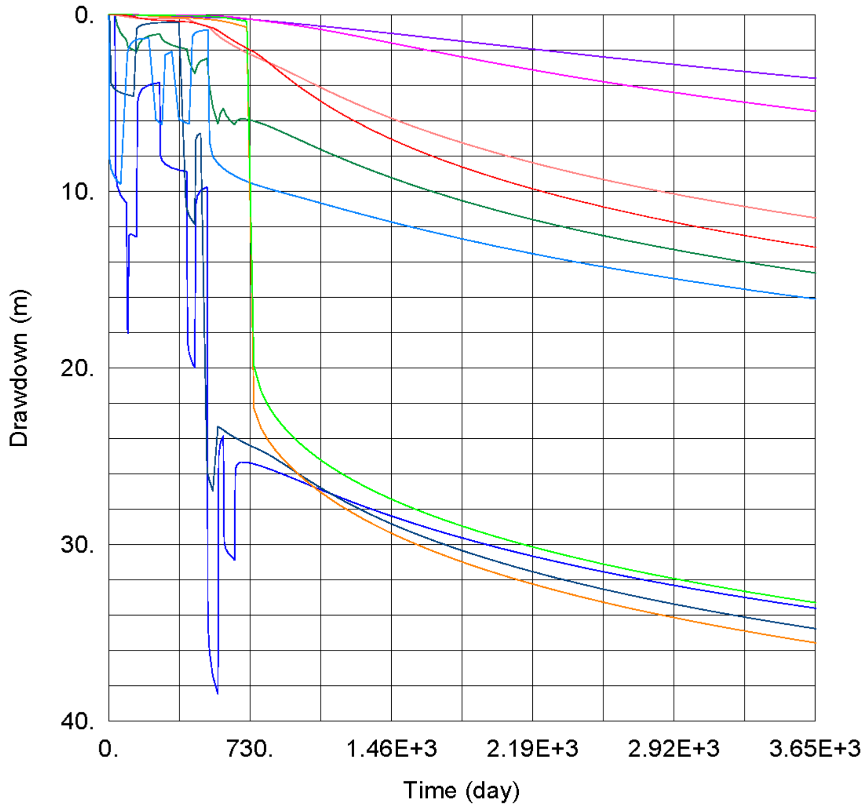
Well Name	X (m)	Y (m)
□ WB5	6521	6640

SOLUTION

Aquifer Model: Unconfined Solution Method: Cooper-Jacob

T = 5.247 m^2/day S = 0.008812

Appendix D. Predictions of Future Drawdown



P1. PREDICTED DRAWDOWNS OVER 10 YEARS AT COMBINED BORE PUMPING RATE OF 700 M3/D

Data Set: D:\...\P1. 5PBores0BNDFWD10yr 700 m3d.aqt
Date: 07/02/15
Time: 11:06:20

PROJECT INFORMATION

Company: Aquade
Client: Aurelia Metals
Project: 2014273
Location: Nymagee
Test Well: 8, 11, BB, 12, 20
Test Date: 2015

WELL DATA

Pumping Wells

Well Name	X (m)	Y (m)
8	7115	4465
11	5231	4889
BB	8098	4799
20	6300	5900
12	4958	6287

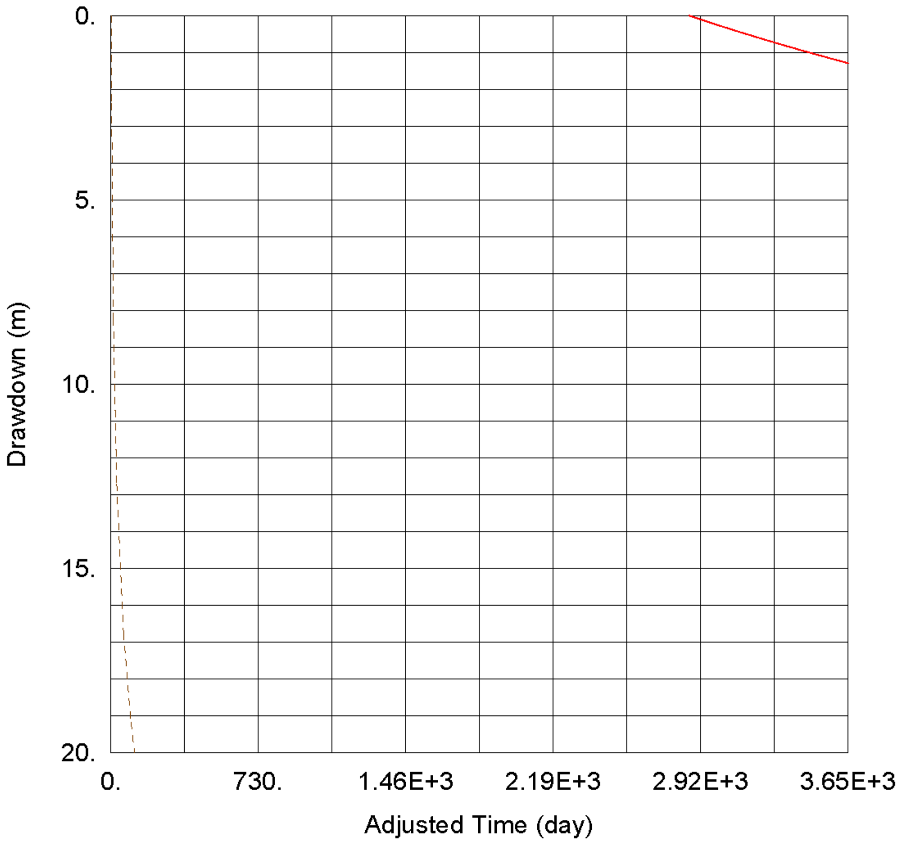
Observation Wells

Well Name	X (m)	Y (m)
+ Obs 2	6994	4566
□ 8	7115	4465
□ 11	5231	4889
□ BB	8098	4799
□ 4	9535	4485
□ 18	5574	4389
□ Harland	3978	3829
□ 20	6300	5900
□ 12	4958	6287
□ Obs 4	6200	5000

SOLUTION

Aquifer Model: Unconfined

Solution Method: Theis



P2. PREDICTED DRAWDOWN AT WB15 (IN RED) DUE TO DECLINE

Data Set: D:\...\P2. DeclineWB15 350 m3d.aqt
Date: 07/01/15 Time: 12:23:48

PROJECT INFORMATION

Company: Aquade
Client: Aurelia Metals
Project: 2014273
Location: Nymagee
Test Well: Decline Third Corner
Test Date: 2015

AQUIFER DATA

Saturated Thickness: 90. m Anisotropy Ratio (Kz/Kr): 1.

WELL DATA

Pumping Wells

Well Name	X (m)	Y (m)
Decline 3rd Corner	6407	7384

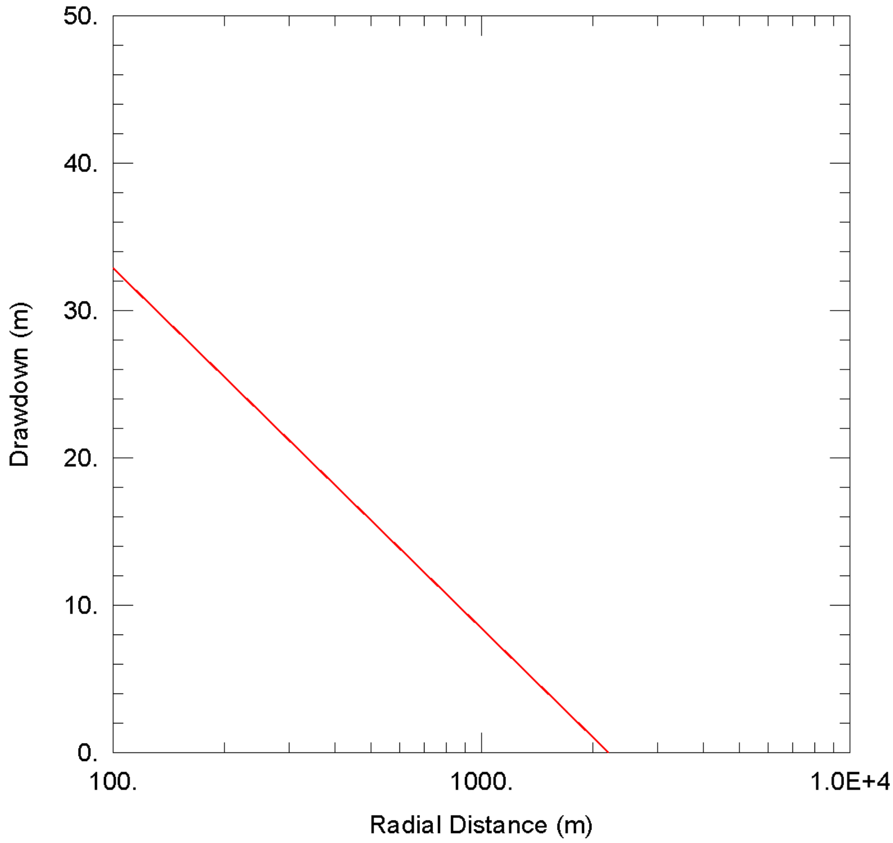
Observation Wells

Well Name	X (m)	Y (m)
Decline 3rd Corner	6407	7384
WB15	4890	8620

SOLUTION

Aquifer Model: Unconfined Solution Method: Cooper-Jacob

T = 5.247 m^2/day S = 0.008812



P3. DISTANCE DRAWDOWN AFTER 10 YEARS DUE TO DECLINE

Data Set: D:\...\P3. DD DeclineWB15 350 m3d.aqt
Date: 07/01/15 Time: 12:23:29

PROJECT INFORMATION

Company: Aquade
Client: Aurelia Metals
Project: 2014273
Location: Nymagee
Test Well: Decline
Test Date: 2015

AQUIFER DATA

Saturated Thickness: 90. m Anisotropy Ratio (Kz/Kr): 1.

WELL DATA

Pumping Wells

Well Name	X (m)	Y (m)
Decline 3rd Corner	6407	7384

Observation Wells

Well Name	X (m)	Y (m)
Decline 3rd Corner	6407	7384
WB15	4890	8620

SOLUTION

Aquifer Model: Unconfined Solution Method: Cooper-Jacob

T = 5.247 m^2/day S = 0.008812

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